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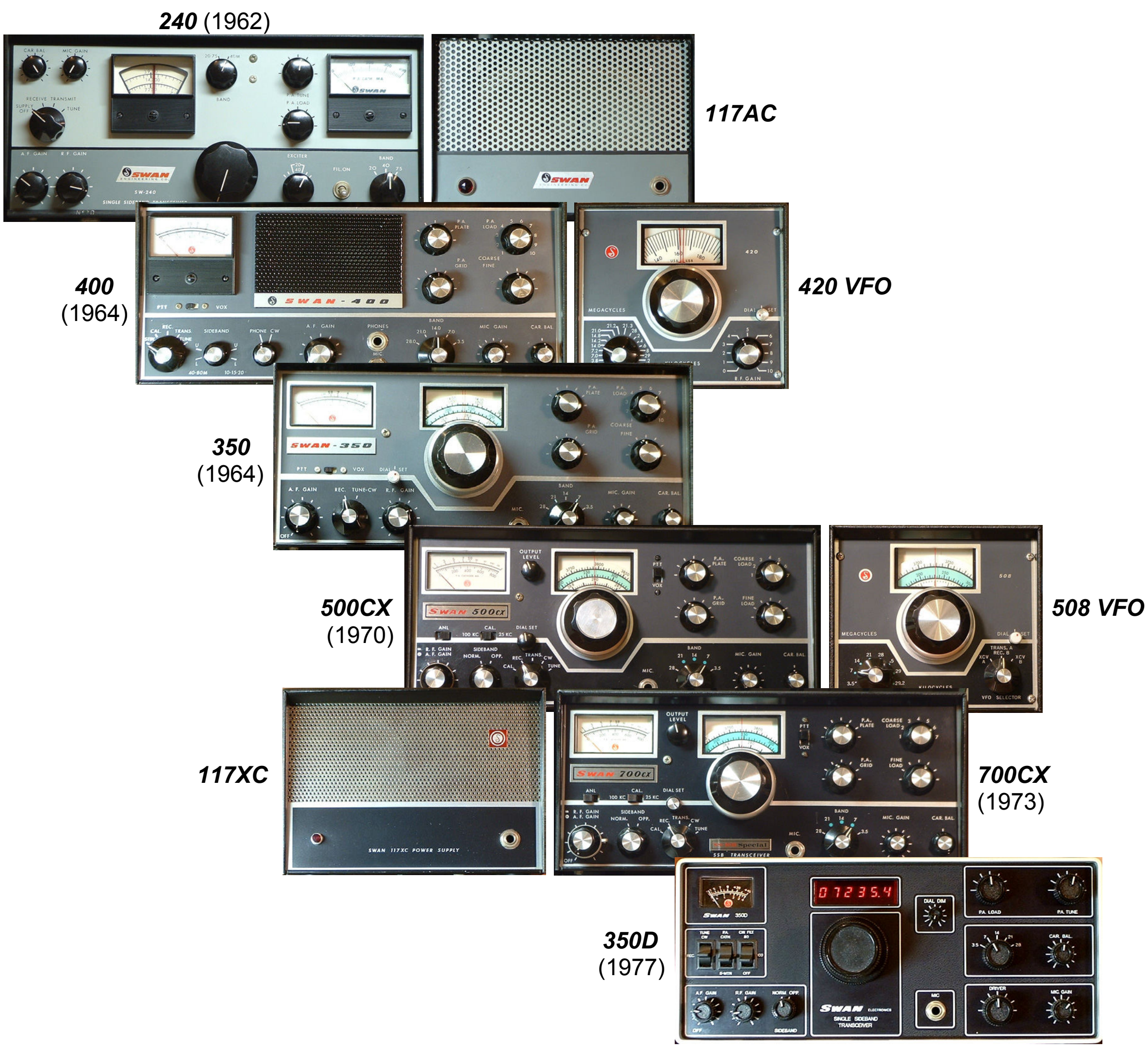
SWAN Tube Transceiver Compendium

(An Edited Collection Of Technical Data)

Rev 4.0, October 24, 2005

Robert Balonis, NB3W



Revision History

- *Rev 0.0 - 7/22/01*
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- *Rev 1.1 - 8/21/01*
- *Rev 2.0 - 6/1/02*
- *Rev 3.0 - 3/10/04*

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PREFACE

The Amateur radio hobby encompasses a wide range of operational (ARES/RACES, DXing, QRPing, contesting, rag chewing, etc.) and equipment related activities (home brewing, kit building, antenna design, etc.). While there is frequently much debate and contention within the amateur community over the merits of specific activities (e.g. code versus non-code, on-air operation versus experimentation, etc.), in reality, all of these interests are equally valid facets of the hobby. Indeed, most amateurs tend to focus on a variety of different aspects of the hobby, which frequently change during their Ham career.

The complexity of today's state-of-the-art (SOA) transceiver designs (hybrid analog/digital) and technologies (surface mount components, very large scale integrated circuits, and microprocessors) preclude many of the equipment modification and maintenance activities common in days past. This is perhaps part of the impetus behind the renewed interest in the refurbishment, repair, maintenance, and operation of tube-design boat-anchor radios. This was certainly true in my case. After purchasing a new SOA transceiver with many bells and whistles in January 1999, a minor distortion problem was finally traced to the rig itself. One look at the innards confirmed that there was no possibility of repair by me. So began a time of intense frustration – numerous phone calls and the hassle of shipping it to the West Coast, not once, but twice before the problem was finally corrected.

Although I was initially licensed in 1957, I had never extensively worked with tube equipment nor was I even in the amateur ranks during the 1960s and 1970s, the heydays of commercial tube-design radios. Nevertheless, this experience with SOA equipment made me yearn for a rig in which I could not only see the components, but could actually repair myself! No nested menus, no triple function buttons, no arcane labeling, and no surface mounted components! A review of the manufactures of that era brought my attention to Swan Electronics, stumbling on the Swan-Network clinched the deal – not only reasonably priced and relatively readily available rigs, but a loose-knit fraternity of Swan users with decades of expertise available and willing to help a neophyte! A Swan would be my first boat anchor (and as it turns out, my 2nd, 3rd, etc.). Obvious many others feel the same way about old tube-era equipment. The semi-regular articles and columns appearing the *QST*, *CQ*, and other Ham publications attest to the popularity of this aspect of the hobby.

For me, this Compendium is just another facet of the boat-anchor aspect of the amateur radio hobby. It assembles into one document, Swan tube-design transceiver information derived from Swan-Net activities (website information, reflector correspondence, on-air discussions), internet boat-anchor newsgroup postings, Swan Manuals and Service Bulletins, archival amateur radio magazines, tube-era electronics books and reference sources, and last but hopefully not least, my own personal experiences. As, such, it represents the collective wisdom, folklore, experiences, opinions, and advice from many Swan and boat-anchor aficionados. While it started out as just a collection of my personal notes as I learned some of the basics of vacuum tube technology in general and Swan transceivers in specific, it became apparent that it might also be useful to other Swan enthusiasts, especially other neophytes and perhaps even old-hands with years of experience. It was assembled in the spirit best expressed by Swan in their receiver sensitivity service bulletin for the model 250 six-meter transceiver, where they " . . . *encourage each owner to make the modifications himself, in the amateur tradition of being a technician as well as an operator."* Sadly, old-timers with experience with Swan radio repair are becoming scarce. Swan owners by necessity are forced to become "*a technician as well as an operator"* in order to maintain their radios. Hopefully the information contained herein will be of assistance to those wishing to keep their Swan radios, a major part of American amateur radio history, repaired, aligned, properly operating, and on the air.

This Compendium focuses primarily on technical aspects and, in most cases, the information has not been verified for accuracy or completeness. When dealing with such a wide variety of transceiver models, synoptic information of this type will not be universally applicable, and indeed in many cases, is transceiver model and even version specific. Much Swan information discussed by the sources is not included, so always cross check to confirm accuracy and completeness. There is redundancy between some sections and the edited Swan Newsletters included in Appendix A, however in most cases, either slightly different information is presented or a different perspective is given. Read the complete unedited Newsletters; they contain a great deal of background and ancillary information not included in the edited versions. Use the Swan-Net to confirm or clarify information; it is a tremendous asset that taps a wealth of information available from old timers with years of Swan and tube-radio experience.

Regards,

Bob, NB3W

ACKNOWLEGEMENTS

I wish to express my heartfelt appreciation to the many who have contributed, through their newsgroup and reflector correspondence, on-air discussions, websites, etc., to the information contained herein. A special thanks is in order to Stu (K4BOV), who has graciously and unselfishly shared his in-depth Swan expertise through his Swan Newsletter articles, reflector correspondence and on-air discussions, Dean (WA9AZK) for his efforts in establishing the Swan User-Net and Newsletter in 1989/90, and all the past and present Swan-Net On-Air Controllers, including (in addition to Stu and Dean), Kent (K1QQ), Norm (W7RXG), Jim (WA5BDR), and Jay (WB6MWL). Appreciation is also extended to the ARRL for granting permission to reprint the review of "*The Swan 350 Transceiver*," published in the September, 1965 issue of *QST* © ARRL. Finally and most importantly, special accolades to my XYL, Chris, for both editing assistance and supporting (or at least tolerating) my amateur radio endeavors.

There were so many other contributors, that it is literally impossible to recognize everyone individually. This is especially true since information from multiple sources was merged when initially assembling the material into a personal technical-notebook format, intended only for my use. Again, my apologies to the many who I have not been able to specifically include. However, a review of some of the original source data and new information enabled me to at least identify many individuals whose information is incorporated. These include, in addition to those cited above:

Ø Bob (KØBGH), Dave (KCØDZF), Dick (WØEX), George (WØHIO), Hank (KØOC), Mark (NØOQC), Pete (NØPQ), Ray (KGØSS), Bud (KBØWKD), Larry (NØXB), Bill (KØZL).

1 Bob (KE1JH), John (WA1LSH), Richard (AA1P), Doug (WA1TUT), Bill (W1UD), Ken (WA1UMD).

2 Chuck (WG2A), James (W2JRF), Mike (KC2KJ), Jeff (KB2QXA), Gerald (WA2TTI).

3 Morry (K3DPJ), Rick (KB3EPJ), Dave (WA3GIN), Bob (W3IGE), Pat (N3XJF).

4 Charles (W4CDF), Jason (KG4DBM), Mike (WD4DUG), Gary (K4FMX), Joe (W4HH), Bob (KD4HLK), Chris (KU4LV), Arthur (W4PQA), Nathan (KE4RCF), Carlos (KF4RRN), Bob (N4VNL), Barry (WA4VZQ), Bill (W4WHW), Bill (W4WHW), Michael (KU4YP).

5 Ken (KD5AIA), Charles (KE5AVC), Frank (K5DKZ), Allan (KB5DOH), Ken (KA5ELD), Harry (K5HML), Bruce (KD5IUG), JR (N5JNX), Tony (N5JVA), Mike (KK5KC), Don (KC5MFA), Dale (KA5WHO).

6 Craig (W6ADV), Dennis (NS6C), Mike (KD6DMH), Dean (WA6IKJ), Jerry (KG6KGP), J (K6LIO), Bruce (KB6LWN), Tony (WA6LZH), Clint (W6OFT), Carrie (KI6QO), Maury (WB6RLP), Shannon (W6SPY), Gene (WB6SZS), Greg (KG6YV), Rick (KD6ZR).

7 Steve (K7DNA), Gene (K7EEK), Mark (NM7L), Mitchell (KD7LZR), Alan (KB7MBI), Rog (KD7MKR), Joe (K7MKS), Bob (KK7MP), (Dave N7RK), Mike (K7WTM), Bill (N7YGU).

8 Jack (K8BVJ), Paul (W8CDM), Emil (KA8GEF), John (N8QPC), Al (W8UT).

9 Bill (N9AAQ), Ben (K9BEN), Craig (WA9HRN/6), Brad (NB9M), John (WB9OFG), Patrick (K9PF), Bob (W9RAN), Mark (K9TR), Jon (KB9WVK).

Fgn. Roger (G3VKM), Sergio (TG9ATX), Earl (VE3AB), Gary (VE4YH), Graeme (ZL3JO).

Misc. Skipp (Siltronix information), Barry (paint information), Phil (old radio information).

1. INTRODUCTION

1.1. Company History

Swan Electronics Corporation, originally called Swan Engineering, was begun as a one-man operation by Herb Johnson in late 1960. Herb named the company in memory of his father, whose given name in his native land of Sweden was Sven, but upon arrival in the USA, it was Americanized to Swan. Fig. 1-1 shows a photograph of Herb taken at the Swan product information kiosk during a 1966 Ham Convention in Miami, Florida. Herb Johnson (W6QKI) became a silent key on February 1, 2001.

Figure 1-1 Herb Johnson, 1966

While the reduced spectrum bandwidth requirements and improved RF signal power utilization benefits of the Single Side Band (SSB) radio transmission mode had been recognized as early as the 1920s, the first amateur SSB QSO didn't occur until September 1947, due to both technology limitations and World War II restrictions on amateur activity, which retarded development. The first viable commercial SSB equipment began appearing in 1950 and 1951 (e.g. the Collins 75A-1 receiver and the WEldico SSB, Jr. transmitter). With limited equipment availability and an amateur reluctance to accept this new mode, only about 300 SSB stations were reported as active in 1953 by the ARRL. General mainstream amateur acceptance of SSB didn't really begin until the late 1950s, spurred on by on-air demonstrations of its advantages and wider equipment availability (e.g. Collins KWM-1 mobile capable transceiver, introduced in 1957). By the early 1960s, even most AM die-hards had conceded that SSB was not only here to stay, but would one day supplant AM as the dominant transmission mode. See the article "*Amateur Radio and the Rise of SSB*" in the January 2003 issue of *QST* magazine for additional information.

A consequence of this transition to SSB was a reduction in home-brew equipment construction due to both the design complexity and associated component costs, making a commercial transceiver especially attractive and even cost effective. Thus, when Swan entered the market in 1961, it was extremely well positioned to capitalize on this burgeoning demand for SSB transceivers, since the only other widely available SSB transceiver on the market was the Collins KWM-2, selling at a premium price. Swan focused on an economical, higher power transceiver design that targeted the mid-price retail amateur equipment market. They used both low cost television sweep tubes in the final amplifier that operated in the AB_1 mode to maximize power capability, rather than true RF tubes, and a less costly multi-range VFO design, rather than the easier to implement but more expensive single range VFO used by most other manufacturers. In the mid 1960s, with the introduction of a multi-band capability, very high power at a very affordable price, solid construction, and good reliability, Swan Electronics became a major player in the early HF SSB amateur radio market. Many Swan tube-design radios remain in service today, attesting to the fundamental quality that went into their design and construction.

Swan built its first single sideband transceiver, the mono-band twenty-meter model SW-120, in a garage in Benson, Arizona during the winter of 1960-1961. In 1961, the companion SW-140 forty-meter and SW-175 eighty-meter mono-band transceivers were introduced. They relocated their operations to Oceanside, California in 1962, where, with the introduction of the SW-240 tri-band transceiver in 1963 followed by the 5-band model 400 in early 1964, and very closely thereafter by the very successful 5-band model 350, Swan's popularity and sales grew dramatically. In 1967, needing more capital and engineering resources to support this rapid expansion, the company merged with and became a wholly-owned subsidiary of the Cubic Corporation, San Diego, California. By late 1968, Swan had a team of ~160 employees designing and constructing transceivers and accessories. While Herb continued managing the Swan subsidiary until 1973, by 1971 most product control and decision-making had been assimilated by Cubic.

Although other manufacturers also introduced SSB transceivers in this era, Swan's very attractive feature, power, and price tradeoff made it the best selling rig in the mid to late 1960s. For example, in 1964, the model 350 with an 117C power supply was selling for $480 and the deluxe 400, including the required 420 VFO and power supply, was priced at $600. The top of the line Collins 75S-3 receiver, coupled with the 32S-3 transmitter sold for a total of $1370 ($620 and $750 respectively) and the KWM-2 transceiver sold for $1,150 (transmitters rated at ~100-W RF output). These prices were clearly in a category that was far beyond the reach of the average Ham (remember these are 1964 prices!). Other more moderately priced competitors with lower power outputs included the Hallicrafters SR-150 with power supply for $750 and the Heathkit SB-300 receiver with the SB-400 transmitter for $665 ($265 and $400 respectively) and even the E.F. Johnson Co.'s Ranger II, a 75-W AM transceiver, sold for $360.

In the mid-1960s, the Drake line of tube-design radios also became quite popular, and while there is some similarity in physical appearance between some Drake and Swan transceiver models (e.g. TR-3/4, particularly the cosmetic trim design about the main tuning dial), there apparently was no direct linkage between the two firms (other than several reported threats of legal action). Such similarity is most likely one of coincidence, since form frequently follows function, and there are just so many ways to logically layout a front panel or design a practical single conversion transceiver.

1.2. Early Production Facilities

The series of historic photographs shown in Figs. 1-2 through 1-8, extracted from information posted on the Swan-Net website, provides a fascinating glimpse into electronics production facilities and techniques of yesteryear in general, and in specific those used by Swan Electronics in the mid 1960s. As illustrated by the activities shown in these photographs, these truly were the days when radios were hand-built and judging by the Swan's staff appearance, facility cleanliness and attention to detail, with a great deal of care.

Figure 1-2 Swan Employees, 1965

Production Facility/Employees. Fig. 1-2 is a picture taken in 1965 of the Swan Electronics employees assembled in front of its production facility at 417 Via Del Monte, Oceanside, California. In this photograph, Herb Johnson is standing at the far right along with his young sons. The 60 employees shown represent only about a third of the total employees that Swan would grow to in just a few short years, during its rapid expansion after transition to Cubic Corporation ownership in 1967.

Figure 1-3 Chassis and Cabinet Fabrication

Hardware Fabrication. Fig. 1-3 shows a 1965 photograph of the portion of the plant dedicated to the sheet metal operations (shearing, bending, and drilling/punching) needed to fabricate the transceiver chassis, front and rear panels, and cabinet cases. Certainly, by contemporary and perhaps even past standards, Swan's production was unique during this time in that almost all hardware was fabricated in-house. With at least five employees involved, it was a considerable effort.

Close examination of this photograph shows transceiver front panel blanks stacked in the left-center, with already painted and slotted black case covers set atop the open-framed heavy metal cart immediately to the right of the large sheet metal shearing or bending machine in the foreground. As indicated by this photo, this capability involves some heavy-duty equipment for the various sheet metal manufacturing processes. Certainly one would suspect that even in those days, outsourcing of such subcomponents may have been more cost effective, but doing so would certainly impact flexibility in transceiver design evolution and perhaps incur some loss in quality control.

Figure 1-4 Primary Component Wiring Area

Primary Assembly. Fig. 1-4 shows an overview of the area where the majority of the component installation and wiring was done, with 20 staff shown assembling transceivers. The employees in the background row are working on transceiver chassis. Close inspection of the chassis being assembled in the left foreground shows that most components and the rear metal panel are yet to be installed. The four people on the right appear to be working on circuit board sub-assemblies and either power supply or VFO units. Nearly

100 transceivers were started here each week and reached completion 5 to 7 days later.

Of particular interest is the extreme neatness and orderliness of this area. Remember, this is a large assembly area – just think of what a typical Ham shack looks like when equipment is undergoing repair or even just during normal operation! Perusal of this and the other pictures show a production environment that can be considered scrupulously clean. While the areas may have been spruced-up somewhat for the photo-op, close inspection of the background in this and the other pictures clearly indicates that such conditions were more likely standard operating procedure rather than a temporary condition produced only for the photo. Herb's emphasis on quality was not limited to design and equipment fabrication; memos on the work environment even included such items as coffee drinking in the work area (permitted with restrictions).

Figure 1-5 Testing and Alignment

Final Assembly and Testing. The photograph in Fig. 1-5 shows technicians conducting what appears to be final hardware testing or alignment of a batch of early 1965 model 350 transceivers. Since each bench-top transceiver has a companion power supply, they may also have also been powered-up undergoing a burn-in process. All the units on the bench top already have their cases affixed while those beneath the bench have no covers installed. Individual paperwork accompanies each unit. Notice also that none of the units has yet had its VFO tuning knobs, bottom cover with the rubber feet, or the Swan 350 plaque installed. Note also the lab coats worn by the electronic technicians and other staff in this and some of the other photos, certainly a dress code and tradi-

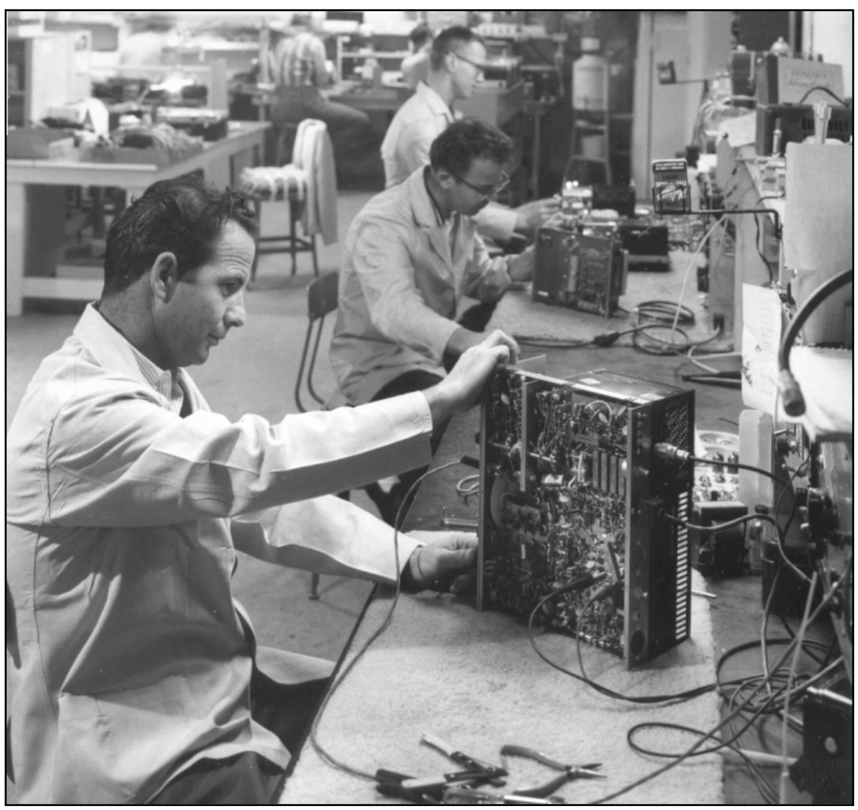

Figure 1-6 Troubleshooting and/or Alignment

tion of the past.

Bench Testing. In the foreground of the photograph shown in Fig. 1-6, bench testing, alignment, or possibly trouble-shooting of an early model 350 is being performed. Either an antenna or dummy load is attached to the RF connector, so the unit is obviously undergoing full-up receiver or transmitter testing and/or adjustment. In the background a smaller unit, perhaps an 117C or mobile power supply and an additional transceiver are also being worked on.

Packaging. Fig. 1-7 shows the final packing room in the February 1965 time frame. Arrayed on the right bench-top are eleven 350 transceivers. On the left bench are four more 350s in the foreground and three model 400s in the background. All transceivers shown are awaiting final cover installation and packaging into their cardboard shipping cartons. The covers are lined up on the upper left-hand shelves.

Figure 1-7 Final Assembly and Packaging

These model 400 transceivers do not have raised rubber front feet installed on their bottom covers like the 350s. The 400s of that period were shipped without an optional plate that the user could mount to the front of the bottom cover for base station operation. Mobile installations normally used the transceiver no-legs, without this optional plate.

Close inspection of the transceivers shows that they are an early version of the 350, which had not yet received neither the dial-set control nor the full 10-meter coverage VFO design modifications, introduced late in 1965. The units on the right clearly show the uncovered access holes on the VFO and a sharp corner on the VFO bracket. The holes were covered and the metal brackets were slope trimmed in later versions of this model.

"Classic" Mobile Installation. Finally, Fig. 1-8 shows what most certainly is not a typical Swan mobile installation, but what can certainly be considered, both literally and figuratively, an example of a "classic" in a "classic." The photos show the 1963 Corvette Stingray of Herb's longtime friend, Barry Goldwater (K7UGA), outfitted with a model 400 SSB transceiver and Swantenna mobile antenna during a visit Barry made to Swan's Oceanside production facility in 1966. Swan subsequently used a photo of Barry's Swantenna installation in 1970 equipment advertisements.

The installation included an external speaker attached to the overhead behind the drivers seat, just barely visible through the rear window. As shown in this photograph, the transceiver was mounted very securely and conveniently behind the passenger's seat of the Stingray. Bolted to the top of the transceiver is a small meter, most likely a field strength meter to obtain a relative measure of RF output power level during tune-up and operation, as indicated by the affixed small whip antenna. An external VFO, a model 406B, was mounted under the dash. Notice the "new" two-tone front panel color scheme, which was introduced in late 1965 to replace the single-tone light gray panel used on the earlier version model 400 transceiver.

1.3. Product Line Overview

The majority of the transceivers Swan manufactured were vacuum tube type designs and through the years more than 80,000 where sold. At its peak, Swan produced as many as 400 transceivers a month from its Oceanside,

Figure 1-8 Swan Stingray Mobile Installation

California plant. The first 20-meter mono-band transceiver was produced in April 1961 and the last tube-design models were produced in 1980, with residual stock sold into 1981. Swan's transition to all solid-state designs began with a 2-meter transceiver introduced in 1971 followed by a number of all solid-state mono-band and 5-band HF models in 1973, and ended with the Astro model line, sold as late as 1982. However, during this time, the Japanese imports had captured the tube-design market and continued that trend with their solid-state radios.

Production Philosophy. During the early years, Herb Johnson, in memos to employees and letters to retailers, clearly indicated he would not sacrifice quality for speed, even though capacity existed at times to produce twice as many units per week. Swan never once got caught up with retail orders prior to its merger with Cubic Communications. This early philosophy of quality control and attention to detail certainly seemed to have also carried over into other areas, such as Operation and Maintenance manuals, which not only include basic operation information, but also design theory, detailed parts lists, schematics, and even alignment and repair information. During this period, Swan provided amazing flexibility in the area of customer service, offering do-it-yourself upgrade bulletins and kits, factory upgrades, and even doing unique one-of-a-kind customer-requested modifications and upgrades.

It is also interesting to note that that Swan perhaps had a more demanding approach than other manufacturers with respect to their expectations of and relationship with their amateur customers. In addition to encouraging user design changes, circuit modifications, and performance upgrades, even their fundamental approach to equipment operation was much more technical than some of the other manufacturers. While Swan transceiver designs included a relatively accurate measurement of cathode current (in addition to a detailed manual discussion of its operational implications), other manufactures merely included a meter labeled to provide relative readings along with instructions of the "*adjust to the red line*" type (e.g. Galaxy V mk4, Heathkit 32A, etc.).

Throughout its corporate life, Swan's philosophy (or perhaps more accurately its capability) in product development and production changed significantly. Prior to the 1965 time frame, Swan generally had only one transceiver model in production at a time with very few accessories. The early mono-band transceivers were replaced by the first multi-band model, the tri-band 240, which in turn was replaced by the 400, the first 5-band model. When the 240 was being produced in late 1963, the only other products in production were the matching 117AC power supply and TCU (external VFO for the 240).

After 1968, when Swan became a subsidiary of Cubic, the expanded financial and manpower resources permitted upgrades and design modifications of nearly all existing models (i.e. C models – the 250C, 350C, and 500C) and the introduction of many new types of equipment, resulting, by early 1970, in a multitude of transceiver models and a wide variety of accessories concurrently in production. For example, during the 1972 time frame, Swan had simultaneously for sale the 160X, 250C, 270B, 310/320 (commercial), 400 (commercial), 500CX, 600T and 600R (plus the 2-meter solid-state FM-2 and FM-1210) radios, as well as a host of accessories, such as the WM series wattmeters, external crystal controlled oscillators, VFOs, linear amplifiers, and a line of base station and mobile antennas! This profusion of transceivers and accessories is clearly depicted by the photo on the front cover of Swan's 1973 equipment catalog shown in Fig. 1-9 and also by the snapshots of available products and their selling prices in the 1971 through 1973 time period as illustrated by Swan advertisements placed in *QST*, shown in Appendix B (Figs. B1 through B5).

Model Evolution. The transceiver designs transitioned quickly from the early mono-band 120, 140, and 175 models produced in 1961 and 1962 to the tri-band model 240 in late 1962 and then in early 1964, to the 5-band 400. The model 400 series is unique in that it is the only Swan amateur transceiver without an internal VFO, requiring either an external VFO or crystal oscillator for operation, a more costly and perhaps unwieldy approach for many amateurs. However, in late 1964, the 5-band 350 model with an internal VFO was introduced, which quickly became wildly successful and an amateur classic. That design then slowly evolved during the next 16 years through a succession of models to the last of the tube-design breed, the HS-700S.

The mono-band transceiver concept was re-introduced in the mid 1960s and early 1970s to address the VHF region with the six-meter 250/C and the lower range of the HF band with the 160/X. Also introduced in late 1968 was the Cygnet ("*Young Swan*") design concept – a 5-band, easily portable transceiver with built-in power supply, but with much lower power than the base station models (e.g. 350, 500, etc.).

Most of these base station and mobile or portable models use either a single or a paralleled pair of television sweep tubes in the RF power amplifiers, such as the 6DQ5, 6HF5, 6JE6C, or 6LQ6. Exceptions to the sweep tube usage includes the 250/C six-meter mono-band transceiver, whose power amplifier uses a pair of 6146 tubes, and the higher power 700CX, which uses a pair of 8950 tubes. Solid-state components were used in the VFO circuits of all but the earliest models and were incorporated into a couple of additional circuits in the last few models. An overview of most tube-design transceiver models and their production and sale time periods is shown in Fig. 2-1.

Most Swan transceivers require a separate power supply, except the Cygnet-like designs and the 600T/R series stand-alone transmitter and receiver pair, all of which have an internal power supply. The last tube radios produced from 1978 to 1980 were the model 350A/B/D, 750CW and HF700S transceivers, which were outfitted with solid-state balanced modulators, calibrators and carrier oscillators, and in the case of the 350D, a digital display and associated solid-state electronics. In general, the overall quality of transceiver construction deteriorated somewhat in the later models, which have higher failure rates in some of the solid-state circuits and smaller, less accurate meters, as attempts were made to remain cost competitive with the Japanese imports.

The first Swan single band radios (e.g. SW-140) had light gray, enameled cabinets with a clear anodized-like Gold-Faced front panel color scheme (later versions of this model had very light-gray panels). This transitioned to the very light blue-gray used on the 240 panel to the mono-tone light gray used on the early 400s (two-tone light and dark gray used on later units) to a darker two-tone gray (light and dark, as shown in Fig. 1-9) used for most of the transceivers produced, to the solid dark gray, and finally to the all flat black front panels of the last models. Some production models used two of the color schemes (e.g. 400 and 700CX), depending on date of manufacture. Likewise, the front panel configuration of some models (e.g. 750CW) was also produced with two or more control layouts and front panel styles, although the internal design remained essentially the same.

Marketing. As noted previously, during the late 1960s and especially in the early 1970s, transceiver models were quickly upgraded and a number of models were simultaneously in production, along with a plethora of accessories, as shown in Fig. 1-9. During that period, upgraded models had both C (e.g. 350C, 500C) and CX suffix designators (e.g. 500CX, 700CX) appended to the model numbers, however in cases such as the 500C to 500CX transition, this was more a marketing gimmick than any real improvement, as changes from the replaced model were minimal. In other cases two models, or variants of the same model, were sold concurrently with one model being marketed as standard and the second as a deluxe or top-of-the-line version, such as the 350 and the deluxe 400, or the standard 260 Cygnet and the deluxe 270 Cygnet. In other cases, the replacement version of the same model was billed as the deluxe version of an earlier design, as in the case of the 500 and 500C.

During the 1965 time frame, Swan had an innovative program that offered 30% discounts off list prices for transceivers, power supplies, accessories, and upgrade kits sold by dealers to amateur radio clubs. This was a win-win situation for both amateurs and Swan. It provided a nice benefit and incentive for radio clubs to purchase Swan equipment, while at the same time providing a way for Swan to give many amateurs hands-on experience and exposure to Swan transceivers, most likely significantly contributing to the great success of the 350.

With the increasing competition and success of the Asian manufacturers in the 1970s, Swan pursued a number of approaches to combat this threat. In addition to design changes oriented to reducing or controlling costs (smaller less accurate meters, elimination of features such as the internal dc power supply in the 270B, etc.), Swan also explored cost saving approaches in the area of marketing. In 1971, they instituted a "*factory direct*," sales policy that offered a 10% savings (from dealer pricing). According to Swan, the rationale behind this sales approach was: "*For more than a year now, American manufacturers and distributors of amateur radio equipment have been faced with a growing challenge from imported products, which in most cases are being sold on a direct basis from importer to user. After considerable deliberation, Swan has decided to meet this challenge by offering a new dual sales policy for 1971. This new program permits us to substantially reduce prices for the entire line and also in-*

Figure 1-9 Swan Equipment Line-Up, 1973

clude the valuable customer relationship provided by knowledgeable distributors. Thus with no sacrifice in Swan's high standards of engineering, reliability, and craftsmanship we can now offer our product for prices which are more than competitive with any foreign-made equipment. (Swan advertisement in February 1971 *QST*)"

While Swan continued to offer its products through local dealers, one has to wonder how enthusiastic the retail dealers were with this marketing strategy and whether in the long run it adversely affected sales and market share. In the 1970s, Swan even offered their own credit card with a "*revolving credit plan*" which could be used to order equipment on credit directly from them or at "*participating dealers!*" In 1972, terms included an annual percentage rate of 18% on the first $1,000 and 12% on that portion over $1,000, so this credit offer wasn't exactly an altruistic endeavor.

It is ironic to note that while Swan was transitioning from a dealer only distribution network to some factory direct sales, the foreign manufacturers were transitioning from direct sales to a dealer distribution network.

Customer Support. Up until the early 1970s, one of the exceptional features of the Swan organization was the outstanding support provided for older equipment in the form of factory upgrade installations, user installed kits, and service bulletins for a wide variety of circuit design updates and modifications. An idea of their customer-friendly support approach and philosophy is illustrated by the type of instructions and advice provided in their service bulletins and modification kits.

For example, in their sensitivity service bulletin for the model 250 six-meter transceiver, Swan digresses to explain the rationale for switching in later versions of that transceiver from the 6CW4 nuvistor to the 6HA5 in the RF amplifier and mixer stages. Likewise, in discussing circuit performance of the IF stages of that same transceiver, they relate reported tube change experimentation experiences from Swan users (e.g. use of a 6GM6 in place of the 6EW6 and the 12AU6 in place of the 12BA6) and, as they put it in their discussion of these changes, *" . . . the AGC control characteristics will be altered, and the experimenter may enjoy trying it.*" With regard to the S-meter modification for that same transceiver, they note: "*We also would like to encourage each owner to make the modifications himself, in the amateur tradition of being a technician as well as an operator. If any problem develops, the set may be taken to your dealer for servicing, or shipped to the factory at Oceanside, California where we will do the work and re-ship within a few days.*"

In addition to this user-friendly approach to standard updates and modifications, they were even quite willing to do some non-standard work on equipment, often based only on an informal phone call to the factory. This was especially true during the earlier model 350 years (1964-67 time period), when Swan service personnel were very receptive to accommodating just about any customer whim. Thus, it is possible to find transceivers from that time that have unique one-of-a-kind modifications that were factory installed (e.g. see discussion of the model 700R and 700T in Section 2.3.14).

The radios could be initially ordered from the dealer or from Swan (after factory direct sales were instituted) with the desired kits factory installed and the radio would be built to your order, kind of like options on a car. Transceivers could also be returned to Swan for kit factory installation (usually done in conjunction with other repair work), however most kits were commonly ordered post-sale for user installation. The cost of such factory installed modifications increased dramatically in the later years. For example, a common 350 factory modification was the SSB Selector Kit – initially the factory installation cost was only $18 for the kit plus $10 for installation, whereas in 1975 that installation cost had increased to a flat ~$75.

Transition to Solid-State. Swan's transition to the all solid-state, no-tune era began in January 1971 with the introduction of the two-meter FM-2 transceiver quickly followed in 1972 by the FM-1210. Late 1973 saw the introduction of Swan's first all solid-state 5-band HF transceivers, the SS-15, SS-100, and SS-200 (15, 100, and 200-W dc input PEP, priced at $579, $699, and $779 respectively) and even a re-introduction of the mono-band HF transceiver concept with the MB40 and MB80 ($250 each, March 1973). In 1974, an upgraded version of the SS-200, the SS-200A was introduced, with an increased input power to 300 W.

Thus began Swan's journey to all solid-state radio designs, but not its immediate abandonment of the tube-design transceiver. During the mid to late 1970s, they still continued a major emphasis on tube-design transceivers, introducing the medium power Cygnet-like 350A/B/C models as well as a series of ever higher rated input power base-station models, progressing from the 500CX to the 700CX and finally to the last of the line, the 750CW and HS700S.

In about 1978, the Swan subsidiary name was changed to Cubic Communications, Inc. and the operation was moved to one of the campus-styled facilities at Cubic's main location. In addition, during this time Swan/Cubic started transitioning away from amateur radio products to focus on high-tech electronics, including sophisticated general-purpose data communication receivers (e.g. built-in RF analyzer, multiple selectable IF bandwidths, etc.). The amateur market wasn't totally abandoned until the early 1980s. They continued to market the all solid-state Astro line of amateur transceivers (102/X, 103/X, 150/A, 151) and some accessories as late at 1982. An early version of the Astro 102 was even initially marketed under the Swan name for a while before the transceiver labeling was finally changed to Cubic.

Post Script. The Swan and other vacuum tube transceivers of this time period literally represent the end of an era when men were men, components could be seen without a magnifying glass, and real live people actually installed and wired the components by hand, one at a time!

1.4. Atlas

Herb Johnson ultimately left the Cubic organization in 1973. He went from the founder and owner of America's leading supplier of amateur radio SSB transceivers in 1966, through a progression of positions of lesser and lesser authority as the manager of the Swan subsidiary. Johnson subsequently left and founded his second company, Atlas Radio in 1974, which produced a line of compact, rugged solid-state transceivers (e.g. Atlas 180, 210/X, 215/X, 350XL) that became a favorite for mobile communications. Over 23,000 Atlas models were sold.

As with every American amateur radio company, both Swan and Atlas experienced severe difficulties in producing new solid-state transceivers that were both feature and price competitive with Japanese radios. In an attempt to revive fortunes, Atlas Radio introduced a new 3rd generation HF transceiver in August 1994, the 400X "*Little Giant*." While the radio was actively marketed with an initial selling price of $699 in anticipation of its full production, the design and development "*wandered into a mire of technical problems*" and the company failed to commercially produce the radio. In 1995, O.M. Radio struck a deal to take over Atlas Radio's assets and manage the company. O.M. Radio also operated an Atlas Radio repair service and even promised to make good on delivering the new transceiver, but nothing ever came of the effort.

1.5. Siltronix

For a short while in the 1971 time frame Swan sold, but did not produce, the tube-design model 1046 transceiver as their initial entry into the CB market. It was built by Palomar Electronics, who also produced the Skipper 71/73 series CB radios upon which the 1046 was based, and relabeled with the Swan name. Shortly thereafter, Swan built and sold the amateur model 1011, a mono-band 10-meter transceiver with 11-meter receive-only capability. The 1011 is of particular note in that it was frequently modified by users for illegal high power 11-meter citizen band operation. That transceiver is similar to the design of the Swan 260 Cygnet, differing in that the electronics associated with other than the 10-meter amateur band were removed, the VFO modified to include an 11-meter capability, and a 6LF6 or 8950 was used in the final power amplifier to increase power output, since the 260 typically only has about 55 to 65 watts RF output on 10 meters.

Because of the disapproval of the amateur radio community, Swan entered into an agreement with Palomar-Siltronix to market the 1011 radios under the Siltronix label. While Swan no longer sold the radio, they continued to design and manufacture that product line in their Southern California plant, along with Siltronix accessories, such as VFOs and wattmeters, which were basically relabeled clones of Swan products.

Although the 1011 series transceivers and associated products were used for CB, Hams did (and still do) use them legally on the 10-meter radio band. For additional information on Siltronix as well as additional Swan/Cubic information, visit the Swan/Siltronix website at: *www.radiowrench.com/siltronix*.

2. GENERAL TRANCEIVER INFORMATION

2.1. Swan Nets and Resources

2.1.1. On-Air

Swan Nets are conduced weekly at the times and frequencies listed below. During holidays or periods when major contests are being conducted, these nets may be cancelled. While the focus of the nets is primarily on the maintenance, repair, and operation of Swan equipment, discussions of other tube-era gear or amateur related questions and comments are welcome. You do not need to own or be operating Swan equipment. See the Internet Chat Room discussion below for information on real-time Internet audio streaming of these nets.

- Swan User Net - Sunday 5 PM Eastern time on ~14,250 kHz.
- Swan Technical Net - Wednesday 2300 UST on ~14,251 kHz.
- Swan Technical Net - Saturday 2-4 PM Eastern time on ~7,235 kHz.

2.1.2. Internet Resources

If you have access to the Internet through a home computer or public library, visit the websites shown in Table 2-1. They contain a wealth of both background and specific information related to Swan transceivers and other tube-era equipment. The Swan-Net Internet websites listed are interrelated and have cross-links in many cases, so transfer between those pages and other referenced resources is easy.

Swan Internet Reflector and Message Archives. Since numerous Swan users and enthusiasts, many with years of Swan equipment background knowledge and technical expertise, are signed up to these reflectors, it is an ideal forum to ask technical questions, obtain equipment information, or just discuss any Swan or tube-radio issue. Remember, every time you send a message, it is automatically retransmitted to all reflector members, so it is usually not helpful or appropriate to conduct personal or off-topic personal discussions.

Reflectors. An Internet e-mail reflector is a system that automatically retransmits any message it receives to all other members who have joined that particular reflector group. There are three independent Swan related reflectors, one located on Yahoo, a second on Topica, and a third at the QTH website. Prior to using any of these reflectors, you must first register or sign up for the service.

Topica. To sign up for the Topica based reflector, simply send an e-mail message to *Swan-Net-subscribe@topica.com*. As an alternative, go to the Topica website located at *www.topica.com*, where sign-up instructions are also outlined. E-mail correspondence with this reflector is addressed to and from *Swan-Net@topica.com*. Any posted responses to received messages are automatically retransmitted to all reflector members. To respond directly to a message originator, you must manually copy the originator's e-mail address from the reflector message (right click on the message and select properties to see the sender's address information) to a new conventional e-mail form.

Yahoo. The Yahoo Groups reflector requires you to first register as a Yahoo user. Go to their website at

Table 2-1 Swan Related Websites

- Swan Radio Network at *www.geocities.com/LateMod97/.*
- Swan Radio Net Trader at *www.angelfire.com/ny2/hamradio/sell.html.*
- Swan Network at *groups.yahoo.com/group/Swan-Network/*
- The Swan Virtual Museum at *www.pcs.mb.ca/~standard/.*
- Swan Transceiver Information at *www.aade.com/hampedia/swan/swan.htm.*
- Siltronix Transceivers Information at *sonic.ucdavis.edu/siltronix/.*
- Swan Reflector Edited Messages at *www.topica.com/login.html.*
- Swan Reflector Message Traffic Archives at *www.qth.net/.*
- Swan/Cubic Manuals at *6mt.com/swan.htm.*
- Swan and Siltronix Manuals at *bama.sbc.edu/swan.htm/.*
- Tube Data and Substitution Information at *www.nostalgiaair.org/otcr.htm.*
- Tube Data and Substitution Information at *www.duncanamps.co.uk/cgi-bin/tdsl3.exe/.*
- Tube Data and Substitution Information at *hereford.ampr.org/cgi-bin/tube/.*

http//groups.yahoo.com/group/Swan-Network and follow the instructions to register and join the e-mail reflector. Any e-mail correspondence with this reflector is addressed to and from *Swan-Network @yahoogroups.com*. Any new messages or posted responses to received messages are automatically retransmitted to all reflector members. To respond directly to a message originator, you must manually copy the originator's e-mail address from the reflector message (right click on the message and select properties to see the sender's address information) to a new conventional e-mail form.

QTH. The QTH reflector requires you to register at *www.qth.net*. After first selecting the displaying the Directory of Lists, simply select the Swan list and you will be directed to the sign-up page. E-mail correspondence with this reflector is addressed to and from the *swan@mailman.qth.net*. This reflector gives you the option to directly respond either to the individual message originator or to the entire reflector membership.

Message Archives. The messages that appear on each reflector are also available in their respective message archives at the Topica, Yahoo, and QTH websites. In the case of Topica and Yahoo, the archival messages have been edited to remove extraneous, non-Swan related material. Go to those website and login as required to access the archives. For example, go to *www.topica.com*. A screen will appear prompting you to login. You will have to either register if you have not already done so or sign-in with your full e-mail address and existing password. Another screen will appear showing that you are subscribed to Swan-Net; click on it and you will go a self-explanatory screen for finding old messages.

Chat Rooms/Streamed On-Air Swan-Net Audio. A chat room is an Internet based system that permits multiple users to simultaneously meet and discuss various topics in real-time. There are two Yahoo Groups based Chat Rooms related to the Swan-Net. The first Swan Radio Chat QSO Room can be accessed by going to *www.geocities.com/latemod97/* and following the instructions – no special password is required to enter this room. It is open 24 hours a day. Once you and others have entered the room, you may freely converse with one another, kind of like an on-air roundtable QSO.

The second Swan Radio Network chat room at Yahoo Groups is being used for streaming live audio from the weekly HF Swan Net on-air operations. So, if propagation conditions or license restrictions preclude conventional on-air net participation from your QTH, use this chat room to participate! Gain access by going to *http://groups.yahoo.com/group/Swan-Network/* and follow the instructions. If you are not already a registered Yahoo member, it will be necessary to do so before you can enter that Chat Room and hear the audio. You will be able to communicate with the net control via the chat-room's text messages.

2.2. General Characteristics

Model Overview. A summary of most amateur Swan tube transceiver models is shown in Fig. 2-1 and Table 2-2. These listings are not all-inclusive and a few of the more esoteric models are omitted. Information on the listed models and some omitted models are included in the Selected Transceiver Comments Section 2.3. For a synopsis of the technical specifications and photographs of some of the transceiver models, be sure to visit the Swan Virtual Museum at *www.pcs.mb.ca/~standard/*. Likewise, a review of the Swan advertisement samples shown in Appendix B, Figs. B1 through B5, can be helpful in gaining a general familiarity with Swan transceivers and accessories. In many cases, Swan's model numbers denote the transmitter's minimum SSB dc input PEP (peak envelop power) capability, although there are also exceptions to this generalization, such as the 350, which is rated at 400 W and the 350C, rated at 520 W.

Physical Characteristics. Almost all Swan tube transceivers have the same physical dimensions (~5.5" H {~6.5" w/feet}, ~13" W, ~11" D {~12.5" with dials and rear panel connectors}). The model 600R receiver and 600T transmitter twins are exceptions to this generalization, as each has a 6.5" height (~7.5" with feet), 15" width, and a 12" depth. Transceiver weight varies from about 11 lbs for the early mono-band models to 24 lbs for the Cygnet designs with built-in ac power supplies. The 600R/T twins, which include built-in power supplies, are also exceptions, each with a weight of approximately 32 lbs.

Manual/Schematic Caveats. The are a number of factors to consider when using the original manual that came with the rig or one that is acquired from a secondary source (web download, vendor, eBay, etc.). The first is to be aware that from the 1968 or 1969 time period on the manuals unfortunately were not up to previous Swan standards, containing many errors, misspelled words, unclear references to coil and component locations, etc.

It is also extremely important to recognize that not all transceivers with the same model number are necessarily physically or electronically identical. There were at least two and as many as seven distinct design versions of every tube-design transceiver model produced by Swan with changes sufficient enough to warrant the issuing of a revised schematic. The entire manual was updated only rarely with new model versions and even then, some of the first rigs of the updated version may have been shipped with the old manual and/or schematic. Thus, it's possible to have a one-owner rig with the original manual and schematic and still have the incorrect one!

Consequently, you may purchase an after-market copied manual for say a 500C version that shows a five-position mode switch while your transceiver has only a three-position switch. On the other hand, when looking at a replacement manual, it may show a 500C with a 17-tube schematic, but your later version unit might have only 15 tubes – there is no V-14 carrier oscillator (replace by a solid-state oscillator) and, since voltage regulation was no longer required to insure stable V14 operation, there also is no 0A2 regulator tube. Conversely, you may also find a 500C schematic that shows 15 tubes, but it's for the intermediate version that has a 3-position switch rather than 5-position mode switch.

To further complicate the situation, there are also cases where the manual and schematic for the last version of one model may be used for the first version of the model that replaced it, as is the case with the 500C and the 500CX. See the discussions on the individual transceiver models below and in the Manual Section 4.9.

Power Supplies. Most two-tube PA transceivers require an external power supply and most one-tube PA units have a built-in supply. Exceptions to this generalization are the early mono-band and tri-band models that have a single-tube PA, but required an external power supply, and the 600T transmitter that has a dual-tube PA but also has a built-in power supply, as does the companion 600R receiver. All 117X and equivalent power supplies (117B and later) are interchangeable with any model 350, 400 or later model transceiver. Only a small modification is required to make these later 117X-type supplies compatible with the earlier transceiver models and likewise only a small change is required to make the earliest power supply model (117AC) compatible with the later transceivers.

For most transceiver and power supplies models, the HV is specified as 800 V. This is just a nominal value, typical of what is measured with an 117X power supply during average transmitter operating conditions. The actual voltage will range from ~925 V in the receive mode, to ~890 V during idle transmitter conditions, to as little as 700 V during maximum dc input power conditions when the supply is used with the highest power transceiver models. Likewise, the MV, bias, and other power supply voltages will not necessarily be the nominal value specified – they will also vary somewhat as a function of loading. The voltage values measured on a particular unit will also be dependent on ac power line voltage. An overview of the specified minimum, nominal, and maximum power supply voltages and current requirements for the early mono-band, the tri-band, and later dual-tube transceiver models is shown in Table 3-1 in the Power Supply Commonality Section 3.2. Measured power supplies voltage levels under various operating conditions are shown in Tables 3-5, 3-6, and 3-7.

2.2.1. Serial No./Schematic/Production Info

Between 1965 and 1971, all transceivers, except for the mono-band models, have a letter designation prefix to the serial number. The letter A was reserved for the 240 transceivers built prior to 1965, B was used for the 400, and C was used for both the 350 and 350C models. The letter O was used for power supplies.

After 1971, under Cubic management, a revised numbering scheme(s) was used. Serial numbers and their format became varied and non-uniform, probably reflecting the production of sub-assemblies and/or transceivers at Cubic facilities other than the Oceanside plant and the use of outside vendors. While one may intuitively think that the C in 350C or 500C refers to the addition of a crystal calibrator or some other specific feature, it reportedly just designates "Cubic." The 250, 350, 400, and 500 were the last transceivers built under the total control of Herb Johnson. In 1968, after Swan became a subsidiary of Cubic, the C was affixed as an upgraded model suffix designator (i.e. 250C, 350C, 500C). Coincidental with this was the decision by Cubic to change from the 5.173-MHz to the 5.5-MHz intermediate frequency used in most later amateur transceiver models. Transceiver models that were originally factory equipped with the SS-16 IF filter include a SS prefix to the serial number.

Fig. 2-1 provides a graphic overview of the approximate production/sale years of most transceiver models. These and some additional models are discussed in Section 2.3. As indicated, many had extended production runs. During these extended runs and indeed, even for those models with production runs of only a year or so, significant circuit design changes resulted in two or more versions of the schematic in all cases. To distinguish between schematics, usually a letter and/or a date is affixed to denote version number (e.g. C would be version 3), although is some cases there is no designation other than the actual circuit changes (e.g. first two versions of the amateur model 400). To find out the actual production date (year and month) of a particular unit, just check into the On-Air Swan Nets or provide the serial number to the Swan-Net via email (*SwanRadio@Anglefire.com*), the reflector, or their website. They have the old Swan production records in a database and can provide the specific date of manufacture, model version, and appropriate schematic information and in some cases, even the name of the original owner and selling store may be available.

As with the circuit design changes made on a given model, front panel and/or cabinet modifications also occurred during a production run. Such features may be used to obtain a general idea of a rig's production year or to identify which schematic is applicable if the serial number is missing or unreadable. Exemplars of the type of change that might be useful to identifying a model version include:

- With the model 140 transceiver, the front panel color changed from the initial gold to a very light gray and the tuning dial changed from a simple panel punch-out scheme to the use of a rectangular plastic bezel/cover in the later version. The meter also changed from an off-the-shelf surface mounted unit to a plastic bezel/cover similar in design to that used on the tuning dial display.
- The 240's meter changed from an off-the-shelf surface mounted unit, similar to that used in the early version mono-banders (e.g. 140), to a custom-scaled meter enclosed in a rectangular bezel/cover similar to that used on the tuning dial.
- During production of the model 350, the tuning dial was changed, with units produced after mid 1965 using the dial with the familiar green band (needed to display full-band coverage), while the earliest version has a solid white dial.
- Cabinets also had various configurations of ventilation holes that evolved over time from: (1) the larger, widely spaced circular holes on the upper cabinet sides used in the mono-band models and early version 240, (2) to the vertically oriented larger, widely spaced oblong slots on the upper sides/top edge used on the later version 240 and early version 350 and 400, (3) to the extension of those slots a bit further down the sides and onto the top on the later version 350 and 400 models, (4) and finally after ~1965, to the grid of small holes over the entire top and sides that was used on all subsequent models. However, since most cases have the same form/fit factor, switching of cases between units is possible.

Accessory Jumper Plug. The one glaring omission from the manuals and schematics is the failure to specify or to make any mention that those models equipped with an accessory socket must have either an external VFO or the factory provided 9-pin jumper plug, with pins 1 and 8 jumpered (VFO signal path) and pins 3 and 4 jumpered (–10/–14 V path), installed in order for the radio to operate. Other models, such as the early mono-banders, the 240 tri-bander, and the Cygnet-like (e.g. 350A/B/D) do not require this plug. Without the plug installed, there will be no VFO signal and the transceiver will not function (just a white noise hiss will be heard on receive).

2.2.2. VFO Drift Issues, Specifications

Swans and other tube-design transceivers are frequently criticized as having VFO frequency drift problems. While this is more likely to occur for some models and/or specific units, one should recognize that with vintage tube radios that do not employ a phase-lock-loop or other exotic stabilization approaches (crystal ovens, etc.), some significant drift during warm-up is both expected and normal. Even after full temperature stabilizations, tube radios will not come anywhere close to matching the tens of Hertz or less of frequency stability and accuracy over the operating temperature range specified for state-of-the-art (SOA) equipment. Before concluding that there is a VFO frequency drift problem, confirm that the reported or observed drift is not due to operational factors (cyclic retuning by the receiving and/or sending station during a QSO) or that it is in fact just due to unreasonable expectations relative to SOA radios.

For most later transceiver models (i.e. post 240) Swan specified a drift tolerance during the first hour of operation of less than ±1 kHz in the 80, 40, and 20-meter bands, and less than ±2 kHz when operated in the 15 or 10-meter bands. The six-meter Swan 250 transceiver also specifies ±2-kHz drift within the first hour. With the 240, drift of less than 500 Hz in the first half hour and 200 Hz/Hr thereafter is suggested by the manual as attainable, but only with proper adjustment of the temperature compensation trimmer capacitors. Beyond the initial one hour warm-up time, drift is not specified in most manuals, however independent measurements suggest that drift rates of less than 200 Hz per hour are reasonable. After a properly functioning radio has operated for a full hour, any frequency variations should be dependent only on temperature variations associated with the transceiver's operational duty cycle and power output.

Frequency drifts significantly in excess of these values or a single band-specific excessive drift problem suggests problems in the VFO circuitry. See the Drift Problems and Solutions Section 9.2 for further discussions.

2.2.3. IF Filter Design Information

Intermediate Frequencies (IF). Swan transceivers use intermediate frequencies (IF) of 5.173, 5.775, 5.500, 5.600, 10.700, or 10.900 MHz, depending on the model and in some cases model version, as shown in Table 2-2. Because of these frequency differences, external VFOs, which are designed for a transceiver's specific IF (see Table 4-1), are not necessarily directly interchangeable among the various transceiver models. VFOs and transceivers that have close IF design frequencies can be used together, but will only display the correct frequency and properly track across the band with re-alignment and/or significant modification of the VFO.

The very first Swan models built (120/140/175) use a 5.775-MHz IF, however this was switched to 5.500 MHz in the later units to help discriminate against unwanted signals that were reported to be leaking-in near the 5.775-MHz frequency. The IF was then switched in the multi-band 240, 350, 400, and 500 models to 7.1745 MHz because in the VFO and carrier oscillator signal mixing process the same VFO frequency can then be used for both 40 and 80 M (depending on which side-band is used); thus, only 4 VFO ranges are required for these multi-band transceiver models. Because of unwanted interfering signals in the front-end circuit stages, RF traps were included. In all later transceiver models (except for the 250 and 250 C, which used the 10.700 and 10.900-MHz IF) the IF was changed to 5.500 MHz; that design required 5 VFO ranges but it was found that unwanted signal leaks were still problem so various types of traps were also included in that design.

There may be some confusion terminology used by Swan in their definition of the IF. Initially Swan sometimes referenced the IF filter to the center frequency of its bandpass (model 240 transceiver), but later on this was changed to reference a nominal frequency on the lower filter skirt, typically in the vicinity of the ~20 dB down point. Thus, an early IF filter designation of 5.1745 MHz is in fact the same as the later 5.173 MHz, which is referenced to the lower skirt frequency (5.173 MHz + 1,500 Hz).

IF Filter Characteristics. All transceiver models use a crystal filter at the IF to provide signal selectivity. The filter evolved from a discrete 4-crystal design (4 pole with ~24-dB/octave skirt slopes) to a discrete 5-crystal design (also 4 pole, but with an extra shunt crystal to further suppress any residual carrier oscillator signal from the balanced modulator) to an encapsulated 8-crystal design (8 pole with ~48-dB/octave skirt slopes), and finally to the optional encapsulated SS-16/B "*super selective*" filter (16-crystal with a ~96-dB/octave skirt slope). That distinctive filter (twice the height of the stock unit) has much steeper skirts with superior out-of-band signal and noise rejection than the stock 8-crystal encapsulated filter and was available for the mid to late production HF transceiver models (both 5.173 and 5.5-MHz IF models). The 250 and 250C six-meter transceivers both used an 8-crystal encapsulated crystal filter; a SS-16 type filter was not available for that IF (10.7/10.9 MHz). Additional filter design comments regarding the shunt crystal operation in the discrete 5-crystal design used in the 240 and early version 350 transceiver models are given in Section A.10.7; also discussed is a modification of that circuit that reuses the shunt crystal as part of a tunable IF notch filter modification. Additional general comments on filter design and terminology (poles, zeros, etc.) are given in the end of this subsection.

The very earliest mono-band models transceiver models (120, 140, 175), the 240 model, and the early version 400 and 350 transceiver models produced prior to mid 1965 all use 4-crystal filters that have an IF 6-dB down bandwidth of 3 kHz. Beginning in mid 1965, the encapsulated 8-crystal filter, with a 2.7-KHz, 6-dB down bandwidth was used as standard in all subsequent transceiver models. The optional SS-16 filter also had a 2.7 kHz, 6-dB down bandpass. Thus, all of the later encapsulated 8/16 crystal filters have a 2.7 kHz bandwidth; except for the encapsulated 8-crystal filters used on the 250/C, which have a 2.8-kHz bandwidth. However it should be noted that versions of the SS-16/B filters designed for the nominal 5.5-MHz IF apparently had slightly different filter center frequencies that could require the installation of different carrier oscillator crystals from those provided with the stock 8 crystal filter – see the additional discussion in SS-16 IF Filter Section 4.5.

The 5.173-MHz encapsulated filters are directly interchangeable with the 5.1745-MHz, four discrete-crystal filter designs (3-kHz BW) used on the early version 350 and 400 transceivers. Even a later 5.5-MHz encapsulated IF filter can be used, however the carrier oscillator crystal(s) must be changed, the IF stages and balanced modulator transformer must be aligned, and the VFO calibrated accordingly.

Shunt Crystals. It has been reported that the Swan encapsulated 8 and 16-crystal IF filters utilize two and four of the crystals respectively for CO shunt purposes, similar to what was done with one crystal of the 5 discrete-crystal design, and therefore these filters might have only 6 and 14 poles respectively. However careful examination of the Swan published IF filter skirts clearly shows that all 8-crystal encapsulated filters have 8-poles since their filter skirt slopes are ~48 dB/octave and therefore use 8 crystals for filter bandpass formation. Likewise the SS-16/B encapsulated 16-crystal filters have 16 poles since their filter skirts slopes are ~96 dB/octave and therefore use all 16 crystals for filtering purposes. In addition, in the case of the SS-16, Swan literature explicitly and repeatedly states that the unit is a 16-pole filter design. Therefore, if shunt crystals are incorporated into these designs, they are in addition to the 8 and 16 crystals used for filter bandpass formation.

Filter Design Comments. The number of poles in a filter is generally determined by the total number of crystal, RC, RL, or LC components used in its construction. The terms “poles” and “zeros” are associated with the

Table 2-2 Summary of Transceiver Intermediate Frequencies

MODEL	BAND COVERAGE	IF (MHz)
SW-115	Mono-band, 15 meter	
SW-120	Mono-band, 20 meter	5.775/5.5/5.173*
SW-140	Mono-band, 40 meter	5.775/5.5/5.173*
SW-175	Mono-band, 75 meter	5.775/5.5/5.173*
SW-240	3 band, 20-40-75 meter	5.173
160/X	Mono-band, 160-meter	5.500
250/C	Mono-band, 6-meter	10.7/10.9
260	5-band, 10-15-20-40-80 meter (Cygnet)	5.500
270	5-band, 10-15-20-40-80 meter (Cygnet)	5.500
270B	5-band, 10-15-20-40-80 meter (Cygnet)	5.500
300B	5-band, 10-15-20-40-80 meter (Cygnet)	5.500
310	Single fixed frequency HF	5.600
320	Dual fixed frequency HF	5.600
350	5-band, 10-15-20-40-80 meter	5.173
350C	5-band, 10-15-20-40-80 meter	5.500
350A/B/D	5-band, 10-15-20-40-80 meter (Cygnet-like design)	5.500
400	5-band, 10-15-20-40-80 meter	5.173
400E/F/G/H	Multi (5/12) fixed frequency HF	5.600
500	5-band, 10-15-20-40-80 meter	5.173
500C/CX	5-band, 10-15-20-40-80 meter	5.500
600T	5-band, 10-15-20-40-80 meter transmitter	5.500
600R	5-band, 10-15-20-40-80 meter receiver	5.500
700CX	5-band, 10-15-20-40-80 meter	5.500
700S	5-band, 10-15-20-40-80 meter	5.500
750CW	5-band, 10-15-20-40-80 meter	5.500
1011	Mono-band, 10 meter transmit, 10 & 11 meter receive	5.500

* See comments in Section 2.3.1

mathematical transfer functions (i.e. differential equations) that define the theoretical filter shape and characteristics (bandpass frequencies, bandwidth, ripple, slope, phase response, etc.), which are implemented by the physical components. One crystal is required for each pole in the network, or for a LC filter, there is usually one inductor/capacitor pair per pole. In general, each pole generates a 6-dB/octave amplitude roll-off, thus a 4-pole low pass filter has a ~24-dB/octave roll-off above or below its design frequency. A 6-pole filter requires either six crystals or six LC sections and has a ~36-dB filter skirt roll-off, and so on. The effect of the number of poles on the steepness of the filter-skirt roll-off is clearly seen in the differences between the standard stock 8-crystal, optional SS-16/B 16-crystal, and mechanical and LC filter design curves, as shown in Fig. 4-2.

2.2.4. Transceiver Intermediate Frequencies

All Swan tube radios are a single conversion design, meaning the audio base-band and RF signals are both translated to one fixed intermediate frequency (IF), which permits; (1) high RF amplification, (2) good selectivity using a single fixed-frequency/bandpass IF crystal filter, and (3) high stability. Consequently, the VFO signal frequency used for each band must be adjusted such that during the mixing process the lower or upper sideband of interest is always precisely positioned so that it passes the signal information through the IF filter's bandpass. The intermediate frequencies used in the various transceiver models are listed in Table 2-2 and Table 4-1 in the VFO Section 4.14.1 lists the corresponding IFs for which the external VFOs are designed.

VFO Mixing Process/Implementation. To obtain the proper operation frequencies across the amateur bands in the 5-band Swan transceivers, the VFO uses four different frequency ranges in early models (the same range is used for both 80 and 20 meters) and five different ranges in later models. Most other manufacturers of that period employed a single frequency range VFO that is used for all bands resulting in a VFO that is easier to implement, but costlier than the Swan approach. For example, the Drake TR-3 VFO tunes from 4.9 to 5.5 MHz for all bands: (1) for 80 and 20 M operation the VFO output is mixed with a 9 MHz IF oscillator (lower and upper sidebands respectively) and (2) for the 40, 15, and 10 M operation the VFO signal is first mixed with a separate crystal oscillator and heterodyned in a pre-mixer circuit – this pre-mixing in effect performs the same function as the frequency shift in the multi-range VFO used in the Swan design described below.

During receive, the VFO signal mixes with the RF signals received through the band-pass of the tank's tuned π network (except in the 250/C which bypasses the tank), creating the sum and difference signal components that translates those RF signals to the fixed frequency of the IF crystal filter. The output of that filter passes only the RF sideband information of interest (lower or upper) for subsequent mixing with the carrier oscillator signal, which in turn translates the signal down to the base-band audio frequencies that are heard on the speaker.

During transmit, the VFO output is mixed with the IF crystal filter's output (containing the base-band audio that had previously been mixed with the carrier oscillator to translate it up to the IF filter's bandpass), which translates the IF signals to the actual operational RF frequency where it is then feed through the driver to the PA.

When tuning, say a model 400 transceiver (5.173-MHz IF) for operation on 80 or 40 meters, the VFO frequency will be ~5,173 kHz higher than the operational RF frequency. For operation on the upper three HF bands the VFO frequency will be ~5,173-kHz lower. Therefore, when you tune through the 7.0 to 7.3-MHz band, the actual VFO frequency will vary from 12,173 kHz to 12,473 kHz. An external VFO designed for a 5,173-kHz IF (Table 4-1) will not properly work with transceivers using a 5,500-kHz IF (Table 2-2). In addition to this obvious major 327-kHz frequency offset, there will also be a linearity discrepancy across the tuning range.

USB/LSB. While you are free to operate either lower sideband (LSB) or upper sideband (USB) within any frequency band approved for that modulation mode, by convention, on the 80 and 40-meter bands, "normal" SSB signals are transmitted using the LSB audio information and the highest three bands are transmitted using the USB. The VFO frequency is completely independent of LSB or USB selection. During either receive or transmit, normal or opposite sideband operation is dependent only on the carrier oscillator (CO) frequency. Using the standard LSB/USB convention, the normal sideband switch setting positions the CO frequency so that the appropriate sideband information falls exactly within the IF crystal filter's bandwidth during the mixing process. When the opposite sideband is selected, the CO frequency is shifted ~3.3 kHz (e.g. from 5,173 kHz to 5,176.3 kHz). This frequency change automatically positions the opposite sideband within the filter's bandwidth.

Additional information on the relationship among the audio information, VFO, and carrier oscillator signals, USB/LSB selection, etc. during the mixing and transmission processes is given in the Transceiver Signal Processing Section 6.2.8. Review of that information should assist in gaining a fundamental understanding of how and why the specific VFO and carrier oscillator frequencies are selected.

2.2.5. First Rig Suggestions

Amateurs considering entering the Swan tube transceiver market frequently ask, "*What would be a good starter rig?*" In response to such questions, Swan owners and users have recommended the transceivers listed below. Regardless of the model selected, it's always a good idea to be sure the radio you are considering has not been heavily modified. This is especially true if the modifications are non-standard (i.e. ones that are not a Swan service bulletin or performance upgrade modification) and if there is no accompanying documentation. You will find units with additional front panel and rear apron switches, stand alone solid-state circuit board additions, and various wiring and parts substitutions. Obviously, such units can be exceedingly difficult to repair and maintain.

- ***240***. While it's only a three-band transceiver, the 20, 40, and 80-meter bands are those favored by many amateurs. It does require an external power supply. An optional TCU (VFO) is available, but it's quit rare.
- ***260, 270, 300***. For compactness and simplicity, these Cygnet transceivers with a built-in power supply are all good candidates as first rigs. The 260 even includes a hard-wired microphone.
- ***500C***. This model closely rivals the 400 model as one of the best dollar values (relative to production costs) and easiest to maintain of all Swan transceivers, particularly the early version 500Cs.
- ***Pre 700CX***. For the first time Swan owner who wishes to maintain his own or her equipment, any of the two-tube PA radios made prior to and including the Swan 700CX would be a good choice.

2.3. Selected Transceiver Comments

As indicated by Table 2-1, Swan produced quite a large number of tube-design transceiver models over its 20-year life span. If you total all of the various tube models and variants (e.g. 350 and 350C; 350A, 350B, and 350D; etc.) along with the all solid-state transceivers models introduced beginning in 1971 through the Astro models of the early 80s and the more esoteric commercial models, such as the MHF-650, Swan easily produced upward of 40 specific models. If one also includes all of the design versions within a specific model (i.e. three versions of the 240, five versions of the 260, seven versions of the 500C!), the number of unique designs truly becomes prodigious! Fig. 2-1 provides an overview of the production and sales time-line of most of the models. To assist in providing a general distinction among the various models, they have been roughly grouped into six general categories with similar characteristics, namely:

- The ***Mono-Band*** transceivers which have a single or dual-tube PA and require an external power supply,
- The ***Tri-Band*** transceiver (model 240) which has a single-tube PA and requires an external power supply,
- The ***High Power*** 5-band transceivers, which have a dual-tube PA and require an external power supply,
- The **Cygnet** and **Cygnet-like** design 5-band transceivers, which have a single-tube PA and an internal power supply (The 260, 270, 270B, and 300B were specifically called "*Cygnet*" with a corresponding front panel nameplate affixed; the 350A, 350B, and 350D models are classed as "*Cygnet-like*" even though they have a later production date and are not specifically named Cygnet because they are similar in design and function to the earlier Cygnet models.),
- The stand-alone receiver and transmitter ***Twins*** *(*models 600R and 600T – dual-tube PA transmitter), that also include individual internal power supplies, and finally,
- ***Commercial/Military*** transceivers that are channelized. Channelized means it is adjusted to operate at a limited number of pre-set frequencies, however it can still be tuned-up anywhere throughout the various frequency bands.

Swan was not rigorously consistent with model numbers. While some model lines were an orderly evolutionary progression within the same design family (e.g. 500, 500C, 500CX), others model series represent significantly different designs. For example, the closely related dual-tube PA, high power, 350 and 350C transceivers are distinctly different and separate designs from the single-tube PA, lower power 350A/B/D, as suggested by their dissimilar production dates shown in Fig. 2-1. The 350A/B/D are in fact closely akin to the Cygnet design series (260, 270, 270B, and 300B). Another example of this model numbering inconsistency is the vast differences between the 300B, a 5-band HF Cygnet design, and the 300, 310, and 320 model family of channelized commercial transceivers.

2.3.1. 115, 120, 140, 175 (Early Mono-Band)

Mono-Band Models. While Swan's mono-band transceivers include the SW-115, SW-120, SW-140, SW-175, SW-160/X, 250/C, and 1011/B, these models actually represent a number of distinct families, each with its own appearance and design characteristics. The early mono-band models (SW-115/120/140/175) are closely related contemporaries (1962) while the SW-160/X, 250, and 1011 were produced during the mid production years and each has unique characteristics. Swan did produce other mono-band transceivers, however they were either citizen's band (1046) or all solid-state 2-meter VHF and HF designs (such as the MX-40 and MX-80).

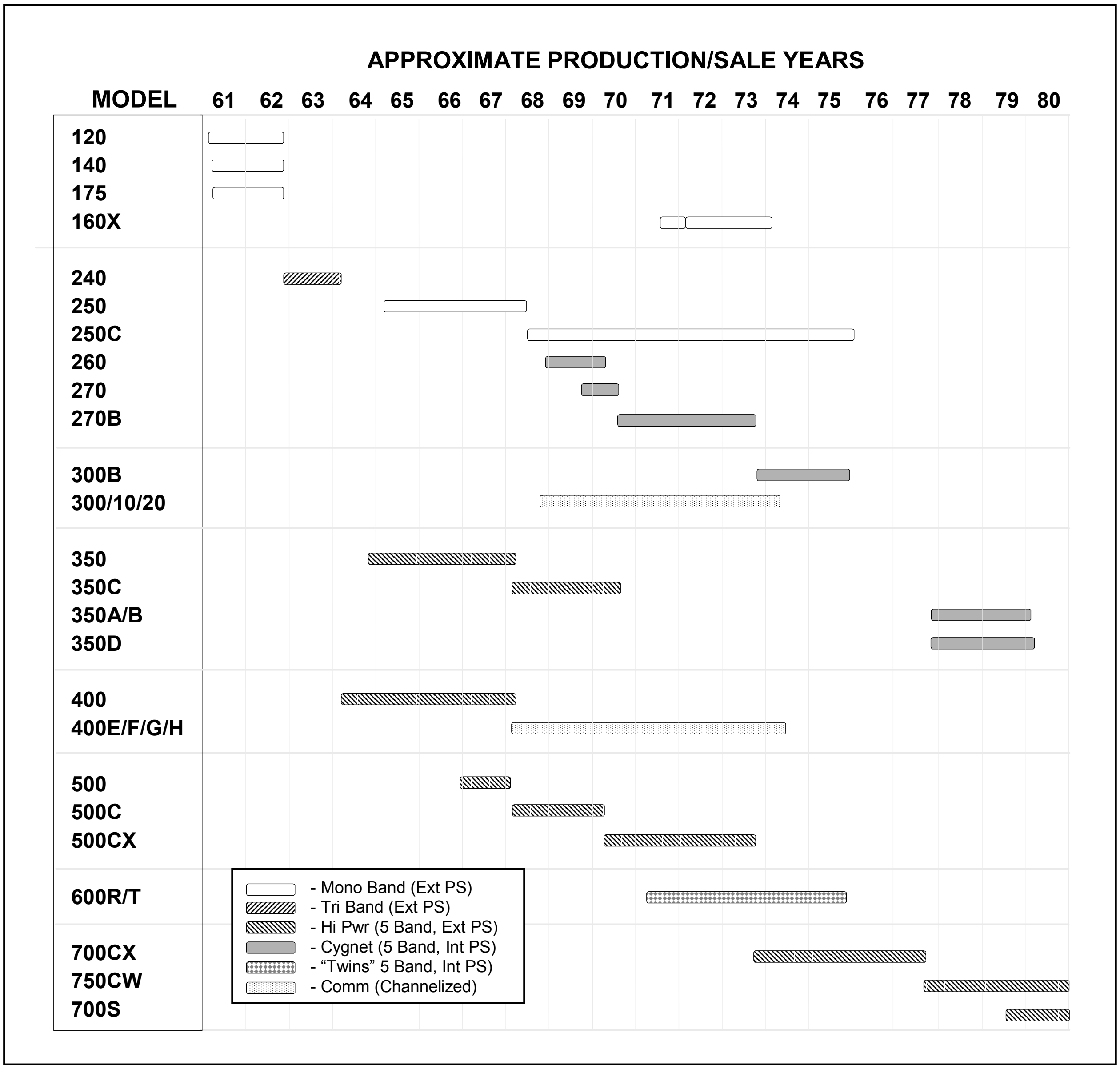

Figure 2-1 Swan Model Production Date Summary

Early Mono-Band Models. These were the very first transceiver models built by Swan Electronics. As noted above, the SW-120, SW-140, and SW-175 are closely related and even share the same Operation Manual, in which they are referred to as the "*series 100 SSB transceivers*." The manual is fairly austere, consisting of only 15 pages and 3 inserts. The early mono-band transceivers were built from 1961 through the end of 1962. They are all rated at 240-W dc input peak envelope power (PEP), use a single horizontally mounted 6DQ5 tube in the power amplifier, and were built for any one of four bands, with the last two digits of the model number indicating the band in meters, namely the 175, 140, 120 and the extremely rare (and maybe even extinct) 115.

The first units built had a gold colored front panel color scheme, while on later units it was changed to a very light gray panel. Since a very late dated schematic (9/27/62) is labeled as D, there may have been four versions produced, although that might not be true for all models since these three models were phased in over a short time period.

Tune-Up Power Issue. While subsequent single-tube PA mono-band models (e.g. Cygnets) switch in a cathode or screen resistor when in the TUNE mode to limit power during tune-up and hence minimize the potential of damaging the PA tube, that is not the case with the early mono-band models, so use extra care (short tune-up durations) when tuning-up.

The 12AV6 AF Oscillator tube (V15) shown on the schematic of the model SW-120/140/175 transceivers was only included in the initial version. It is used as an audio oscillator that is connected to the microphone amplifier circuit in order to provide a tone for transmitter tune-up. Since later versions were modified to use the offset carrier balance method for tune-up, that tube became superfluous and was removed.

IF Comments. These models all have a 3-KHz IF bandwidth filter. Two different IFs were used as the design evolved. The very first versions use a 5.775-MHz IF and in the last version it was changed to 5.500 MHz (the joint 120/140/175 Operation Manual's schematic (D, date 9/27/62) clearly labels the IF filter as 5.5 MHz), reportedly to help discriminate against unwanted signals that were "leaking" in near the 5.775-MHz frequency.

Power Supply Issues. All early mono-band transceiver models required an external power supply. Since Swan did not produce an ac power supply at that time, they recommended a Heathkit HP10 (12 V) or HP20 (117-V ac). However there was a 12-V supply available from Swan in 1962 that sold $100. For operation with homebrew or other power supplies, the manual specifies minimum, nominal, and maximum operating voltage sets, corresponding to HV levels (PA plate voltages) of 250, 800, and 900 volts, along with associated screen and bias voltages. The dc input PEP (peak envelop power) capability will vary accordingly.

Swan ac power supplies can operate these transceiver models, however a simple modification has to be made to the transceiver and, in most cases to the power supply, depending on model. Regardless of the Swan power supply used, there needs to be a jumper installed between the transceiver's Cinch-Jones connector between pins 7 and 9. Pins 7, 9, and 11 should all be un-used on that connector. The transceivers expect to see ~+275 volts (MV) on pin 10 of that connector. However all Swan power supplies route the medium voltage (MV) to the transceiver via pin 9 and also include an internal jumper within the power supply's Cinch-Jones plug between pins 7 and 10. Thus, with the added jumper between pins 7 and 9 on the transceiver's Cinch-Jones socket, the MV is routed from pin 9 on the cable to pin 10 on the transceiver socket. On later model transceivers, the MV is routed to pin 10 using a similar Cinch-Jones connector jumper (e.g. 500CX) or through other transceiver internal circuit wiring and switching (e.g. 240, 400).

Since the SW-117AC (designed specifically for use with the follow-on tri-band model 240 transceiver), has output voltages nearly consistent with those required for early mono-band model transceiver operation, no additional modification are needed to that power supply (the 117AC schematic, along with Cinch-Jones connector pin wiring, is shown in Fig. 3-5). If a later model power supply, such as the 117X is used, the bias supply voltage is a bit too high and it should be reduced with a simple modification to the bias output circuit. Insert a ~1.5-kΩ, 1-W or 2-W resistor in series with the bias output. The 4.7-Ω relay resistor is also a bit low, since only one relay is used in the early mono-band and tri-band transceiver models, and should be replaced with a 15-Ω value, as is used in the SW-117AC power supply. See also the discussion is the Power Supply Commonality Section 3.2 and the model 117AC Power Supply Section 3.3.5.

SW-115. The 15-meter model 115 mono-band transceiver should probably be considered more of a developmental production prototype than a commercial production model, since reportedly only four units actually left the factory. The VFO tube operated at too high a frequency, resulting in a badly drifting VFO frequency that was not stable enough to provide satisfactory operation. Obviously, in the very unlikely event you run across one of these in any condition, rescue it for posterity.

SW-120. The SW-120 model is a single-band transceiver operating on 20 meters. There were reportedly three versions made of this model. It was the very first transceiver built by Swan, introduced in early 1961, and initially sold for $275. The first nine units were serial numbered from 101-1 to 109-1.

SW-140. This transceiver, a 40-meter variant of the basic SW-120 design, was the second model built by Swan. As with the 120, it was produced during the 1961 to 1962 period. The first unit of this model built and the tenth transceiver built by Swan was serial numbered 110-1.

SW-175. This transceiver is the 75-meter variant of the SW-120 and was the last of the initial group of mono-band designs, produced in 1962.

2.3.2. 160, 160-X (Mono-Band)

While the SW-160 and 160-X are 160-meter mono-band transceivers and share the same 100 series designator as the early SW120/140/175 models, they bear little resemblance to those units in either appearance or design. The baseline 160 model was introduced in the 1971 time frame and sold for $429 in August 1971. Since only ~450 units were built, it is a relatively rare transceiver. The 160-X model replaced the baseline 160 in 1972 and also sold for $429 (or $489 when factory equipped with the SS-16B filter). The 160/X uses a 5.5-MHz IF (2.7-kHz filter bandwidth), covers the frequency range from 1.8 MHz to 2.0 MHz, uses a pair of 6LQ6 PA tubes in the PA, and includes a front panel switch for selecting SSB dc input PEP levels of 50, 100, 200, or 400 W. An external 117X(C) or equivalent power supply is required. A matching external VFO (the model *160 vfo*) was available to permit split-frequency operation.

2.3.3. 240 (Tri-Band)

The SW-240 was Swan's first multi-band and only tri-band SSB transceiver, covering the 20, 40, and 75-meter bands. This transceiver contains no S-meter function. The 240 replaced the early mono-band models (120, 140, etc.) and was built from November 1962 through February 1964, when it was subsequently replaced by the 400 model 5-band transceiver. An external power supply is required. As with the early mono-band models, the power amplifier uses a single, horizontally mounted 6DQ5 PA tube and the SSB dc input PEP is specified as either 240 or 180 W, depending on the power supply's PA plate voltage level (800 or 600 V respectively).

Two accessories were offered for this unit, the matching 117AC power supply and the TCU (external VFO), both of which matched the light gray color scheme of the 240's front panel.

Reduced Tune-Up Power. This model, like many of the other single-tube PA designs, limits input power when in the TUNE mode. The 240 switches a resistor in series with the PA tube screen grid to decrease power and protect that tube during tune-up (most other later single-tube PA models switch in a cathode resistor to accomplish the same objective). Since this dc input power limiting resistor is not used during normal (CW or SSB) operations, the actual operational input and output powers will be greater than that achieved during tune-up.

However, the amount of PA screen voltage decrease during tune-up is dependent on the model version. For a specific exemplar of the earliest version, this resistor reduced the screen voltage from ~206 V to ~184 V – in that version a 6-kΩ resistor is switched in series with the screen during tune-up and the manual specifies tuning-up loading to a ~275-mA cathode current dip when in the TUNE mode. For a later version production unit, the screen voltage dropped from ~201 V to ~114 V – its manual specifies tune-up loading to only ~160 mA in the dip. That version switches in a 6-kΩ and 10-kΩ resistive voltage dividing network (with the 6 kΩ in series with the screen grid and the 10 kΩ resistor connected to ground) when the mode switch is in the TUNE position, causing a ~60% decrease in screen voltage (the measured drop was 57%, in very close agreement to the expected value). For the later version (160 mA in the dip), expect to see about 60 or 65 W RF output in the TUNE mode. For any of the versions, expect to achieve a SSB PEP output in the 100 to 120 W range for a rig in average condition.

Version Differences. There were three different versions and schematics (labeled A, B, and C) and alignment procedures applicable to this model. The earliest version has: (1) a series of circular ventilation holes punched in the upper sides of the cabinet, (2) a surface mounted commercial off-the-shelf direct reading 0-400 mA reading cathode current amp-meter (similar to that used in the early 120/140/175 mono-band models), (3) a limited frequency converge (i.e. the 7.000 to 7.050-MHz range was not covered), and (4) uses a single tone, very light blue-gray front panel color scheme with a black horizontal accent/trim strips. Since the direct reading meter wasn't back-lighted, a notch was cut into the front panel directly above the meter and a small angled metal plate installed to reflect pilot lamp light onto the meter face (the interior top-view photograph in later version manuals still show this original configuration, even though the front cover shows the updated meter described below).

The later version(s) use: (1) a two-tone light blue-gray color front panel color scheme (with black accent strips), (2) has slotted ventilation holes along the upper portion of the cabinet sides extending onto the top surface, (3) uses an indirect sensing voltmeter (a resistive network is used to establish calibration for a low current voltmeter, similar in concept to the meter sensing circuit design employed in later transceiver models) with a matching plastic covers/bezels over the tuning dial and meter that transitioned from a rounded-corner configuration to a square cornered design in the last version (similar to that used on the later transceiver models), and (4) has full-band frequency coverage. Two different tubes were used in the VFO, either the 6AU6 or the 12AU6, depending on version.

Common Problems/Issues. There are a number of common problems or issues encountered with this model. These include:

Front Panel Cleaning/Wear. A common cosmetic problem with this model is excessive wear of the front panel labels (either the white or black printing on the lower or upper portion of the panel – one section may adhere much better than the other) and horizontal/boarder black accent stripes. These features can easily be damaged or removed during cleaning, even when using the mildest cleaning products. Use extra care to prevent damage – test a small portion and use Q-Tips to clean around the labeling.

It is not uncommon to see this model with ugly Dynamo or masking type labels affixed to the front panel, replacing the labeling inadvertently wiped-off during cleaning. Other than completely re-silk-screening, a costly proposition, the only other alternative is to affix new labeling. One option in re-labeling that has been used successfully and looks very presentable is to: (1) remove all remaining original labeling, (2) use a computer graphics program to generate the appropriate sized text and graphics, (3) print new labels on a clear Mylar adhesive backed printer sheet (available at larger copy stores) or on specialized decal paper (available at *http://www.decal-paper.com/*), and finally, (4) cut-out the labels with a X-Acto® type knife and carefully affix the new labels/symbols to the panel – a tedious process.

Standby/Filter Switch Operation. The Swan 240 (and the 400) uses two inter-connected switches to control power distribution – the FILAMENT on-off switch and the SUPPLY OFF switch on the mode control. The manual incorrectly states and the front panel switch labeling suggests that only filament voltages are present when the filament toggle switch is up (FIL ON) and the mode switch in the SUPPLY OFF position. This is incorrect. All power supply voltages are present within the transceiver. The Swan 240 (and 400) employed the SUPPLY OFF function switch only to cut-off the 275 V at the switch when in the OFF position. This switching arrangement was deemed helpful in keeping the filaments warm for quick operation and especially for having a fully warmed up VFO. Since the MV is unloaded when in SUPPLY OFF mode, its level will increase to ~325 V. This dual switch system was discarded with the introduction of the Swan 350.

Power Supply Issues. If this transceiver is used with a power supply that is intended for later transceiver models (e.g. 350, 400, etc.), such as the 117X, the bias supply voltage will be far too high for the 240. Operation with older transceivers requires a 1.5-kΩ (or thereabouts), 1 or 2-W resistor in series with the bias output. The resistor can be inserted directly in the power supply or, if the supply is also to be used with a later model transceiver, it can be placed inside the transceiver; just break the bias supply line directly from Cinch-Jones terminal 3 and insert the resistor. The relay resistor in the 117X type power supplies also should be changed since the 240 employs only one relay versus the two used in later transceiver models – the 4.7 Ω resistor needs to be changed to a 15 Ω unit. See also the related discussion in the 117AC Power Supply Section 3.3.5.

The measured unmodified bias voltage from an 117X of about –141 V (in receive mode) decreased, after this modification (a measured 1.27-kΩ resistor was used), to –126 V (PS-4*, Table 3-5). However these measurements might be a bit higher than normal, as typical 117X measurements are in the 132 V range (unmodified), which should result in a modified BIAS voltage of ~–117 V. For comparison, the measured BIAS voltage from an 117AC power supply was –99.4 V (in receive mode), but the HV and MV levels are also a little lower than that of the 117X (Table 3-6). In transmit mode, the measured BIAS levels will drop a couple volts from these values at full output power. This lower voltage range obtained from a 117X type supply with bias dropping resistor installed is much more compatible with the maximum power supply voltages recommended in the manual, namely, HV_{max} = 1000 V, MV_{max} = 325 V, and $BIAS_{max}$ = –120 V.

Low Carrier Level Tune-up Issue. Note that you may not be able to tune-up reliably using some alternate low-level carrier insertion methods (Section 6.4). For two versions of the 240 transceiver (early and late) that functioned and operated properly when tuned-up in accordance with the manual's procedure (i.e. TUNE mode), it was found that when tuned-up using very low to moderate carrier insertion levels, a cathode current dip was not achieved at resonance, but rather an increase in cathode current was noted, which also corresponded to maximum RF output power, suggesting proper tuning. At high carrier insertion levels, tuning was normal and as expected (with a dip at maximum power output), similar to that achieved when in the TUNE mode.

Neither the cause of this behavior was reported nor its universality over all units confirmed. However, such behavior might perhaps be associated with an inherent design related self-oscillation that occurs under such low-level carrier conditions and the associated LOAD and PLATE control tune-up positions. In any event, it is highly desirable to use an external wattmeter to ensure that it is tuned to near the maximum power point and to prevent excessive loading.

6DQ5 Tube/Filament Wiring Issues. The tube filament wiring configuration used in this transceiver is quite unusually in that it depends on a number of parallel-wired miniature tube filaments in series with the PA tube's filament to obtain the proper voltages. There is a problem with some GE brand (and other) 6DQ5 tubes in that two identical looking and labeled versions with different filament currents were produced. Because of the parallel/series tube filament wiring design used by Swan, this filament voltage is critical and can cause operational problems – see the related discussion in the 6DQ5 Section 8.6.3. The physical PA design is also unusual in that the tube is mounted horizontally, so if it is abused during operation it may have an increased potential for electrode sag with excessive heat and perhaps an increased likelihood of inter-element shorting.

Filament Voltages. As noted above, you may also find that some 6DQ5 tube brands do not yield the ideal 50% split in the filament voltages between the 6DQ5 tube and the 9 paralleled miniature tubes that are in series with it (i.e. V5, V7-14). For example, with a measured 13.8-V ac filament supply voltage, a Sylvania brand 6DQ5 tube yielded 8.6-V ac across its filament and only 5.4-V ac on the parallel tube filaments. So it's possible that a number of manufactures, in addition to GE, somewhat reduced the high 2.5-A filament current specification of the 6DQ5 to save on heat and power consumption, assuming that the tube would not be operated in series with other tubes having dissimilar current requirements.

It has been reported that some makes of the 7360 used in the 9 parallel-wired mini-tube series can also draw filament currents much lower than the specification nominal (0.35 A). However, even if that were the case, because of the multiple parallel tubes and its much lower current draw than the 6DQ5 (0.35 A versus 2.5 A), the impact of even a 50% reduced current would be minimal.

Filament Re-Balancing Modification. What can you do if your filament voltages on this tube series are excessively unbalanced? Perhaps nothing if the transceiver's been operating proper for an extended time with a somewhat higher voltage difference, but certainly if its on the order of say only 4.5-V ac on the parallel tube filament string and 9.3-V ac on the 6DQ5, you're in trouble. The 4.5 volts is so low that that the tubes' electronic performance may become erratic and the voltage on the filament of the 6DQ5 is so high as to cause undo stress. Something should be done. Of course, putting in a 6DQ5 tube with the proper filament current draw is the easiest and best solution.

But what is you have a rack of four pristine GE NOS tubes that, when checked in the rig, have pin 2 filament (filament pin 7 is connected the full filament voltage, 13.8-V ac in this case) voltages of only 4.3, 4.4, 4.4 and 4.6-V ac? One solution is to rebalance the current draw between the 6DQ5 and the parallel tube string by rewiring the 12AU7 (V11) and 12AX7 (V12) filaments, both of which are part of the paralleled tubes, from 6.3-V ac to 12.6-V ac filament operation. With 6.3-V ac operation of these tubes, the two ends of the filament (pins 3 and 4) are tied together and grounded, and pin 9, the filament center tap, is used as the 6.3-V ac feed (or visa versa). This will remove a total of 0.6 amperes of current from the parallel tube string side.

You can easily test the effect of this modification prior to doing it by simply removing each of the V11 and V12 tubes sequential from the rig while powered-up in the standby mode. In a test case, with a low current GE 6DQ5 installed, the voltage level on pin 2 was 4.63-V ac, with 13.8-V ac on pin 7 (therefore 8.17-V ac on the 6DQ5's filament). With the 12AX7 removed, the pin 2 voltage increased to 5.12-V ac and with the 12AU7 also removed, it further increased to 5.89-V ac.

While this is probably satisfactory, the voltage split between the filaments can be further improved by wiring a resistor in parallel with the 6DQ5 filament. With the filaments of V11 and V12 rewired for 12.6-V ac operation as discussed above, and a 50-Ω resistor installed across the filament, the voltage on pin 2 increased to 6.25-V ac (with therefore 7.55-V ac across the 6DQ5's filament). While a somewhat lower resistance can be used to achieve an even better a filament voltage balance, because of its large current draw, the required resistor's power dissipation rating becomes prohibitive. In the case of ~50 Ω, the power dissipation is 1.125-W and a 2-W resistor is required. If a 10- Ω resister yielded a perfect 6.9-V ac voltage split, then a 4.6-W power dissipation would be required and a resister rated at least 6 W or greater would be prudent to permit an adequate safety margin.

Neutralization/PA Oscillation. The 240 is a bit unusual in that it contains an adjustable neutralization capacitor for both the PA tubes and the driver tube. On most models, the driver tube's neutralization capacitor is a fixed value (see Section 7.7 for further information on 240 driver neutralization). Note that there are two forms of the unwanted, autonomous and self-sustaining power amplifier oscillations: (1) a *self-oscillation* whose frequency is at or near the tuned frequency, and (2) *parasitic oscillation*, whose frequency is much lower or higher than the tuned frequency (normally much higher and usually in the VHF region).

There are many problems that can cause or contribute to self-oscillation. Just how bizarre some causes can be is illustrated by personal correspondence from Swan to the owner of a late version 240 (one of the very last off the production line), in which the following advice is given to correct a persistent self-oscillation problem: "*Most certainly your rig driver or final stage is self oscillating. This problem can sometimes be a real stinker to track down, but we have found in most all cases that it can be traced to the grounding of the band-change switch. There are ground loops which are often reduced or illuminated in strange ways. You will note three beryllium copper straps on the band change switch. Try prying (up) the loose end of these and letting them snap back a few times each. We found also that tightening the nuts on the ends of the supporting shaft through-bolts can be helpful. Also take two screw drivers and apply pressure on the supporting shafts of the band change switch inward (toward each other) using the edge of (the) chassis for leverage against the out-board shaft and the slots in the chassis for leverage against the in-board shaft. This sounds like it borders on sorcery, but after tracing the problem on several rigs, it appears to be the best answer.* (Dated Nov 5, 1964)"

IF Filter Alignment Comments. The IF filter alignment procedure specifies the use of a RF generator to inject a sinusoidal signal during transmit into the center of the IF crystal filter's bandpass to adjust the balance modulator's transformer and filter ripple. Unfortunately, this is a somewhat complicated procedure involving the actual measurement of the filter's ripple amplitude to determine its exact center frequency. The availability of a RF generator with an accurate vernier capability needed for these measurements may also be a problem for many owners.

Inspection of the manuals from later model transceivers (e.g. 500CX) shows that this area of the alignment procedure was revised to require merely injecting a ~1,500-Hz audio tone (the approximate IF filter's center frequency, relative to the 6-dB down frequency of its lower skirt) into the microphone input prior to adjustment and then merely adjusting the two coil slugs on the balanced modulator transformer for peak transmitter power output. This basically performs the same function as the RF signal generator approach and is certainly much easier to do.

CW Operation. While the SW-240 is not advertised as a CW transceiver, Swan did offer two options for CW operation in their Operation and Maintenance Manual.

(1) The first is to simply plug a key into the microphone jack (center contact and ground, sleeve unconnected), rotate the CAR BAL control full cw or ccw, and tune-up for maximum RF output. During CW operations, key closures activate the relay and transmits the unmodulated carrier; it automatically provides for break-in type operation, but it does not shift the frequency up ~700 Hz in frequency as is commonly done when in the CW mode. They claim the relay will follow fairly high speeds from a bug or electronic type keyer. Note that the specified keyed tune-up method circumvents the screen resistor normally switched in when in the TUNE mode, so use extreme care and short transmit periods during tune-up.

(2) The second method requires a minor modification that provides for grid-block keying. It specifies that the wire (white-black) in the cable harness leading to terminal 8 of the relay be broken and a closed circuit 1/4 inch jack be installed in series. The jack must be insulated from the chassis with shoulder washers since the dc potential on the jack is –45 V at low current.

Transmitter Control Unit (TCU). The SW-240 does have an optional TCU unit that provides split frequency external VFO operation, VOX capability, 100-kHz crystal calibrator, WWV or WWVH reception on 15 MHz, and extended CW band coverage in the 80-meter band. A minor modification to the SW-240 is required for TCU installation, as discussed in the TCU instructions. The transceiver's power supply (because of form-factor constraints, the 117AC will not fit, so it must be a modified 117B or 117X) may be mounted inside the TCU cabinet, which is physically the same size as the transceiver. No separate power supply is needed for the TCU. See Swan Newsletter, Issue 8, Section A.8.4 for additional details.

2.3.4. 250/C (Mono-Band)

The Swan 250/C models are 6-meter mono-band transceivers with specified dc inputs of 240-W SSB PEP, 180-W CW, and 75-W AM. Both models are somewhat atypical of Swan transceivers in that each uses a pair of 6146B tubes in the PA vice the sweep tubes used in most other models. There is a small IF deviation between the two models (10.7 MHz versus 10.9 MHz) – their IFs are significantly different from the HF transceiver models ~5.173/5.5 MHz). With both of these models, problems have been reportedly encountered when using two different versions of the PA tube (e.g. 6145A and a 6146B) – see the discussion in Section 8.6.13.

250. The selling price of the 250 when introduced in the spring of 1965 was $325.00. The 250 covers the 50 to 54-MHz frequency range, except for a narrow segment about 53.5 MHz. It uses a 10.7-MHz intermediate frequency filter with a 2.8-kHz bandpass. The baseline 250 does not include a S-meter function – front panel switching only permits the meter to monitor either relative RF power output or PA cathode current. As with all HF models, there were a number of versions and schematics. Design changes associated with the various versions resulted in an altered tube line-up. For example, when Swan found there was "*no measurable advantage*" in using the 6CW4 nuvistors in the RF amplifier and mixer, they were replaced in later versions by the 6HA5, designed specifically for VHF use.

In addition to the TV-2 two-meter transverter option, an external 210 VFO was made for the 250C, but it will also work with this model, providing the VFO adaptor socket is installed. If the frequency dial is to read and track properly, its frequency must be realigned, since the 210 was calibrated for the 10.9-MHz IF of the 250C rather than the 10.7-MHz IF used by the 250.

Modifications. A number of Swan recommended and other modifications were routinely made to this model. The early version had potential problems with sensitivity due to inherent defects in the design used in the initial production run. A service bulletin was issued that identifies those transceivers with this potential problem (those built before July 25, 1967) by their serial number and Swan offered a modification/upgrade kit to correct it. It is likely this modification has been made on most existing early-version 250s. Those with higher serial numbers and later production dates had that design change factory installed. See the Modification Sections 5.9 and 5.10 for further details. Another simple modification to increase sensitivity was also discussed in the "*Update Your Swan 250,*" article in *Ham Radio, December 1969*.

Additional modifications frequently made on this model include: (1) a S-meter circuit, since the lack of this function was considered a serious drawback to many users, (2) a CW side-tone (Swan issued a side-tone circuit modification and an additional one for the 350, which should also work in the 250, was discussed in *Ham Radio*, *June '72*, "*Ham Notebook"*, (3) a CW break-in capability, requiring the installation of the accessory socket and a VX-2 VOX, and (4) a crystal calibrator. When used with the optional TV-2 two-meter transverter, additional changes were frequently made to the transceiver's –10-V power supply (resistor values and the addition of 0.01-µF bypass capacitors).

Issues. Among the most common complaints with this model are poor frequency stability and inadequate carrier suppression. Poor transceiver frequency stability is discussed in Section 9.2. In the case of carrier suppression, a number of fixed were recommended, including: (1) two approaches suggested in a *Ham Radio*, *October '76*, "*Hints and Kinks*" article, (2) carefully matching (within 1%) the 100-kΩ balanced modulator resistors (some also recommended using matched resistors throughout that circuit, i.e. R1302/1303, R1305/R1309, and R1306/R1310), (3) carefully readjusting the carrier oscillator as outlined in the manual, and (4) using a sensitive external wattmeter rather than relying solely on the cathode current meter minimum during tune-up to ensure that that the CAR BAL is nulled as precisely as possible.

250C. The 250C is an upgraded version of the 250 introduced in 1968, with a list price of $420. This model uses a 10.9-MHz IF with a 2.8-kHz bandpass, rather than the 10.7 MHz used in the baseline 250. In addition to the full 6-meter band (50 to 54 MHz) frequency coverage, a number of improvements, most of which were frequently made post-production upgrades to the baseline 250, included: (1) a selectable USB/LSB, (2) a S meter, (3) a built-in 250-kHz crystal calibrator, (4) an improved frequency-readout scales and locking MHz dial, (5) an improved front-end using cascaded nuvistors, (6) a built-in accessory socket, (7) a change of the 7360 balanced-modulator tube to a 6JH8, (8) a rearrangement of the function and mode switches, (9) circuitry for inserting the optional noise blanker, and (10) the elimination of AGC switching in the IF amplifier, freeing that set of relay contacts for the S-meter circuit.

Optional accessories include a matching external model 210 VFO and an off-board NS-1 Noise Silencer, both designed for the 250C's 10.9-MHz IF.

CW Break-in Modification. Since the early Swan 250C does not have the key line connected for semi break-in CW operation when used with the VX-2 VOX, a modification needs to be made to the transceiver to enable use of this capability. If there is a wire connected to pin 5 of the VOX socket, the modification was made by a previous owner or was installed at the factory.

2.3.5. 260 Cygnet

The 5-band model 260 was the first of the "*Cygnet*" ("*Young Swan*") single-tube PA design transceivers, selling for $395 in February 1969. The primary marketing emphasis was on its potential for both base station and portable operation, since it was their first model to incorporate both internal ac and dc power supplies and even includes a carrying handle. However, those benefits came at the expense of a much lower power rating than the dual-tube PA base-station oriented models – it was rated at 260-W SSB PEP and 180-W CW dc input power. While it was produced for only about one year, from late 1968 to late 1969, it went through five design changes during that short time, with five different schematics. The first four versions have similar PA circuitry; a major change to that stage didn't occur until the final version. The earliest version used a 5-pin Cinch-Jones connector for battery power and included a 12-V dc/110-V ac switch for power source selection. Later versions used only a single 12-pin Cinch-Jones connector and did not include the power source switch since that function was provided through jumper wiring on the connector. This model is unusual in that it had the microphone physically hardwired to the transceiver.

The 260 did not include as standard equipment a meter to monitor PA cathode current but, along with early version 270 and the 600T transmitter (which also included a meter), was the only Swan equipment to use the 6FG6 Electron Ray Indicator tuning eye tube. The tuning eye system was used to adjust for maximum power during tune-up and was touted as a more accurate method to set SSB modulation levels because of its instantaneous response to varying signal levels. The manual also provided instructions for adding an external meter to provide quantitative PA cathode current readings, along with the corresponding tune-up procedures. In addition, the 260 did not include a separate audio gain potentiometer on the front panel, just a RF GAIN control labeled REC GAIN. A modification upgrade bulletin was subsequently issued to add a separate dedicated RF gain pot to the front panel, along with the circuitry to convert the REC GAIN pot to an audio-frequency gain control.

During tune-up on most Cygnet and Cygnet-like design transceivers, a resistor is switched in series with the cathode to protect the PA tube by limiting current. Therefore, the less than 100-W maximum RF output power seen during initial tune-up is less than the actual RF output power when operating either CW or SSB.

2.3.6. 270, 270B Cygnets

270. The 270 "*Little Giant*" was first introduced in late 1969 as an evolutionary improvement (more accurately, a replacement) of the 260 and was also sold for only about a year. Approximately 1,400 units were produced between September 1969 and October 1970. It was sold concurrently with the 260 for awhile, with the 270 marketed as a deluxe and the 260 as the standard Cygnet. The 270 sold for $529 and the 260 for $435 in December 1969. Like the 260, it's a single-tube PA, 5-band Cygnet design with a built-in ac/dc power supply and the same 260-W SSB dc input PEP rating as the model 260. Design improvements made to the 270 during its production include: (1) a separate AF gain control on later versions, (2) a normal/opposite sideband selector switch, (3) a DIAL SET control on later versions, and (4) the addition of a cathode current/S meter on later versions.

The earliest version of the 270 has: (1) no S or PA cathode current meter, (2) employs a tuning eye for PA tune-up (like its predecessor, the 260), (3) has a hardwired microphone, (4) has no separate AF gain control, and (5) has a plastic, rear-illuminated dial. Later versions of the 270 can be identified by the presence of a small rectangular PA current meter about the same size as the tuning eye, which it replaced, and a metal VFO dial scale, which is illuminated from the side. This dial change was reportedly made to make tuning smoother by reducing the potential for shaft binding. Later versions may also have a factory modification incorporated to improved carrier suppression (an additional capacitor and trim potentiometer in the balanced-modulator/input-transformer circuit).

As with most Cygnet-design transceivers, a resistor is switched in series with the cathode to protect the PA tube by limiting cathode current during tune-up. Therefore, the less than 100-W maximum RF output power seen during initial tune-up is less than actual operating power.

270B. About 2,200 model 270B radios were built from October 1970 through October 1973. During that time period minor design variations resulted in five versions (schematics). While the 270 and 270B were produced concurrently for a short time, the 270B is just a slightly stripped down version of the 270 that permitted Swan to sell it for a lower price. The only significant difference from the 270, other than minor circuit changes, is that it only has an internal ac power supply – it does not contain the internal dc-to-ac inverter. Since "*customer feedback on the 270 indicated only a small number of users were taking advantage of the built-in dc inverter . . .*" it was deleted from the 270B and the optional 14A plug-in dc module was offered for mobile use. Swan marketed this dc supply removal to tout the price reduction from the "*deluxe*" model 270. The selling price of the 270B in July 1970 was $499, with the optional model 14A, 12-V converter priced at $39.50.

As with most single-tube PA design transceivers, during tune-up a resistor is switched in series with the cathode to protect the PA tube by limiting current. Therefore, the less than 100-W maximum RF output power seen during initial tune-up is much less than actual operating power.

2.3.7. 300B Cygnet

The 300B belongs to the Cygnet family of amateur transceivers rather than the family of commercial model 300 series of channelized transceivers discussed below. The 300B Cygnet "*de novo*" or Latin for anew, was introduced in late 1973 with a selling price of about $500 and sold through 1975. It was essentially the evolutionary replacement for the Swan 270B. Like its predecessor, it's a single-tube PA, 5-band HF transceiver marketed primarily for both its portable and mobile uses. The PA tube was changed to an 8950 with a 30% higher plate dissipation capability (which in 1973 was also being used in the 700CX and 1200 linear amplifier) permitting the specified dc input PEP to be increased to 300 W. A CW side-tone was also added.

Like all Cygnet designs, it retained the internal ac power supply, but as with its immediate predecessor, the 270B, it does not have an internal 12-V dc supply. Mobile operation requires the use of the optional 14A dc supply. After production of this model was terminated, the 350A, which provides a similar multi-functional capability (portability, mobility, base station) and similar design features (built-in power supply, single-tube PA, etc.) was introduced, essentially as its replacement, but it was not marketed under the Cygnet moniker.

As with tune-up on the other Cygnet model transceivers, a resistor is switched in series with the cathode to protect the PA tube by limiting cathode current. Therefore, the 100-W RF output power range seen during initial tune-up is less than actual operating power.

2.3.8. 300, 310, 320 Commercial (Channelized)

This line of transceiver models was designed for commercial applications and as such, the emphasis was on simplicity of operation. Each model permitted operation only on a small number of user pre-selected frequency channels (with very limited operator frequency tuning about the selected channel) anywhere within the 2 through 50-MHz band and required no operator PA tuning. They have internal driver (GRID), plate, and load controls that were pre-tuned at the desired operation frequencies by technicians.

These models are distinctly different in design from the amateur Cygnet 300B, Cygnet-like 350A/B/D, and base station 350/C transceivers. Many of the 300/310/320 units were sold for foreign commercial applications and are relatively rare. The 310, 320, and 400H were sold concurrently for a time (circa 1973).

300. The 300, introduced in about November 1968, was designed and marketed for commercial applications. It can be tuned to four user selected transceiver channels and included an internal power supply. As with its companion models, it was designed for minimal technical expertise of the user, having only the 4-position channel frequency selector switch, volume control, fine tuning control, USB/LSB selection control, tuning eye display, and microphone jack on the front panel.

310. The Model 310 contains only a single RF section (channel), combined with an internal power supply, audio section, and speaker. It operates on only one user pre-set frequency channel – there is no channel selector switch. It is ultra simple to operate, having no USB/LSB selector switch and tuning/loading controls are located inside the cabinet, away from operator access. Limited transmitter and receiver frequency tuning about the preset frequency is permitted via a front panel control.

320. The Model 320 is similar to the 300 and 310, but it contains two RF sections, permitting operation on two widely separated frequency channels. A front panel control switches the circuitry to either the A or B operation frequency. It includes an USB/LSB selector switch for each channel. The unit has a duplicate set of controls for the second frequency and like the other models, it is also ultra simple to operate, with the tune-up and loading controls located inside the cabinet. Limited transmitter and receiver frequency tuning about the preset frequency is permitted via a front panel control.

2.3.9. 350, 350A, 350B, 350C, 350D

Single Versus Dual-Tube PA Designs. While the 350/C and 350A/B/D transceivers bear the same model series number, they represent two distinctly different families. The 350 and 350C are evolutionary versions of the same design and both are part of the family of Swan dual-tube PA, high power transceivers requiring a separate power supply and primarily intended for base station use. On the other hand, the 350A/B/D series belong more to the Cygnet family of single-tube PA, lower power transceivers with an internal power supply, intended for both portable and base station applications. There is also a drastic difference between the 350/C and 350A/B/D models in their production timeframe. The 350/Cs were designed and built in the 1964-1967 period, while the 350A/B/Ds were all produced more than a decade later, in 1978-1980 time frame.

The 350A/B/D are minor variants of the same basic design, with the 350B and 350D nearly identical, other than for the digital display on the 350D. The 350A/B/D, along with the 750CX and the HS700S were the last of the tube-design models that Swan built – production ceased in 1980, but residual stock continued to be sold in 1981.

Single-tube PA Design Comments. Like the Cygnet designs, the 350A/B/D models switch a high wattage resistor into the cathode circuit when in the TUNE/CW mode to limit cathode current, so the maximum power seen during initial tune-up is less than actual operating power. Thus, RF output power during tune-up is usually limited to between 60-W and 90-W PEP, while during SSB operation the resistor is bypassed and about 125 to 175-W PEP is typically achieved. The meter on these Cygnet-like transceiver designs is relatively inaccurate and it is quite easy, due to adjustment or meter error, to have the PA cathode idle current set somewhat high. If that is the case, during longer transmissions it is possible to blow the fuse due to the higher average duty cycle power (average SSB modulation current coupled with higher idle current).

350. The 350 is a 5-band transceiver that uses a pair of 6HF5 PA tubes to obtain the specified 400-W SSB dc input PEP. The selling price of the 350 in November 1964 was $395, with the companion 117XC ac power supply with speaker selling for $85. The 350's circuitry is quite similar to the model 400 (it uses the same IF as the 400) that preceded it in production in the Spring of 1964, except of course for the internal VFO (the 400 requires an external VFO). More 350s were produced during its 3½-year production run from late 1964 to early 1967 than any other Swan transceiver. There were 8,975 built with serial numbers affixed and at least 25 without, many of the latter went to VIPs, were presented as gifts, or mysterious disappeared around the end of the production run. All 350 versions have serial numbers beginning with the letter C.

The 350 uses a 5.173-MHz IF. It has four VFO ranges, using the same tuned circuit for both 20 and 80 meters. Because of the co-use on 20 and 80 meters, the VFO circuit cannot use the 5.5-MHz IF employed in later models with five VFO ranges. The 406, 406B, 410 or 420 external VFOs can be directly used with the 5.173-MHz IF and their frequency dials will accurately read and track the operational frequency. However, the 350 requires the addition of an external VFO socket (offered as an upgrade kit) and a VFO adaptor model 22 or 22B (which plugs into the transceiver's optional VFO socket) is also needed, in addition to the VFO (which plugs into the adaptor), to permit split-frequency operation. Along with the 400 and 500 models, the LOAD control has a 10-position control, versus the 7-position switch used in later models (350C, 500C, etc.)

The initial version used full carrier insertion when in the TUNE mode. This was changed in later versions so that variable carrier insertion during tune-up and CW operation is obtained by adjusting the CAR BAL control cw or ccw. Swan routinely updated 350 transceivers returned to them for service or other upgrades to include this feature and provided updated tune-up instructions. As it turns out, this change was made not because of any tune-up considerations, but rather to address a harmonic problem during high-power, full-carrier CW operation on 15 M. See the Modification Sections 5.3 and 5.4 for discussion of this issue.

Four versions of the 350 design were produced, with the schematics dated July 1964 (A), March 1965 (B), November 1965 (C), and April 1967 (D). The earliest versions have a discrete four-crystal (4 filter crystals + 1 shunt crystal) IF filter with a 3-kHz (6-dB down) bandwidth, while later versions use the encapsulated 8-crystal filter that has a 2.7-kHz bandwidth. The manuals for versions 1 and 2 suggest that the RF GAIN control be rotated 3/4th of maximum (not full-on) for optimum receiver sensitivity. With the gain adjusted too high, some reports of audio distortion on high-level signals have been reported.

During alignment, the early version 350 should be aligned and neutralized on 10 M with the main frequency dial set to 28.5 MHz and the GRID adjusted to the 11:00 O'clock position. See additional information in the Alignment Section 7. Some of the version 3 production units were initially shipped with the version 2 schematic, however most should have the correct one, as about 6,000 of those schematics were produced. The schematics for versions 3 and 4 show the accessory socket installed.

There are a number of distinctive transceiver design features that can also help identify the applicable schematic version. These include:

- The earliest version uses a S-meter scale that reads backwards. Like the 400 model transceiver, it reads right-to-left and the pointer doesn't have the nasty habit of slamming against the stops when ac power is applied – see the Meter Issues and Problems Section 9.8.7 for additional information.
- Earlier versions also have a three-position function switch and do not have the DIAL SET control.
- For a short time in the March 1965 time frame, the VFO transistor was repositioned into a small steel box protruding beneath the bottom cover, as discussion below.
- In ~June 1965 the IF design was also changed to used the 8-crystal encapsulated filter rather than the 5 discrete-crystal (4 pole) design.
- In October 1965, the design was changed to make full-band 10-meter coverage standard (early 350s covered 500 kHz, but an optional full-band conversion kit costing $15.00 was available). The earlier, limited bandwidth units have a solid white tuning dial; the later units with full-band coverage have the green-banded multi-scale dial.

Factory Updates. The 350 model received more factory updates and post sale modifications than any other piece of Swan equipment. The most popular factory installed options or modifications included: (1) a full coverage 10-meter VFO range, (2) a 100-kHz crystal calibrator – if this option is installed, the original RF GAIN-ON/OFF switch will have been changed to a pull-on type switch that was included with the 100-kHz Crystal Calibrator Kit, (3) an opposite sideband selector – with this feature the dot on the skirt of the REC/CW/TUNE selector switch is used to reference those functions when operating in the opposite sideband (switch positions three and four), (4) a conversion to 6LQ6 or 8950 PA tubes (covered in detail on page 42 and page 47 of *QST April 1979* and in *QST "Hints & Kinks," August 1978*), (5) a dial-set capability (not on early 350s), (6) a CW side-tone circuit, (7) a change from the 7360 to the 6JH8 tube for the balanced modulator, (8) 15-meter RF driver circuit modification, (9) optimization of out-of-band operation for MARS, FAA and other commercial and government use, and (10) many low volume or one-of-a-kind changes to meet owner needs. This rig was also often modified by owners (and perhaps by the factory) to use 8950 PA tubes to increase RF output power from 200 or 250 W to about 400 to 500W. Note that the 8950 tubes are now extremely expensive!

PI Network Air-Core Coil Sag. A common problem on the first two versions of the 350 (and also the early 400s) is sagging of the top of the air-core coil to one side (located within the HV gage) due to melting of the plastic reinforcement turn separators/supports. This is caused by excessive heat build-up from the high RF currents in the top few turns of the coil when the transceiver is held in the TUNE/CW too long, especially on 20 meters. A moderate amount of sag should not affect 15 or 10-meter operation but can reduce efficiency slightly on 40 meters at the high end of the band. Swan corrected this problem by installing the more familiar hard ceramic coil-form on all radios built after 1966.

If the sagging is only minor and confined to the top few turns, it probably does not need to be corrected. However if it's markedly slumped over, it can be either repaired or replaced. To avoid the trouble of a coil change, try repairing by carefully softening the deformed plastic coil supports with a heat gun or small propane torch and pushing-out/repositioning the coil/form on the most compressed side, aligning the turns by eye. If you decide to change to a ceramic coil salvaged from a later version parts rig, it will not require any pruning – just make the connections at the appropriate band taps. Since it's almost impossible to work within the small confined VFO cage, in either case it is advisable to take off the back panel (relatively easy to do, just disconnect the antenna connector and unscrew about 7 or 8 screws).

Factory VFO Design Modifications. The earliest versions of the model 350 had the VFO compartment's coil adjustment holes on the top plate uncovered. Since excessive VFO drift was attributed to temperature stability problems due to air circulation though those holes, these holes were covered in later units with a metal plate.

One mid-version 350 model transceiver has the VFO board physically mounted in a separate box perturbing from the bottom plate of the cabinet. In mid (~June) 1965, many Swan 350s were closing in on a year's worth of operation and were beginning to develop drift problems in varying degrees. Swan reasoned the Q1 VFO transistor might be going thru some warm-up changes that caused the frequency to slowly vary. They decided to put Q1 outside the bottom chassis cover to reduce any effect caused by heat. A year later it was determined that heat and the under chassis mounting had nothing to do with the kind of drift they were experiencing, so they put the Q1 transistor back onto the board underneath the chassis.

To gain access into the belly of the radio this box first has to be removed in order to take off the bottom plate, since the tiny enclosure screws go through the small Q1 transistor circuit board, bottom plate and enclosure box, with the small nuts exposed on the bottom. It's quite a nuisance removing and replacing that small square box, especially since the long transistor leads, which extend through the Q1 circuit board to the interior VFO board, could easily get broken or shorted, in addition to just losing the small nuts and washers that fasten the box itself. So, for owners of one of these 350 units who want to avoid this problem, Q1 can be repositioned back onto the VFO board.

350A. The 350A, a Cygnet-like transceiver design introduced in 1977, uses a single-tube PA, includes a built-in power supply, and has a much lower power output than the 350/C models, with 300-W dc input PEP on SSB and 200-W input on CW (note: a cathode resistor limits dc input power during tune-up – see discussion in the Single-Tube PA Design Comments paragraph of this section). Therefore, typical PEP SSB RF output is in the range of 125 to 175 W. It was introduced after production of the 300B Cygnet model was terminated, basically as its replacement, having similar functionality and design characteristics. It was sold concurrently with the 350D and is closely related in design to the 350B/D models. Since there were only ~325 of the 350A models made, they are quite scarce.

The front panel of the earlier version 350As retained the color scheme and style of the 500CX, 700CX, etc. model series, while the last group of 350As produced used a modified front panel design, similar to the HS700S. Features include a two-step audio filter (80 and 100-Hz bandwidth) for improved CW reception, similar to that incorporated into the 750CW.

350B. The 350B is a Cygnet-like design transceiver introduced in 1977. It includes a built-in power supply and, since it uses only a single-tube PA, it has a much lower rated PEP input than the dual-tube PA 350/C models, the same as the 350A (note: a cathode resistor limits power during tune-up). There are a number of circuit differences between the 350A and the 350B/D models, including: (1) a change in the keying relay circuit (provides a ground) for direct compatibility with the 1200Z linear amplifier, (2) implementation of variable carrier level injection via the CAR BAL control (including when in the TUNE mode), and (3) the inclusion of the SIDETONE on/off switch (the side-tone must be off if no key in inserted, or audio feedback may occur).

It is nearly identical in design to the 350D (they share a common Operation Manual), other than the conventional analog display dial (and associated calibration circuits) versus the red digital LED display (and associated digital logic/display-driver circuits) used in the 350D. Features include a two-step audio filter (80 and 100-Hz bandwidth) for improved CW reception. As with the 350A, only ~325 of this model were produced, so these units are also relatively scarce and also like the 350A, this model was also produced using both the older and the newer front panel styling. In fact, the first 50 units manufactured used excess 350A front panels (same styling as the 700CX) while later units had the panel design changed to an all flat-black format, similar in appearance to the 350D and HS700S.

It is interesting to note that this is one of the few transceivers (along with the 350D) in which the RF power output, rather than the dc input power level is specified by Swan. While it apparently has the same power amplifier/driver design and therefore should have near the same dc input power capability as the 350A (300 W), the expected RF output power is specified as only 125-W SSB and 90-W CW, with about 10% less on 10 M and 15 M.

In the Swan 350B, the 6AV6 AGC amplifier AGC attack and decay rates can be controlled by adjusting the values of R112 and R116. If you wish to experiment with this adjustment, just replace R112 (270 kΩ) with a

500-kΩ variable potentiometer in series with a 100-kΩ fixed resistor. This gives an adjustment range of 100 kΩ thru 600 kΩ.

350C. The 350C was an evolutionary replacement for the very successful 350 and was produced during the 1968-1970 period. It is a distinctly different design from the 350A/B/D Cygnet-like models. A major change relative to the 350 is the use of 6LQ6 instead of 6HF5 tubes in the power amplifier, resulting in a significant increase in SSB power rating from 400 to 520-W dc input PEP, the same as the "*deluxe*" 500C, which was sold concurrently. The rated minimum CW and AM dc input power is 360 W and 125 W respectively.

The 350C model incorporated most of the 350 service modifications and update options into its design and also included the dial-set function and full-frequency 10-meter coverage. Other major design changes included the use of a 5.5-MHz IF and five-range VFO that uses separate tuned circuits for the 20 and 80-meters bands. With this change in IF, the 406, 406B, 410 or 420 external VFOs, which are directly compatible with the 350, will neither indicate the correct operational frequency nor maintain tracking linearity across the bands if used with the 350C. The model 410C and 508 external VFOs are designed for use with the 350C's 5.5-MHz IF.

350D. The 350D, a Cygnet-like design introduced in 1977, contains an internal ac power supply and uses a single 6MJ6 PA tube (some late production units were reportedly equipped with the 6LQ6 tube), so it has considerably less power capability than the dual-tube PA transceiver models, the same as the 350B (note: a cathode resistor limits power during tune-up). The 350D was sold concurrently with the 350A/B models and it's a minor variant of the 350B model, with the major difference being a red LED digital frequency display in place of the analog dial. Both the B and D models share a common Operation Manual.

There were ~700 units of this model produced. Features include a two-step audio filter (80 and 100-Hz bandwidth) for improved CW reception, similar to that incorporated into the 750CW. There were two front panel styles used on this model. The first 200 units manufactured have the front panel configuration and two-tone gray color scheme similar to that of the Cygnet design transceivers (e.g. 260). The last five hundred units have an updated front panel layout and color scheme (all black with aluminum bezel around the front) similar to that of the HF700S transceiver. See also the related discussions in the 350A and 350B sections above.

The counter/display sub-assembly inputs, via cables, the VFO and 5.5 MHz carrier oscillator signals, which are basically mixed together, effectively adding or subtracting the 5.5 MHz carrier from the VFO signal (subtracting on the 80/40 M bands and adding on the 20/15/10 M bands). If one of those two inputs is missing, most likely only the VFO or carrier oscillator frequency will be displayed – on 80 M the display were to show a frequency of 9,500 K, the 5,500 KHz signal is probably missing, and the "real" frequency would be 4,000 KHz. Other problems with the display have been associated with poor grounding – see Section 3.5.1.3.

The digital display and associated logic electronics of this model can be made to operated with other 5.5-MHz IF model transceivers (350C, 500CX, 700CX, etc.), however considerable effort would be required to extract the unit, repackage, and interface it to a different transceiver.

2.3.10. 400 (Amateur)

The 400 series transceiver model is unique in that it is the only Swan transceiver without an internal VFO. Like most other dual-tube PA models (other than the 600T), it requires an external power supply. An external VFO designed for the transceiver's 5.173-MHz IF (model 406, 410, 420) or the 405/X Crystal Controlled Oscillator (all of which also contain the transceiver's RF GAIN control) and an 117X type power supply are required for operation. The amateur 400 models have features that were not included in the 350 that followed it in production, including a sideband selection, a 100-kHz crystal calibrator, and a built-in speaker.

When the model 350 (which also uses the 5.173-MHz IF) was introduced at end of 1964, the amateur model 400 was not dropped, but continued to be produced, since Swan had a considerable investment in this model. They finally terminated production of the amateur model 400 in 1968. Most of the units manufactured towards the end of that production run were sold to governmental agencies such as the FAA, FCC, CHPS (California Highway Patrol), and reportedly, even to the CIA. While production of the amateur version was terminated, the 400 model series still continued in production; it was significantly redesigned (including a 5.6-MHz IF and channelized tuning) and marketed to both military and commercial users as the 400E/F/G/H.

The 400 was introduced in the spring of 1964 to replace the Swan 240 (tri-band), as the first 5-band SSB transceiver offered by Swan. This design uses a 5.173-MHz intermediate frequency. Since mobile operation was on the increase during the period, Herb felt he could meet the demands of both mobile (see Fig. 1-8) and fixed station operation in one package. This step back to an external VFO from the internal VFO used in the earlier mono-band and tri-band transceivers was one way of making the 400 attractive to all Hams. The use of an external VFO permitted the transmitter to be physically separated from the transceiver in mobile installations and circumvented the internal VFO heat related drift as all those tubes warmed-up the transceiver to its static steady-state temperature after the first hour of operation.

The earliest version 400 retained the 240's light gray front panel color and used the same meter surface mounting method. Its introduction just preceded that of the 350 and it was marketed concurrently with the 350. While both were rated at 400-W dc input PEP and used a pair of 6HF5 PA tubes, the 400 was touted as the deluxe transceiver since it included a sideband selector, full frequency coverage with the external 420 VFO, internal speaker, etc. The 400 sold for $395 in December 1965, but required the 420 or 406 VFO and power supply, so the complete package, including power supply was about $600, rather pricey for the time. Even with the higher package retail price, it was very expensive for Swan to produce due to engineering overhead and Herb's demand for high mechanical and electronics quality, limiting profitability. The 400 is considered by many to be the best dollar value of anything Swan built, relative to the cost of production.

Over a 3½-year period, 1,150 units were built. There were three versions of the 400, with the earliest using four discrete crystals (plus one shunt crystal) in the IF filter (3,000-Hz IF bandwidth), rather than the hermetically sealed 8 crystal, 2,700-Hz bandwidth unit used in later versions (after mid 1965). It received a facelift in late 1965, with the front panel being refinished in two-tone light gray. Along with the 350 and 400 models, the LOAD control has 10 positions, versus the 7-position switch used in later models (350C, 500C, etc.).

The were a few hundred model 400s of the last version made at the end of the production run, but only about 100 schematics, however that later schematic is nearly identical to the initial version of the model 500 transceiver (less the VFO). The schematics for the first two versions have no identification (date or letter), while the last has a date affixed. Model 400 units with serial numbers B19.. & B20.. use the later schematic, which also shows, in addition to the date, an encapsulated crystal filter instead of the five individual crystal filter design. The later schematic also shows a border around the 12-pin Cinch-Jones connection, whereas the earlier schematic does not. On the earliest versions, the design applied full power during tune-up; on version three this was changed to protect the PA tubes from damage by switching a resistor into the screen grid circuit when in the TUNE mode, which decreases the screen voltage and hence the maximum dc input power.

A common problem on early model 400 production units (and the 350) is sagging of the PI output stage air-core coil (on the top and to one side) due to melting of the plastic reinforcement turn separators/supports. See the discussion of this problem in the model 350 transceiver Section 2.3.9.

Issues/Comments

VFO Options. For mobile operation with the 400, Swan offered the partial frequency-band coverage (most of the audio portions of each band) external 406 VFO (matching panel, but approximately ½ the height of and less length than the 400) with an extended length interface cable, which permitted the transceiver to be placed anywhere in the vehicle, even the trunk. The full-coverage external 420 VFO (height and style match that of the 400), which has 20-frequency ranges (200-kHz per range), was offered primarily for fixed station operation. A replacement VFO was developed in mid-1965, the 410, which is also full coverage but band switching is considerably simplified (and production costs reduced) as it has only eight frequency range selections. When the inventory stock of 420 VFOs was depleted, Swan 400 owners had to buy either the 410 or 406B. The 405/X Crystal Controlled Oscillator was also available for net or other fixed-channel type applications.

Standby Switch. This model (along with the 240) employed an inter-connected STBY (standby) mode switch and an ON-OFF switch on the audio gain potentiometer to control power distribution within the transceiver. The manual's discussion and switch labeling suggests that only the filament voltages are present when the ON-OFF switch is ON and the mode switch is in STBY – this is not true, as all power supply voltages are present within the transceiver chassis. The STBY switch merely interrupts the MV (~+275 V) within the transceiver. The rationale behind this arrangement was to keep the filaments warm for quick operation. Since in standby the MV is unloaded it will rise to a higher than normal operating voltage value. This system was discarded beginning with Swan 350 and on all later models.

5,175-kHz and 13-MHz Filter Trap Alignment Comments. These two traps are used as part of the receiver RF amplifier input circuit. There are no alignment instructions in the 400 manual for the 13-MHz trap adjustment. However, the model 350, which contains a similar circuit, does provide the following information on alignment: "*Tune the VFO to 14,325 kHz, insert a RF signal into the antenna at 13,000 kHz, and tune the RF generator for a beat signal in the speaker. Adjust L603 and L604 for minimum beat signal*."

5,175-kHz Trap. Alignment instructions for the 5,175-kHz trap require the adjustment of L602. Unfortunately, the chassis labeling of that coil and the 13-MHz coils (L603/L604) is a bit confusing. The two 13-MHz trap coils are mounted on the bottom of the chassis and the 5.175-MHz IF trap is mounted on the top.

13 MHz Trap. The 13-MHz trap system uses a pair of LC tuned circuits. The parallel combination of L604 and C606 is really the trap for 13 MHz; it is in series with the incoming signal and grid of the RF amplifier and has a high impedance, which significantly attenuates any signal in that frequency region. Even though that trap is good, a little residual signal voltage still gets by to the grid because it needs to be sort of a broadband and doesn't focus in on a very narrow frequency segment about 13 MHz. Therefore, the second resonant circuit made up of L603 and C605 is included in the circuit. It's not really a trap at 13-MHz, but at that frequency it functions as a low impedance signal path that channels any residual 13-MHz signals reaching the grid of the RF amplifier (V6) to ground.

2.3.11. 400E/F/G/H (Commercial/Military)

The Swan 400E/F/G/H model transceivers are redesigned versions of the amateur model 400, intended for commercial and military applications. The commercial 400 model series continued in production after the baseline amateur 400 was dropped from the product line in the beginning of 1968. As with the amateur model 400, all of these models require an external VFO signal to operate, since they contain no internal VFO.

Among the significant differences from the amateur 400 was the change of IF from 5.173-MHz to 5.6 MHz, so none of the 406, 410, or 420 external VFOs will directly work properly with these models. The military/commercial models are also notably different in that they are capable of operating without modification on the 160-meter band. A toroid is used in the **π**-output network of sufficient inductance to permit them to be easily tuned down to 1.8 MHz, making them an excellent 160-meter SSB transceiver. On the high frequency end, they will tune to the 12-meter band. Swan went back to a air-core coil design in the **π**-output network in later versions in order to cut costs, but the frequency range capabilities remained the same.

These transceiver models were intended for use with an external crystal oscillator (405/X), since for military or commercial operations, ease of use on preset frequencies (channelized) with little or no operator knowledge, is essential. Most military radio operators were just as the name implies, operators – hence the commercial units had fewer controls on the front panel to be accidentally fiddled with. In the E/F/G/H models the number of operator accessible controls progressively decreased until the operator had only control of the frequency channel and transmit/receive selection.

While there was no specific VFO produced for use with these commercial units, the 410C VFO, intended for use with 5.5-MHz IF transceivers, is sufficiently close to the 5.6-MHz IF of the 400E/F/G/H transceivers so that it can be adjusted to function satisfactory (without calibration adjustment, there will be a 100 kHz dial reading offset error), although there will still be perhaps up to a couple of kHz of linearity error from a mid-scale calibration frequency to the high and low VFO band edges. The transceiver's accessory socket must also be modified (disconnect wires going to socket pins 5 and 6) to remove the 12 V required for relay switching in the 405/X Crystal Control Oscillator.

Any of the Swan amateur radio 117X or equivalent power supplies is compatible with these commercial units and conversely, the 400-PS ac supply that was offered with the 400E, F, G and H is also directly compatible with any of the post model 240 Swan amateur radios. They are all plug and go – no wiring changes at all.

E/F/G Models. The Swan 400E started leaving the Swan factory within a few months after the last amateur 400 model unit was built. The same pre-punched and labeled chassis used for the amateur 400 was also used for the 400E. Only about 50 of this model were produced before Swan transitioned to the F model. In the case of the 400E, the microphone gain and carrier balance controls were re-located inside the cabinet on the chassis top and the bias control potentiometer has a locking nut to prevent maladjustment. These models have no S meter, as that function was not considered important for the intended government and industry applications. The intent was to make the units as simple as possible, so that little or no technical knowledge was required for the operator to effectively use the radio. As this model series evolved, front panel controls were progressively removed from the front panel to the inside of the case, where the operator could not adjust them.

H Model. By the early 1970s, feedback from users indicated something had to be done in order to even further limit the front panel operator controls. This resulted in the final version of the series, the 400H. The H model, like its immediate predecessor, has no PA PLATE, PA LOAD, or GRID controls on the front panel. Indeed, this design actually uses five separate sets of PLATE and LOAD capacitors, with adjustment only from within the transceiver's cabinet. Each capacitor set is selected via the 5-position switch on the front panel. This means the radio can be pre-set to five different frequencies. The maintenance technicians would tune each range to the frequency and antenna to be employed and, if neither the frequency nor the antenna was changed, an operator could simply switch from say 4,685 kHz to 16,992 kHz and talk. Both frequencies would already have been tuned at an earlier time, maybe weeks previously. This makes the H series good for net operations or a sort of no-tune radio within a user adjustable 25 to 50-kHz frequency tuning spread on five different bands or different sections of a single band.

Commercial/Military Model 400E/F/G/H Audio Level Issues. The audio on 400 commercial units was intentionally designed so that it could not be completely silenced. The military did not want the operator to be able to turn the AF gain down so low that a transmission could be missed. Other government and industrial users felt the same way, so the 400E is outfitted with a 100-kΩ resistor in series with the AF gain potentiometer. When the AF gain is at minimum, there remains a 100-kΩ resistance between it and ground, thus the control grid of the 6GK6 AF tube cannot be fully grounded – full ground will prevents any AF signals being passed on from the 6GK6.

Since carbon composite resistors can change value over time (usually increasing in value), minimum audio levels on some 400s got progressively louder with time and in some cases, a little distracting. Therefore, in the 400F and G models, the series resistor was changed to 22 kΩ, but that didn't work either, as the level was quite often too low. When the 400H was introduced in the early 1970s, the design reverted to the 100-kΩ series resistor. To enable full AF silencing of 400 commercial radios, merely remove the resistor and ground the potentiometer lug (or put a jumper wire across the resistor). On early models, that resistor is designated as R1204 and in later units, it's R1202.

2.3.12. 500, 500C, 500CX

The 500 model series is an evolutionary development of the same transceiver design, with each model incorporating capabilities that were added during production of the previous model (i.e. the last version of the 500C is nearly identical to the 1st version of the 500CX), as well as additional features (e.g. the peak relative power tune-up procedure of 500C/CX versus the cathode current dip tuning technique of the earlier model). Because some units could experience VFO drift problems (as with other models), during the 500 series production Swan issues a specific "*Special Note*" service bulletin to address potential problems that could cause excessive drift and related fixes for these problems. This service bulletin is shown in Fig. 9-4.

500. A total of 2,950 units were produced during the 500's limited one-year (1967) production run. The 500, using a pair of 6HF5 PA tubes, has specified dc PEP inputs of 480, 360, 125 W respectively, during SSB, CW, and AM operation. The transceiver uses a 5.173-MHz IF and all circuit stages use tubes. This transceiver design requires manual carrier insertion during tune-up (and for CW operation) by adjusting the CAR BAL control to the full ccw or cw position (unlike some other designs, which automatically inserted full carrier when in the TUNE or CW modes). See the Modification Sections 5.3 and 5.4 for a discussion on changing full carrier TUNE/CW design transceivers for variable carrier insertion or vice versa.

There were two versions of this model built, with the earliest version having separate RF gain and volume controls. In mid-production these two controls were co-located on a ganged dual-potentiometer/on-off switch assembly. With that configuration, based on customer feedback Swan made an additional change in May 1967 to reverse the position of the RF gain and volume controls on the shaft, so that assembly is not necessarily directly interchangeable among 500s. Along with the 350 and 400 models, the LOAD control has a 10-position control, versus the 7-position switch used in later models (350C, 500C, etc.). The 406, 410 and 420 external VFOs are directly compatible with this model.

500C. After discontinuing the Swan 350C, 400 and 500 models at the end of 1967, production of the 500C commenced in January of 1968 and continued through March/April of 1970, with a total of about 4,100 units sold. The use of 6LQ6 tubes permitted the specified dc input PEP to be increased to 520 W (same as the 350C, which was sold concurrently for a time), with a potential to achieve as much as ~570 W without flat topping. Selling for $520 in March 1968, it was marketed as their top-of-the-line or deluxe transceiver since it included a crystal calibrator, sideband selector, CW side-tone, ALC, and other features missing from the 500 and 350C models. The 500C (particularly the early versions) compares favorably with the 400 model as one of the best dollar values and easiest to maintain of all Swan transceivers. The last version of the 500C is almost identical to the initial version of the 500CX, except for the 100-kHz calibrator with 25-kHz signal spacing.

Relative to the 500, major changes made to the 500C included the use of a pair of 6LQ6s tubes in the PA, a 5.5-MHz IF, the addition of a CW side-tone, and the inclusion of a relative RF OUTPUT LEVEL control. The 500C (along with its 500CX successor) uses a different tune-up methodology than its predecessors (e.g. 350, 500, etc.) because in the TUNE position, the meter indicates relative power, rather than cathode current as in previous models, but it still indicates cathode current when in the SSB or CW mode. Thus, when tuning-up, the meter is peaked rather than dipped to achieve maximum RF power output for a given LOAD setting. The OUTPUT LEVEL control adjusts the sensitivity so that the relative RF output power displayed remains within the meter's display range. This model is directly compatible with the model 508 external VFO.

During its production run, the 500C underwent more changes than any other Swan transceiver model (7 different versions and corresponding schematics!), yet each version was a very good and reliable unit in its own right – the earliest are considered by some to have a slight edge in dependability. The schematic diagram versions are identified with a letter appended on the lower edge; G and F versions are very close and can be considered interchangeable for troubleshooting purposes. The last 25 of the 500Cs produced are unique in that they use the 6JH8 tube for the balanced modulator rather than the 7360 used in all previous units. In 1968 Swan switched from the 7360 to the 6JH8 tube, which was then used in all subsequent designs, except for the very last models, such as the 350D and HS700S, which employ a solid-state balanced modulator.

The first two versions of the 500C have three-position function switches: CAL, REC, and TUNE/CW. Later units have five-position function switches: CAL, REC, TRANS, CW, and TUNE. Unfortunately, that later five-position switch takes such a beating going back and forth while tuning-up and during CW operation that it has a much higher failure rate than the three position switch used on the first two versions. The very first 500C was an all tube design like its predecessors, using a tube crystal calibrator, tube carrier oscillator, and tube voltage regulator.

The second version of this model is distinguished by having the 6BN8 AGC tube repositioned from the top and mounted horizontally under the chassis. Only 400 units of this version were produced. This tube orientation permitted installation of the carrier oscillator crystals and associated trimmer capacitors on top of the chassis in place of the tube socket. However, this design was short lived – in the next version the 6BN8 was relocated back to its original position and compression type capacitors were installed under the chassis for trimming the carrier oscillator frequency.

Solid-state stages started showing up in the 500C during the middle production period with the inclusion of a transistorized crystal calibrator and carrier oscillator. Since the VR (voltage regulator) tube was then no longer required to keep the carrier oscillator tube stable, it too was deleted. Some versions use a 3-transistor VFO design which was installed in an effort to correct the frequency drift that appeared in many transceivers after two years or so of use, however that design was dropped when they found the earlier 2-transistor design was just as good, had a lower failure rate, and had nothing to do with the drift problem.

6LQ6/6HF6 Conversion. While the 6LQ6/6JE6 PA tubes used in the 500C are still readily available, they are becoming somewhat pricey. Some users have reported doing a PA circuit modification to convert it to the 6HF5 PA deck used in the model 350 transceivers (but with a little lower power), by: " . . . *look at the underside of your 350 and you will see the precise layout and wiring configuration that you will need to duplicate. You will need a couple of new sockets for the 6hf5s and a few disc caps as the old ones will probably break, but overall it's pretty straightforward. There are no odd or fussy details to worry about. The sockets are available from places like "Antique Electronic Supply" and "Ocean State Electronics" at a fair price. The usual things like solder and buss wire are nice to have. Be patient and just duplicate that 350s wiring. The prices on NOS 6HF5s are around $18.00 each, which is great. They have 28 watts of plate dissipation each and the 8950 is only a little more at 30 watts, which makes the old reliable 6HF5 a very good choice"*.

500CX. The 500CX was produced from early 1970 (February/March) through the first week of October 1973. The first couple hundred 500CX transceivers produced have a serial number much different from the remaining production run (i.e. I657756 versus the #4140 type serial numbers of the later units). The serial numbers for the early units are similar to those used for the last 500Cs produced, since the chassis used on the initial 500CXs were left over from the 500C production run. This model was marketed as their deluxe transceiver and sold for $565.

The initial version of the 500CX is almost identical to the last version of the 500C. Incorporated in it were most of the features that had been added to the 500C during its design evolution, in addition to a new AGC/ALC amplifier and a 25-kHz crystal calibrator. The 500CX (along with its predecessor, the 500C) uses a different tune-up methodology than preceding models because in the TUNE position, the meter indicates relative power, rather than cathode current as on most other models. Thus, when tuning-up, the meter is peaked rather than dipped to achieve maximum RF power output for a given LOAD setting. An output level control is used to adjust sensitivity so that the relative measure of power shown remains within the meter's display range.

500CX MARS Special. Swan made many transceivers for MARS work during the early 1970s. Those 500CXs produced specifically for military related use have a "*Swan Mars Special*" plate located directly under the VFO tuning knob. It also has a grid-tuning knob with a wide skirt on it with a numeric calibration from 0 to 100 and a VFO vernier tuning with a 3½ to 1 tuning ratio. The PA course and fine-tuning loading controls are also calibrated from 0 to 100, instead of the typical one through seven (numeric or graphic markers) labeling. Military operators needed the 0-100 scales to more accurately log the control positions that were determined to produce the most power on a particular frequency so they could easily reset the controls when returning to that frequency.

The 500CX MARS Special has a slightly different π-output section in order to operate more efficiently beyond the high end of the normal ham bands. Note that in general, MARS operations were conducted using the opposite sideband from that normally used in the ham bands, so that the sideband normal/opposite switch incorporated on most Swan transceivers is a necessary feature for such operations.

MARS. The MARS (Military Affiliate Radio System) is an organization sponsored by the Army, Air Force, and Navy that includes many FCC licensed Amateur Radio Operators interested in military communications and electronics. It is a volunteer manned communications system of trained radio communications personnel to provide auxiliary communications for military, civil, and disaster officials during periods of emergency and provides Department of Defense sponsored emergency communications on a local, national, and international basis as an adjunct to normal communications. These auxiliary communications include administrative traffic, morale and quasi-official record and voice communications traffic for U. S. Armed Forces and authorized U. S. government civilian personnel stationed throughout the world – most noteworthy are the phone patches provided for military personnel (especially in the 1960s and 1970s). Go to the U.S. Army website at *www.netcom.army.mil/MARS/* for further information.

2.3.13. 600R/RC/T Twins

The model 600R (a.k.a. 600RC) and 600T twins were introduced in 1971 and in April of that year the transmitter sold for about $495, the baseline receiver sold for $395, and the Custom receiver for $495. Therefore, the total system price was pushing $1,000 without any of the optional accessories, considerably more than the other contemporary Swan transceivers (e.g. the 500CX sold for about $489 plus power supply). These units are a matching receiver and transmitter pair that are slightly different in physical size (6½" H, 15" W, and 12" D) from the other Swan tube transceivers. Each includes its own built-in power supply and contains or had as options, a number of features not found on the other Swan models. While the two units may be operated independently, when used together there is an interconnecting cable with 11-pin male and female connectors (wired pin-to-pin, that is 1→1, 2→2, etc.) that controls transmit/receive switching, etc.

700R/700T. It is interesting to note that there was a special version of the 600R/T made (probably only one unit of each) that was labeled under the Siltronix brand name as the 700R and 700T models. They was reportedly made for a Swan/Siltronix distributor back in the 1970s. Supposedly, when ordered from the factory he did not have his ham radio license so he had the basic 600R/T design factory modified to put the 27-MHz band in instead of the 28-MHz band. The front panel design is identical to the 600R/T and all other bands and features remained the same, other than for the label/model plaques, which are similar in appearance to the standard Swan design. See discussion of the Siltronix brand in Section 1.5.

600T. The 600T transmitter includes a high/low power switch on the front panel to reduce the rated 600-W SSB PEP and 500-W CW dc input power by about 50%, particularly useful for novice power restrictions during that time period and also for driving transverters or amplifiers that require lower drive levels. To implement this feature the switch does two things. First, it inserts a second resistor in the screen lead, reducing screen voltage from a nominal high of 215 V down to about 150 V. Second, the switch selects a second bias adjustment circuit with a separate potentiometer, required because of the significant change in screen voltage. The 500-W CW dc input power rating is the highest of any Swan transceiver, including the 700CX or 750CW (400 W).

The 600T and the 260 and 270 (early version) Cygnet transceivers were the only Swans that used the 6FG6 Electron Ray Indicator tube (tuning eye), however the 600T also includes a conventional meter. The tuning eye provided a means of displaying peak relative RF output power modulation levels and was touted by Swan as a more accurate method to adjust SSB modulation levels because of its instantaneous response compared to a conventional meter movement, which is dampened by inertia effects.

600R/RC. There were two versions of this stand-along receiver sold, the baseline 600R and the 600RC custom model. There were early and late versions of the 600R/RC produced, with several small design differences between the two. The 600R/RC receiver, when used with the matching optional model 330 general coverage tuner, provides reception capability over the entire 3 to 30-MHz portion of the HF spectrum (excluding a 2-MHz guard band about the 5.5-MHz IF). The internal VFO covers only the conventional amateur HF bands.

The special 600R Custom version (a "*Model 600R Custom*" plaque is affixed on the front panel below the main tuning dial) of the receiver also includes: (1) a built-in IF Noise Blanker (used to clip signal impulse noise pulses prior to feeding it to the crystal filter – it is a similar circuit to that used in the stand-alone Model NB-500 IF Noise Blanker accessory kit that was available for some Swan transceivers), and (2) an IC Audio Filter (in the notch mode it provides a tunable null to suppress heterodynes and unwanted CW signals or, when in the peak mode, it provides a tunable and variable narrow bandpass for enhanced CW operation – it is a solid-state integrated circuit design similar to that used in the ICAF Audio Notcher-Peaker, which was available as a stand-alone accessory for Swan transceivers). A version of the 600R/RC was also offered and advertised with the SS-16 IF filter factory installed (as were other transceiver models).

A choice of two external speakers with cabinets that matched the 600 twins in styling and height was available: The 600S ($18 in November 1971) includes only the speaker in a cabinet (similar in design to that used for the 117XC) and the Deluxe 600SP ($59) includes not only the speaker, but also the FP-1 phone patch with the controls located along the lower front panel. Also offered as an optional accessory along with the 600S/SP speakers were a 600-Hz BW CW filter ($22) and a 6-KHz BW AM filter ($29).

2.3.14. 700CX, HS700S, 750CW

Swan made at least one unit each of a transmitter and receiver labeled as the Siltronix 700R and 700T. The 700R/T models do not share any common design traits with the 700CX or HS700S, but rather are essentially identical to the 600R/T, except that the 27-MHz CB band is used instead of the 28-MHz ten-meter band (see related discussion in Section 2.3.13). The 700R/T model numbers were probably just a convenient designation used by the factory for this special order (probably one of a kind).

700CX. With the introduction of the 700CX "*Champion*" in 1973, Swan yet again increased the minimum dc input PEP the power rating of their top-of-the-line barefoot base-station transceiver to an astonishing 700-W SSB and 400-W CW. This model is an evolutionary development of the 500CX, which it replaced, and it is nearly identical except for the PA tubes, using twelve-pin 8950s operated at a higher screen voltage in place of the nine-pin 6LQ6s. It sold for about $570 and continued in production until 1977. The decision to use the 8950 tube was probably due to both the desire to increase power for marketing purposes and the economies of scale achieved (better price per unit when purchased in volume) since they also used it in the 300B Cygnet and 1200 series linear amplifier at the same time.

The 700CX is unique among Swan dual-tube PA transceivers in that it will operate with only one tube in place. That is because the PA tubes have 12.6-V ac filaments wired in parallel and thus can run one at a time, while all other two-tube transceivers use 6.3-V ac filament tubes wired in series. With one PA tube filament open on the 700CX, the PA control tuning will be a little off normal, but it will still produce power from the one remaining tube.

The 700CX, like the 500CX, is a little different to tune-up because in the TUNE position, the meter indicates relative power, rather than cathode current as is shown on early models. Rather than tuning to a cathode current dip, the user simply tunes for a meter peak, the same as one would do if an external RF wattmeter were used. Note that when the mode switch is in either the CW or SSB position, cathode current is still displayed on the meter, so if you wish to tune-up while monitoring cathode current, simply select CW mode and use a key and the CAR BAL control to inject carrier. However doing so is probably ill advised unless an external wattmeter is used since peak RF power output, rather than maximum cathode current dip, is the better indicator of proper tuning at the maximum power/efficiency point, hence Swan's inclusion of the relative output power indication capability for tune-up purposes.

The later 700CX units manufactured had the serial number stamped in two places on the chassis, directly beneath the antenna connector and in the lower mid back apron where the ID sticker had previously been placed. Note that the original 700CX manual and schematic dated 10/73 contain several errors, including an incorrect table entry at pin #2 of V12. It should read –8 V in the receive mode, however the design range is roughly –6 to –10 V. Ironically, the closest accurate schematic and voltage chart for first 700CX units produced is that contained in the manuals for last versions of the 500CX, dated 11/4/71 or later.

Power Reduction Modifications. Because of the high stress placed on the components and PA tubes due to the extremely high dc input power levels, some users decrease power using: (1) the power supply modifications discussed in the Section 3.6 (which changes the power supply's HV level from ~900 V to ~600 V, significantly reducing RF output power by 125 to 150 W), or (2) the screen operating voltage modification discussed in Section 5.8.1.2 (which inserts a resistor in series with the screen grid, reducing that voltage from ~270 V to ~245 V and thereby modestly reducing RF power output).

8950 Tube issue. A major drawback to this transceiver is the current exorbitant cost of 8950 tubes, especially if they are a matched pair (2003 retail prices range from $75 to $90 per NOS tube, unmatched). Couple this cost factor with the potential of being unable to neutralize on 10 meters, even with a new set of matched tubes (see discussion in the 8950 Tube Section 8.6.15), and ownership/operation of this rig on higher bands (10/15 M) can be problematic. However, a simple modification to rewire the filaments in series will permit the direct substitution of a number of much lower cost tubes such as the 6LB6, which is essentially identical to the 8950 tube, except for the 6.3-V ac filament voltage, or the 6LF6.

8950 to EL-509 Conversion for Higher Power. A number of users have converted various Swan transceiver models to obtain an even higher input power. With the 700CX, EL-509 tubes have been used in place of the stock 8950 PA tubes. The EL-509s can be driven quite easily on 75 thru 20 meters. However, they rapidly lose gain at higher frequencies. Thus, more drive is required on 15 M and especially on 10 M. The 6GK6 RF driver is not capable of providing any additional drive on those higher frequencies. When used in the 700CX, the pair of EL-509s is capable of at least 800-W PEP input on 75 through 20 meters, 500 W on 15 meters and 250 W on 10 meters when the driver stage is re-aligned and the PI output stage optimized. Since this tube substitution modification is relatively uncommon, it's best to request information via the Swan-Net Reflector from those who have done it or are thoroughly familiar with the procedure.

HF700S. The HF700S (a.k.a.700S) is the final dual-tube PA transceiver model built by Swan and is the evolutionary dead end of their tube-transceiver designs. It is quite similar in design to the 750CW. Relative to early models, changes include the use of a solid-state IC balanced modulator (built around the mc1496 chip), and newer style switches, front panel and case. It uses a pair of 6LQ6 tubes in the power amplifier and its rated dc input power is 550-W SSB and 350-W CW. It was marketed during 1979-80 and only about 950 units were produced. By the time this model was introduced, the Asian manufacturers had already captured the market and continued production was not economically viable. The front panel of this unit uses a more streamlined and modern looking all flat black with a surrounding aluminum bezel styling, similar to the later version of the 350B, 350D, and the subsequent Astro models. The matching power supply for this transceiver is the PSU-3A, a redesigned and repackaged 117X, which is directly interchangeable with the 117X.

This model was outfitted with a front panel selectable two-step audio filter for improved CW reception (80 and 100-Hz bandwidth, similar to that on the 350A/B/D and 750CW). While, as with the 750CW, no companion external VFO was produced, it uses a 5.5-MHz IF and the 508 VFO is directly compatible. The internal VFO is identical to earlier units and should be stable, if only because it has minimal use compared to the ~35 year age of the earlier transceiver models.

There were a few shortcuts in design, hardware, and manufacturing used with this model in order to try to compete with the foreign equipment and still make a profit. The meter is one area of cost savings. It is not nearly as accurate as the familiar 2½" meter used on most earlier Swan dual-tube models. There were also more solid-state circuits in this unit compared to earlier transceivers such as the 700CX, but unfortunately, they are more prone to operational failures. The solid-state balanced modulator was one of those solid-state circuit changes; in addition to its higher failure rate, a frequent complaint with that design is a "tinny" sounding audio. However even with these cost-cutting changes and solid-state circuits, in good operating condition it can perform as well as earlier units – the received audio may not always be as pure, but it can be, with a suitable speaker and careful alignment.

As with many other of the later model transceivers, the manual contains a number of errors. In various places throughout it you may find the model referred to as the 700-S and in others, as the 750-CW – this latter reference is most likely just a re-write/editing error that occurred when the 750-CW's manual was updated to reflect the HF-700S's design. Also, as in a number of other manuals, it refers to the adjustment of the PLATE TUNE control (there no such control labeling) during the tune-up process when it should be PA PLATE.

750CW. This model was introduced in 1977 as a replacement for the 700CX. It is more functionally equivalent to the HS700S. It sold for a $700 and represents, along with the 700S, the evolutionary end point of Swan's high power, base station, tube-design transceivers. Despite the higher power suggested by the 750 model number, the dc PEP SSB power rating remained at 700 W, the same as the 700CX.

Changes in the 750CW relative to the 700CX included: a smaller and less accurate meter, 6MJ6/6LQ6 PA tubes instead of the more costly 8950s, a solid-state balanced modulator (1496 chip), and a two step audio filter (80 and 100-Hz bandwidth) for improved CW reception. With the inclusion of the audio filters, this transceiver's marketing claim to fame was that it was a "*CW operator's dream*." The front panel configuration was flat black with the same general styling as earlier transceivers (e.g. 700CX). There were less than 1,000 units produced of this model.

The first 12 of the 750CW units produced are unique in that they still had the tube-design balanced modulator versus the solid-state design used in the remainder. Failure rates on the solid-state design balanced modulator are as much as 20 times higher than the 6JH8 tube-design employed in the 700CX and earlier transceiver models, so if problems are encountered with the 750 in the balanced modulator area (e.g. no carrier, malfunctioning carrier balance, etc.), that circuit is high on the list of likely suspects. Note that the 750 manual refers to peaking the PA TUNE control for maximum meter indication during tune-up. This is a manual error; the PA TUNE is labeled as PA PLATE on the front panel. Swan used these two terms interchangeably.

2.3.15. 1011 (Mono-Band)

The mono-band Swan 1011 transceiver has full ten-meter amateur-band receive and transmit capability, but also includes an 11-meter CB band receive capability, hence the 1011 moniker. This model was introduced in the early 1971 time frame during the CB craze and while clearly advertised as having only "*tunable coverage of the 11-meter Citizen's Band*," Swan also noted that at CB frequencies "*the transmitter relay circuitry does not function.*" One could perhaps read into that advertised information an implication that with a little modification, the relay would function.

The 1011 is a Cygnet-like design containing a built-in ac power supply and speaker (similar to the 260 on which it was based) and uses a single 6LF6 PA tube to obtain a 10-meter dc input PEP rating of 260-W SSB and 180-W CW. For mobile operations, the 14-A dc converter was required. The 1011 sold for $500 and the 14-A for $40.

This model was only produced and sold under the Swan name for a short time. Because of the potential to easily modify the transceiver for illegal high power 11-meter CB operation, the amateur community pressured Swan to stop production and sale of the unit. While Swan stopped directly selling the transceiver under their name, they continued to manufacture this unit as well as other models and accessories for a separate corporate and legal entity (Siltronix), thus giving Swan a hands-off relationship with this product line. For additional information of the 1011 (and other Siltronix models) go to the following web-link: *www.radiowrench.com/siltronix.*

2.3.16. 1046 CB Transceiver

The 1046 is a 12-tube Citizen Band (CB) transceiver, sold by Swan in the 1971 time frame. While not an amateur model and not even produced by Swan, it is included because of both its uniqueness and for completeness. It was produced by Palomar Electronics, packaged with the same styling (cabinet type, front panel colors) as other contemporary Swan-built amateur transceivers, and relabeled with the Swan name. Comparison of its front panel control layout and styling to that of the Skipper 71B type CB transceivers built by Palomar Electronics shows them to be quite similar. As with the Skipper 71B, it has: (1) a small rectangular meter, (2) a square center-mounted front panel speaker grill, (3) a built-in power supply, (4) a tuning dial that is labeled for CB channels 1 through 24, and (5) the same front panel controls, including a MIC GAIN, AF/ON/OFF, RF GAIN, AM/LSB/USB mode selector switch, and a CLARIFIER control to fine-tune about the main tuning dial selected channel.

2.4. Operating Issues (SSB, AM, CW, PSK31)

The following comments are derived from discussions and measurements presented in other sections of this document. Refer to the Table of Contents or Index for detailed discussions of the various topic areas.

2.4.1. Tune-Up Essentials

Warm-up Drift. Allow sufficient warm-up time for the majority of VFO frequency drift to occur during initial power-up, at least 20 to 30 minutes. The frequency should be stable (i.e. less than 100 to 200 Hz/hr drift rate) within an hour, usually within a half hour. Drift on tube-design radios is both normal, expected, and indeed is part of their charm.

Meter Zeroing. The cathode current meter's pointer should be at zero when no power is applied, if not, the displayed cathode current will likely be correspondingly higher or lower. It the pointer position cannot be adjusted to the zero position with the mechanical zeroing control, the idle current level should be adjusted to compensate for any error (e.g. if the meter reads 5 mA with no power applied, then a 55-mA idle setting would most likely be a true 50-mA current).

Bias Setting. The PA bias level and associated bias current (also called idle current) refers to the amount of negative voltage from the power supply needed on the control grid of the PA tube(s) to maintain a specific cathode current when no other signal is applied. This sets the operating point on the characteristic curve such that when the varying modulating signal voltage is added to the static bias voltage, the tube(s) operates over the portion of the characteristic curve consistent with the AB_1 amplifier class.

The nominal bias current is typically ~25 ±5 mA for single-tube models and ~50 ±10 mA for dual-tube PA Swan transceivers. Adjusting the idle current significantly lower will cause signal distortion and reduced output power. Adjusting the idle current too high will cause a corresponding increase in average current during SSB or CW operation with an increased potential to damage the PA tubes due to excessive heat.

The CAR BAL must be fully nulled and the MIC GAIN must be minimum when the BIAS adjustment is made. If not, the meter will measure the total current due to both bias and signal. With the CAR BAL fully nulled, the GRID control has no effect on cathode current.

Grid Peaking. It is essential to peak the cathode current with the GRID control immediately (using only a small account of carrier injection) prior to any subsequent tune-up operations. Peaking this control simultaneously resonates the driver (i.e. 6GK6) and mixer (i.e. 12BE6) tube circuits so that maximum power is delivered to the PA circuit and, more importantly, minimum power is dissipated by the driver tube. Failure to fully peak this circuit during tune-up or on-air operations will reduce power output and can potentially damage the driver tube due to excessive heat build-up or cause failure of its HV plate supply RF choke due to excessive current. Never detune the GRID to obtain a lower RF power output level.

Tune-Up Duration. Prior to commencing any transmitter tune-up procedure, adjust the GRID, PLATE, and LOAD controls for maximum receiver and S-meter signal or noise level, as specified in the Swan manuals. These adjustments approximately resonates the PA tank, mixer, and driver circuits for the selected frequency, thus all controls should be near, but not necessarily identical to their correct positions after transmitter tune-up. The 250/C model 6-meter transceiver is an exception to this rule since its receiver signal is routed around the transmitter's tank circuit (i.e. the PLATE and LOAD controls have no affect on the receiver).

Any tuning should be completed with the least amount of sustained TUNE mode or key-down time. Use tuning periods of no more than 5 seconds at a time while adjusting the GRID, PLATE, and LOAD control settings. A full, continuous carrier with the least amount of inefficient operation is very taxing on PA tubes (and the driver tube if the GRID control is un-peaked) and excessive tune-up periods under such conditions are a leading cause of premature PA tube failure or other component breakdown (wafer switches, etc.) due to the additional power dissipation required.

To save wear and tear on the mode switch, especially on those models with five-position switches, consider tuning-up in the CW position, using a key to control transmit time. With a key, it is easy to adjust the PLATE and LOAD controls during very short transmit periods, rather than alternately increasing LOAD and dipping the PLATE while constantly in the TUNE mode. If desired, initial tune-up at a lower carrier insertion level can be used on transceiver models that permit variable carrier insertion levels via the CAR BAL control. Transceiver models without that feature can be modified to provide that capability (see Modification Section 5.3). Tuning-up using the CW mode in single-tube transceiver designs should be done with extreme caution, as the CW mode bypasses the cathode or screen grid resistor that is normally inserted in the circuit when in the TUNE mode to protect PA tube from damage due to excessive current during tune-up.

Receiver Versus Transmitter Control Settings. The GRID, PLATE, and LOAD control settings obtained while in the receive mode will not necessarily be exactly the ones obtained during transmitter tune-up. You will likely find that the transmit settings obtained after tune-up yield slightly less signal level when switched back to the receive mode than was obtained with the preliminary control settings. This behavior is both normal and expected. While the receiver and transmitter circuits ideally are both tuned to the same load, there are circuit aspects discussed below that result in slightly different control positions, especially on the 15 and 10-M bands.

The transmitter tune-up settings take priority as they are much more critical to the overall operation, since those control adjustments are essential to obtain maximum RF power output and efficiency. When tuning-up to a specific load impedance, these controls are generally adjusted for the maximum RF power output condition at maximum signal level (i.e. full carrier) – if adjusted for even slightly lower carrier level conditions (or when lightly loading), the LOAD control position (and to a lesser extent the PLATE) will change somewhat.

In addition, the PLATE control's position is dependent on the PA tubes' neutralization adjustment and hence its position will change to some extent depending on the degree of neutralization (which varies from band-to-band). Therefore, different receive versus transmit control settings, especially of the PLATE and LOAD control are expected, although position changes are usually not pronounced (especially for the GRID control).

Tuning-Up to Maximum Power. Always tune to near the full-carrier maximum-RF power output and efficiency point prior to SSB, AM, and full carrier CW operations, as this insures best linearity and efficiency. As you tune-up and the LOAD control is progressively advanced while the PLATE control is used to dip the cathode current (or preferably, to peak the RF power output, if an external wattmeter is used), you will reach the maximum RF power point. At LOAD control positions below that point the dipped cathode current and RF output power would be lower, but with a lower efficiency. At LOAD control positions above that point, the RF output power will begin to decrease, while the dipped cathode current will continue to increase. The dip at the maximum power point will be typically ~10% to 15% down relative to the off-resonance cathode current (i.e. if the PLATE control is rotated off-resonance, the current might increase to say 600 mA and will typically dip to approximately ~540 mA when properly tuned) when near the apparent maximum power/efficiency point, however that dip minimum will not necessarily correspond to the maximum RF output power point when it is adjusted using an external wattmeter, as discussed below.

This behavior is depicted by the data shown in Figure 6-8, where the RF power amplifier output (curve labeled PA output) is shown as a function of transceiver loading. Since that data were collected by tuning-up to the maximum power point by using an external wattmeter (see following sub-section), cathode current in the "dip" is not shown. Although that current will increase in unison with the power output curve as loading in increased, it is important reiterate that beyond the maximum power point, where RF power output actually decreases, the cathode current will still be increasing and the "dip" will become very shallow (much less than 10%).

Note that in Section 6.2, Herb Johnson, in quoted correspondence with QST, emphasizes that the transmitter should always be tuned-up under full carrier, however, implicit in that declaration is that any succeeding on-air operations will be conducted at full SSB or CW modulation levels and not with a significantly, intentionally reduced carrier level. Nevertheless, an exception to this axiom of tuning to the full-carrier maximum-power point is perhaps if very low RF output level CW (or even SSB) operation is desired. In that case, it should be advantageous to tune to the maximum power at the lower carrier insertion level used during CW operation to increase efficiency and minimize power amplifier tube power dissipation requirements under those operating conditions (see Section 6.2.9.3).

Recognize also that if a transmitter is tuned-up at significantly different frequencies within a band, the GRID, PLATE, and LOAD control positions at the maximum power, peak efficiency point will generally vary since the PA tank output network sees differing loads (i.e. the resistive, inductive, and capacitive load components of the load's impedance frequently vary significantly across a band) – in other words, if two differing antennas loads are used (e.g. a 50-Ω dummy load with a SWR = 1 and an antenna with a SWR = 2), the PLATE and LOAD control positions will not be the same for both conditions.

Also, recognize that the measured forward RF power output will vary as a function of the load's SWR. With a 50-ohm dummy load (SWR = 1) the measurement will accurately represent the true RF output, but as the SWR increases from unity, the reading from the wattmeter will become progressively higher than that obtained with a SWR = 1, since the meter reading will be artificially increased by the effects of the reflected power phenomenon (see Sections 4.16.1 through 4.16.3) – the reflected power is added to the true power output.

Tune to RF Output Maximum rather than Cathode Current Dip. The most efficient operation is achieved when the PA is adjusted for maximum RF output power using an external wattmeter (or the relative power output meter function on later transceiver models). The cathode current dip is really only an approximate indication of proper PA stage tuning, as the dip will only coincide with the maximum RF output power setting if the PA tubes are perfectly neutralized. Since neutralization does not track exactly from band-to-band, some inconsistency between maximum power output and PA cathode current dip is both normal and expected. So, when tuning-up using an external wattmeter, the cathode current reading is essentially ignored and, most likely, the current dip will not correspond to the minimum current dip.

It is easy to see why tuning-up to the maximum power output point using an external wattmeter is beneficial by perusing the data shown in Figure 6-8, which shows the measured RF PA output as a transceiver is tuned-up with an external wattmeter at various transceiver loading settings. That curve clearly shows the expected progressive increase of output power as the loading is increased and, more significantly, the obvious maximum output power peak – if loading in increased beyond that peak, a user can very easily see the decrease in maximum power output on the wattmeter with any further LOAD control increases. With the load and "dip" tune-up method, the procedure is subjective – there is no such direct and obvious indication of peak power.

After Swan incorporated a relative RF output power measurement capability into the design of the 500C and later dual-tube PA transceiver models, they changed their tune-up procedure from the cathode current-dip method to a tune-to-maximum relative power procedure (which is equivalent to using an external wattmeter) for this reason. Gross discrepancies between the cathode current's dip minimum and a wattmeter's maximum RF power output point give a strong indication that readjustment of neutralization is needed.

Do Not Use Significantly Light or Excessive Loading. Be careful during tune-up not to adjust the LOAD control such that it is significantly light or excessive (LOAD control either much too low or much too high) for the carrier insertion level used (usually full carrier). Do not light load, as this will cause the PA to operate at significantly reduced efficiencies and could actually require the tubes to dissipate more heat than if it were tuned to maximum power! Do not excessively load; while the LOAD control can be adjusted beyond the maximum power point and the dipped cathode current readings will still continue to increase, RF output power will actually decrease, efficiency will radically decrease, and tube power dissipation requirements will drastically increase, as shown in Figure 6-8 and discussed in Section 6.2.9.1.

Tune-Up Accuracy. Don't get wrapped-around-the-axel trying to precisely adjust the PLATE and LOAD controls so that tuning is absolutely perfect. Even if the transmitter were adjusted exactly to the maximum RF power output point under full CW carrier insertion conditions, ironically it still would not be optimally adjusted for the range of actual operational SSB grid signal levels anyway (see discussion on amplifier efficiency and performance discussion in Section 6)! Prolonged peaking and tweaking just puts excessive wear and tear on the PA tubes. Close is good enough. It is far better to slightly lightly load than excessively load during tune-up as the consequences in terms of RF power output, efficiency, and PA tube heat dissipation are more benign (see Section 6.2.9).

Inter-Band Retuning. Always retune, or at least check the tuning conditions, with any appreciable change of frequency within a band until you have a good "feel" as to how the control positions are affected by frequency changes (for a given antenna system). While the LOAD and PLATE settings seldom require significant adjustment, other than for gross frequency changes within a band, the GRID control can be particularly sensitive to frequency changes in some bands. At a minimum, insert a little carrier and re-peak the GRID for maximum cathode current after significant frequency changes until you understand how the system (transmitter, feed-line, and antenna) behaves.

Snap, Crackle, and Pop. It is not normal to hear any high voltage arcing snap, crackle, and pop sounds during tune-up. Such startling sounds should never be heard, but when they do occur, they are usually due to arcing between the PA tuning capacitor plates or between PA tube internal electrodes.

If it occurs, check to ensure that the tuning capacitors are dust free. Stop and review the tune-up procedures to be absolutely sure you are not inadvertently improperly performing the tune-up process, as excessive loading or significantly inaccurate PLATE adjustment can severely stress the system. Of course, such sounds can also be heard with a discrete component failure, such as a RF choke in the driver tube plate supply or a capacitor failure, however such cases they are usually accompanied by smoke and/or odor and the transmitter will usually no longer function.

Fan Cooling. Always run a fan on the PA tubes to aid in heat dispersal, especially during AM or CW operations when the PA tubes are operating at or even somewhat exceeding their power dissipation rating.

2.4.2. SSB

2.4.2.1. Audio Quality

Most tube-era gear produced excellent SSB audio, although it can be said that some manufacturer's equipment did produce better quality audio than others – maybe not a lot better, but discernible none the less. Swans have always been known for excellent audio quality on SSB. The Swan transceivers of the early 1960s sounded just as good back then as the new equipment of today. Nothing has changed in SSB transmitting technology over the years; SSB is still SSB. Therefore, since the human voice and ear haven't changed and a near perfect reproduction of a person's voice was achieved in the early days, there is little or nothing further to be accomplished to make it sound any better. While one can consider narrower ~2.1-kHz IF filters, audio frequency response shaping and/or compression advancements that improve operations in high QRN, QRM, or a contesting environment, they certainly aren't necessarily an improvement to the sound of the audio.

2.4.2.2. Modulation Level Adjustment (1/3rd Rule)

Swan manuals typically recommend that the MIC GAIN be adjusted such that maximum modulation peaks produce cathode current readings no higher than 150 to 225 mA (dependent on transceiver model) on the transceiver's cathode current meter. This adjustment insures that the power amplifier operates over the highest efficiency linear portion of the characteristic curve without overdriving or flat-topping the transmitted signal, thus achieving optimal audio fidelity while limiting RF splatter and distortion. The corresponding cathode current during tune-up might be 500 to as much as 600 mA or more (e.g. 500 mA for the model 400). In some cases, an expected tune-up current is not directly specified, but inferred by discussions in the power specification section of the manuals (e.g. a 500CX achieves 500-W dc input PEP for a 600-mA cathode current). These values are all predicated on a properly aligned transmitter with new driver and power amplifier tubes.

As tubes and components age, and alignment settings change with time, a transmitter's capability will diminish. The maximum cathode current at the maximum power/efficiency point during tune-up may fall from 625 to 500 or even 300 mA or lower. Most Swan manuals do not address how the MIC GAIN should be adjusted for such cases. A general rule-of-thumb used by some is to adjust the MIC GAIN such that the peak SSB current meter reading is a maximum of 1/3rd of that obtained during tune-up. If the cathode current at the dip or at the maximum RF power output point, as indicated by an external wattmeter, is say 400 mA, then the cathode current on SSB modulation peaks should be no higher than ~135 mA.

This 1/3rd rule conservatively maintains the same tune-up current to modulation peak current ratio as that recommended in some manuals for a properly aligned, new condition transceiver. For example, the manual for the model 400 transceiver indicates that with a 500-mA tune-up current in the dip, the SSB modulation peaks should be in the 175 to 200-mA range.

Carrier Balance. Always remember to fully null the CAR BAL control during SSB operation. Failure to do so causes the carrier to be transmitted along with the SSB signal, not only causing needless QRM, but also increasing the average cathode current and placing an additional power dissipation burden on the PA tube(s).

2.4.3. AM

Just as with SSB, if a Swan transceiver is properly aligned and in peak form, the AM quality will also be of the highest order. Comments for ensuring optimum AM performance include the following items.

2.4.3.1. Balanced Modulation Signal Generation

Swans have an edge in AM transmission capability over some of the other SSB transceivers of the 1960s and 1970s since their design uses a balanced-modulator AM generation as opposed to screen-grid modulation. Balanced-modulator AM is about as close to plate modulation as one can get. The Swan AM mode lacks only the double sideband process. Meaning, the AM carrier is only modulated by a single sideband audio frequency due to the IF crystal filter's suppression of the unwanted sideband as it normally does during SSB operation. This has absolutely nothing to do with the audio output quality of the transmitter, which remains excellent, since both sidebands contain the exact same audio information, but with the LSB just inverted in frequency.

In fact, efficiency is increased by not wasting the power needed to amplify the unwanted and more specifically, unnecessary sideband. The only drawback that comes to mind with single sideband-with-carrier type AM is at the receiving station. If one is copying an AM signal produced by a Swan transceiver and has the BFO (beat frequency oscillator) turned on, the proper SSB position must be selected in order to hear the AF signal. The BFO is an additional stable oscillator incorporated in a receiver when it is used to receiver a CW signal, so that the mixed (or beat) output produces an audible tone. With the BFO off, as most AM receivers are set, demodulation of the AM transmission is normal and oblivious to which sideband is present, although precise adjustment is more difficult for weaker signal conditions.

2.4.3.2. Carrier Level Adjustment

It is not absolutely required that the 150-mA cathode current recommended in many Swan manuals (dual-tube PA models) be used for the AM carrier operating level; 125 mA or even 100 mA is satisfactory as long as modulation peaks barely nudge the meter 5 to 10 mA above the selected carrier level.

As indicated in Fig. 3-4, 150-mA carrier power is equivalent to ~130-W dc input power and 100-mA corresponds to ~90 W. In addition, as noted in Fig. 6-8, which shows measured CW efficiency and PA power dissipation as a function RF output power, the transmitter efficiency falls off dramatically at lower power levels. So based on those measurements, at 150 mA the steady-state carrier efficiency will be much lower (i.e. ~15 to 20%) than the ~60% attained during tune-up under full carrier and RF carrier output power will be only ~25 W. Therefore, PA tube plate power dissipation will be almost 105 W.

Of course, during voice operations the carrier is not steady state, it's constantly being amplitude modulated. The resultant signal includes periods of where the signal has higher RF output power where the cathode current is much higher, but is much more efficient and periods of low signal current levels where not only the efficiency, but also the required dissipation is much lower. Even though the average power output/efficiency condition during AM operations may reduce the heat dissipation requirements of the PA tubes to acceptable levels (relative to a steady-state, unmodulated carrier), AM operation still clearly places a high stress on the transmitter.

Operating with a 100-mA carrier level would decrease the unmodulated carrier level to only ~10-W RF output, but it will also significantly reduce the average PA tube power dissipation requirements. In any case, a fan on the PA tubes is obviously highly beneficial, or even essential, during AM operation!

2.4.3.3. Separate Receiver

Consider using a separate receiver for AM operations. Otherwise, unless you have a means of turning off the carrier oscillator between transmissions, you will be constantly zero beating the carriers of the many participants of a round table QSO. A good communications receiver can also enhance AM operation by offering variable selectivity, filtering, split frequency, BFO OFF, etc. An external receiver is easily paired with a Swan transceiver by using the relay terminals on the rear of the Swan to mute the receiver and feed the antenna's signal to the receiver.

The V6 (receiver RF amplifier) output plug on the rear of 500CX and later model Swans can be used to feed the received signals to the external receiver. The benefit of doing this is that the signal coming into the transceiver is first amplified by V6, then fed to the transceiver's receive mixer stage and to the V6 output plug. This means the received signal is pre-amplified before it goes to the external receiver, essentially adding an extra RF stage to the front end of that receiver. In order to use this set-up on Swan 500C and older models, the V6 output wiring will have to be installed. Just use a RCA jack or coax connector, a 5 or 10-µµF capacitor, and a short piece of hook-up wire or coax.

2.4.4. CW

The mode switch, particularly the 5-position switches (CAL, REC, TRANS, CW and TUNE), takes quite a beating, especially when used frequently for CW operations. However, if you have an optional VOX (a modified VX-1, or a VX-2/3/4) unit installed, it can be used for normal semi break-in operation when the mode switch is in the CW position and the PTT/VOX switch is in the VOX position. If the mode switch is left in the CW position, the PTT/VOX slide switch can be used to switch between continuous transmit and continuous receive modes, saving the wear and tear on the mode switch. In the PTT position, the transmitter will be continuously activated and CW may be sent normally. When switched back to the VOX position, either semi break-in CW operation can be conducted by normal keying, or, after the VOX's short time delay has elapse, the transceiver will revert to a continuous receive mode for CW signal reception.

If it is desired to operate at very low CW RF output levels, say 20 W or so (and the transceiver model is designed for or has been modified such that the CW insertion level is controlled by CAR BAL control), it is advisable to tune-up to the maximum RF output power point at that lower carrier insertion level. Normally a transmitter should always be tuned to the maximum power point under full carrier to obtain maximum efficiency and minimum PA tube power dissipation. However, when the transmitter is intentionally operated at low carrier insertion levels to obtain a very low CW RF level (after first tuning-up under full carrier as is normally done), this forces the power amplifier to operate at a very low efficiency. By re-tuning under the very low carrier level insertion condition, the power amplifier tuning is adjusted to best match that operating condition. Efficiency at these low carrier insertion operating conditions will be improved and power dissipation requirements will be dramatically decreased (relative to the same operation conditions after a full carrier tune-up), reducing stress on the PA tubes. See detailed discussion on low carrier level CW efficiency in Section 6.2.9.3.

CW Output Level. In the circuit design of many transceivers, the carrier level during CW operation is controlled by the CAR BAL control. But, because of the way the balanced modulator circuit is designed, you might find that with the later model transceivers (e.g. 500, 500C, etc.) with this variable CW carrier insertion feature that you will achieve somewhat higher CW output levels when the CAR BAL is rotated fully to the left (ccw) versus to the right (cw).

Grid-Block Keying. Note that many tube-design transceiver models use grid-block keying. For Swan models, this means that about –110 V (referenced to chassis ground) is applied to the transmitter mixer tube's control grid through a 100-KΩ resistor when switched to the CW/TUNE mode. This shuts the tube off and you have no output to the driver. When the key is closed, the –110 volts is shunted to ground, the mixer tube conducts, and you have output.

This –110 V appears across the key jack, so be careful what you connect to it. In general, that voltage doesn't present a significant safety hazard since it is fed through the 100-KΩ resistor. Newer CMOS and TTL keyers designed for solid-state rigs generally don't like that much voltage applied to them unless buffered by a relay or high voltage MOSFET or transistor switch. Some keyer models are designed with this in mind, having grid-blocked output options (i.e. some MFJ Models).

CW Side-tone. Some early transceiver models do not include the CW side-tone feature as part of their basic design (e.g. 350). While a modification for adding this capability is available, another option is to just use an off-board electronic keyer (e.g. MFJ-401, MFJ-8043 IC, or equivalent) that generates an audio tone and includes an output option to drive a grid-block keying design transmitter, such as is used in the Swan transceivers. In the case of the MFJ keyers, simply wire-up a RCA phono plug (that mates with the keyer output) to the ¼ inch mono plug (ground-to-ground and center contact-to-tip contact) via a coax cable (e.g. RG 174), plug an appropriately wired paddle into the keyer, and you have both paddle capability and audible side-tone from the MFJ unit.

2.4.5. PSK-31

Go to the *www.teleport.com/~nb6z/psk31.htm* Internet website for basic connection information for PSK-31, including a PTT keying circuit. PSK-31 works well on a Swan since it automatically handles the drifting of the older tube-design transceivers. The simplest configuration uses the optional Swan VOX unit to key the transceiver and it requires only two cables, one for sound-in and one for sound-out. One male mini (for PC sound/mike input) to ¼ inch mono-headphone 2-conductor jack is required for Swan audio output. One male mini (for PC sound output) to ¼ inch stereo headphone 3-conductor jack is required for Swan microphone input (caution: the Swan keying circuit is on the tip of the ¼ inch plug so make sure you don't wire the microphone input to the tip of the ¼ inch plug.).

An inline attenuation circuit that needs only two resistors is desirable, requiring only that: (1) the grounds are wired direct on both plugs, and (2) the signal lines are wired with approximately a 50-kΩ to100-kΩ resistor in series with the cable with a 1-kΩ to 5-kΩ resistor wired in parallel with the Swan input. This reduces the signal down to ~10% of its normal level and makes it easier to adjust your Swan input/output and computer input/output to their mid-range positions. Some users have also inserted a 600-Ω to 600-Ω isolation transformer inline to cut down on hum and ground noise.

Be sure to keep the power output level of the Swan down real low and watch the modulation levels carefully since it is very easy to overdrive and splatter using PSK31. See the discussion in the Modification Section 5.8 on RF power output reduction methodologies. Monitor the waterfall display of your signal on the PC screen to confirm that it is within specification. Increased frequency stability can be achieved by using a Swan fixed-frequency crystal controlled oscillator (e.g. 510X, see VFO Accessories Section 4.14) that can be employed with just about any Swan. Each of the crystal control oscillators has a vernier that permits tuning ±3 to ±5 kHz around the tuned frequency.

2.4.6. MARS

You should have no difficulty operating on the MARS frequencies with Swan transceivers; indeed, they even offered a 500CX MARS Special model. MARS operations on 40 M (e.g. 7.6 MHz) are no problem, as the main tuning dial on most transceivers will already cover that frequency range. For 80-M operation, the easiest way (and also for 40 M, if very frequency stable operation is desired) is to use a highly stable external crystal control oscillator (e.g. model 405/510).

An alternative for 80-M operation (on 4,025/4,035 kHz) is to intentionally adjust the VFO trimmer capacitor (on top of the VFO case) for that band to a higher frequency. Of course, after doing so, you will have to remember what the real frequency is on the VFO dial! If you're doing this, it's a good idea to go a full 100 kHz up on 80 M, so that the top end is 4.1 MHz (rather than the normal 4.0 MHz) – there should be enough trimmer capacitor tuning range. Just listen for the net control station and tune to it to establish the correct frequency relative to the main tuning dial, or you can also adjust the dial set so the calibration signal falls at one of the 5-kHz ticks on the dial to be relatively accurately calibrated.

2.5. Published Articles and Reviews

2.5.1. *QST*

Table 2-3 shows the search results of the ARRL database for Swan articles and comments published in *QST*. Multi-year collections of *QST* issues are available on CDROM. Some hard copy back issues are also available at the cost of the current cover price, $5.00 in 2004. Contact the ARRL Publications Sales Department (*pubsales@arrl.org*) for back issue information. Photocopies of articles are also available for $3.00 per photocopy for ARRL members and $5.00 per copy for non-members (prepayment is required for non-members). Contact their Technical Department Secretary (*reprints@arrl.org*) for reprint information.

Table 2-3 Swan Articles in *QST*

Issue	Page	Title	Author
Jun 92	84	Swan Net (Strays)	
Oct 82	42	Swan 45 Mobile-Antenna Repairs (Hints & Kinks)	Webb, John, KO5D
Oct 82	42	Expanded RIT Range For The Astro-150 (Hints & Kinks)	Holt, Lance, N9CDD
Dec 80	54	Improving The Swan 500 CX Calibration Oscillator (Hints & Kinks)	Torgenrud, Dave, WA0PDB
Jul 80	41	Swan Astro-150 Transceiver, The (Product Review)	Pelham, John, W1JA
Jun 79	35	Swan 100MX HF Transceiver and Accessories (Product Review)	Woodward, George, W1RN
Apr 79	47	On Updating the Swan 350 (Hints & Kinks)	Coleman, Carl, K4WJ
Aug 78	32	Kink (Hints & Kinks)	Schwartzbard, C., WB2IWH
Jul 77	50	Two More Tips for the Swan 250 (Hints & Kinks)	Mollentine, Richard, WA0KKC
May 77	49	ALC for the Swan 250C (Hints & Kinks)	Richardson, Hamp, K5EFW
Nov 76	42	Updating the Swan 350 (Hints & Kinks)	Coleman, Carl, K4WJ
Oct 76	19	CW Monitor for the Swan 270, A (Feedback)	
Aug 76	44	A CW Monitor for the Swan 270 (Hints & Kinks)	Arnold, Jerry, WA6MBP
Feb 74	22	Rec/Counter for Swan 500 Receivers	Daigh, Robert, K6ZCN/5
Feb 73	54	Swan Model WM-1500 RF Wattmeter, The (Recent Equipment)	Myers, Robert, W1FBY
Feb 73	23	Add AVC to Your Swan 260 (Feedback)	
Jan 73	44	Swan Twins (Recent Equipment)	Niswander, Rick, WA1PID
Jan 73	44	Swan Twins (Recent Equipment)	Nelson, John, W1GNC
Dec 72	20	Add AVC to Your Swan 260	Sears, Stanley, W2PQG
Oct 69	42	Swan Multidrive 2-Meter Antenna, The	Tilton, Edward P., W1HDQ
Sep 69	85	Swan Prototype 432 Ant. (photo) (World Above 50 Mc)	Smith, Bill, K4AYO
May 69	86	Swan 250 Notes (The World Above 50 Mc)	Smith, Bill, K4AYO
Jan 69	77	Stolen Swan Recovered (Correspondence)	Willingham, F.F., WA4EWC
Dec 68	44	Semiautomatic CW Break-In with the Swan 350 (Hints & Kinks)	Willard, D., W1UXS/K1ATG
Oct 68	96	ZF1DT Swan 250 (photo) (World Above 50 Mc)	Smith, Bill, WB4HIP
Jun 68	39	On Swan 350 Modification (Hints &Kinks)	Johnson, Herbert G., W6QJI
Jan 68	42	Swan 350 Modifications (Hints & Kinks)	Carpenter, Wayne, W4JMU
Sep 65	61	Swan 350 Transceiver, The (Recent Equipment)	Blakeslee, D., A., W1KLK
Aug 62	52	Swan Mobile SSB Transceivers (100 series) (Recent Equip)	Campbell, E. Laird, W1CUT

2.5.2. *Ham Radio*

Table 2-4 shows the search results of the ARRL database for Swan articles and comments published in the now defunct *Ham Radio* magazine. All back issues of *Ham Radio* are available from both ARRL and *CQ* magazine on CD ROM.

Table 2-4 Swan Articles in Ham Magazine

Issue	Page	Title	Author
Aug 79	42	Swan 350, curing frequency drift	WA6IPH
Nov 78	92	Swan Electronics SSB Transceiver (100 MX) (New Products)	
Oct 78	36	Swan 160X birdie suppression (Ham Notebook)	W6SAI
Aug 77	90	Swan Electronics/Cubic New Antennas (Swan TB-4HA; TB-3HA; MB-40H; 742; 1040V; TB-2A)(New Products	
Oct 76	79	Swan 250 Carrier suppression (Ham Notebook)	WB8LGA
Jan 75	60	Swan SSB Transceiver (700CX) (New Products)	
Sep 74	77	Swan's World of Amateur Radio (catalog) (PR Bandstand)	
May 73	77	Swan 350 CW monitor (Comments)	Correction: letter
Apr 73	75	Solid-State High-Frequency SSB Transceiver (Swan SS-200. SS-100, SS-15) (New Products)	
Jun 72	63	Swan 350 CW monitor (Ham Notebook)	K1KXA
Jul 71	64	Swan 350, receiver incremental tuning (Ham Notebook)	K1KXA
Apr 71	46	Swan television interference: an effective remedy	W2OUX
Dec 69	84	Swan 250, update your (Ham Notebook)	K8ZHZ
Aug 69	67	Swan 350 and 400, RTTY operation (Ham Notebook)	WB2MIC
May 68	8	Swan 120, converting to two meters	K6RIL

2.5.3. *CQ*

Table 2-5 shows a partial summary of Swan articles and comments published in the *CQ* magazine. All back issues are available from *CQ* magazine on CD ROM.

Table 2-5 Swan Articles in *CQ* Magazine

Issue	Page	Title	Author
Apr 69	50	*CQ* Reviews: The Swan Model 500C Transceiver	Wilfred M. Scherer, W2AEF
Nov 69	64	*CQ* Reviews: The Swan Cygnet Model 260	Wilfred M. Scherer, W2AEF
Oct 71	51	*CQ* Reviews: The Swan Twins	Wilfred M. Scherer, W2AEF
Feb 83	23	Converting The Swan 350C To 30 Meters	Romig, WAØKHV
Mar 71	39	A Crystal Controlled WWV Converter For The Swan Cygnet	John L. Clark, W1OE
Oct 71	64	*CQ* Reviews: The Swan FM02X Meter FM Transceiver	Glen E. Zook, K9STH
Oct 71	101	Some Notes on the Swan 350	Paul K. Pagel, K1KXA

3. POWER SUPPLYS, DC CONVERTERS

***Caution** – when working on tube transceivers and power supplies, lethal ac and dc voltages are present. Under the wrong conditions, even lower voltages can be fatal! Always disconnect the ac power, always disconnect the transceiver from power supply, always wait at least a couple of minutes for the bleeder resistors to discharge the high and medium voltage filters, and to be absolutely sure, always discharge all power supply filter capacitors and other terminals to ground with an insulated handle tool, even if power has not been applied for a long time. The –110 V bias (~–140 V unloaded) and the ~18 V relay supplies have no bleeder resistors and if the supply is disconnected from the transceiver, those capacitors retain a charge for a long time, so these must be manually discharged.*

3.1. General Information

Swan power supplies are extremely reliable, although after 20 or 30 years of use, the original bridge rectifier diodes and electrolytic filter capacitors are prone to failure. While most of the following discussions are oriented toward the 117X, the most commonly available Swan power supply, much of the information is also applicable to the other models. The number of power supplies built was significantly less than the number of transceivers, since Swan did not initially offer an ac power supply for the 175, 140 and 120 model mono-band transceivers. Even during the 1964 through 1967 period, during the production of the popular 350, 400, and 500 transceivers models, Swan built ~14,000 transceivers, but only ~13,000 power supplies. Also, see the discussion on various aspects of model 117X power supply operation discussed in the Swan Newsletter, Issue 8, Section A.8.3.

Nominal Vs. Measured Voltage Levels. Many Swan ac power supplies use 117 in their model number most likely since they were originally specified for operation from a nominal 117-V ac power source. While the typical ac power line voltage was ~117-V ac when these equipment were designed, most voltages today are typically in the 120 to 125 V range (unless it's a hot day and all those air conditioners are on). As such, the power supply output voltages and those measured in the transceiver may be 3% to 7% percent higher than if operated at 117 volts.

In the various transceiver and power supply manuals Swan assigns nominal values for the required operation voltages. These are not the actual voltages you will measure, but usually are the values you might see when the power supply is under an average load (see Section 3.3.8). For example, the high voltage is typically listed as 800 volts. Under no-load conditions (no transceiver attached) and with the ac line power voltages in the mid 120-volt range, you might measure as much as 950 V (or even higher, depending on measurement error), during receiver operation that will drop to ~920 V, under idle transmit conditions it will be ~900 V, and under maximum RF power output conditions it will drop to ~750 V or less, depending on PA cathode current. The other power supply output voltages will also vary somewhat with increasing total RF power input load. See Tables 3-5, 3-6, and 3-7 for voltage measurements for a variety of power supplies and operating conditions and Fig. 3-4 for a detailed graph illustrating the power supply's high voltage level draw-down as a function of transceiver PA cathode current.

Bleeder Resistors. The HV and MV supplies have 100-KΩ, 2-W bleeder resistors installed in parallel with the electrolytic filter capacitors for safety reasons to draw-down the stored voltage levels to low levels 30 to 45 seconds after the power has been turned off. Neither the bias or relay supply have bleeder resistors installed, so the charges in those filter capacitors can be retained for a very long time, especially if the power supply is being worked on without the transceiver attached. Consideration should be given to installing a bleeder resistor across the filter capacitor in the bias and relay supplies. With a –130 V to –140 V typical bias operating voltage range, a 50-KΩ, 1-W (0.45 W dissipation at 150 V) resistor should work fine.

Capacitor Values/Voltage Rating Issue. The actual electrolytic capacitor values used may differ somewhat from that shown in the schematic. Also, because of the higher ac power line levels discussed above, the electrolytic capacitors used in many power supply filter designs are operating near their rated value. For example, in the 117X, the filter is composed of three 350-V capacitors (1,050 V total) in series across the ~925-V HV output. Although no endemic failures are caused by this situation, consideration should be given when replacing these capacitors to increasing the rated voltage from 350 V to 400 V or more. For further information on this, see the Capacitor Replacement Section 3.4.1.4.

Physical Size. The 117AC, 117C, 117XC, 230X/XC, 400PS ac power supplies all include a cabinet with a front panel speaker. They all have the same physical size, approximately 8¼" W, 6¾" H, 11" D, but front height may vary slightly because of differences in the rubber front feet. The 117X is the proverbial "black box" (5" H x 8" W x 11" D) that is the power supply module used within the 117XC. The 117B is the design maverick of the ac cabinet type supplies offered by Swan, having no speaker, a long rectangular form-factor (5" W x 6" H x 15" D), a grill type enclosure over the entire upper and side portions of the unit, and a simple battleship gray type color. No attempt was made to make the cabinet size and styling anything like that of the transceivers (e.g. 350, 400, etc.).

3.1.1. Grounding

Always connect the power supply chassis (as well as the transceiver, tuner, etc.) directly to earth ground (ac service ground) to minimize shock hazard in the event of component failure. This is especially necessary if the power supply, like most of those built, is one that has the non-polarized two-prong ac plug.

AC Power Wiring. Inspection of the 117X schematic (Fig. 3-7) shows one side of the 117-V ac line routed directly to transformer's primary winding and the second side through a fuse and the transceiver's on/off switch (and through interconnecting cables to-and-from the transceiver) to the other side of the primary transformer winding. A 0.0047-µF, 1.4-kV RF ac line-filter safety capacitor is affixed to each side of the ac line (i.e. NEUTRAL and HOT) to the 117X's case ground. Since the two-prong ac plug used by Swan on most equipment manufactured prior to the mid 1970s is un-polarized, the plug may be inserted in either direction and ac HOT or NEUTRAL may be on either side of the primary winding. The ac line-filter capacitors and the transformer's primary winding isolates both legs of the ac from the power supply's chassis ground.

AC Filter Capacitors. The two 0.0047-µF, 1.4-kV RF ac line-filter safety capacitors are also known as interference suppression capacitors. These important capacitors are used to filter-out/remove RF line disturbances and interferences that are picked up by your home's power lines. The dual capacitor design on the legs of the primary input is superior to those designs that use filter only one side of the ac input (transformer-less AM radios, etc.), since they filter both legs of the ac input.

There are two major classes of interference-suppression ac line filter safety capacitors; namely, X and Y. Class X capacitors are used in across-the-line (between the HOT and NEUTRAL wires carrying the incoming ac current) applications where their failure would not normally lead to electric shock. A high leakage or shorted capacitor type failure will cause the fuse or circuit breaker to open.

Class Y capacitors are used in ac line-to-ground (RF bypass) applications where their failure (high leakage or short) could lead to electric shock if a proper ground connection were lost. Without a separate ground connection, the failure of this type of line-to-ground capacitor would not necessarily open any safety fuse. In other words, the failure of a line bypass capacitor could create a 120-volt hot chassis that could give you a potentially fatal shock. This is the type used in the Swan power supplies.

In the Swan design using the two-prong ac plug, there is no ac line service GROUND connected directly to the power supply's chassis since the ac cord does not have the third GOUND wire! If neither the power supply nor the transceiver chassis (chassis grounds are interconnect via the power supply cable) is grounded through a separate connection to the ac service earth GROUND, the power supply's outputs (HV, MV, FIL, etc.) are essentially floating with respect to the ac power's NEUTRAL or GROUND lines. Both RF bypass capacitors junction at the chassis's floating ground and, in the absence of a direct chassis to ac GROUND connection, measurement with a high impedance voltmeter between an external ac ground and the 117X's chassis will show a reading of ~60-V ac. The two capacitors act as a simple voltage divider.

Since the 60-cycle ac impedance (X_C) through the capacitors is extremely high (many MΩ), when the chassis is grounded, the current through the capacitors will be extremely small and, even when an operator touches an ungrounded 117X/transceiver chassis, this voltage/current is not normally noticeable. Because the electrical resistance of skin is relatively low (~500 kΩ dry to ~1 kΩ wet), the major voltage drop is across the capacitors and the resultant current is limited to very small values (i.e. assuming 5-MΩ X_C, the current is 0.000024 A, well below perceptible levels). In the event of bypass capacitor replacement, they must be rated for ac operation, rather than capacitors that just have a 1,400-V dc specification.

If one of the capacitors (or transformer primary winding, etc.) has high leakage, the ungrounded transceiver/antenna/power supply's chassis voltage relative to earth ground will be different from ~60-V ac. The higher this difference, the stronger an indication of leakage imbalance (one of the bypass capacitors has a much lower impedance) and the higher the probability of chassis shock hazard. The ac voltage measured will depend on both the leakage imbalance and how the ac plug is inserted - if it's inserted one way and the measured voltage is ~80-V ac, then if reversed it should be about ~40-V ac. This also further emphasizes that in the event of catastrophic component failure (e.g. by-pass capacitor, primary transformer winding, or on-off switch or associated wiring failure), the possibility exists for 117-V ac to be present on the chassis if there is no direct chassis connection to earth GROUND.

Remember this discussion assumes no direct earth GROUND to the transceiver, power supply, or antenna system. Bear in mind that some antenna systems (e.g. ground mounted verticals) connect the coax shield, and hence the transceiver's and power supply's chassis (they are interconnected by the power supply cable wiring), to ground at the antenna, so in such cases the chassis will be at near ground potential even without a braid connected to the ac service ground, however that is no substitute for a proper equipment electrical ground. Connecting the system to ac GROUND will reduce the measured chassis ac level to near zero (essentially zero, if all chassis are individually grounded to eliminate any ground loop effects). Given all this, it's obvious that for safety, all Swan equipment must be connected to ac GROUND. Likewise, serious consideration should be given to switching from the 2-prong ac plug to the 3-prong ac plug, which adds extra safety insurance.

Interestingly, even when the non-polarized two-prong ac plug is connected (plugged in, but not on) and the power supply and transceiver chassis are un-grounded, the ac level measured on the chassis will be about 2 V or 122 V (assuming a 124-V ac line level), depending on how the ac plug is inserted. Even without the transceiver's power switch off, ac hot or ac ground is directly connected to one of the ac line filter capacitors, and stray capacitance also couples some energy from the other ac power line leg (either ground or hot), which is routed to power supply's cable to/from the transceiver's on/off switch. As with the power-on case, the impedances are extremely high and these voltage levels do not normally present a danger. However, it again points to the wisdom of always including a case ac ground to protect against component failure that might place line voltages directly to the chassis/case (e.g. ac line filter capacitors, wiring insulation, etc.).

> ***Post Script***. The Galaxy V Mark3 uses a similar bypass arrangement as Swan, however they had the foresight to note: "*The very first connection, and the most important consideration is a good ground connection. . . . The ac line in the Galaxy V Mark3 is by-passed and the lack of a ground will result in a slight "shock" between the equipment and anything grounded, unless you do have a good ground. Also, lack of a good ground will often result in improper operation in several respects, including TVI problems.*"

Power Cord/Power Supply Cable. Neither the ac power cord nor the power supply cable should be warm or hot to the touch during operation. If so, the cord's or cable's wiring is probably an after-market installation and the wire gauge is too small. The standard Swan power cord length is 8 feet. Remarkably, Swan offered a 30-foot 12-V dc cable for those wishing to mount the transceiver in the trunk or the rear compartment of a motor home when the power supply itself was located in the engine compartment.

Power Cord/Plug Replacement. Early version Swan power supplies and Cygnet type transceivers with an internal power supply came with 2-prong un-polarized ac plugs, using 18-gauge stranded wire. This gauge of wiring is rated at 10 amperes, 117-V ac. It may be advisable to convert the stock cord/plug to the three prong polarized plug, as Swan did in the later production units (e.g. 117XC, 350D, etc. manufactured after the mid to late 1970s). Doing so will insure that in the event of transformer, bypass capacitor or other component failure, the cabinet/chassis will always be connected to earth ground, minimizing the possibility of any shocking experiences.

For late model equipment, in which Swan used the 3-prong plug, the 117X ac cable assembly's Cinch-Jones plug internal pin jumper connections should be exactly as shown in the standard 117X schematic (Fig. 3-7), except that the 3-prong ac plug's 117-V ac GROUND is connected to pins 7/8/9 (internal Cinch-Jones plug jumpers), the 117X's chassis ground. Inspection of a factory installed 3-wire ac cord showed: (1) Cinch-Jones connector pin 1 (which is wired directly to one side of the primary winding) was connected to 117-V ac NEUTRAL, (2) the ac HOT was wired through the fuse to pins 2/3 (internal Cinch-Jones connector pin jumper), which is routed through the on/off switch to the other side of the transformer's primary winding, and (3) the ac GROUND was connected to pin 7/8/9 (this is also essentially what is done anyway when a short electrical ground strap is connected from the chassis to ac service ground or a ground rod). This is consistent with electrical code, which typically requires the ac HOT to be immediately routed through the fuse and/or switch to minimize exposure.

3.1.2. Initial Power Up

When using a new Swan power supply whose pedigree is unknown, it is prudent to check the output voltage pin-out wiring assignments going to the Cinch-Jones connector to ensure that it hasn't been rewired for use with a non-Swan rig. It is also wise to thoroughly clean corrosion from all male and female Cinch-Jones connectors on both the ac power cord and HV output cable, as these are frequently the cause of a number of problems ranging from intermittent power supply voltages to audio intermittency, noise, and distortion.

If the power supply and transceiver have been in storage for more than a year or so, a Variac or step-type transformer should be used to slowly increase ac line voltage to allow the electrolytic capacitors to re-form (hopefully) over a period of hours under progressively higher voltages. If there is any sign or suspicion of dampness, it is worthwhile to first place the unit in a dry, warm environment to drive out the moisture. See additional discussions in the Smoke Test sub-topic in Section 10.2.

3.1.3. Load Capacity (117X)

Specified model 117X power supply output voltages and currents (under average transmitter load) are shown in the Table 3-2. A comparison of measured output voltages from various power supply units and models is shown in Tables 3-3 and 3-4.

Filament. The filament supply of the 117X is taxed most when used with the Swan 350, 400, 500 and early 500C, since those transceiver models have more tubes than later units (e.g. voltage regulator, VFO, carrier oscillator, and balanced modulator tubes). However even with that heavier loading, there is still another 1 A of 12-V ac filament current available.

Relay. The relay secondary transformer windings are capable of providing 250 mA of current so there is also plenty of reserve within the power supply. There is a dropping resistor in series with this output, usually 15 Ω for early power supply models intended for use with the early transceiver models that have only one relay, or 4.7 Ω in later models that are used with later transceiver models that have two relays.

Medium Voltage. With the medium voltage (MV) supply, the early transceiver models also tend to place a somewhat higher load on the supply due to the higher tube counts. Therefore, later models tend to have less loading and screen voltages are typically higher than the nominal values listed in the manuals. Since early model transceivers (early mono-banders, 240) have a lower screen voltage specified than later models, if a 117X power supply is used with them, it is desirable to lower the MV level (from which the screen voltages are derived) by inserting a dropping resister in series with the output (see details in Section 3.2).

High Voltage. The high voltage supply is taxed very heavily during maximum power transmit operations, resulting in significant drops in the supply voltage from ~920 V under receiver only loading to ~730 V or less at maximum dc input power for the highest power transceiver models (e.g. 700CX).

3.1.4. Fusing/AC Current Draw

Some Swan transceiver manuals and schematics for the 117X power supply show the ac power line fuse as 3AG-10A, a fast-blow 10-ampere fuse. This is an error. Regardless of whether the fuse is a quick blow or slow blow, a 10-amp rating is much, much too high. The correct value is a 6-amp slow-blow fuse, but even a 5-amp slow-blow should work when the power supply is used with all but the highest power transceiver models.

When operated with no load, that is with no transceiver connected, the 117X should draw about ~0.6 amperes, 120-V ac, however a transient current spike during initial power up will still require a 2 or 3-A fuse (slow blow) for no-load testing purposes. When operated with a transceiver (e.g. 700CX) connected in the receive mode, expect to see ~1.25-A, 117-V ac current draw.

3.1.5. Current Inrush Protection

When power supplies are first turned on, they experience a high initial current surge with a fast rise time as the large electrolytic filter capacitors charge (they initially appear as a short across the output windings during the first half cycle of ac current flow), current flows to the filaments, etc. The peak-inrush current can be several times greater than the steady-state current. In certain designs, this power surge can seriously damage or degrade components, such as tube filaments, switch contacts, stressing rectifiers, blowing fuses, etc.

Fortunately, neither the Swan power supplies nor transceivers have any reported systematic failures associated with a high current surge during initial power application. Indeed, there is only one transceiver case study (out of perhaps as many as a hundred discussed on the reflector, Swan-Net newsletters, etc.) presented in Section 3.4.5 that could be directly related to a current inrush, namely a transceiver's ac on/off switch whose contacts were vaporized due to arcing, but this is certainly not a common failure.

Nevertheless, many boat-anchor transceiver and tube-design amplifier owners frequently like to include some method to "soft start" to mitigate this surge, either because a particular piece of gear is sensitive to this problem or as a precautionary measure. While there are active (and more expensive) approaches to accomplish this, if one wished to provide some measure to soften the current and voltage surge when power is initially applied, a quick and easy solution suggested is to install a passive NTC Inrush Current Limiters (i.e. Negative Temperature Coefficient thermistors), in series with the ~120-V ac hot line (or both the hot and neutral) to the power supply. This passive device, also sometimes referred to as a Surge Limiter, is most frequently used on switching power supplies. It is usually packaged in a disk configuration, similar in size, shape, and appearance to a high voltage ceramic disk or RF-bypass capacitor, and typically costs only two to three dollars.

A thermistor is a thermally sensitive resistor whose resistance changes significantly and predictably as a function of temperature. The resistance of an inrush Surge Limiting thermistor quickly (in milliseconds) decreases as its temperature increases. The surge limiter rapidly self-heats due as the current begins to flow through it. Its resistance rapidly drops after the initial high current turn-on surge that charges the capacitors in the power supply. After they are charged, the current, heat, and limiter resistance drops during normal operation so that its voltage drop is insignificant compared to the total impedance of the circuit.

The design resistance of the NTC Inrush Limiters varies widely from an ohm or so to 200 Ω or more at cold resistance (prior to power application) and from a few ohms to fractions of an ohm at maximum current. The cold and maximum resistances and maximum current rating vary widely, so be sure to check the manufacturer (e.g. Keystone Thermometrics, Western Electric Components Corp., Ametherm, etc.) data sheets to select a properly sized unit. The resistance is proportional to current load, with the minimum resistance only at the maximum current rating and increasingly higher resistances as the steady-state operation current decreases. In general, the higher the maximum steady-state current rating, the lower the initial cold start resistance (e.g. ~ 2 Ω @ 20 A).

3.1.6. Cover Installation (117X)

The rubber grommets on the stanchion rods supporting the power supply circuit board are normally positioned ½ the way up the rod. These spacers are needed to keep the grounded case cover away from the terminal strips inside the case, which are perilously close to the installed cover. To maintain the grommet positioning when replacing the black or brass colored box cover, spread the sides out enough so that each side clears the rubber grommet while pushing down the cover and/or place a few turns of electrical tape around the stanchion rods below the grommets. When the cover is nearly closed, press in on both sides to fit it into the bottom grooves.

3.1.7. Operation Temperature

The transformer core in the 117X characteristically runs warm when properly functioning, so expect the case of the 117X to be warm to the touch when in operation for any length of time. No systematic failures are associated with this higher operation temperature.

3.1.8. Ventilation

Although these power supplies are very reliable even with the totally enclosed black-box design of the 117X, ventilation can be beneficial when operating in higher ambient temperature environments. If additional cooling is desired, a few holes in the sides of the cover to encourage a little ventilation can be made without allowing any substantial amount of dust to enter. Drill a short string of ¼" or so holes along either side of the removable cover in the area of the power transformer. It’s best not to position the holes in the top of the case, as this will permit easier dust entry. Of course, remove the cover before drilling to prevent any possibility of metal drilling chip contamination. An alternate approach is to use perforated sheet aluminum to replace the solid sheet aluminum on the supply to provide maximum convection cooling, but this will also permit dust entry.

3.2. Model Commonality

Swan did not build any matching ac power supply for its first mono-band transceivers (120, 140, etc.). In the mono-band transceiver manual, they specified power supply operating voltage requirements and recommended for ac operation the Heathkit HP20 or Collins 516F-2 and for 12-V operation the Heath HP-10, Topaz C10WDG, Ad-com 250, or the Collins MP-1, even including instructions in the manual for modifying the widely available Heath HP-20 and HP-10.

Interchangeability. Swan maintained a fairly standard operating voltage set and transceiver plug interface configuration that was directly compatible with all post model 240 tube-design transceivers, as illustrated by the summary of transceiver power supply voltage and current requirement specifications for the earlier 120, 140 and 175 model mono-band, the 240 tri-band, and the later dual-tube PA models (350 and 700CX) shown in Table 3-1. The 350 and 700CX have identical specifications, except for the values highlighted in italics.

Therefore, once Swan began building power supplies, other than for the initial 117AC model, output voltages were essentially identical. In the 117AC, the bias voltage was lower than in later models to conform to the model 240 and early mono-band transceiver voltage requirements (–90 V to –100 V bias, versus the –110 V specified for dual-tube PA transceiver models) and a higher dropping/isolation resistor was used in the relay circuit (~15 Ω versus 4.7 Ω) since only ~100-mA current draw was required (versus the 200 mA needed for the dual-tube PA models that have two relays).

All Swan 117X-type ac power supplies (117B, 117C, 117X(C), 400-PS, and PSU-3/A) made during the 1964 through 1980 time frame as matching units for the various 5-band and the 160 and 6-meter mono-band tube-design radios (e.g. 350, 400) are directly interchangeable – no wiring changes, just plug-and-play. Even the 117AC power supply, designed for use with the model 240 transceiver, needs only a minor change to the bias/relay supplies for use with these later models; conversely, the 117X type power supplies also only need minor changes for operation with the older model transceivers. See discussions later in this section for modification details. The schematic for the 117AC is shown in Fig. 3-5, for the 117B/C in Fig. 3-6, and for the 117X in Fig. 3-7

Transformer. While the voltage set and output cable configuration remained consistent, there was a fundamental change in transformer and rectifier/filter design between the 117X and earlier models. The changes are clearly illustrated by a comparison of the 117AC (Fig. 3-5) and 117C/117B (Fig. 3-6) schematics with that of the 117X

Table 3-1 Specified Transceiver Power Supply Power Requirements

	120/120/175			**240**			**Dual Tube Models(350 – *700CX*)**		
	MIN	**NOM**	**MAX**	**MIN**	**NOM**	**MAX**	**MIN**	**NOM**	**MAX**
HV (V dc)	250	800 25- 275 mA	900 300 mA	250	600-800 25-300 mA	1000 350 mA	600	600-800 500-***800*** mA	1000-***1200***
MV (V dc)	225	275 100 mA	325	225	275 100-110 mA	325	225	275 150 mA	325
BIAS (V dc)	-70	-90 6 mA	-100	-70	-100 5 mA	-120	-100	-110 100 mA	-130
REL (V dc)	10	12 100 mA	15	10	12 100 mA	14.5	10	12 250 mA	14.5
FIL (V ac)	11	12.6 3.45 A	14.5	11	12.6 3.45 A	14.5	11.5	12.6 5.5-***6.7*** A	14.5

(Fig. 3-7). Unlike the earlier models, the 117X uses a non-stock transformer built specifically for Swan with multiple primaries with taps that permitted it to be used with 117-V ac or 230-V ac for base station operation and with the 12-V dc inverters for portable or mobile operation (the inverter output is fed into the transformer's filament winding via Cinch-Jones connector jumpers, which then acts as the primary winding during dc operation). The 117X transformer also uses separate secondary windings for the MV and HV supplies, as opposed to the center tapped HV secondary winding used in the 117C and earlier model power supplies.

117AC Modification for Use with Post 240 Transceivers. For the modification needed to use the 117AC with later model transceivers (e.g. 350, 400, etc.), see the discussion in the 117AC power supply section.

117X/(Or Equivalent) Modification for Use with 240 and Earlier Transceivers. If other than a 117AC model power supply (i.e. 117X, PSU-3/A) is used with one of the earlier transceivers (i.e. 240 and the early mono-band models), the bias supply voltage is too high and it needs to be reduced with a simple modification to the bias output circuit. Insert a ~1.5-kΩ, 1 or 2-W resistor in series with the bias output. The typical measured bias voltage of ~–130 V in the receive mode will decrease to ~–115 V range, much more compatible with the power supply voltages recommended in the manual for the nominal and maximum operating voltage conditions, namely, HV_{nom} = 600-800 V, MV_{nom} = +275 V, $BIAS_{nom}$ = –100 V; and HV_{max} = +1,000 V, MV_{max} = +325 V, and $BIAS_{max}$ = –120 V. The resistor can be inserted directly into the power supply or, if the supply is to be also used with a later model Swan transceiver, it can be mounted inside the transceiver – just break the line directly from pin 3 and insert the resistor. The relay resistor in the 117B/C/X is also much lower than that used in the 117AC supply (4.7 Ω versus 15 Ω) and should be replaced.

The measurements shown in Table 3-6 indicate that the 117B and the 117C bias output levels are somewhat lower than the 117X level (–110 to –105 V range versus ~–130 V), but even so, with the resistor inserted, the reduced BIAS level will still be near the –90/–100 V nominal bias values for the early transceiver models.

AC Power Control. No Swan power supply was wired to apply ac power other than via the transceiver's main on/off switch, which activated all of the power supply's operational voltages. In addition to the on-off switch, the 240 and 400 models employ a second switch to control only the 275-V MV. When in the SUPPLY OFF (240) or STBY (400) mode switch positions, the MV is cut off from the transceiver's circuitry, but this is only internal to the transceiver. The power supply still generates all voltages and feeds them to the transceiver. This dual switch system was discarded with introduction of the Swan 350.

3.3. Model Specifics, Differences

3.3.1. SW-12DC/SW-12A DC

This is a stand-alone power supply was designed for use with the Swan 240 transceiver during mobile operation. Unlike the model 14 series dc converters discussed below (which only converts a ~12-V dc input power source to an ac output), this unit is a complete hard-wired, integrated dc converter/power supply unit that uses an 11 to 15-V dc input and outputs the necessary operating voltages for transceiver operation. The nominal output voltages are: HV +600 V @ 415 MA, MV +300 V @ 500 MA, and Bias –90 V, along with relay and filament voltages. Therefore, the nominal HV level from this unit is about 200 V less than that generated by the 117X type supply. Specified output power is 250 VA maximum.

3.3.2. 14A DC Converter

This is a plug-in dc converter (it is not a stand-alone power supply, but an inverter that attaches to the Cygnet and Cygnet-like model transceivers) that provides for 12 to 14-V dc mobile operation of the Swan 270B, 300B, 350A/B/D transceivers. It is designed specifically for the Cygnet-type transceivers that have built-in power supplies and is not interchangeable with the 14C or 14X. See the model 412/512 section for a discussion of a similar unit designed for the 350/400 and later model transceivers.

3.3.3. 14C, 14X/P DC Converters

These converters are designed for use with the 117X ac power supply. None of these units is a stand-alone power supply, but merely an inverter that takes the 12-V dc power source and flip-flops it back and forth from positive to negative, simulating a 12-V ac power source. The resulting 12-V ac square-wave is fed into the 117X transformer through a filament-winding tap, which becomes the primary of the transformer during dc operation.

All of these dc converters must be attached to the back of the 117X(C) or 230X(C) power supply, plugging directly into the Cinch-Jones connector (that normally connects to the 117-V ac power cord) and powered from a 12 to 14-V dc power source. The 14C sold for $65 in April 1968. The existing 117X power cable to the transceiver is connected in the same manner as during 117-V ac operation. The 14X model is configured for a negative automobile ground while the 14XP is configured for positive ground systems.

The 14C has an additional control circuit (not in the 14X) that most users negate by connecting the middle terminal on the 14C directly to the +12 dc power source, essentially converting the unit into a 14X. That middle terminal is normally connected to the power source through an external switch to control the on/off relay. With those two posts connected together, the transceiver's power is controlled by its on/off switch.

Swan schematics indicates that either a 50-A fuse or 45-A circuit breaker should be used with the unit, but neither is included in the converter module – that protection must be added separately. See Appendix A, Newsletter, Issue 8, Section A.8.3 for further discussions on using the 14X with the 117X power supply.

3.3.4. 14-117 DC

This unit merely combines the separate 14C dc converter with the 117X ac power supply as a complete package (including cables) for mobile operation with Swan transceivers, except for Cygnet and Cygnet-like models that use the 14A (e.g. 270B, 300B, 350A/B/D). The 117X can still be operated from 117-V ac source by detaching the 14A dc module, however the ac cord was not provided with this package.

3.3.5. 117AC

This power supply, also labeled SW-117AC, operates from 117-V ac, was designed as the matching unit for the 240 transceiver, and was manufactured during the early 1963 to late 1964 time period. There were two slightly different versions built. The schematic for one is shown in Fig. 3-5. It was the first 117-V ac supply produced by Swan, but appears to be more of a learning effort than a practical design – its mechanical and electrical wiring quality is significantly inferior to subsequent power supply models. The chassis is formed using simple metal bends and lacks mechanical rigidity. Both it and the front panel support brackets are thinner gauge aluminum that can easily be deformed with any rough handling, especially if the cabinet cover is not installed. The electrical wiring is unsophisticated, with terminal strips and soldering lugs used only for some components (diodes, resistors, etc.), while the numerous capacitors (seven 100-µF, 350-V electrolytics!) are lead-to-lead inter-wired, with individual snap-in mounting brackets holding each capacitor in place. However, despite these critiques, its electrical performance, as with all Swan ac power supplies, is quite reliable and trouble free.

It includes a metal cabinet with circular or oblong ventilation holes and an enclosed 5 by 7 inch oval, 3.2-Ω impedance speaker. It has the same footprint, form-factor, and general front panel design as the later 117C, 117XC, etc. models, with an upper metal grid (but with a much courser grid pattern than later models) and light gray paint on the lower portion, consistent with the model 240 transceiver's front panel color scheme. On later versions, the cabinet's front panel color scheme may have been changed (probably in late 1964 when the 240 was discontinued and the 400 and 350 were introduced) to match that of the model 350 transceiver design. The nominal power supply voltage outputs from the 117AC required for model 240 transceiver operations are shown in Table 3-1.

This model's power supply circuit design is significantly different from the later 117X in that: (1) the supply has the power transformer directly mounted on an aluminum chassis (which has a footprint the same size as the cabinet), (2) the ac power cord is physically attached to the chassis (no Cinch-Jones connector), (3) it has no dc battery power capability, (4) it derives the MV from a center tap on the transformer (as opposed to a separate secondary winding, as in the 117X), and (5) the HV is derived from a single winding, rather than from the series connection of a 600-V (HV) and 275-V (MV) rectifiers as in the case of the 117X power supply.

Modification for use with Later Transceiver Models. Comparison of transceiver power requirements (Table 3-1) with the voltages from the this model and the 117X type (117B/C/X) power supplies (Section 3.3.8) show that the principal differences are in the BIAS supply (–100 V versus –110 V) and in the current requirements for the relay supply (~100 mA versus ~200 mA). The 117AC's design includes a resistor in the BIAS that lowers the output voltage somewhat and the relay output has a 15-Ω versus a 4.7-Ω series resistor used in the later models.

Therefore, if used with later model transceivers that employ a solid-state VFO and/or other solid-state circuits (i.e. all post 240 models), the following changes, as outlined in the 400 Operation Manual, should be made:

- *Disconnect power and remove bottom cover,*
- *Short out (or remove and jumper with a piece of hook-up wire) R6, a 1,000-Ω, ½-W resistor in the bias voltage circuit*,
- *Replace R5, a 12-Ω, ½-W resistor (connected to the red and black diode)* (117AC schematic dated 3/15/63 shows it as R7, a 15-Ω, ½-W) *in the relay circuit, with a 4.7-Ω, ½-W resistor* (preferable 1 W),
- *Re-install the cover*.

3.3.6. 117B

The 117B is the second ac model power supply produced by Swan (replacing the 117AC) and the first that is directly compatible with all post-240 Swan tube transceivers. While Swan vastly improved its construction quality from the 117AC, they apparently had a power supply design identity crisis when they designed this one. Its form-factor and styling radically departs from the 117AC model that preceded it and from the 117C and later models that followed it, and most significantly, it in no way matches the styling of the contemporary transceiver models (e.g. 400, 350). It is a totally enclosed rectangular box with a ventilation grid covering the upper portion, is physically larger (and much more rectangular, with dimensions of 5" wide by 6" high by 15" long) than the more compact 117C that replaced it, and it has the voltage output cable directly affixed to the unit midway along the bottom of the long side of the chassis. The upper 2/3rd grid portion is painted black and the lower chassis portion is gray.

There were two versions of the 117B, with some minor component changes between the two. Fig. 3-6 shows the schematic for the 117C model power supply, however comparison with that of one version of the 117B shows it to be identical except that: (1) there is no neon indicator light, (2) there is no speaker or headphone jack (or associated wiring), and (3) a 0.5-μF, 600-V capacitor is added in parallel with the first choke in the MV filter. As revealed by a comparison of the schematics shown in Fig. 3-5 and Fig. 3-6, there were significant circuit changes from the 117AC to the 117B, primarily in the MV filter design.

Like the 117AC, it also differs from the later, more common 117X in that it derives the MV from a center tap on the transformer's HV secondary, as opposed to the separate secondary winding used in the 117X. In addition, as with the 117AC, the nominal 800 V is derived from a single winding, rather than from the series connection of the 600-V (HV) and 275-V (MV) rectifiers, as is done in the 117X power supply. A comparison between the schematics shown in Figs. 3-5, 3-6, and 3-7 depicts this transformer difference.

If this power supply is used with one of the earlier transceiver models (i.e. 240 or earlier), the bias supply voltage will be too high and it needs to be reduced with the simple modification (in-series voltage dropping resistor) to the bias output circuit. The relay series resistor is also too low and should be changed from 4.7 Ω to 15 Ω. See the discussion of this modification in the Model Commonality Section 3.2 and the 117AC Section 3.3.5.

3.3.7. 117C

This power supply operates from 117-V ac, was introduced in late 1964 as a replacement for the 117B for use with the 350, 400 and later model transceivers, and was sold until the October 1965 time frame. The schematic for the 117C is shown in Fig. 3-6. As indicated by the annotation on that figure, the schematic was essentially identical to that of the 117B, except for the addition of a 3.2-Ω speaker, a headphone jack, and power-on indicator lamp. However, the component layout and size are very different from the 117B – its physical style reverted to that used in the 117AC.

While the 117C model uses the same form-factor and sheet metal/chassis fabrication techniques as the 117AC, there are some notable differences. The speaker grill pattern was changed from the wider spaced hole matrix to the smaller, more dense matrix used in all subsequent models, the lower front panel paint was changed from the powder blue to a the darker gray, similar to that used on the 400/350 transceiver models, and the large round ventilation holes in the upper portion of the side cabinet were changed to large slotted holes extending from the upper side portion onto the case top. The sheet metal used in chassis and bracket construction was changed from the flimsy aluminum to steel, making it much more sturdy. The circuit design and component selection was also changed, with the multiple 100-μF HV and MV filter capacitors replaced by two can-type, multi-section electrolytic capacitors to clean us with point-to-point wiring used in the 117AC, two chokes were used in the MV supply, and a 4.7-Ω resistor, rather than the 15-Ω resistor, was in the relay supply, since the 117C is intended for use with the later 350/400 dual relay transceiver models.

While the 117C (and 117AC) cabinet is quite similar in design and styling to that used by the much more common 117XC that replaced it, the physical power supply configuration is significantly different from that model, in that the supply is not in a totally enclosed black-box, but has the power transformer exposed and directly mounted on the chassis (as was done with the 117AC model) that has a footprint the same size as the 117XC cabinet. The ac power and output cables are attached directly to the rear chassis apron. Like the earlier 117B and later 117X-type power supplies, it will also power all 350, 400 series and later tube-design transceivers. It includes a cabinet and loudspeaker like the 117XC, with a similar footprint and cabinet/front panel styling. However, the front panel may differ somewhat with a grid pattern with fewer and larger holes akin to those used in the 117AC, but it is still similar in overall design to the 117XC.

Like the 117AC and 117B, it also differs from the 117X in that it derives the MV from a center tap on the HV secondary, as opposed to a separate secondary winding used in the 117X, as can be readily seen by a comparison between the schematics shown in Figs. 3-5 or 3-6 and 3-7. The nominal +800 V is derived from a single winding, rather than from the series connection of the +600 V (HV) rectifier and +275 V (MV) rectifier as is done in the 117X power supply. As noted above, the 117C model uses a dual-choke MV filter design – such a configuration can have a much higher no-load voltage than when under typical operational loading, so if troubleshooting without a transceiver connected, expect to see MV levels on the order of 380 V that will be drawn down during operation to about 278 V. Power supply voltage measurement for no-load conditions and while powering a 500CX transceiver are shown in Table 3-6.

If this power supply is used with one of the earlier transceiver models (i.e. 240 or earlier), the bias supply voltage will be too high and it needs to be reduced with the simple modification to the bias output circuit. The relay series resistor is also too low and should be changed from 4.7 Ω to 15 Ω. See the discussion of this modification in the Model Commonality Section 3.2 and the 117AC Section 3.3.5.

3.3.8. 117X/117XB/117XC

This power supply is directly compatible with all 350, 400 and later tube-design transceiver models. Even with the higher dc input PEP requirements of the 700CX and 750CX transceivers (700 W vs. the 400 W specified for the 350/400 model transceivers), there was no beefing-up of the standard 117X design. The nominal input and output power ratings for the 117X, when it is under an average 350C/500CX type transmitter load, are listed in Table 3-2. See Table 3-1 for the power voltage specification for the various transceiver models.

The 117X model number denotes only the actual stand alone black-box power supply package, while the XC suffix refers to the same 117X enclosed in a cabinet (with a speaker and headphone jack) that matches the 250C/350C/500C/etc. transceiver's style and appearance. When initially introduced, the 117X/XC may also have been designated as an 117XB for a short time – they are the same unit. It was first manufactured in 1965 as a replacement for the 117C and was advertised as Swan's "*Universal*" power supply, since it was intended to be used for 117-V ac, 230-V ac, and 12-V dc operation – only ac power cord Cinch-Jones connector rewiring for 117/230 V operation or an additional inverter for dc operation is required.

The 117X was manufactured for 15 years, the longest production run of any Swan product. It normally operates from a 117-V ac power source (unless an optional dc converter is used for 12-V battery operation) and all versions have the same operational specifications and connectors, consistent with its immediate predecessor (117C). The last year of production for the 117XC model as a complete unit

Table 3-2 117X Voltage Specifications

Voltage Specification (Nominal)	
AC Input Power	– 200 W average, 500-W peak
HV:	800-V dc @ 200 mA average, 600 mA peak
MV	275-V dc @ 150 mA
BIAS	-110-V dc @ 100 mA
REL	12-V dc @ 200 mA
FIL	12.6-V ac @ 5.5 A (117-V ac input)

(power supply and cabinet) was 1977. However, production of the 117X continued for another two and a half years, primarily for use with the 14C dc inverter for mobile or battery operation.

The 117XC's cabinet contains a 3 to 4-Ω impedance loudspeaker, neon lamp, and a ¼" phone jack for use with headphones or an external speaker. The threaded hole, located in the rectangular reinforced section of the 117X's case just below the Cinch-Jones connector, is provided for mounting the 14C dc-to-ac module on the power supply. If that module is not used, it is a convenient place to attach a ground braid between the power supply and transceiver, however be absolutely sure the screw used is not excessively long, as the power transformer is mounted directly behind the hole. A schematic that includes component part number designations (omitted from most schematics for this unit), useful in technical discussions of this power supply unit, is shown in Fig. 3-7.

The 117X remained fundamentally unchanged over its entire production run, with only minor alterations, such as a slightly different transformer construction, MV rectifier bridge-diode upgrades, minor changes in filter-capacitor values, a 17-μH RF choke added to the HV output to suppress RF from entering the power supply, etc.

If this power supply is used with one of the earlier transceiver models (i.e. 240 or earlier), the bias supply voltage will be too high and it needs to be reduced with the simple modification to the bias output circuit. The relay resistor in series with that output is also too low and should be changed from 4.7-Ω to 15-Ω. See the discussion of this modification in the Model Commonality Section 3.2 and the 117AC Section 3.3.5.

Transformer Comments. The 117X uses a non-stock power transformer fabricated by the manufacturer specifically for Swan and it is designed so that it could be used with 117-V ac, 230-V ac, or on battery if used in conjunction with the ~12-V dc inverter. When operated on dc, Cinch-Jones plug jumpers connect the dc inverter output to the filament winding tap of the power transformer, which then serves as the primary winding.

Four versions of the same basic transformer design were produced. The very first version is referred to as the tarred unit, since it is sealed with transformer tar to tighten the core and laminations and to keep contaminates out. Unfortunately, when owners suspected power supply problems and opened the black box, the tar smell was erroneously attributed to overheating due to shorted transformer core windings. Generally, this was not the case, as the normal operational heating of the tar caused that odor. Power transformers were replaced without further troubleshooting. After getting enough of these false alarms back to the factory for repair, Swan switched to the un-tarred version, which halted the hot or burned transformer reports.

These first two versions (1965 – 1968) were actually the best, having a slightly higher current reserve than the third and fourth versions. The early versions can be identified by their tarred transformer coating or cloth type insulated wires (and their lower dc resistance of the HV secondary). The later transformer versions had vinyl type insulation on the wires.

Choke Comments. Antique Electronics Supply is reported to have an exact replacement for the choke (part # P-T156R – $10.50) used in the MV supply filter. It's made by Hammond – it has a 1.5 Henry inductance and the same mounting hole spacing. In addition, the Peter W Dahl Co. is reported to make a custom wound choke replacement for the 117B/C that should also work for the 117X.

3.3.9. 230X/230XC

This power supply is identical to the 117X/117XC. The only difference (besides the 230X labeling) is that the supplied ac power cord is wired for 230-V ac operation via Cinch-Jones connector jumpers that connect two transformer primary windings in series. In late 1972, the 117XC sold for $110 and the 230XC sold for $116. Power supply plug wiring for both the 117-V ac and 230-V ac operation is given in most transceiver manuals.

If this power supply is used with one of the earlier transceiver models (i.e. 240 or earlier), the bias supply voltage is far too high and needs to be reduced with a modification to the bias output circuit. The relay series resistor is also too low and should be changed from 4.7 Ω to 15 Ω. See the discussion of this modification in the Power Supply Commonality Section 3.2.

3.3.10. 400-PS

The 400-PS ac power supply is the matching model for the commercial model 400E/F/G and H series transceivers. It is compatible will all later Swan tube-design transceivers (e.g. 350, 400, etc.). No wiring changes or modifications are required; it has the same connectors and voltage levels as the 117X(C) series power supply. If this power supply is used with one of the earlier transceiver models (e.g. 240 or before), the bias supply voltage will be too high and it needs to be reduced with the simple modification to the bias output circuit as discussed in the Power Supply Commonality Section 3.2. The relay series resistor is also too low and should be changed from 4.7 Ω to 15 Ω.

3.3.11. 412/512

These are both mobile dc power supplies, requiring 12 V @ 40 A to produce the necessary operating voltages for non-Cygnet type transceivers, such as the 350, 400 and later models. The high and medium voltage outputs are rated at 800 V @ 500 mA and 275 V @ 100 mA. The 512 power supply was manufactured in the mid to late 1960s and includes a hard-wired, built-in transistorized dc-to-dc converter. The unit operates off 12 V (12 to 14 V) and supplies all voltages necessary for transceiver operation.

The later 14C/X/P series dc converter, when coupled with the 117X, provides the same capability as the 412/512. See the 14A Converter Section 3.3.2 for a discussion of that dc converter unit designed for the Cygnet and Cygnet-like transceivers (e.g. 270, 350A, etc.) that includes a built-in power supply. For use with a model 240 or earlier transceiver model, also see the discussion in the Power Supply Commonality Section 3.2.

3.3.12. PSU-3, PSU-3A

The PSU-3 and PSU-3A, introduced in 1977 to replace the 117XC, are ac only supplies that include a cabinet with a built-in speaker and are interchangeable with any of the 117X-type power supplies. Like the 117X, the ac power connector can be wired to operate from either 117-V ac or 230-V ac. They use a power transformer similar to that used in the Swan 600T transmitter.

The PSU-3 has the same form-factor and appearance as the 117XC (the front panel uses a similar color scheme as the 500CX transceiver panel); however, the familiar 117X black box containing the stand-alone power supply is not used. The power supply components are incorporated into a full cabinet-size chassis/enclosure with a full back plate. Both the ac power cord and the output voltage cable with affixed standard Cinch-Jones connector for tube transceiver interface are hardwired to the chassis and, along with the fuse, mounted on the chassis's rear apron.

The PSU-3A's cabinet and front panel have an updated styling (black with white lettering and aluminum bezel around the perimeter) consistent with that of the HF-700S transceiver.

For use with a 240 or earlier transceiver, see the discussion in the Power Supply Commonality Section 3.2.

3.3.13. PSU-2, PSU-5/C, PSU-6

The PSU-2, PSU-5/C, and PSU-6 operate from 117-V ac and are low output voltage power supplies designed for the use with Swan's all solid-state transceiver models. They will run any of the Swan solid-state transceivers (e.g. Astro 150, Astro 102BX, Cubic 103BX), supplying 12 V @ 20A (PSU-5C has a Cubic nameplate).

3.4. Repairs and Troubleshooting

3.4.1. Common Problems/Issues

3.4.1.1. Fuse Size

If the fuse blows, there may be a hard failure (power supply or transceiver) or there may have been a high transient current surge, perhaps due to an arc in the PA tubes or between the tuning capacitors plates. If a fuse failure coincides with a sharp snap arc-like sound, try another fuse to determine if that problem was of a one-time arc-caused transient. The fuse installed in the power cord connector should be rated at 6 A slow-blow, although a 5 A should also work. If a higher value fuse is required, there is likely some problem causing excessive current draw.

3.4.1.2. Cinch-Jones Connector Problems

The power supply's Cinch-Jones connectors are high on the list of likely suspects for many intermittent power and audio related problems. Poor electrical contact, primarily due to corrosion, loose mechanical contact between the plug pins and socket, and even cold or broken solder joints on the plug (this is a high mechanical stress point due to cable and plug movement) can produce weird symptoms, including: intermittent power or missing voltages, audio hum, and sporadic static/cracking audio noise. With any new power supply or as part of periodic maintenance, it is advisable to:

- Always ensure all male and female Cinch-Jones connectors on both the ac power cord and HV output are thoroughly clean and corrosion free. Burnish/clean with a strip of heavy paper dampened with petroleum distillate or contact cleaner (e.g. DeoxIT) or fine very emery cloth for heavily pitted contacts.
- If the Cinch-Jones plug/connector mating appears loose, carefully twist the pins slightly to cause a very small misalignment to make a tighter mechanical and better electrical contact. Remove the shell (make sure ac is unplugged!) to check the soldered wire connections.
- Run a short ground strap between the transceiver and power supply (even though there already is a ground connection between the two internal to the power supply cable) and from each to a common earth ground point. Use a very short #14 or larger solid copper wire or tinned braid.
- If an intermittent problem is suspected, reseat and/or wiggle the ac power cord and power supply voltage output connectors to determine if the noise or problem varies.

Audio Loudspeaker/Headphone Hum. Audio hum is a common problem with Swan tube-design transceivers when using the power supply's loudspeaker or headphone jack. Its cause is a fundamental design defect in that the audio cable runs parallel to the other ac and HV power cables and all share a common ground, which induces the ac hum into the audio. This almost universal hum problem is particularly noticeable when headphones are used. Fig. 3-1 shows a service bulletin that Swan issued to address this problem. This correction procedure is basically the same as that discussed in the Modification Section 5.6 and in the Swan Newsletters Issue 2, Section A.2.4 and Issue 3, Section A.3.1.

3.4.1.3. Overheating, 117XC

The transformer core in the 117X characteristically runs warm to hot when properly functioning for any length of time. No systematic failures are associated with this higher operational temperature. While a higher operational temperature is normal, care should be exercised to insure there is no transformer problem or high current condition causing the transformer to feel uncomfortably hot to the touch during operation. Check to ensure that a component failure has not occurred (e.g. leaky electrolytic capacitor(s), a short in the filter choke, etc.) that is taxing the transformer but not blowing the fuse, especially if a 10-A fuse had been used. In no case is a fuse rated at more than a 6-A slow blow required.

3.4.1.4. Capacitor Replacement

See additional discussions on electrolytic capacitor testing and replacement in Section 10.3.1.

Capacitance Value Issue. Some 117X power supplies may have factory installed electrolytic capacitors that differ in value from those shown in the schematic included with the transceiver's Operation Manual or Universal Power Supply Manual (e.g. the bias filter capacitor may be listed on the schematic as a 80 µF but a 100-µF unit might be installed, the HV filter may be listed as 100 µF, but a 150-µF unit might be installed). Likewise, with other models such as the 117C, there can be similar inconsistencies (e.g. different schematic versions show both 100-µF and 250-µF, 25-volt electrolytic capacitors in the relay supply). Such capacitance value changes are usually not critical because of both filter design considerations and electrolytic capacitor tolerance specifications, which can be as much as +100% to –50% of the stated value.

A general rule of thumb when replacing electrolytics when the exact nominal value is no longer available is to use values up to 50% or even 100% greater than that specified, but always use a replacement with a working voltage rated at least equal to or greater than the original value. A moderate amount of extra filtering capacitance will not hurt. Since new component and manufacturing technology is used in the replacement units, the physical size will most likely be half (or even less) that of the units being replaced. Use any new manufacture electrolytic capacitor that meets these two criteria (capacitance value and working voltage).

When installing, be absolutely sure to observe polarity. It's a good idea to make a simple physical capacitor layout sketch with polarity indicated prior to removal of the old units, just to be absolutely sure the new ones are reinstalled correctly – it's a lot easier than re-checking your work against the schematic. It's amazing how easy it is to lose orientation by turning the power supply or flipping the removed capacitors when working on the unit, even when you are positively sure you haven't done so! Additional information on replacing capacitors (especially electrolytics) can be found at the following web page: *antiqueradio.org/recap.htm*.

Voltage Specification Issue. Note that in most model power supply designs (e.g. 117X), three 100-µF, 350-V capacitors are used to achieve the nominal HV output of 800 V. With actual ac power line voltages of as much as 125-V ac (versus the nominal 117 V that was more common when the supplies were originally built), the power supply output voltages are proportionately higher – in the case of the HV and MV outputs this means upwards of 950 and 330 volts or more respectively (see Tables 3-5 and 3-6). Consequently, the HV electrolytic capacitors are operating near their specified voltage rating (1050 V total). Considerations should be given to replacing the capacitors with new units having a rating of 400 V or more – unfortunately, the price differential going from 350-V units to 450-V units can be quite substantial.

3.4.1.5. Relay Supply Short

If a short occurs in the relay circuit in the transceiver, the 4.7-Ω series resistor (or 15 Ω in the early model) in the relay power supply can become overheated, causing either a change in its value or burning it completely open. This resistor serves to provide a measure of supply isolation from the relay circuits and to control the voltage applied to the relay coil(s). Its exact resistance value is not critical; values in the 2-Ω through 5-Ω range should function fine. Many people replacing that resistor can't read the color bands and use the wrong value. Replacement resistors of 0.47, 47, 470, and 4700 Ω have been found in some repaired power supplies.

Hard failure of this 4.7-Ω resistor is not a very common problem, however resistance measurements frequently show the value has increased significantly with age up to the 7 to 9-Ω range. Of course, when it does burn open, the transceiver's relay(s) will not be activated when switching to the transmit mode via the microphone's PPT or when switched to the TUNE/TRANSMIT position. If the resistor increases in value to the 10 to 15-Ω range, the transceiver's relays may also fail to operate consistently or chatter because of a marginal coil voltage caused by the higher voltage drop across this resistor.

As with many schematics and manuals produced after the Herb Johnson era, there is an error in some 117X(C) schematics as to the value of this series resistor. For example, schematics issued during the Swan 700CX pro-

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Manufacturers of Communication Equipment
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AC HUM WHEN USING HEADPHONES WITH THE 117XC

Reports have been received of loud ac hum when using low-impedance headphones with the 117XC power supply. Investigation has revealed that this is being caused by a ground loop existing between the transceiver and power supply.

Corrective action entails insulating the headphone jack on the power supply with insulated shoulder washers, and running the ground for the headphone jack and speaker to the transceiver. The headphone jack and speaker ground can be picked up in the power supply module on terminal 5 of the terminal strip. A short piece of stranded wire can be connected between the headphone jack and this terminal.

CUSTOMER SERVICE

Figure 3-1 Swan Audio Hum Service Bulletin

duction period (one is dated 6/74) have that resistor shown as 47.0 Ω. This is incorrect and won't work. Change the schematic to read 4.7 Ω.

3.4.2. Troubleshooting (117X)

If the fuse blows immediately or the transformer is excessively hot to the touch, possible problems, in rough order of likelihood, include: (1) diode failure (especially in the HV and MV rectifier bridges), (2) high leakage/bad electrolytic capacitor(s), (3) excessive current draw by component failure in the transceiver, (4) shorted connector or cable, or (5) shorted (or partially shorted) transformer primary or secondary winding(s).

Take special caution if you are working with the power supply totally disconnected from the transceiver (Cinch-Jones connector removed). Since the –110-V bias and –12-V relay supplies have no bleeder resistors, there is no load on those circuits without the transceiver connected and the charge remains in the filter capacitors for a very, very long time before dissipating! To be absolutely safe, always confirm that the ac plug is removed, wait a couple minutes to allow the bleeder resistors to do their job, and just to be absolutely sure, discharge all output terminals to ground with a very well insulated handle tool, even if power has not been applied for hours.

3.4.2.1. Problem Isolation

A good first step is to isolate the problem to either the power supply or transceiver. Try swapping transceivers or power supplies if another unit is available. If not, simply isolate the power supply from the transceiver by disconnecting the Cinch-Jones connector from the transceiver and installing a temporary jumper between the ac switch terminals (#1 and #2) on the power supply circuit board. If the power supply operates (fuse does not blow, the transformer does not get too warm, and the voltages are correct (they will be higher than the nominal values since the outputs are unloaded), a transceiver high current problem or shorted condition is indicated.

3.4.2.2. Component Testing

If the fuse still blows or the transformer overheats when transceivers are swapped or with this no-load test condition, carefully inspect all components for physical signs of failure. If all appear good, then test individual components.

Diodes. Check each diode's forward and reverse resistance with a VOM or diode checker, if available. One direction should yield very low resistance while the opposite polarity should be high. Since the diodes are interconnected with other circuit components, their measured values may vary somewhat, however in no case should any diode indicate real low resistances for both forward and reversed polarity measurement. If one is suspect, unsolder one lead and re-measure. Since a failed diode can damage other diodes and/or capacitors, check all components within the circuit section with any bad diode.

Capacitors. Check capacitors for resistance readings, noting the typical resistance reading change with charging effect as the capacitor charges. A good capacitor should have >>MΩ resistance, however such measurements are problematic. Because of component interconnections, capacitors will not necessarily yield the expected high resistance readings unless one lead is physically disconnected from the circuit. In addition, because of the large capacitance values, there is a lengthy charging time using a VOM before a valid reading is obtained. Make sure the capacitor is discharged before starting any measurement.

Another very useful measure of a capacitor's health is its effective (or equivalent) series resistance (ESR). A real benefit of this testing is that it may be performed with the capacitor still in the circuit – no unsoldering! However, either a rather expensive ESR meter or an oscilloscope (and audio signal generator) is needed. See further discussion in the Capacitor Testing and Replacement Section 10.3.

Filter Choke. The MV filter choke in the 117X power supply should have a dc resistance between 65 Ω to 75 Ω. Antique Electronics Supply is reported to have an exact replacement (part no. P-T156R – $10.50) - it's made by Hammond, has an inductance of 1.5 Henry, and has the same mounting hole spacing. Peter W Dahl Co. is reported to also make a custom wound choke replacement for the 117B/C – it may also work for the 117X.

Bleeder Resistors. Bleeder resistors seldom are the source of an excessive current problem, since carbon composition resistors rarely decrease in resistance as they age. They usually increase in value or just open

SWAN 271-008 POWER TRANSFORMER

DC RES		WIRE COLOR	AC VOLTAGE (NO-LOAD ON ANY CK)
SHORT	DC	BLK-BRN	9 VAC
SHORT	windings	BLK-YEL	14 VAC
SHORT		BLK-GRN	18 VAC
2.4 Ω	primaries	BRN-ORG	117/220 VAC INPUT
2.4 Ω		YEL-GRN	(LINE)
24 Ω	(H.V.)	RED-RED/GRN	415 VAC
11 Ω	(M.V.)	BLUE-VIO	224 VAC
20 Ω	(BIAS)	WHITE-GRAY	95 VAC

Above measurements made with a Simpson Model 260 VOM, ac Voltage measurements made with 117 VAC input – Primaries connected in Parallel.

Figure 3-2 Swan Transformer Resistance and AC Output Measurements

up and are then no longer in the circuit, thus they do not increase the transformer load and would not normally cause transformer heating for fuse blowing. If the resistor is open or its value has become excessively high, it must be replaced for safety and that failure is in addition to your other problem.

3.4.2.3. Transformer Failure

To further investigate the problem if there is no detected component failure, the transformer can be isolated from the rectifier bridges by disconnecting its secondary winding leads from the circuit board. Carefully label which lead goes to which circuit board lug, as the wire coloring can be quite difficult to discern is some cases.

When the 117X's transformer is connected and powering a transceiver (e.g. 700CX) operated in the receive mod, expect to measure ~1.25-amperes current at 120-V ac. When the transformer secondary windings are disconnected from the rectifier and filter circuit, expect to measure a no-load current of about 0.56 to 0.67-amperes at 120-V ac.

If ac power is applied with the secondary windings disconnected and the fuse does not blow and the transformer cools down, celebrate – the transformer most likely is not bad! The problem is in all probability downstream of the transformer secondary in the rectifier or filter circuits. If the fuse blows, the transformer is still excessively hot when disconnected, and/or resistance measurements show a winding short, the transformer is bad. An idea of the expected dc resistance values of the various primary and secondary windings is given by the measurements shown in Fig. 3-2. These data are internal Swan engineering measurements probably made in the 1974 time frame. The transformer secondary windings used for filament and relay power will normally show a near zero resistance. Since the 117X uses a transformer specifically designed for Swan, replacement options are pretty dismal, namely, (1) rewind the transformer (expensive), (2) purchase a replacement unit from Peter W Dahl Co. (expensive), (3) obtain a used transformer from a parts unit, or (4) buy another power supply.

Table 3-3 Diode Rectifiers for 117X Power Supply

Model	Current (A)	Surge (A)	Peak Reverse Voltage (PRV/PIV)
1N4005	1	30	600 (original Swan HV MV bride values)
1N4006	1	30	800
1N4007	1	30	1,000
1N5397	1.5	50	600
1N5398	1.5	50	800
1N5399	1.5	50	1,000
1N5408	3	200	1,000

3.4.3. Rectifier Diodes

3.4.3.1. Diode Ratings

The first two versions of the 117X (1965-68) employed 1-A, 600-PIV (or PRV) diodes in the MV (+275 V) and HV (+800 V) rectifier bridge circuits and 1-A, 200-V PIV diodes in the 12-V dc relay and –110-V bias circuits. The terms Peak Inverse Voltage (PIV) and Peak Reverse Voltage (PRV) mean the same thing and are used interchangeably.

In early 1969, a record of slightly higher failure of the 110-V bias circuit rectifiers over the previous years led Swan to switch to a 600-PIV diode in that circuit. To simplify diode installation, the 12-V dc relay circuit diode was also switched. Thus, all diodes in the last two versions of the 117X(C) are 600 PIV.

3.4.3.2. Diode Failure and Replacement

If a diode failure occurs, others may also be weak, so it is advisable to replace all the diodes in the rectifier bridge as a preventive measure. In addition to a simple diode failure, a possible cause of a bad diode is failure of another component, such as a short in one of the filter capacitors. Replace diodes with new ones rated for at least 1 A, 1,000 V to insure trouble free operation.

With the cost of diodes such as the 1N4007 only four or five cents each, it makes sense to replace all 10 diodes when repairing a failure or reconditioning a power supply. Table 3-3 lists some commonly available rectifier diodes that have been recommended or are suitable replacements, although using anything with a current rating of much more than 1.5 A is a bit of over-kill.

3.4.4. Rectifier/Filter Board Refurbishment.

An alternative to the repair or refurbishment of the existing 117X circuit board is to install a replacement using an updated circuit design with all new components, similar to that discussed for the HP23 supply in the Power Supply Alternatives Section 3.5.1 and also in the October 2003 issue of *QST*. A benefit of this type of new board design is that it has more filtering and can be configured so that the reduced HV output modification, discussed for the 117X in the HV Reduction Modification Section 3.6, can be easily made via board level jumpers. Two sources of such replacement board kits are reported to be available, namely:

- One can be found on the Internet at: *www.theheathkitshop.com*, although it has been reported that it may have been discontinued. The cost of the board is ~$15 (+S&H) or the cost of the board plus parts kit is about ~$50 (+S&H).
- A second source is one offered by Bob (KØBGH), also for about $50 (+S&H). For additional details and purchasing information either visit: *www.K0BGH.com* or email: *rojellis@mchsi.com*.

It should be noted that the existing board and circuit design is very reliable and performs extremely well. For comparison purposes, the complete refurbishment of the 117X's existing circuit board with all new rectifier and filter components (except for the MV filter choke) should be less than $30.

3.4.5. Failure Case Studies

Besides the generic problems listed and discussed previously in this section, summarized below are case studies of specific problems and solutions that have been reported by Swan transceiver users.

- **Fuse Blows on Power Up**

  Problem. Immediately upon ac power application, the power supply (117XC) blows its fuse, even when tested no-load (with no transceiver connected).

  Cause. There was a bad diode in the HV rectifier bridge with low resistance measured in both directions.

  Solution. Replace all diodes in the HV rectifier bridge and tested other components in power supply filter (i.e. choke, capacitors, etc.).

- **Power Supply Blows Fuses**

  Problem. A power supply blows fuses (117XC w/700CX) after a few hours of operation – problem is repeatable. With no power applied, a physical component examination and in-circuit VOM tests indicated that all components were good. Unit still had original filter capacitors and diodes installed.

Cause. The measurement of voltage levels across the two 150-kΩ bleeder resistors in the HV filter (no transceiver connected) showed equal voltage at power turn-on, but a slow decay of the voltage across one resistor as the unit warmed up, indicating increasing current draw in the filtering circuit. When the filter capacitors were physically disconnected, the 100-μF capacitor at the output of the HV (going to the input of the MV filter choke) was found to have high leakage with only ~100-kΩ resistance indicated under VOM test, which probably became worse under operating voltage and temperature conditions.

If the pair of paralleled 100-μF capacitors and 150-kΩ bleeder resistors are the same value, there will be roughly equal voltage (~300 V) across each leg. If the voltage is not balanced across the two capacitors, one voltage could get high enough to arc-through and damage the diode. If one of the voltages is not stable (decays with time under steady-state load conditions), capacitor leakage is likely to be varying with temperature. Under such higher leakage conditions, the fuse may not blow until after many minutes of use.

Solution. Replaced all filter capacitors. All HV and MV bridge diodes were replaced with 1-kV, 3-A diodes.

- **No/Intermittent AC Power**

  Problem. A 500CX has intermittent ac power when the switch is turned-on or it is operating.

  Cause. Bad on-off switch on the 500CX, brass internal components had been vaporized by arcing.

  Solution. The switch/pot assembly was replaced with one from a parts unit. An alternate solution is to jumper the switch contacts so that it's always on when plugged-in. Another approach is to attempt to rebuild the assembly using new parts as described in Section 9.9.1.

- **No/Intermittent AC Power**

  Problem. A HF700S intermittently will not turn-on or turns itself off, with some trace odor but no smoke.

  Cause. Inspection of the ground terminal lug, located almost under the Cinch-Jones power socket (difficult to see, near the metal shield), showed that the ground wire from the soldered side of the power connector was just wrapped around the terminals lug – it was never soldered during assembly.

  Solution. The wire was soldered and the ac power problem was solved.

- **Intermittent Filament Voltage at Transceiver (240)**

  Problem. The power supply (117X modified for use with 240) was generating all voltages, but the filament voltage is intermittent at the receiver. When receiver is inoperative, there is no filament glow in the tubes.

  Cause. Problem was traced to the ac Cinch-Jones plug and connector. Slight movement of the plug caused erratic power connection. Close inspection of the plug revealed that the pins were heavily corroded. Since internal plug jumpers and the pins are used to route the filament voltage to the power supply's terminal strip, the corrosion was causing inconsistent filament power.

  Solution. Burnished and cleaned ac male and female Cinch-Jones connectors on the ac power cord and HV output cable. Problem solved.

- **Pronounced Transformer Hum (117X)**

  Problem. When powered-up using an isolation transformer, an unloaded 117X power supply generated a pronounced, ugly sounding ac transformer-like hum, as if it was under extremely heavy load or excessive current draw conditions. The hum became progressively louder with increasing ac voltage. The transformer unit seemed warm, but not uncomfortably hot. With the power supply unloaded (no transceiver attached), a 2-ampere quick blow fuse failed at full 117-V ac, but a 4 or 5-ampere fuse did not blow.

  Cause. Problem was due to a mechanical case vibration! After electronic troubleshooting (disconnecting secondary windings, etc.) and finding no transformer problems, a very slight deformation in the metal case beneath the transformer was noted, with the case just barely touching the transformer structure. The 2-A fuse failure was due to the normal current surge during switching between the isolation transformer's fixed step transformer windings that was used during testing. The 117X's measured transformer current draw was 0.56 to 0.67-A @ 124-V ac when unloaded (no receiver connected) and ~1.25-A @ 124-V ac when connected to a transceiver and operated in the receive mode.

Solution. Case was straightened and transformer was mounted on thin rubber pads (faucet gasket material) and the hum was completely gone.

- **No Output/Power Light On**

  Problem. Power light comes on whenever the supply's power cord is plugged into the ac receptacle and connected to a 350C transceiver. The transceiver's on/off switch has no effect and there is no power at the transceiver. Unit had previously been operating fine. When the power supply is disconnected from the transceiver and plugged-in, the power supply's lamp also remains on.

  Cause. The ac power cord was swapped with another cord and the power supply operated properly. Inspection of the ac cord's Cinch-Jones connector showed that the fuse connection tab was bent upward slightly, obviously just shorting against the one or more of the Cinch-Jones connector contacts – fortunately the shorting was of a benign nature, since no fuse blew or damage occurred within the power supply.

  Solution. Fuse tab was bent away from the Cinch-Jones connector and a double layer of tap applied to the fuse connection tab as extra insurance – power supply then functioned normally.

3.5. Power Supply Alternatives

3.5.1. Heathkit HP20, 23

An alternative to a Swan manufactured power supply is to convert a HP20 or HP23A/B/C Heathkit power supply for use with Swan transceivers. These power supplies may be found at HamFests at very modest prices and can be easily converted. Since Swan did not originally manufacture a power supply for the early mono-band transceivers, the joint manual for the SW 120/140/175 models even came with conversion instructions for the Heathkit HP10 or HP20. The HP23 series needs only a 12-pin Cinch-Jones plug, a capacitor, and a diode for the modification.

If you want to do a complete refurbishment, a detailed article on reconditioning of this unit (by installing a completely new circuit board containing an updated rectifier and filter design) appeared in the October 2003 issue of _QST_. The circuit board for this modification and other information is available on the Internet at: _www.theheathkitshop.com_.

3.5.2. Galaxy AC35

The Galaxy AC35 (also the Galaxy AC400) power supply, originally built for the Galaxy III and V, is one of the easiest to modify for Swan use. After rewiring the Cinch-Jones plug for the Swan configuration, replace the bias current series resistor R8 (1.5 kΩ) with a piece of hookup wire. The full capacity of the bias voltage output is needed for Swans with solid-state VFOs, as the VFO also relies on the bias supply for current. Then perform one of the following two modification options:

Modification Option #1. Replace R5 with a 400-Ω resistor rated for at least 10 W, or add a 300-Ω resistor in series with the existing R5 100-Ω, 10-W resistor. The actual drop in output voltage depends on the current used by the transceiver. Swan specified a nominal requirement of 150 mA for the medium voltage, however that much is seldom needed. The current draw normally runs between 90 and 130 mA depending on the transceiver model and whether a remote VFO and/or VOX unit is installed. Early models (350, 400 and 500) draw the most current. Because of this high/low current draw range, it may be necessary to add another 100 Ω of series resistance to the total specified above. The resistors will get hot, but power dissipation should be within their rating. If there was a concern, particularly if calculations show the dissipating power is exceeding 80 percent of the 10-W resistor rating, use of a 15 or 20-W resistors would provide even more reliable, long-term service.

Modification Option #2. Forget all the medium voltage series resistance changes and replace the 10-Ω, 2-W resistor (R4) with a filter choke. The choke value is not extremely critical, but should be around 1.5 to maybe 5 Henry or so.

Remember, the supply is already well filtered. The choke is not there to reduce the ripple any further, but just to reduce the medium voltage by opposing the voltage peaks at the output of the rectifier, thereby preventing the full amplitude peaks from getting to the filter capacitors.

Filter Coke Selection Comments. Selection of filter chokes for JAN, Mil-Spec and state-of-the-art big company projects requires the design engineer to possess extensive knowledge of specifications and application criteria. However, a good practical guideline is to assess a replacement choke based on its physical size and dc resistance. Any choke that measures roughly 2½" to 3" on the long side, around 2" high and about 1" wide in frame size is a good candidate. For that physical size choke, check the dc resistance to determine if it is between 20 and 45 Ω. Chokes with these two parameters (size and resistance) in that range indicate the choke can handle the high-end 150-mA current mentioned earlier. Resistances below 20 Ω tend to show that the choke wire diameter is too large, taking up a lot of the choke size and therefore will have insufficient inductance. Resistance beyond 45 Ω or so needs further analysis as to whether the wire is too long, size is too small, inductance is too high, etc.

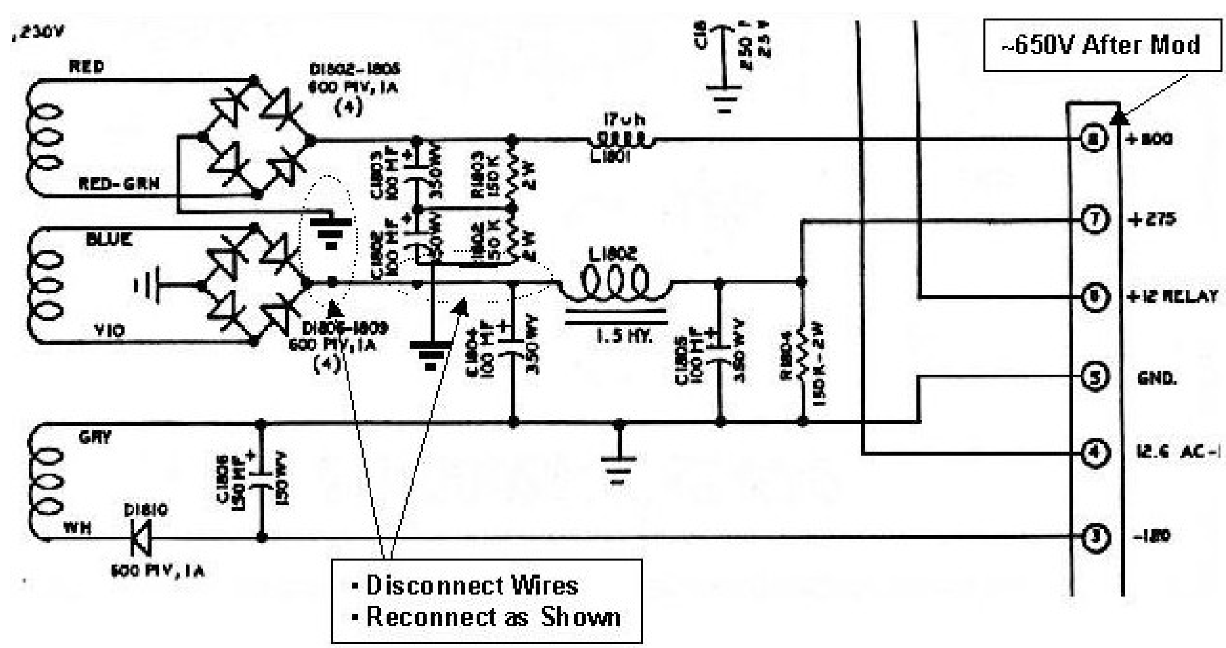
If lucky, you may find a choke laying around in a junk box with the specification sheet. One of the choke specs refers to insulation properties, but it may also be defined in other terms. All transformers and chokes have a BIL rating. There are three or four different groups of words used for that abbreviation, but people in the electrical field use Basic Impulse Level. That is, how much voltage can it take before the insulation breaks down. A ratings of 1,500 V is desirable.

Before mounting a candidate choke permanently to the end/side of the chassis (there is no room other than on the ends and sides of an AC35), temporarily wire up it in for a trial. When you are satisfied the correct choke is in hand, complete the mounting. This option converts the medium voltage section of the power supply to a choke input filter similar to the existing high voltage section of the AC35.

3.6. HV Reduction Modification

Often Swan owners desire to reduce a transceiver's maximum RF power output level capability (especially for the higher power 500/700/750 model transmitters) to preserve PA tube life and minimize stresses on other transceiver components that occur at the rated peak power levels. A reduced fundamental RF output capability is also prudent when a two-tube PA transceiver model is used to drive a linear amplifier, since it limits input power to the linear.

To achieve either of these two objectives, the 117X(C) power supply can be modified to reduce the HV from a



117XC HIGH VOLTAGE MOD

Figure 3-3 HV Reduction Modification Schematic (117XC)

nominal +800 V to approximately +525 V, bringing the maximum RF output power down to about 125-150 W. This modification, shown in Fig. 3-3, isolates the MV circuit (~275 V) from the ~600-V circuit, which are normally connected in series to obtain the nominal +800 V HV output.

Because the 117AC, 117B, and 117C all use a single winding and rectifier bridge to derive the 800 volts, rather than the series connection of the ~300-V MV and ~600-V HV circuits as is done in the 117X, it is not possible to make this modification on those models.

3.6.1. Plate/Screen Voltage PA Issue

A reduction in plate voltage is normally accompanied by a corresponding reduction in the screen and/or bias voltages, otherwise the screen current tends to increase, which may significantly reduce tube life as the higher required screen power dissipation approaches (or exceeds) the tube's rating (see related discussion in Section 6). With 6HF5, 6LQ6, and 8950 type sweep tubes, and the Swan PA circuit in which they are operated, this moderately lower plate voltage does not significantly increase the likelihood of surpassing the screen grid dissipation rating. These big horizontal sweep TV output tubes are normally run at much higher screen grid voltages than true RF tubes (like the 6146), but they also have almost twice the screen dissipation capability.

After this power supply HV modification, the PA circuit parameters are almost identical to those used in the Tempo One, which uses 6JS6C tubes. While the Tempo AC One power supply has transformer taps for both 600 V and 800 V, Tempo strongly suggested that the 800-V tap never be used, only the 600 V was recommended. Under those conditions, the 6JS6Cs sometimes outlived the owner.

3.6.2. Impact on Circuit

The voltage levels from the 275-V supply will not be appreciably affected by this HV modification. The MV is not always an exact 275 V due to variations in 117X(C) power supply components, loads, line voltage, etc.; it typically runs between 265 and 300 V. During receive, the current load added to the HV circuit from the 275-V MV circuit is very low, essentially the current drawn by the bleeder/divider resistors. Therefore, that's as high as it's going to get.

Going into transmit idle conditions and adding 50-mA of cathode current is still no significant burden on the 275-V section. However, with CW or on SSB modulation peaks, about 500 mA or so current load is added from the 275-V supply. Since the 275-V section is already providing 125 to 200 mA (depending on transceiver model and accessory load) for the rest of the circuits, that could mean as much as 700-mA peak is drawn from just the MV alone. Nevertheless, the MV, with two capacitors and a choke, is much better filtered than the HV– it also has a transformer secondary winding that has a much higher current capability than the HV winding, so the MV circuit's output voltage variation is minimal. After this modification, the removal of the large instantaneous current peaks imposed by the plate's HV variations results in an even better MV regulation.

3.6.3. Procedure

Modify the power supply by isolating the HV from the MV circuit (the HV and MV are combined in the 117X circuit designs to achieve the nominal +800 V HV output), as shown in Fig. 3-3. See Fig. 3-7 for the circuit before modification. If one desires, this modification can be made reversible by installing a switch (with proper voltage and current rating) to revert to the original circuit.

SOURCE	Rxr On	Xmt On
HV (VDC)	571	534
MV (VDC)	287	273
Relay (VDC)	16.4	10.62
Fil (VAC)	12.3	12.02
Bias (VDC)	-118.6	-114.4
AC line (VAC)	116.4	116.4

Table 3-4 Modified Power Supply Voltages

- Disconnect the connection going from high voltage rectifier bridge to the positive (+) output of the medium voltage (MV) rectifier bridge and connect it to ground.
- Disconnect the high voltage (HV) filter capacitor C1802 (100 µF, 350 V) and the bleeder resistor R1802 (150 kΩ, 2 W) that are connected to the positive (+) output of the MV rectifier bridge and connect both C1802 and R1802 to ground.

- Reset the idle current to 50 mA and re-tune when the transmitter is first operated with this lower voltage. The same idle current is used for both modified or normal 117XC high voltage operating levels

3.6.4. Measure Voltages (Mod for Lower HV)

Table 3-4 shows reported voltage levels measured on an 117XC power supply (powering a 350C modified to use 8950 PA tubes) after making the HV reduction modification discussed above. The high voltage level has decreased about 65% from the ~900 V typically measured when the transceiver is in receive mode to 571 V. The transmit-on measurements were made on 20 meters with a two-tone modulation test signal (cathode current reading not specified). For comparison, unmodified power supply voltage levels measured on a variety of power supplies, transceiver, and operation combinations are shown in Table 3-5.

3.7. Measured Power Supply Voltages

3.7.1. 117XC Voltages (Unmodified)

While the power supply voltage levels for a given model can be expected to vary a little from sample-to-sample due to component variations, transceiver model loading, ac line-voltage variations, VOM error, etc., measurements show that the output voltages are remarkable consistent. Reported measurements of 117XC power supply voltage levels from eight different units are shown in Table 3-5, along with the HV measurement from a 350D (a Cygnet-like transceiver with an internal power supply).

The NL columns refer to a no-load condition with no transceiver physically attached; all others were made with the supply powering a transceiver (as specified) operated in the receive mode. In the case of the PS-4 (240), the two bias voltages refer to measurements made before and after the modification (using a 1.27-kΩ resistor (measured value)) needed to lower that voltage for operation with the 240 transceiver.

Note the significant drop in all voltage levels from the no-load case to the receiver mode case – an even greater drop occurs during maximum dc input power transmit conditions, as shown by the data given in Table 3-7. Despite the number of different power supply units and the mixture of transceiver loads, in general the reported measurements are quite consistent. Excluding outlier values that are most likely measurement error related (e.g. a HV measurements of 950 V for PS-8 when operated with a 500CX), most measurements are within 5% of one another. Therefore, these values, particularly the 0.5% accuracy (per cent error of actual readings), should be a good indicator of expected 117X(C) measured levels.

Measurement Issues. If a voltmeter has a measurement error of *2% of full scale* (FS) accuracy, a +900 V reading made on a 1-kV scale can only be expected to be at best within ±20 V of the actual value. Accuracy with a percentage of full-scale meter is highly dependent on scale range selected – is the same 1-kV scale were used to measure a 100 V level, the same ±20 V applies. A meter with *2% of reading* accuracy would be ±18 V for a 900 V reading and only ±2 V for a 100 V level. A Simpson 260 with a 2% of full scale accuracy was used for some measurements (indicated by a $^{+}$ superscript), a 0.5% of reading digital meter for others (indicated by a * superscript), and in the remaining cases, the measurement accuracies were not reported and are unknown. Since the ac line voltage will also proportionately affect the readings, its measurement was also included, when available.

3.7.2. Inter-Model Voltage Comparison.

In Table 3-6, inter-model power supply output voltage comparisons are given. In all cases the measurements were made while powering a transceiver operated in the receive mode, using a digital VOM with a 0.5% of reading measurement error. The 117XC values shown are the average values for the PS-1, PS-2, and PS-4 units

Table 3-5 Measured 117XC Measured on Various Units

SOURCE	Nom.	PS-1* NL	PS-2* NL	PS-3 NL	PS-4* NL	PS-1* 250	PS-2* 350	PS-3 700CX	PS-4* 240	PS-5 N/A	PS-6 350C	PS-7 500CX	PS-8^{+} 500CX	N/A^{+} 350D
AC LINVE		123.9	123.8		124.1	123.9	123.8		124.1				124.3	
HV (VDC)	800	925	938	940	943	914	905	927	917	910	905	893	950	840
MV (VDC)	275	320	324	332	327	302	304	305	309	320	299	298	330	
BIAS (VDC)	-110	-137	-143	-143	-145	-128	-128	-124	-141/-126	-135	-126	-125	-144	
REL (VDC)	12.0	18.2	18.5	20.0	18.5	17.6	16.0	18.0	17.7	18.0	17.0	16.7	18.6	
FIL (VAC)	12.6	13.7	13.9	15.0	13.9	13.5	12.9	13.6	13.4	12.6	12.6	12.1	13.7	

* 0.5% Accuracy, $^{+}$ 2.0% FS Accuracy, NL – No-load

Table 3-6 Power Supply Model Output Voltage Comparison

PWR SUP MODEL	LINE (V ac)	HV (V dc)	MV (V dc)	BIAS (V dc)	REL (V dc)	FIL (V ac)
Nominal (117X Type)	117	800	275	-110	12	12.6
117XC (Avg, PS1/2/4))	**124**	**912**	**305**	**-132.3**	**17.1**	**13.3**
117C No-load 0.5%	124.4	901	380	-123.5	19.8	14.2
117C (500 Rxr) 0.5%	123.5	891	277.5	-105.5	17.6	13.2
117C *(Normalized)*	124	887.4	276.4	-105.1	17.5	13.1
117B (400 Rxr)	125.3	891	275.3	-110.9	17.5	13.2
117B (Normalized)	***124***	***881.8***	***272.4***	***-109.7***	***17.3***	***13.1***
117AC (240 Rxr)	123.4	872	277.7	-98.9	18.6	13.8
117AC (Normalized)	***124***	***876.2***	***279.1***	***-99.4***	***18.7***	***13.9***
Nominal (117AC Type)	117	800	275	-100	12	12.6

shown in Table 3-6, powering a 250, 350, and 240 model transceivers operated in receive model respectively. The 117AC, 117B, and 117C model data show both the measured value at the operating ac line voltage and calculated normalized measurements that would be obtained if they were operated at the 124-V ac line voltage measured during the 117X readings. In addition, the 117C's no-load (i.e. no transceiver attached) are also shown for reference.

This table also shows two manual specified nominal power supply output voltage values, one for the 117B/C/X-type supplies that are used to power post-model 240 transceivers, and one for the 117AC, used to power the model 240 transceiver. Note that for the bias supply, there is a difference between the two nominal operating voltage sets, –110 V versus –100 V. This voltage differential is consistent with the power supply modifications required when a late model supply is used with the 240 or the early model (117AC) is used with a later model transceiver.

While the sample size is very small, the measurements nevertheless clearly show measurable voltage differences from the 117X(C) model, namely:

- ***HV***. The 117B/C's HV levels are somewhat lower than the 117X, as are those from the 117AC. In the case of the 117B, the HV is about 3% lower (31 V) and in the case of the 117AC, the HV is about 4% lower (35.8 V).
- ***Bias***. The bias voltage levels from the 117B and 117C are 22.5 V (17%) and 27.2 V (20.5%) lower than the 117X, while the 117AC is 32.9 V (24.9%) lower. In the case of the 117AC, its design uses a 1-kΩ resistor in series with the BIAS supply, not used in the other models.
- ***MV***. The 117C measured MV level was ~380 V when under no-load (far high than any of the other power supply models) versus 277 V when under receiver load. The 117C uses a dual-choke filter design for the MV – in an unloaded condition, such designs have an abnormally high output voltage level. In contrast, as shown in Table 3-5, the relative MV drop between the no-load and load conditions for the 117X single-choke filter drops only from ~325 V to ~304 V. The operating MV levels of the 117B/C were near identical, but significantly lower than the 117X (~30 V), as was the 117AC's level (~26 V).
- ***Conclusions***. The 117C's values are virtually statistically the same as the 117B's, except perhaps for a slightly higher bias (~6 V). While the HV levels among the models vary somewhat, this is for a lightly

Table 3-7 Power Supply (117XC) Voltages as Function of Load

Power Supply Source	Voltage Range Spec (V)	Nominal (V)	No-load (V)	Rxr On (V)	Transmit (V) 50 mA → 580 mA
HV (dc)	600 to 1200	800	962	927	906 → 750
MV (dc)	225 to 325	275	332	305	300 → 242
BIAS (dc)	–100 to –130	–110	–143	–124	–124 → –123
FIL (ac)	11.5 to 14.5	12.6	15	13.6	13.6 → 12.6
REL (dc)	10 to 14.5	12	20	18	11 → 10

loaded condition – under maximum dc input power conditions (not measured for the 117AC or 117B), the HV drawdown will not necessarily be consistent. Such small HV differences will have very little impact on a transmitter's realizable maximum dc input power. Recall that the 117AC, 117B, and 117C have a physically different transformer and rectifier/filter design than that used in the 117X(C).

3.7.3. Voltage Levels as Function of Load

Table 3-7 shows measurements made on an 117XC mated with a 700CX transceiver under varying operating conditions to examine the overall power supply voltage levels as a function of operating extremes. The nominal voltages shown are those listed in Swan manuals (500CX). The no-load condition is for operation with no transceiver physically connected – the power supply was operated with a jumper between the ac power switch terminals 1 and 2.

The voltage ranges listed in the "Transmi*t*" column reflect the measured HV level in the CW transmit mode when the PA cathode current varied from a 50-mA idle condition to ~580 mA when the transceiver was tuned for maximum RF power output. Measurements shown include VOM errors, so each measurement's true value may be anywhere within ±2% of the full-scale range, but the relative voltage differentials between the measurements should be much more accurate since they were made with the same meter and are confined to the same portion of the meter's display range. The 750-V HV measurements under maximum current conditions are consistent with the independent measurements shown in Fig. 3-4 (at 580 mA, that data ranges from 735 to 752 volts).

3.7.4. HV Load Versus DC Input Power

When making measurements of dc input power (HV_{plate} x $I_{cathode}$), the CW steady-state PA current is directly available from the transceiver's meter, however the power supply's high voltage level is not readily accessible and an estimate must be used in order to calculate dc input power. Depending on transceiver power amplifier

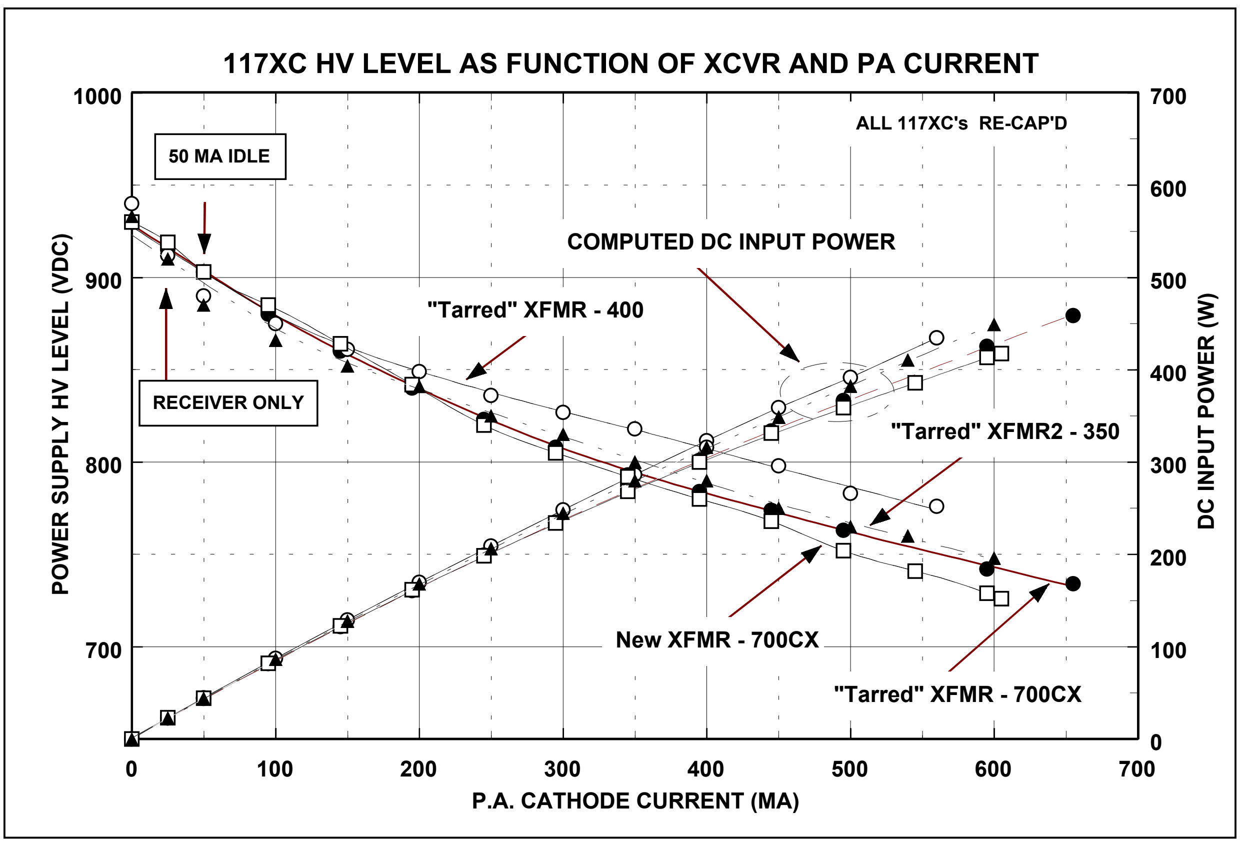


Figure 3-4 Power Supply (117XC) HV Level As Function of Load

current requirements, the HV level will vary significantly, as stated in the Swan Operation manuals and indicated by the measurements shown in Table 3-7.

Therefore, to estimate dc input power levels at a specified cathode current level, it is very desirable to have a good estimate of HV_{plate} to minimize error. To that end, Fig. 3-4 shows detailed comparisons of measured high voltage levels as a function of cathode current for four power supply/receiver combinations.

Measurements were made with a 0.5% of reading accuracy digital voltmeter. In all cases the ac line voltage level was 123.8-V ac and the measurements were made in the 7-MHz band with the voltage and current measurements sampled at the end of a ~3 second transmission period. After first tuning for maximum RF power output into a dummy load, the CAR BAL control was then used to adjust the CW level. While there will be some meter error (both VOM and cathode current) and equipment sample-to-sample variation, the results (especially the relative HV level changes within a curve) should be typical of actual operational values. None of the transceiver equipment was equipped with NOS tubes, but all were in good repair and alignment.

Review of these measurements shows:

Low/No Current Loads. The measured high voltage levels for each equipment combination when operated under no-load (at the zero current point), receiver only, and idle current only (50 mA) operating conditions appended to Fig. 3-4 are consistent with expected values. Under these no/low load conditions, all equipment combinations yielded essentially identical measurements. The total data spread for the no-load, zero-cathode current condition was between 930 to 943 volts, while during receiver only conditions the levels were between 911 and 919 volts. Moreover, during 50-mA transmitter PA idle current conditions, the measurement variance was also quite low with values between 883 to 903 volts, only a 20 V spread.

Measured HV Loading. A number of equipment configuration comparisons are depicted by these data sets. All of the voltage measurements are referenced to the four individually labeled curves that use the graph's left-hand axis scale. In all cases, the data sets have been curve-fitted, so in some cases an outlier data point is not on the specific curve. Two measurement sets show a tarred transformer power supply mated with two different transceivers, a 400 (denoted by the empty circles) and a 700CX (solid circles). A third data set shows measurements from the same 700CX mated with a later version un-tarred transformer power supply (empty squares). And finally, a fourth curve shows measurements collected with a second early version tarred transformer power supply that was operated with a 350C transceiver, labeled Tarred XFRM2 – 350 (solid triangles).

Transmitter High Load Comparison. Despite the differences in transceiver types, one would expect all power supplies to exhibit similar HV level draw-downs, since the cathode current is the overwhelming dominant power consumer. The differences in filament or screen supply power demands because of disparities in tube count or model type are insignificant compared to a ~500-mA of HV current. Therefore, one would anticipate that under a 500-mA cathode current load, all equipment combinations would yield similar HV loadings.

All curves show the expected progressive higher voltage draw-down with increasing cathode current, with the curves very well behaved and near linear. Perusal of the data shows that essentially identical curves were measured in all cases, except perhaps for the 400 transceiver data (empty circles), which has slightly higher voltages levels than the other three data sets at high current conditions. However, the left-hand axis uses a high-resolution scale so the measured differences appear pronounced, but are in fact quit minimal. At 500 mA, there is only a 15-V spread among the other three and, even including the 400 transceiver's data set, the spread is only 30 V, well within the measurement error tolerance. While the VOM had a 0.5% proportional accuracy, most assuredly, the transceiver's meter calibration and linearity (not checked) were much greater, certainly at least in the 2 to 5% range, especially since the highest measurements were in the mid to full-scale region while the meter calibration point is at 50 mA. Therefore, for the curve spread shown, one would suspect that the slightly high 400 readings are most likely due to cathode current meter calibration/linearity error.

Transformer Comparison. The curve comparison (solid circles and empty squares) between the older tarred and the newer un-tarred transformer 117X power supplies, when both were mated with the 700CX transceiver, suggest some possible measurable differences. While both have a quite similar HV variation with load, under extreme conditions, the newer un-tarred transformer's power supply HV is somewhat lower (at 600 ma, 728 V versus 745 V), indicating that indeed the tarred transformer might have a bit more overall reserve capability than the newer versions, as suggested by anecdotal information. However, because of the limited sample size measurement errors these results are far from conclusive.

Measured DC Input Power. Appended to this graph are the corresponding computed CW dc power input curves set (the four unlabelled curves that use the right-hand scale and the same transceiver/transformer curve symbols relationship) for each transceiver and power supply combination, based on the measured voltage and cathode current levels shown in the labeled curves. As illustrated by this plot, the four equipment configurations have near identical dc input powers for any given cathode current level, emphasizing that the 20 to 30-V level differences among the various high voltage loading curves are operationally insignificant.

Estimated DC Input Power. Therefore, based on the information in this figure, adjusting the estimated high voltage level as a function of indicated cathode current should provide a better estimate of true operational dc input power levels for use in efficiency calculations or other measurements. However, recall that these current and voltage data are for maximum steady-state CW RF output conditions. They cannot be directly compared to the SSB dc input PEP levels specified in the Swan operation manuals.

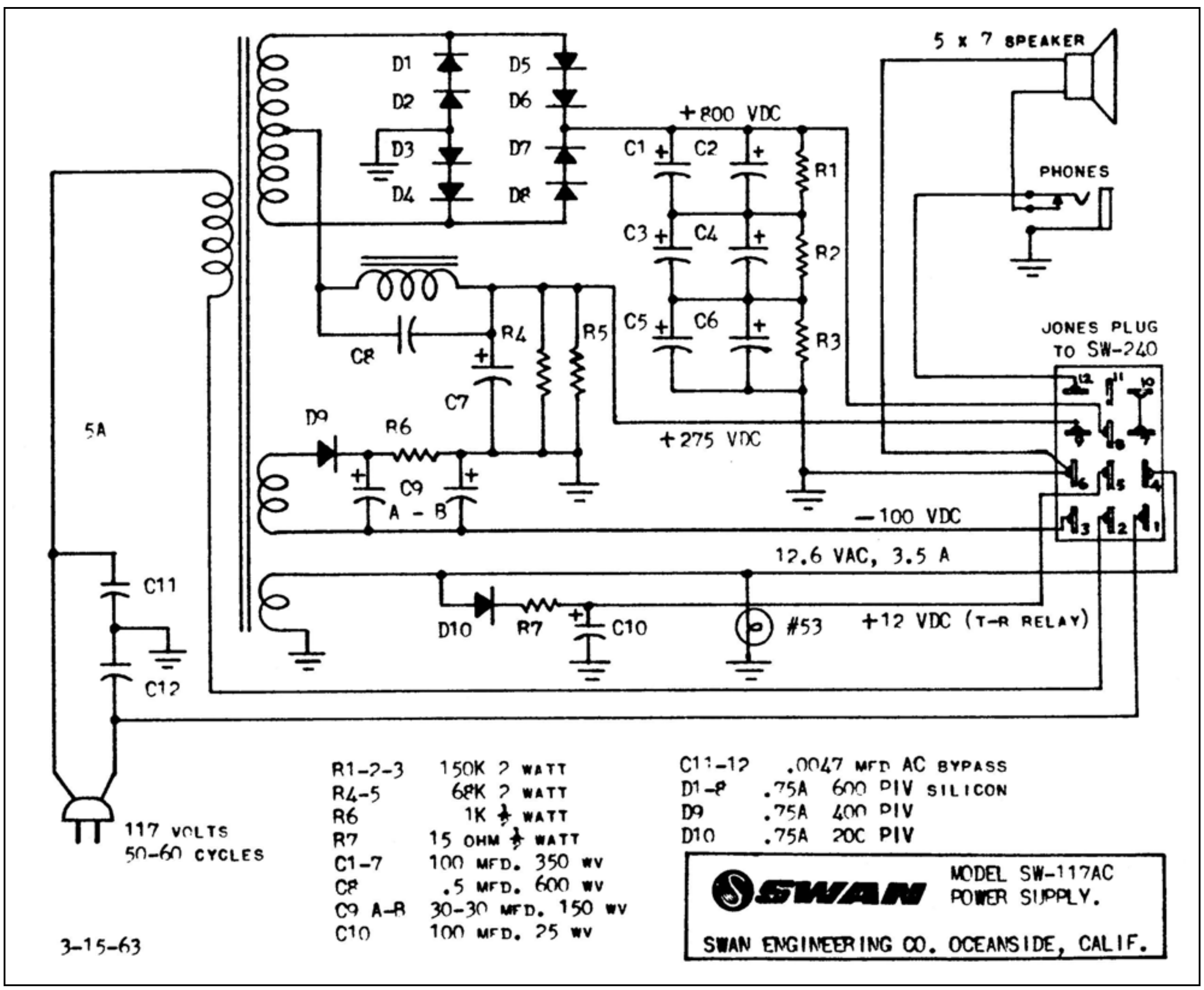


Figure 3-5 117AC Power Supply Schematic

CW Vs. SSB Caveats. Various operating manuals indicate the expected high voltage power supply levels should be approximately: (1) ~925 V under idle current conditions (50 mA), (2) either ~700 V (700CX) or ~720 V (350C, 500C) during TUNE or CW operation, and (3) on the order of 800 V to 850 V during peak SSB loading (variable rather than steady-state modulation). The measurements in Fig. 3-4 only address the TUNE or CW case. These measurements are in fairly close agreement to the Swan values – note that none of the transceivers were equipped with NOS PA tubes, so the specification maximum dc input power and associated cathode current conditions were not necessarily achieved.

The shorter duration maximum SSB dc input PEP values will have an appreciably higher cathode current than indicated by the transceiver's meter, which is providing only a measure of average SSB current. In addition, the power supply's voltage level will drop far less than indicated by this data set due to the transient nature of the load, which will not discharge or load down the capacitors as much as a steady-state CW signal. Thus, a transceiver's instantaneous dc input PEP and corresponding RF output level is substantially greater than the rated CW specification or as indicated by these measurements.

For additional comments related to this area, be sure to review the discussions on power and tube dissipation capabilities in the Swan manuals and peruse the RF output data shown in the Expected/Measured RF Power Output Section 6.2.10.

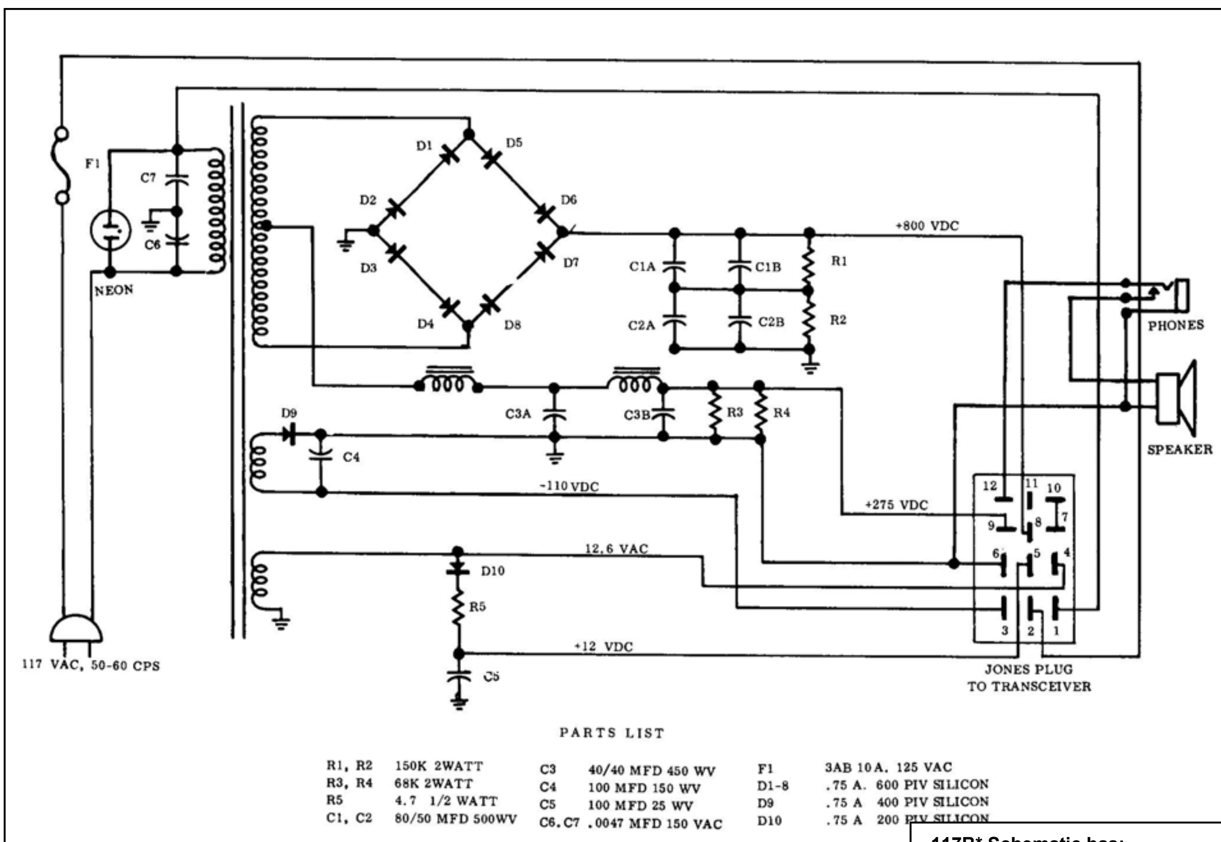


Figure 3-6 117X Power Supply Schematic

117B* Schematic has:
- **No Speaker, Phones Jack**
- **No Neon Indicator Light**
- **A 0.5 uF, 600 V Ceramic Cap across the 1st MV Filter Choke.**

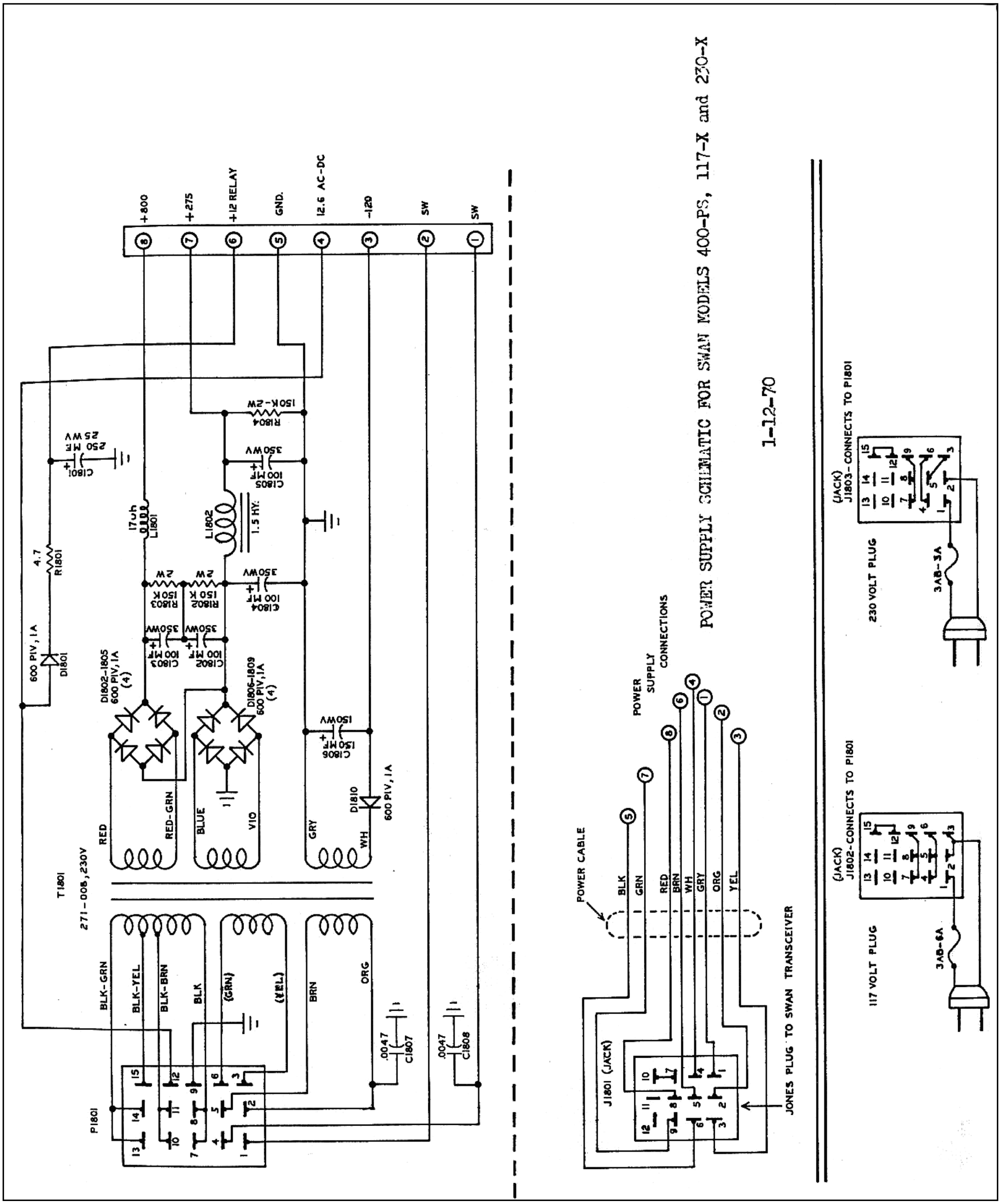


Figure 3-7 117C (117B*) Power Supply Schematic

4. ACCESSORIES

4.1. Amplifiers, Linear

Swan transceivers have hefty dc input PEP levels, ranging from 240 to 700 W and when optimally tuned-up, the dual-tube models can routinely generate PEP RF output levels of 400 to 500-W PEP or more (Fig. 6-11). Relative to today's barefoot solid-state rigs, which typically have a maximum of 100-W PEP/CW RF output, Swan transceivers can be considered to already include a linear amplifier! Since a doubling of power results in a 3-dB signal level increase, a linear amplifier adds little in terms of S-meter signal increases (one S unit equals about a 6 dB increase in signal strength) compared to the barefoot higher-power transceiver models. A 3 to 6-dB power (100 W to 200 W or 400 W increase results in only ½ to 1 S unit of signal level increase on the receiving end and will not be dramatically noticeable.

However Swan did produce a line of linear amplifiers for those who needed or desired to operate at full legal power limit, often marketing them as stand-alone options for use with other equipment or in conjunction with the lower powered Cygnet-type transceiver models. The linear amplifiers offered by Swan were configured with both internal and external power supplies, depending on model. They generally had physical sizes larger (the VHF-150 2-meter amplifier is the exception) than the transceivers (i.e. the typical transceiver is 5.5" high and the 600 "*twins*" are 6.5" high while the linear amplifiers are 8" high and somewhat deeper). Since the typical linear amplifier's maximum RF input power is specified as about 100 W, use with a high power dual-tube PA Swan transceiver becomes problematic.

Swan Transceiver Modifications for Use with a Linear. If you have one of the powerful dual-tube transceivers and want to use it with a linear amplifier, in addition to tune-up and/or operating control adjustments to reduce output power (see Section 5.8.2), there are a couple of hardware modifications that will address the high transceiver RF power output issue. These include: (1) a relatively simple transceiver ALC modification that can be made to permit them to be used more easily with linear amplifiers (see Swan Newsletter, Issue 7, Section A.7.6) and (2) a transceiver power supply modification that will limit the fundamental power from the transceiver by reducing the high voltage level from ~800 V to ~550 V under average transmitter load (see Section 5.8.1.1).

4.1.1. Mark I

The Mark I is rated at 2,000-W dc input PEP, includes a built-in ac power supply, and with a 55-lb weight, this unit certainly falls into the heavy-metal boat-anchor category. It sold for $493 ($425 plus $68 for the tubes) in July 1965. A realistic key down RF output power expectation for the Mark I when powered with 120-V ac is in the 900-W range.

AM Operation Comments. To use this linear amplifier for AM operation, select the TUNE/CW switch position. First load the amplifier to full power to make sure it's set for best linearity. Then, adjust the transceiver's AM carrier power level sufficient to push the amplifier to 250 mA of plate current. For a Mark I equipped with three 400Z PA tubes, keep an eye on the plates to make sure 250 mA is not making them too red. If there is no redness evident, the carrier current level can be increased to 300 mA. A little redness is normal and at 300 mA the dc input power on AM will be approximately 450 W.

Tube Replacement. It is reported that the 3-400Z PA tubes may be replaced with 4-400As. However, while cheaper than the 3-400 tube, the 4-400 does have a lower power capability, which should result in about 100 mA lower cathode current than the 3-400 tubes when loaded to the maximum power and efficiency point. The tube-pin configurations are identical; the same socket is used and the metal ring around the base on the 4-400A does not interfere with its insertion into the flat-ceramic socket meant for the 3-400Z tube. Although the 4-400A is a tetrode and the 3-400Z is a triode, any socket wired for a 3-400Z should automatically connect both grids of the 4-400A together making it operate as a triode in the Swan linear. Just make sure that the 4-400As you are substituting are not too much taller than the 3-400Zs in the unit. Some were a little taller so you have to make sure there is adequate cover clearance. In addition, in most cases, the idle current will be somewhat lower, but as long as it is at least 100 mA, it should be satisfactory, even if the amplifier is operated in the high power position all the time.

4.1.2. Mark II

Like the Mark I, the Mark II linear amplifier also provides 2,000-W dc input PEP on SSB and 1,000-W CW, AM and RTTY on all amateur HF bands plus the MARS frequencies. The Mark II sold for $395 (August 1967) but it did not include a built-in power supply; the matching supply sold for $235. It uses a pair of Eimac 3-500Z triodes and requires a power supply that provides 2.5 kV @ 1.2 amperes. The total weight of the amplifier and power supply is over 50 lbs and the physical height of both the amplifier and power supply is 8", so they do not match the Swan transceivers in height.

There were three design variations used during its production run and the early and late production Mark II power supplies are not interchangeable without rewiring the power cord. The early version(s) has a two-tone front panel, while the later version(s) has an all black panel (similar in appearance to that used on the model 750CW transceiver), uses 3-400-Z versus 3-500-Z tubes, and a 15-pin instead of a 27-pin Cinch-Jones plug on the back. The later versions are a bit lower in overall quality, as after the Herb Johnson era some production corners began to be cut in construction. During Cubic ownership the serial number format was revised – units produced after that time can be identified by their 4 and 5 digit serial numbers, with 2xxxx five digit numbers being the latest. All 4 and 5-digit numbered Mark IIs have a larger π output coil. The meter movement used on this unit is the same as that used on all mid-term dual-tube PA transceiver models (350 through 700CX).

4.1.3. 1200X (Cygnet)

The 1200X portable HF linear amplifier was marketed as a companion for the Cygnet-type transceivers and sold for ~$260 in July 1973. It includes an internal 110/120-V ac power supply and provides 1200-W PEP dc input on SSB, 700 W on CW and 300 W on AM. A 100-W input-drive power is required. The early 1200X amplifier used four 6LQ6 (9 pin) PA tubes operating as grounded grid triodes while later units, built from 1973 on, employed 8950s (12 pin). Although improvement in performance capability with the change in PA tubes (plate dissipation about 30% higher) was probably a consideration, per unit tube price was also certainly a big factor, since that change coincided with the introduction of the 300B and 700CX transceivers, which also used that tube.

High-voltage, high-value replacement capacitors for linear amplifier power supply applications can be very difficult to find. The 225-µF 300-V capacitors originally used in the 1200W and 1200X amplifiers are no longer readily available. However there are other capacitors, which may be used as replacements, namely Sprague DX36 series Powerlytics (Sprague/Vishay part number 36DX261F350AB2A). This unit is a drop in replacement for the original capacitors and is rated at 260 µF @ 350 V. It is available from Newark Electronics for only ~$7 each, so replacing all the units is a good idea. Don't forget to check the old bleeder resistor values while the capacitors are out. If they're out of tolerance by more than 5-10%, replace them with metal film resistors of the same value and wattage.

Cygnet Versus Non-Cygnet Keying. The Cygnets use a floating DC relay keying. The 1200Xs from the factory are wired for 12-V keying, so the relay requires an external 12-V dc source such as from the Cygnet transceivers. The entire 12-V dc line is isolated from ground. The 1200X's factory keying circuit was routinely changed by users to a more common configuration used by other Swan models and brands of exciters/transceivers. In such cases, a rectifier circuit has been (or needs to be) installed in the 1200X, which in most cases uses the existing 12-V ac filament power. The 12-V ac is rectified, filtered, and wired in such a way as to energize its own internal transmit relay. The transmit relay contacts (e.g. 500 transceiver's auxiliary relay terminals) of the exciter completes the circuit that keys the amplifier relay. Check to see if the relay control on the 1200 has already been modified. The 1200X linear amplifier manuals and schematics show the method for changing the keying circuit to conform to the needs of non-Cygnet radios – just reverse the process if you find it has been modified.

8950 to 6KD6 Tube Conversion. NOS 8950 tubes are becoming prohibitively expensive. If you have the late version 1200X that uses those tubes, only minimal modifications are required to change from the 12-volt filament 8950 to the 6-volt filament 6KD6 tubes, as both have 12 pins. Merely change the filament connections so that V1 and V2 are in series and V3 and V4 are in series. Note that the 1200X was built for several years with a few variations in the manner in which they laced the socket wiring – if there is a connection to pin 6 of each tube make sure the same wire (or a jumper) is also at pin 2. In addition, the tubes' plate caps are the smaller C1-2 size, so you will have to change or modify the existing plate-cap connectors. If you have an early 1200X equipped with the 6LQ6, these modifications are considerably more complicated and time consuming.

4.1.4. 1500ZA

The 1500ZA is a high frequency (80, 40 20, and 15 meters) linear amplifier produced in the 1980 time frame that is rated at 1500-W dc input PEP, when driven by an exciter with 100-W RF output PEP. Its styling is similar to that of the 350D and HS700S transceivers (black front panel with aluminum bezel). A built-in power supply uses a transformer with a split primary winding so that it can be internally configured to operate on either 110/120-V ac or 220/240-V ac. The amplifier circuit uses a pair of 572B/T160L triode tubes operated in a grounded grid configuration, in conjunction with a wide-range Pi-network output circuit. Features include a meter for monitoring plate voltage, cathode current, or relative RF output power and front panel switching that permits the unit to be operated in the bypass mode, with the exciter transmitter's output directly coupled to the antenna.

4.1.5. Mark 6/B

The Mark 6 and 6B linear amplifiers were built over an 8-year span with a number of design variations that were made to keep its components consistent with those of the Mark II. The Mark 6 sold for ~$599 in June 1972 and the Mark 6B for ~$680 in July 1973. It was designed for use with the 250C 6-meter transceiver, provides 2,000-W dc input PEP on SSB and 1,000 W on CW, AM or RTTY. A 100-W input drive power is required. Like the Mark II HF linear, it uses two Eimac 3-500Z triodes. The required external power supply provides 2,500 V at current levels of 1.2 amperes. In addition, like the Mark II, each model has a total weight of about 50 lbs (including the power supply) and is 8" high.

4.1.6. VHF-150

This linear amplifier provides 150-W dc input power on 2 meters and includes a built-in 117X power supply. It sold for ~$300 in July 1973. For the FM and CW modes, it operates as a class C amplifier and, with a switch change, as a class B amplifier for SSB and modes requiring more linear operation. With the addition of the 14C dc converter module, it can be used mobile. Only 6 to 10-W RF drive is required to provide the full 150-W RF output. The height of this unit is 5.5", the same as the 250/C transceiver.

4.2. Antenna Tuners

Swan did not market antenna tuners until well into the solid-state era; the initial tuner models (e.g. ST-1) were styled and designed for use with the later high power base-station transceivers models (e.g. 700CX) and/or linear amplifiers. Later tuner models (e.g. ST-3) were styled (flat black panel with aluminum bezel) and designed for used with the portable, lower power tube-design (e.g. 350D) and solid-state transceivers (e.g. 100MX). However no tuner is generally required for use with tube-design transceivers (unless impedance matching to a long wire, balance feed-line, and/or an unusually problematic antenna/feed-line system with high SWR (such as the GR5V) or other RF problems are encountered) since the π network performs essentially the same impedance matching between the PA circuit and the antenna/coax system as is done by an external tuner.

The ST-2 and ST-3 model designs were both changed mid-production run to include a PEP RF output measurement capability, however when this function was incorporated, there was no change in the model number. Therefore, tuners that have the same model number may or may not include this feature. With tuners that have wattmeters that include both forward and reverse RF power measurement capability but without the PEP function, Swan provided a nomogram that permits the user to quickly determine SWR, similar to that shown in Fig. 4-5. Small production modifications to each of the tuners resulted in model designator changes to the ST-2A and ST-3A.

ST-1. The ST-1 is rated for 3-kW PEP over the 1.7-MHz through 30-MHz frequency range. Matching is provided for coaxial (SO219) and random wire or balanced line tuned feeders using ceramic feed-throughs. The unit includes a built-in 4:1 balun and it has no meters.

ST-2/A. The ST-2/A is also rated for 3-kW PEP over the 1.7-MHz to 30-MHz frequency range, has antenna inputs and a built-in 4:1 balun similar to the ST-1, but also includes both a forward reading 0 to 2,000-W and a reverse reading 0 to 200-W meter, which measure RF power simultaneously. The unit did not initially have RF

PEP measurement capability, but some later versions with this same model number did include this function. The factory direct price for the ST-2 in 1977 was $250.

ST-3/A. ST-3/A is rated at 200-W CW (steady carrier) and should handle from 250 to nearly 300-W PEP on SSB over the 1.7-MHz to 30-MHz frequency range. Running at higher power will usually takes out one or two small fixed coupling capacitors. It includes both a 0 to 200-W forward and a 0 to 20-W reverse reading RF wattmeter. This tuner is designed to match the appearance of the 100MX model HF transceivers (or later tube versions such as the 350D) with an all black front panel, black main-tuning dial, and a curved aluminum bezel around the front perimeter of the panel. As noted above, tuners with this model number may or may not include the PEP function. This unit is similar to the Kenwood AT-230; it has the same specifications and maximum power rating.

MMBX. The MMBX, is a small (only about 2" x 3" x 2.5") mobile antenna matchbox (impedance matcher) that handles 500 W over the 3 to 20-MHz range. It is designed to minimize transmission line losses and maintain a low SWR. A rotary switch is used to select any one of seven fixed impedance adjustment settings, which taps an appropriate selected impedance from the MMBX's torroid coil.

4.3. Cooling Fans

Needless to say, with a complement of 12 (e.g. 260) to 17 (e.g. 400, 500) tubes, Swan transceivers, like all tube-era gear, can generate a considerable amount of heat during normal operation. While this may be good on a cold winter day, it is not too healthy for the rig (especially for the PA tubes) if it's operated under adverse conditions. Among the conditions that can cause excessive heat build-up are: (1) long tune-up periods, (2) incorrect tuning/operational adjustments (bias, loading, overdriving), (3) lengthy CW or AM operations, (4) high ambient temperature environment, and (5) insufficient air circulation space around the rig.

Measured Rig Temperatures. So, just how hot does a typical Swan transceiver get during normal operations? Fig. 4-1 shows temperature measurements from a 500CX with a temperature probe placed directly atop the cabinet, towards but not over the PA cage. The ambient room temperature was initially 67 °F (19.4°C) and the transceiver was located on a shelf with ~1" clearance on each side and about 2" between the top of the rig and the next shelf – not ideal, but perhaps representative of the operating set-up used by many amateurs. After the initial ac power turn-on, the transceiver remained in receive mode until the rig's temperature stabilized. As shown, with normal convection cooling (no external fan operating), the temperature increased from the 67° F to ~118° F (47.9° C), where it became fully stabilized after about 40-60 minutes. During this time, the room ambient increased to 70° F. A similar stabilization temperature was attained directly on the top-center of the cabinet. Is it any wonder that Swan specified VFO drift stabilization period of one hour?

What happens when fan cooling is added? In this case, a 5" low velocity computer type 12-V dc fan was placed atop the cabinet over the PA cage area – the temperature sensor remained in the same position on top and towards the right-hand middle of the cabinet, near the PA tubes. The fan had an open-cell dust filter on the intake and was oriented to push air into the cabinet; effective airflow fan was probably 30 CFM or less with the flow re-

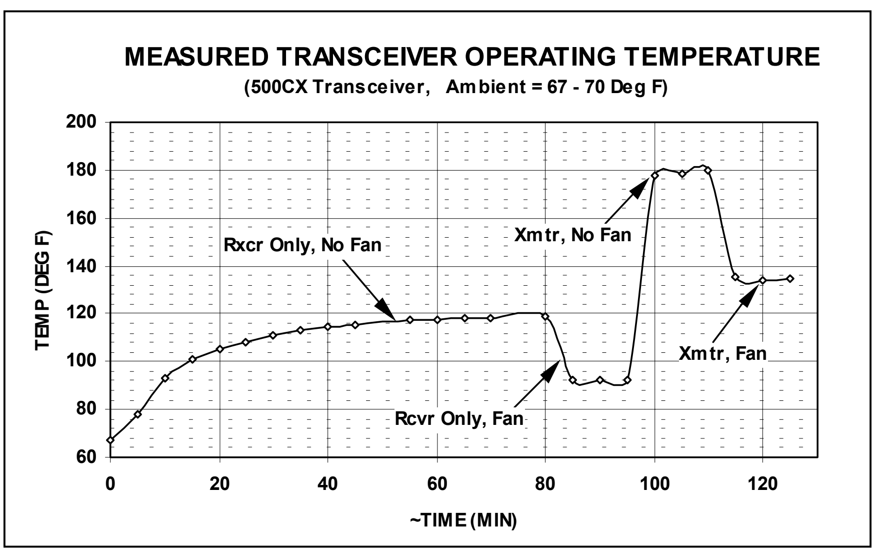


Figure 4-1 Measured Transceiver Operation Temperature

striction by the foam filter and transceiver case. As shown in the graph, with the transceiver still in the receive mode, the temperature decreased ~28° F (14.6° C) to a rather comfy 92° F (33.3° C)!

The fan was then turned off and the transmitter exercised during tests to measure the CW and SSB RF PEP output in each band. During this extended measurements, the transmit periods were extremely short (~3-5 seconds), with similar short periods (~5-10 seconds) of transmitter idle time between adjustments and measurements, and somewhat longer time periods (20 or 30 seconds) for receiver operation mode and band changes. Therefore, while the transmitter is being exercised vigorously for an extended period, its duty cycle was likely no more severe than during normal CW or extended SSB operations. With just normal convection cooling (the fan was turned off, but left in place), the temperature near the PA cage increased to ~180°F (82.2° C), a whopping ~62° F (34.3° C) increase from the receiver only condition with no external fan cooling! With more aggressive transmitter operation, this temperature would be even higher. Of course, such high transmitter temperatures are not surprising since tubes, such as the 6JE6C are specified to have a maximum 482° F (250° C) hottest point envelope temperature, when operated at the maximum rated conditions (e.g. 990-V, 350-mA average or 1,200-mA peak cathode current). When the fan was turned on and the tune-up and RF power output measurements continued, the temperature decreased 45° F (25° C) to ~135° F (57.2° C)!

Of course, a whole host of variables (transceiver model, sensor placement, ambient temperature, transmit levels and durations, etc.) can affect the measured temperature and its increases as a function of time, but these data certainly give a good conceptual representation of what's happening heat-wise. Obviously, a cooling fan will always be beneficial for the PA tubes, regardless of its operational environment, since it helps to disperse destructive centralized heat. While many Swan rigs have been used extensively for years relying only on the convection cooling permitted by the transceiver case ventilation holes, in such cases adherence to proper operating procedures was essential to prevent the overheating that shortens tube and component life. Proper cooling is particularly important during AM or CW operations, which place the greatest heat dissipation demands on the tubes.

Cooling Fan Options. While additional cooling is obviously of great benefit, it must be emphasized that it doesn't replace proper operating procedures. Don't push the finals just because cooling has been added. You have a number of options with respect to fan types, installation, and orientation, including:

Orientation. You can orient the fan so that it either pushes air into or pulls air out of the cabinet. Each orientation has its pros and cons. The puller configuration can certainly remove warm air from the PA tube compartment more efficiently, but as it draws air in through any opening in the transceiver cabinet, it also brings in anything floating in the air, including dust, smoke, pet hair, and dander, etc. The pusher, on the other hand, blows the air out of those openings and its airflow is more restricted by the cabinet, but, with the addition of a simple filter element (open cell foam window air conditioner filter, etc.) placed at the intake of a pusher fan/blower, cleaner air passes over the PA tubes and throughout the transceiver.

12-V dc Fans. Use a 12-V dc power supply brick and a 12-V dc brushless fan (CPU/Computer). If desired, a simple variable dc-to-dc voltage regulator may be used to adjust the voltage and thus the fan speed. While power can be tapped off the Swan's internal power supply, using an external brick-type power supply does not add any load to the rig and permits swapping a fan between radios. Another alternative is to full-wave rectify the 12-V ac filament line from the transceiver and wire two 12-V fans in series (or power it off the filtered 17-V dc). The fans will be very quiet when run at voltages below their nominal rating.

120-V or 220-V ac Fans. Use a 120-V ac fan plugged into an ac receptacle – if it's on the same power strip that powers the rig, it can be turned on/off with that strip. For quieter operation, use a 220-V ac fan running on 120-V ac. Note that some impedance and stall protected fans have a problem when operated at a lower line voltage, causing failure or just not working at half voltage, although this probably is not a common problem.

Portable. The easiest way to utilize a fan is to simply stick rubber, felt pads, or adhesive magnetic strips on the bottom of the fan cage and simply rest the fan on top the transceiver case. With this configuration and an external power supply (rather than physically attached with screws or bolts and using internal power), one fan can easily be used between multiple rigs.

Fixed Installation. A larger size computer type fan may be directly mounted to the exterior of the case. If a very thin 12-V CPU-type fan is used, it can even be installed inside of the PA tube cage using thin screws thru the existing vent holes. Orient fan to blow into (or out, depending on your preference) the PA cage. The fan should be powered with a shielded cable, cutting the wires as close as possible to the fan. Run the cable through the bottom of chassis, connecting the shield to ground and the hot wire to +12 V with a bypass capacitor to ground to keep out RF. One primary benefit of this method is that it will not be visible from the outside of the cabinet and the fan will run quietly.

4.4. Filters, Audio/Noise Blanker

The normal acoustic loudspeaker or headphone output you hear is whatever audio information is passed through the 2.7 kHz (3 kHz in the 120, 140, 175, 240, and early version 350 and 400 model transceivers, and 2.8 kHz in the 250/C models) bandwidth IF filter. Other than for this IF filter, which has quite good bandpass characteristics (steep skirt slope, high out-of-band signal attenuation, etc., especially if the SS-16/B optional filter is installed) that provide excellent selectivity, Swan transceivers have none of the capabilities for signal processing typically found on newer state-of-the-art radios (variable bandpass, narrowband and notch filters, automatic tone removal, etc.). However a number of Swan optional kits and modifications, and other aftermarket products can be used to enhance SSB and CW reception, null-out heterodynes, or reduce impulse noise, as delineated below.

4.4.1. AF-800 and CW Built-In Filters

Some Swan transceivers (e.g. 350A/B/D, 600T, HF700S, 750CW) include a built-in or optional audio filter with a selectable audio bandpass switch that permits use of the standard SSB full-audio bandpass (2.7-kHz standard – an optional 6-kHz AM filter was available on the 600R.) or a narrower-band audio filter for CW operation (i.e. selectable 80-Hz or 100-Hz bandwidths and an optional 600 Hz bandwidth for the 600R).

An optional narrowband audio filter, the Swan Audio Filter Model AF-800 was also available for installation within the 117XC cabinet for narrowband CW operation. This unit was initially offered as an accessory to the 117XC power supply in early 1970, with a selling price of $28. Since it only processes the audio output to the speaker, it is compatible with any transceiver model using a power supply with an external speaker, however space constraints may prevent it from being mounted within some cabinets, depending on speaker size.

4.4.2. Audio Notcher-Peaker – I.C. Audio Filter

The Swan I.C. (Integrated Circuit) Audio Filter (ICAF), or Audio Notcher-Peaker Kit, was available as a stand-alone accessory for Swan transceivers, selling for ~$59 in December 1972. Installation requires some modification to the transceiver. The unit provides front panel controls to select NO FILTER, NOTCH, or PEAK modes. The NOTCH mode provides a tunable audio notch to suppress heterodynes or unwanted CW signals by up to 50 dB. The PEAK mode provides a tunable and variable narrow audio bandpass to enhance CW reception – the 6-dB down bandpass is variable from ~1.1 kHz to ~200 Hz. This unit is one of the built-in features that is included in the Model 600R Custom receiver twin.

The signal processing was performed in-part by a 14-pin integrated chip made by KTI in Santa Clara, CA that is labeled FX-60. Unfortunately this IC is no longer available and substitutes for it have not been reported, however in the February 1978 edition of *Ham Radio* magazine there is an article describing the inside of the chip and alternate chips to replace it, which may be of assistance for problems in this area.

4.4.3. Filter, Notch (Modification)

A notch filter modification can be made on early Swan 350 and 400 transceivers (See Newsletter, Issue 10, Section A.10.7.). This modification provides a tunable notch by modifying the shunt crystal circuit in the 5 discrete-crystal IF filter that is normally used for additional carrier oscillator signal suppression. It cannot be made on versions of these transceiver models that employ the encapsulated IF filters.

4.4.4. Filter, Audio (External)

To add an economical external SSB, CW, and notch filter capability, an older analog operational amplifier design tunable audio filter (e.g. Autek Research QF-1A or the less capable QF-1) or one of the newer digital processor based filters (e.g. Timewave DSP-9) can be simply added at the speaker output. Note that with the

Timewave, the ¼" input male plug at the 117XC external speaker jack needs to be an old style non-stereo type plug to properly feed the audio input to the Timewave unit, otherwise, no audio will be heard.

An added off-board audio filter will often have a very high input impedance and, when installed using the speaker jack, the 3 to 4-Ω speaker load will be removed from the output of the audio transformer. While an open audio transformer can cause transformer failure, in general, it should not be a problem with the Swan transceivers. Inspection of the schematics for a variety of later designs (500Cx, 700CX, etc.) shows that a fix resistance in the 60 to 350-Ω (total) range (associated with the CW side-tone monitor function) is across the audio transformer at all times. The early 350 Series design does not include these resistors unless the CW side-tone upgrade modification has been made. If desired, a low value resistor can be included across the input to the off-board audio filter to preclude any possible problem with an unloaded transformer secondary.

4.4.5. Noise Blanker, NB-500

The NB-500 Noise Blanker Kit was available as a stand-alone add-on accessory for the model 270/B, 350C, 500C, and 500CX 5.5-MHz IF transceivers. Some modification of the transceiver was required. The circuit amplifies and clips impulse noise pulses prior to feeding the signal to the crystal filter, eliminating the pulse stretching effects that occur in a high selectivity filter. Two levels of blanking (medium and maximum) were selectable via a front panel control (as well as Off).

4.4.6. Noise Silencer NS-1

The NS-1 Noise Silencer is a small stand-alone off-board black-box accessory specifically intended and marketed for use with the 250C, selling for ~$40 in July 1973. It is designed and factory tuned for the later 10.9-MHz IF, but can be retuned for the 10.7-MHz IF of the baseline 250 model. Swan issued instruction sheets for modifying the 250 to accept the NS-1. If used with other rigs, such as the 350, the two IF transformer circuits must be modified.

When used with a 250C, a one S-unit improvement in background noise level has been reported (without loss of signal); test measurements indicated that a S9 was equal to –73 dBm (or 50 uV) and that the minimum detectable tonal signal levels were –120 dBm on SSB and –115 dBm on AM. Minimum detectable signal level measurement procedures were not specified (most likely aural). Recall that S-meter calibration and linearity can be quite variable, so actual readings on other transceiver units may differ significantly, even though the true performance might be similar.

4.5. Filter, Intermediate Frequency (SS-16/B Option)

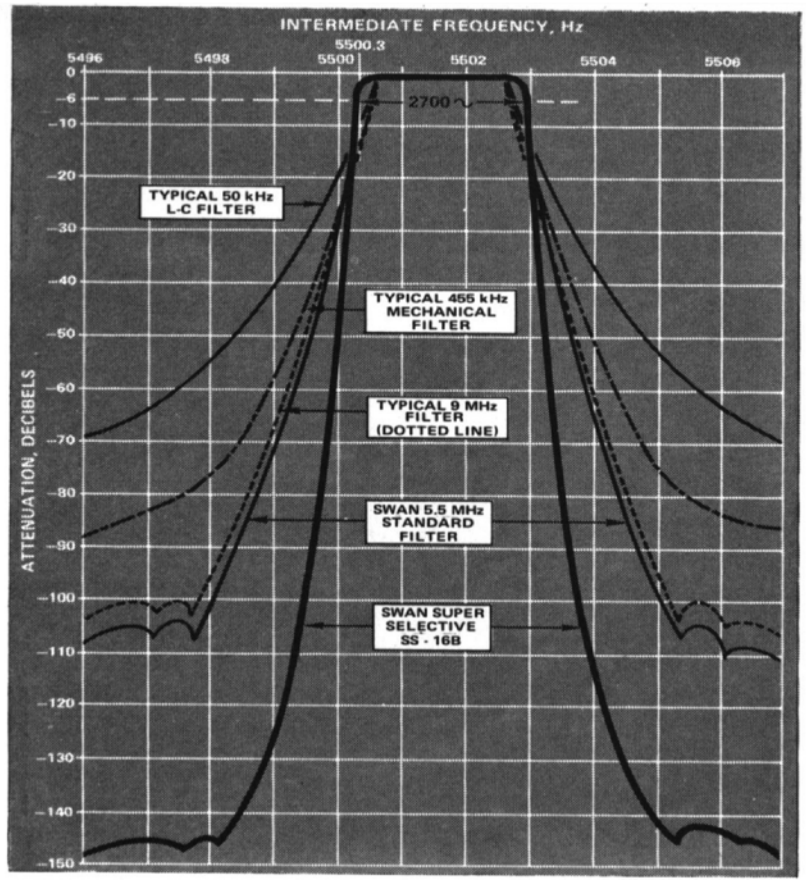
The SS-16/B (Super Selective, 16 crystals) IF filter is a highly selective version of the standard encapsulated 8-crystal filter design. It was available as an option for both 5.173-MHz and 5.5-MHz IF transceiver models. The SS-16B version of this filter was introduced in mid 1971. The SS-16 sold for ~$75 in February 1971 while the SS-16B sold ~$80 in September 1973. This encapsulated filter has the same footprint as the standard 8 crystal filter, but at 2¾" high, it's just over double the height of that unit – it may be two stock filters cascaded and encased in one shell, probably with some minimal matching network between them to obtain 16-crystal design out of two stock 8-crystal filters.

This filter was factory installed on some units during production and marketed as a special version of a particular transceiver model (e.g. 500CX, 700CX), installed as a factory upgrade, and sold as a kit for user installation. When installed at the factory during transceiver assembly, Swan not only affixed a SS-16 Special (or SS-16B for the later version) plaque under the VFO tuning dial, but it also appears that transceiver serial numbers on such factory-installed units begin with a SS designation.

As shown in Fig. 4-2, the SS-16/B has much steeper filter skirts and much greater out-of-band signal rejection than the stock 8-crystal filter. According to Swan's advertisement information, the SS-16/B has the same 6-dB down bandwidth as the standard crystal filter (2.7 kHz), but has a shape factor (defined as the 60-dB to 6-dB down bandwidth ratio) of 1.28 versus 1.7 for the stock 8-crystal filter (~3.5-kHz BW versus ~4.6-kHz BW respectively at the 60 dB down bandwidth). It also has a theoretical maximum out-of-band rejection of 145 dB versus 104 dB for the stock filter. This steeper filter slope and higher out-of-band rejection more effectively attenuate very high level signals outside its bandpass and thus permit improved operational capability in crowded band conditions or when extremely strong signals are near your operation frequency.

Also shown in Fig. 4-2 with the standard Swan stock 8-crystal and optional 16-crystal IF filter responses are those from other competitor's typical filters of the day, normalized for plotting purposes to a ~5,501.65 kHz center frequency. The Swan 5.5-MHz IF designation (and also the other IFs) is normally referenced to the lower filter skirt – in the case of the stock 8-crystal encapsulated filter, the actual center frequency is approximately 5,501.65 kHz.

There were reportedly four versions produced, with the early version SS-16 designed for use with 5.173-MHz IF transceivers (i.e. 240, 350, 400, 500 models) and later versions for the 5.5-MHz IF transceiver models (i.e. post 350C, 400C, etc., except for the 250/C six-meter models). The 2nd and/or 3rd SS-16 versions apparently have an actual design frequency slightly different from that of the stock 8-crystal filter (5,501.65 kHz versus 5,500.25 kHz center frequencies), requiring a carrier oscillator crystal(s) with a slightly different frequency. The last version, the SS-16B appears to have the same nominal design frequencies as the stock filter (5,500.25 kHz) and to use the same CO crystals as the standard stock IF filter. Note that even when filter modules are of the exact same version, their actual filter center frequency and bandpass characteristics are still not precisely the same – the carrier oscillator adjustment compensates for any small manufacturing variances.



SS-16 versus Standard Filters

Figure 4-2 IF Filter Bandpass Comparison

Even to this day, these filters are as good as anything there is out there. They are not difficult to install, but the carrier oscillator will need to be aligned and the installation of different carrier oscillator crystals might be required. While the original filter manufacturer is still in business and could build some of these excellent filters for current use, the cost is prohibitive, with a $150 per filter cost in large quantities (e.g. 1,000).

Shunt Crystal Comments. It has been reported that the standard stock 8 and 16-crystal designs might utilize two and four of the crystals respectively for shunt purposes to further suppress any residual carrier oscillator signal from the balanced modulator, similar to what is done in the 5 discrete-crystal design used in the early version 350 and 500 transceiver models. If so, the filters would then use only 6 and 12 crystals respectively for filter bandpass formation. However careful examination of the published IF filter skirts clearly shows that all stock 8-crystal encapsulated filters appear to have 8 poles (8 crystals are used for filtering) since their filter skirt slopes are ~48 dB/octave and likewise the SS-16/B, encapsulated 16-crystal filters have 16 poles (all 16 crystals are used for filtering) since their filter skirt slopes are ~96 dB/octave. Swan advertisement literature also repeatedly and specifically refers to the filters as 8 and 16-poles. So, if shunt crystals are incorporated into their design, it is in addition to those used for filter bandpass formation. Additional general information on IF filters and their design is given in Section 2.2.3.

Filter Design Comments. The number of poles in a filter is determined by the total number of crystal, RC, RL, or LC components used in its construction. The term poles (and zeros) are associated with a mathematical transfer functions (i.e. differential equations) that defines the theoretical filter shape and characteristics (bandpass ripple, slope, phase response, etc.), which are implemented by the physical components. One crystal is required for each pole in the network, or for a RC, RL, or LC filter, there is usually one pole per component pair.

In general, each pole generates a 6-dB/octave amplitude roll-off, thus a 4-pole low pass filter has a ~24-dB/octave roll-off above or below its design frequency. A six-pole filter requires either six crystals or six LC sections and has a ~36-dB filter skirt roll-off, and so on. The effect of the number of poles on the steepness of the filter-skirt roll-off is clearly seen in the differences between the standard stock 8-crystal (8-pole) and optional SS-16/B 16-crystal (16-pole) curves shown in Fig. 4-2.

4.5.1. GRID Peaking and AM Operation Issues

Examination of the nominal IF filter curves shown in Fig. 4-2 illustrates that the SS-16 filter has ~20 dB or more attenuation at the carrier oscillator frequency (e.g. 5.5 MHz on the graph) than the standard 8-crystal filter. With this much steeper filter skirt, AM transmission may no longer be possible due to the inability to inject sufficient carrier and have it pass through the filter skirt to obtain the required AM carrier power output level. Remember, the carrier oscillator's frequency is normally adjusted such that a 300-Hz audio signal is just at the 6-dB down point of the IF filter skirt, with the actual CO signal (used during AM) 300 Hz further down the filter slope. With that adjustment the SS-16 significantly reduces the CO signal, relative to the stock 8-crystal IF filter, to such an extent that when the microphone is keyed, you may not even have sufficient carrier signal level to obtain an adequate power level to adjust the GRID for a peak!

Because of this, the tune-up instructions provided in the standard manual are probably not useable for transceivers with the SS-16 filter installed. An addendum was provided by Swan for transceivers with it installed; the instructions for the 500CX SS-16B transceiver tuning are shown in Fig. 4-3. They specify that GRID tuning be done in the TUNE mode where full CW carrier can be inserted (rather than CO insertion via the CAR BAL control when the microphone is keyed). In the TUNE mode, the carrier oscillator signal frequency is increased ~700 Hz in frequency (the same as is used in the CW mode), which places the carrier well within the SS-16 filter's bandpass. For transceivers that allow variable carrier level insertion when in the TUNE (or CW) modes via the CAR BAL control, or transceivers that have been modified to have this feature, tuning is much easier, since lower carrier levels can be inserted for GRID control adjustment purposes, as is normally done when the microphone is keyed and the CAR BAL is rotated slightly. Of course, with the potential to insert full carrier, one must still be extremely careful to rapidly peak the GRID, even with limited carrier insertion. An alternative to using the TUNE position is to use the CW mode with a key – even if the variable signal insertion via the CAR BAL control is not available, the key can be used to transmit for only very short intervals while the GRID is peaked and the PLATE and LOAD controls are adjusted.

Instruction Paradox. It is interesting to note that these operating instructions are in direct conflict with (some) SS-16 filter kit installation instructions. In the first case, it is stated that AM operations are not feasible because of the reasons cited above. In the second case, procedures are given for adjusting the carrier oscillator (CO) trimmer capacitor using carrier only (as opposed to the 1,500 and 300-Hz audio signals), to ensure that ~150-mA cathode current is available during carrier injection for AM operation. Doing this adjustment (described below) insures that sufficient AM carrier is available, but also misadjusts the 300 to 1,500-Hz audio signal ratio that is normally used during CO adjustment. It moves the CO frequency up the IF filter slope so that more of its signal passes through the filter. Thus, relative to the normal CO adjustment procedures specified in the Operation Manuals, the carrier frequency is intentionally adjusted too high, so the audio may sound a little low (bassy).

4.5.2. Filter Installation

When a transceiver's crystal filter is changed from the stock filter to the SS-16 filter, the normal and opposite sideband (if available) carrier oscillator crystals might have to be changed depending on SS-16 version. According to Swan's manuals (for the 500C/CX, 350C, etc.), the stock 5.5- MHz 8-crystal filter has a nominal 6-dB down bandwidth from 5,500.3 kHz to 5,503.0 kHz with a center frequency of ~ 5,501.65 kHz consistent with the upper and lower sideband carrier oscillator's crystal frequencies of 5,500.0 kHz and 5,503.3 kHz that are used in those transceivers.

SS-16 CO Crystals. In the case of the 2nd and/or 3rd version of the 5.5-MHz SS-16 filter, it has a 6-dB down bandwidth of approximately 5,498.8 kHz to 5,501.7 kHz with a center frequency of ~5,500.25 kHz. The frequencies of the carrier oscillator crystals included with the SS-16 kit, intended for 500C/CX, 350C, and 270/B installation, are 5,498.5 kHz and 5,502.0 kHz.

SS-16B CO Crystals. In the case of a factory installed 5.5-MHz SS-16B IF filter version (installed in a 700CX), it should have the same 6-dB down bandwidth and center frequency as the stock 8-crystal filter since the frequencies of the carrier oscillator crystals used are stock 5,500 kHz and 5,503.3 kHz frequencies.

With the stock CO crystals, there is apparently insufficient carrier-oscillator trimmer-capacitor adjustment range to handle the 2nd and/or 3rd versions of the SS-16 IF filter without the carrier oscillator crystal change, thus the inclusion of replacement CO crystals in some SS-16/B installation kits.

The kit installation instructions for the 500C, 500CX, 350C, and 270B are relatively straightforward (they might differ somewhat for later transceiver models). However they do specify two minor changes to existing components: (1) the ground termination of the 430-pf capacitor connected to the filter input terminal is changed to the mounting screw that holds the balanced modulator transformer to the chassis, and (2) the ground termination of the 0.01-µF disc capacitor attached to one terminal of the balanced modulator transformer is changed to the same

500CX/SS-16B SPECIAL TUNING INSTRUCTIONS

This addendum provides new tuning procedures for the Swan 500CX/SS-16B special. This new procedure is necessary because of the steep skirts of the SS-16B filter. It is no longer possible to obtain sufficient carrier insertion with the FUNCTION SWITCH in the "TRANS" mode. Therefore, all preliminary and final tuning of the transceiver must be accomplished with the FUNCTION SWITCH in the TUNE position. Extreme caution must be exercised when using these new procedures, because full carrier insertion is possible, and serious damage to the final amplifier tubes may result. Follow the instructions carefully, observing the 30 second time limit, and quickly resonate the plate tuning as described.

With the addition of the SS-16B filter, AM operation is no longer possible with the 500CX/SS-16B Special Transceivers.

TRANSMITTER TUNING:

SPECIAL NOTES: Read carefully. Be sure that you understand and remember these notes when tuning the transmitter.

The most important detail to keep in mind when tuning the transmitter portion of your Swan 500CX/SS-16B Special Transceiver is that the **PA PLATE *MUST BE RESONATED AS QUICKLY AS POSSIBLE!*** The PA tubes are dissipating all the power input when they are not in resonance, and can be permanently damaged in just a few seconds. Once resonance has been established, the PA tubes can operate at full power input for a considerable length of time, although we recommend 30 seconds as a safe maximum. But it is most important to realize that the 30 second time limit assumes that the PA PLATE has been IMMEDIATELY resonated. This rule applies generally to all transmitters.

PA PLATE resonance is obtained by tuning for a PEAK with the FUNCTION SWITCH in the "TUNE" position.

In the 500CX/SS-16B Special, you are reading cathode current in the Press-To-Talk and CW modes.

In the TUNE mode, you are reading RELATIVE OUTPUT, and the PA PLATE must always be tuned for the PEAK in meter reading.

Read these items over carefully to be sure you fully understand them.

The OUTPUT LEVEL control located on the right hand side of the panel meter adjusts the meter reading to a convenient level when in "TUNE" mode. It is important to realize that this control has NO EFFECT WHATSOEVER on transmitter power. When in "TUNE" mode, the meter is strictly a relative indication of power output.

Figure 4-3 SS-16B Operating Instructions (500CX)

new ground point used by the 430-pf capacitor (this change is deemed as critical in the instructions).

There is no coil trimming or other alignment required, except for the adjustment of the carrier oscillator frequency, which is critical. Recall that even when changing the filter with one of the same type, carrier oscillator adjustment will probably still be required, since all filters are unique, having some variations in center frequency and bandpass filter characteristics.

Carrier Oscillator Adjustment Summary. The standard carrier oscillator adjustment procedure outlined in most manuals is to introduce a 1500-Hz sine wave audio signal into the microphone input and adjust the power for ~40-W RF output into a 50-Ω dummy load. The audio generator frequency is then swept down to 300 Hz (the early mono-band 120/140/175 models specified adjustment to 250 Hz), and the trimmer capacitor for the carrier oscillator crystal is adjusted until the output is ~10 W (6-dB down or 1/4th of the power output at 1500-Hz). The CO trimmer capacitor adjustment at 300 Hz will be quite sensitive, since the signal is being moved up or down the steep filter skirt (especially in the SS-16 case), so small changes in frequency will result in large changes in signal amplitude. This procedure is repeated until the required levels are obtained without the need to further adjust the trimmer capacitor. This adjustment also must be done for the opposite sideband if it is to be used. This adjustment places the mixed audio and carrier frequency signal component (e.g. a 300 Hz tone + ~5,500 kHz) ~6-dB down the slope of the IF filter, so the audio information from ~300 Hz to ~3,000 Hz lies within the 2.7-kHz bandpass of the filter. See Alignment Section 7.5 for further discussion on this adjustment.

Rather than using this standard adjustment procedure, the installation instructions for one SS-16 kit specifies the following procedure: Tune for maximum power (e.g. about 500 to 600-mA cathode current) and then while transmitting full carrier (CAR BAL fully cw or ccw) in the SSB mode, adjust the carrier oscillator (CO) frequency trimmer to obtain a cathode current to 150 mA. This adjustment moves the carrier oscillator frequency up the slope of the IF filter skirt so that more of its signal passes thru the filter and thus a higher signal level is on the control grids of the PA tubes. If you do not intend to operate AM, these SS-16 installation instructions specify that the trimmer be adjusted for a cathode current of 100 mA, rather than 150 mA.

Recall that during normal tune-up (TUNE or CW mode) the CO signal is shifted up in frequency by 700 Hz or so, well into the bandpass of the filter, but the SSB signal generated by the unbalanced modulator is not shifted, remaining at the CO frequency (e.g. 5.5 MHz) and well down the filter's bandpass slope, as shown in Fig. 4-2. The consequences of this adjustment for AM and SSB operation is that the audio bandpass will be somewhat lower than the 300 to 3,000-Hz audio bandpass (perhaps 100 to 2,800 Hz) for which Swan transceivers are normally adjusted. This is not necessarily bad, indeed, depending on your voice characteristics; you may even think it sounds better.

4.6. Filter, Low Pass LP-3400

The LP-3400 low pass filter is intended to be inserted in the coax transmission line between the transceiver/tuner and antenna to attenuate unwanted higher frequency harmonic components in the transmitted signal, primarily to minimize RFI or TVI problems. It has an insertion loss of less than 3 dB, a 50 Ω impedance, and is rated at 2,000 W PEP for frequencies below 21 MHz and 1,500 W for frequencies between 21 and 30 MHz.

4.7. Frequency Display/Counter, DD-76/FC-76

DD-76. The DD-76 (Digital Display, introduced in 1976, hence the DD-76 model number) accessory is a stand-alone digital display that plugs directly into the accessory socket and displays the transmission or receive frequency with a 1-KHz read-out resolution. It does not correct the drift problem experienced with some Swans, however it ends the problem with Swan's fairly poor frequency readout/calibration and provides an accurate means to readjust the tuning during on-air operations to compensate for drift. The DD-76 sold for $170 in August 1977 and works with the 350, 500, 700CX, twins, etc. Only one production run of these units was made.

There are internal jumpers in the DD-76 for three different IFs (e.g. 5.173, 5.500, 5.520 MHz) that are shown in the jumper chart on the schematic. In order to function properly with the different transceiver IFs, multiple jumpers must be re-routed/connected. Unfortunately, these are not mechanical pin and plug type jumpers, but are hardwired, so the connections must be clipped and/or soldered on the circuit board. The display directly reads the frequency of the VFO and internally corrects for the carrier oscillator frequency used by the transceiver. For example, on 80 meters (or 40 M), if the sideband carrier oscillator's frequency is 5.500 MHz and the VFO's frequency is 9.430 MHz, the counter displays algebraic value of the sum of 9.430 - 5.500 and shows 3.930 MHz on the LED display.

The DD-76 is working like a digital calculator – its effectively subtracting (for the 80 and 40-M bands) or adding (for 20, 15, and 10-M bands) the IF to the VFO frequency and displays the result. When the transceiver is switched to its opposite sideband, on the DD-76 the frequency changes from 5.500 MHz to 5.503 MHz, which is the frequency of the opposite sideband carrier oscillator. If you have not touched the VFO, the same 9.430 MHz is still coming out of the transceiver's VFO, but it is now subtracted from the 5.503-MHz IF. That is why a 3.927-MHz frequency would be displayed on the readout when the opposite sideband is selected.

To install the DD-76 along with an external VFO to the single accessory socket, simply open the VFO plug and solder the digital readout leads to the appropriate pins (1 hot and 9 shield/ground). Another solution is to install a separate plug (e.g. RCA phono plug, etc.) of your choice on the rear chassis apron, however that obviously modifies the rig and might not be as desirable from a collector standpoint. Pin 8 is the transceiver's VFO signal output sent for switching purposes to the external VFO via the accessory plug and pin 1 is the VFO signal input from the external VFO (either the external VFO's or the transceiver's internal VFO signal) to the transceiver. On most transceiver models (exceptions include the early mono-band models, the 240 tri-bander, and the Cygnet-like models (i.e. 350A/B/D), if an external VFO or crystal oscillator isn't used there is a plug installed in the accessory socket with a jumper between pins 1 and 8 (as well as a jumper between 3 that 4 what provides –10 V to the internal or external VFO). If the DD-76 is connected to pin 8 (the transceiver's internal VFO output), then it will only read the transceiver's VFO output, even when an external VFO's signal is being used during split-frequency transmit or for both transmit and receive).

Ground Issues. It may be critical to affix a separate connection from the DD-76's chassis ground terminal to earth ground for proper operation – without it, erratic or display meaningless fixed alphanumeric readouts have been reported.

Display Segment Replacement. The digital display uses a FND507 common anode seven-segment display. Replacement elements for this display are still available from Jameco Electronics (*www.jameco.com*) for only $0.99 per display in small quantities. If that item is unavailable, they reportedly also stock a functionally equivalent item (orange rather than red color), Jameco #104213, Mfg Ref #LSD5124-10

FC-76. The FC-76 (Frequency Counter, 1976) is similar in appearance to the DD-76, but differs in functionality. Whereas the DD-76 measures the VFO frequency and automatically calculates the actual transmission frequency, the FC-76 is a general-purpose frequency counter that directly samples the RF output (via a small built in antenna) or other signals to measure their frequency with a 1-KHz resolution.

4.7.1. Digital Display Alternatives

Almost All Electronics. A frequency display kit from Almost All Electronics (~$50.00) has been used on a Swan transceiver (300B) and found to work well. The kit is easy to assemble, requiring 2 to 3 hrs. Information can be found at: *www.aade.com*.

Blue Sky Digital. The Blue Sky Digital 4 Digit LCD Display (~$35.00) has also been used with a Swan 260. The unit takes about 2 hours to solder together and uses one PIC 16C924 microprocessor, several resistors and capacitors, and one 32-kHz crystal. It requires only a 100-mV RMS signal level for frequency counter operation. The 260 VFO output has more than 1-V peak-to-peak level. This unit has software and switch settings (similar to the DD-76 internal jumper settings) that provide an adjustment capability to obtain the direct reading of the transceiver operating frequency. Information can be found at: *www.fix.net/~jparker/blusky/ccd.htm*.

Digital Dial. The Digital Dial (~$80 kit, ~$110 wired) should also be usable as a frequency readout. Information on it can be obtained at: *www.radioadv.com/products/FreqMC/A2.htm*.

Palomar PD-700 Digital Frequency Display. The Palomar PD-700 Digital Frequency Display has been used with good results with a 500CX. Only two simple wire connections are required to install.

PC 1. The PC 1 programmable counter from S&S Engineering can be programmed to read transmitter frequency. Available in kit form, it can also be purchased wired and tested. Just wrap a signal pick-up wire around coax and transmit a carrier to obtain a frequency readout (reads 4 digits: e.g. 14250.5 MHz reads as 250.5).

Commercial Frequency Counter. If you are just going to sample the RF CW signal from the transmission line, an option is to use a general-purpose commercial frequency counter that has a suitable frequency range. Depending on its sensitivity, just using a simple wire antenna or pick-up coil about the coax may be sufficient to obtain RF frequency readings when a carrier or steady-state CW signal is transmitted.

CB Oriented Counters. In addition to the specific digital display options mentioned above, there are a number of commercial units designed primarily for CB users that only sense the transmitted signal's frequency (usually at lower power), so the readings are only available when a carrier is transmitted. One could also hook such a unit to the VFO, However the indicated frequency will not correspond to the transmit frequency as there is no provision to correct for carrier oscillator frequency mixing off-sets, such as is done in the Swan DD-76 and some other commercial units. These counters sell in the ~$50 to ~$60 price range and model/brands include: Texas Ranger FC-390, Aries A-FC356, and the Land Matic® LM 260 Frequency Counter.

Buffer/Clipper. When digital frequency counters are connected to high impedance vacuum tube equipment, it is often desirable to install a buffer to the equipment. The BK-174 Buffer/Clipper performs this function. It provides a high impedance interface and normalizes the output to the DigitalDial or other equipment by clipping the signal waveform. The unit can be powered by connecting it to the 6.3-V ac filament circuit. The buffer should be mounted near the oscillator circuit being measured. A small diameter coaxial cable like RG-174 can be used to connect the buffer to the DigitalDial or other digital display. Information can be found at: *www.radioadv.com/products/Accessories/BK174.htm*).

4.8. Headphones

The speaker impedance on Swan transceivers is typically 3 to 4 Ω, however any LO-Z headphones with an impedance between 4 and 600 Ω or so should work fine. If possible, use monaural headphones designed specifically for amateur communications that have a frequency response that matches the output audio bandwidth (i.e. from 50 to 3,000 Hz), such as the Kenwood HS-5. The limited bandwidth will help reduce out-of-band high and low frequency noise relative to the wider-response stereo-type headphones used for music reproduction.

A pronounced audio ac hum is endemic when using the headphone jack on any Swan power supply, due to an inherent design defect. A common ground and an un-shielded audio speaker line are routed in parallel with the power supply output voltages, which induces 60-Hz ac signals (both from the 12.6-V ac filament and ~120-V ac power line going to/from the transceiver's ac power switch) into the audio line. For information on correcting this problem, see the Power Supply, Common Problems Section 3.4.1.2 and the Swan issued Service Bulletin shown in Fig. 3-1.

4.9. Manuals/Upgrade Instructions

If you are lucky enough to have the manual and any modification/upgrade kit installation sheets that came with the receiver, it is a good idea to make a photocopy to serve as a working copy for everyday use to prevent wear and tear of the original.

Manuals. Caution! There are errors in nearly all Swan manuals, especially those produced after the Herb Johnson era (i.e. post 1967/1968). There are also numerous versions (as many as seven) of some transceiver models, most of which use the same manual but a revised schematic. To make matters even worse, the first units of an updated transceiver model version with minor (or even major) circuit changes were sometimes still shipped with the old manual and schematic. Or, as Swan put it in their *Addendum To Swan 350 Manual*, which is a loose-leaf sheet that was included with the outdated manual shipped with the initial newer version transceiver units (the this particular version, the full-band frequency coverage and other changes were made to the design), "*This operating manual for the Swan 350 does not coincide completely with the current production model. A number of im-*

provements have been made, and invariably the manual lags behind on these changes." While they further noted, "*An up-to-date schematic will be available soon, and may be secured by written request,*" knowing the procrastination nature of many people, it's likely that updated schematics were ever obtained in many cases! It's ironic that even this short addendum contained an error, instructing those users interested in CW operation to add a 0.5-pf capacitor across the key, rather than a 0.5-mf value specified in a later manual updates.

The importance of acquiring the correct manual is further illustrated by the following situations, which could occur. You might have an early version 500CX that has a 3-position function switch and uses 17 tubes. However, you may obtain an aftermarket reproduction of the manual and schematic for a later version that shows only 15 tubes (since the carrier oscillator was changed to solid state, there is no V14 carrier oscillator or 0A2 regulator tube, which was used for oscillator stabilization). Alternatively, you may want and obtain a 15 tube, later version schematic, only to find it depicts a 5-position mode switch rather than a 3-position switch that's on your unit. Ironically, there are even cases where the schematic from the initial version of a new model may be used for troubleshooting the last version of the model which it replaced, as in the case of the 500C and 500CX.

Therefore, it's very important to determine which schematic/manual is most correct for your transceiver, especially if your are planning to do any troubleshooting. To find out the actual production date (year and month) of a particular unit, just check into the On-Air Nets or provide the serial number to the Swan-Net folks at: *SwanRadio@Anglefire.com*.

The issue of manual errors and version uncertainty are also more reasons to prepare a separate resistance and/or voltage chart for each piece of transceiver equipment when it is functioning properly to assist in troubleshooting (See the Swan Newsletter, Issue 8, Section A.8.1). The nominal chart values of these measurements included in the Operation and Maintenance manuals may be voltage, resistance, or both, depending on transceiver model. However, in either case they are only nominal values – your measured values can be expected to easily vary from those values by as much as 10 to 15% or more!

Upgrade Kits/Bulletins. As noted above, even upgrade instruction/information sheets were not immune typos and errors. Another example of such errors is the crystal calibrator kit installation instructions for the 250 six-meter transceiver that: (1) shows the plate supply for the 12BA6 oscillator connected to ground (rather than to the 275-V supply), (2) omits to include the grounding of the suppressor grid, incorrectly identifies the tube from which the 12.6-V ac filament supply is to be obtained (a 6.3-V ac tap-point is specified), and (3) fails to note the need to ground the filament's other terminal. Fortunately, in this case the transceiver's schematic also shows the correct wiring for the optional crystal calibrator installation, however that's quite a number of errors for a rather simplistic modification and two-page instruction sheet!

The moral of the story is to always cross-check when implementing a modification, especially if you're in the auto-pilot mode and just merely following a pictorial or line-by-line cookbook instructions, rather than reading a schematic and/or actually thinking about what the various changes are doing. Be sure to do a check to ensure the tie points to other parts of the existing circuit make sense (e.g. plate is connected to high voltage, grid has proper voltages, etc.).

4.9.1. Internet

A number of websites have manuals on line available for downloading, but bear in mind the manual may not contain the correct schematic version and the quality will be much poorer than a high resolution quality copy (fine details of the schematic may be unreadable) made directly from an original. Websites that have PDF and ZIP file formats for Swan equipment (and other boat-anchor equipment) can be found at:

- *6mt.com*
- *www.pcs.mb.ca/~standard/*
- *bama.sbc.edu/*

4.9.2. Hard Copies

A number of internet-based business are currently selling reproduced copies of Swan transceiver and accessory manuals, however as with the internet-based downloads, their quality may be inconsistent and their inventory incomplete (e.g. only one version of a specific model and, more importantly, only one version of the schematic may be available). Use one of the Internet search engines to obtain a listing of those sites.

Another option is to try to obtain an original manual for the transceiver by posting a message via the Swan-Net E-mail Reflectors, advertising at Internet boat-anchor Hamfests or Sell-It sites, or scanning the commercial (e.g. eBay) on-line auction sites. Of course, you must know specifically what manual is needed, and more importantly, what schematic is the proper one for your radio. Note that the manuals for most models remained unchanged when a new transceiver version was produced (usually when no significant component position or tube line-up changes were made during production) – only the schematics were modified.

By far the best source for quality reproduction manuals for literally all Swan radio models and accessories, as well as most amateur radio equipment manufactured under the Swan associated Siltronix, Atlas, and Cubic brand names is D & M Publications (formerly Brock Publications). They have been authorized by Swan/Cubic Communications (former manufacturer of these equipment) to reproduce this technical documentation from the original company file copies of the manual. A bonus of this source is their in-depth familiarity with Swan equipment (so you can get the right schematic for your transceiver version as discussed above) and access to most of the technical support material (service bulletins, etc.). They can be reached at:

D & M Publications
3655 Quail Run Trail
Wellington, NV 89444
(775) 266 9586
e-mail wa5bdr@nanosecond.com

4.10. Microphones

With any electronic circuit, the greatest transfer of energy occurs when the source and load impedance are identical. The closer they are matched, the greater the energy transfer. Large differences in impedances will cause loss of both signal level and fidelity, degrading the designed amplitude and frequency response of the audio circuit. Microphones come in two basic flavors: HI-Z or LOW-Z (Z referring to impedance). While there is no real standard for defining what is high and what is low, in general LOW-Z is considered 500 Ω or so and HI-Z 10,000 Ω to 50,000 Ω or more. In the case of the Turner 444D (dual impedance) microphone, low impedance load is specified as 200 to 1,000 ohms and high impedance as 15 kΩ to 10 MΩ. The two types of microphones are not usually interchangeable – they may function, but will likely have significant distortion or amplitude problems. LOW-Z microphones generally have much lower output levels, typically in the millivolt range – those impedances and levels are usually not satisfactory for operation with Swans transceivers.

The microphone amplifier in Swan transceivers likes to see a HI-Z ceramic element microphones with an impedance of 50 kΩ or higher. Swan specified a high impedance microphone and recommended either the Shure or the Turner models. Using HI-Z microphones with impedances of less than 50 kΩ will generally require that the MIC GAIN control be increased relative to higher impedance microphones, but this increased gain will not necessarily result in any audio distortion unless the impedance is excessively low. Swan tube type transceivers use a 12AX7 microphone audio amplifier with in a ~2.2-MΩ series resistor for swamping in many designs – they do not need any additional amplification or microphone audio bandpass shaping (although they can be used with a Hi-Z microphone that has such features).

The typical reported Swan transceiver's operating microphone gain settings when used with high impedance microphones range from about the 9 O'clock (25% of full scale) to the 3 O'clock (75%) positions. Remember to use microphone gain settings that provide no more than the specified cathode current peaks on SSB modulation (~1/3rd the current achieved during tune-up at maximum RF power output), otherwise the amplifier will be overdriven on voice peaks and audio distortion and RF splatter will occur. If you are using a two-wire microphone (no switch), you must manually switch the mode switch to TRANS or have a separate PTT switch to ground the center contact of the microphone jack to activate the transmitter. Likewise, if you are using a VOX unit, ensure that the microphone output is continuously active and not disconnected via an interlocking switch when the microphone's PTT switch is not activated.

Among microphone brands commonly used with Swan transceivers are the Turner, Shure, and Astatic high impedance models. The Shure 444/D and 404 (~$29 and ~$22 respectively in July 1973) are identical to the base station and hand microphones sold by Swan with just a different logo. As a marketing incentive during the mid 1960s, Swan even offered the Turner 254 model for 1 penny when purchased with a new Swan 350. The Astatic D105 un-amplified G or UG8 stands were designed to work with high impedance inputs with recommended loads (impedances) of greater than 50 kΩ. Therefore, transceivers such as Swans, with a microphone amplifier grid resistor in the 1 to 5-MΩ range, are fully compatible.

Users have reported contradictory results when using the Astatic D-104 with the amplified T-UG9 base with Swan transceivers. That microphone is specified as having a flat frequency response from 200 Hz to 20 kHz and an output impedance of 5 kΩ or less. In most cases, users have reported good results, but distorted audio has also been reported. In such cases, it's possible that the performance achieved is a function of both the microphone's amplifier gain and transceiver's MIC GAIN settings.

Impedance Measurements. One should recall that impedance is a function of frequency. A simple VOM or VTVM dc resistance measure will not give an accurate measure of impedance and generally will yield lower values than the actual impedance. However, dc resistance readings are still useful to indicate an open microphone and/or matching transformer.

Recommended Models. Besides the Swan products (i.e. the Shure produced CM17L/444 desk and CM4AB/404 hand microphones), specific microphones often mentioned by Swan aficionados include: (1) Shure 444, (2) Shure 444D (dual impedance), (3) Shure 404B/C, (4) Shure 405C (recommended by Swan in their 240 manual), (5) Turner Plus Three (dual impedance), (6) Turner 454 and 254C, (7) Astatic D-104, (8) Electrovoice 600EH handheld, (9) the Shure Model 5655H Unisphere I Dynamic Dual Hi-Z/Lo-Z microphone, and (10) the ElectroVoice EV 638 or 644.

4.11. Phone Patch, FP-1 Hybrid

The Swan phone patch was designed to be used with any Swan radio. It provides a means to easily and quickly connect an amateur station to a telephone line and was once a relatively common accessory before the days of readily accessible, relatively cheap telephone links and current state-of-the-art internet e-mail, voice, and video capabilities. For decades, the phone patch provided an essential communication link (and in many cases, the only) to isolated areas, most notably to the many armed forces personnel stationed at remote locations around the globe.

There was an unusual 19" rack mounted (with a 5¼ " height) configuration of the phone patch made, with the phone patch unit positioned on the left-hand portion of the panel and a WM-2000 wattmeter positioned on the right-hand side – the front panel configuration, labeling, and styling is the same as that of the individual units. This rack version might have been a special build for the federal government/NASA, since on one such rack the serial numbers of both units was #525 with a *NASA* prefix.

4.12. Speaker - 600S/SP

The 600S and 600SP speakers were offered as a matching accessory for use with the 600R transceiver. While the front panel and cabinet have the same styling as the more common 117XC power supply/speaker, the physical height of the 600 S/SP speakers is 6½" (matching that of the 600R/T twins) versus 5½". The 600S sold for about $18 (November 1971) and, in addition to a 5" x 7" oval speaker, it includes on the lower front panel a headphone jack and a high/low tone control (along with an associated simple internal RC network on the audio input).

The 600SP sold for about $59, but it also includes the FP-1 phone patch, with the controls mounted on the lower front panel. While there are mounting holes in the bottom plate of the case that appear to be the correct configuration for mounting the 117X power supply module in the unit, the physically larger speaker size would most likely prevent it without replacing the speaker.

4.13. Transverter, TV2/B/C

The TV2 Transverter provides 2-meter capability when used in conjunction with Swan transceivers. Using a 5894 (TV2B/C) PA tube, it provides 240-W dc input PEP transmitting capability on SSB, 180-W CW, and 75-W AM. It sold for $265 in June 1968, and was marketed for use with the 250, 350, 350C, 400, 500, and 500C transceivers.

The unit uses 14 MHz as the standard IF, although 21, 28, and 50-MHz band IF options were available. The maximum RF drive should be limited to about 15 W. A downside of the 5894B tube is that it is very expensive. It is reported that the 6-meter IF was preferred because it tuning tracked better when on 2 meters.

The same external 117X(C) type power supply that is used to power the transceiver will also power the transverter. The unit is installed by connecting the 117X(C) to the transverter, which in turn connects to the transceiver using a Cinch-Jones connector identical to that used on the power supply. Most Swan transceivers (e.g. 350C) require several changes at the 12-pin Cinch-Jones plug, as shown in the TV2 manual. Internal to the transverter, the HV is rerouted so that the HV seen by the transceiver is ~275 volts, limiting the maximum transceiver RF output to about 10 W or so. The most a Swan 500CX, etc. can deliver to the TV-2 is maybe 20 W or so and that is more than enough to provide sufficient drive levels for maximum output. Even 10 W would be adequate when transverting 6 M to 2 M.

4.14. VFO, External

The physical size of the VFOs is typically 6¾" W, 5½" H, and 11" D, with a weight of about 12 lbs. The 330 (for use with the 600R receiver) and the 160 (for use with the 160 transceiver) are about an inch higher. The 406, intended for mobile operation is much smaller, about half the height and not as deep as of the base station models. The crystal controlled oscillators are about 6" W, 2½" H, and 4½" D.

4.14.1. IF Design Frequencies

The design frequencies of the VFOs associated with Swan's tube-design transceivers are listed in Table 4-1. See also Table 2-2 for transceiver IF design frequencies in the Swan Transceiver General Characteristics Section.

Since the various models are designed for specific transceiver IFs, they are not directly interchangeable unless they have the same IF. This does not mean the VFO will not function at all – when mated with a transceiver with a different IF, the main tuning dial indicated frequency will be offset by the difference between the two intermediate frequencies and the frequency linearity across the band will be off. Bear in mind that the only output signal difference among the various VFO units is its frequency. The output frequency is adjusted so that when the carrier oscillator's frequency (i.e. the same as the IF) is added or subtracted (depending on which amateur band is selected) to the VFO's signal in the mixing process, the frequency of the resultant RF signals fed to the PA corresponds to the main tuning-dial setting.

When the design IFs are significantly different, such as between 5.5 MHz and 5.173 MHz, this 327-kHz offset makes such use impractical – it can be made to function near properly, but the VFO trimmer capacitors must be

Table 4-1 Summary of External VFO Features

MODEL	IF DESIGN FREQ.	COMMENTS
160	5.500	Designed for use with the 160X transceiver
210	10.900	Designed for use only with the 250C 6 meter transceiver
330	5.500	General coverage tuner for operation with the 600R receiver
405	5 Crystals <15 MHz	MARS/Net Ops on later model 350/400 transceivers, RF gain pot
405X	5 Crystals <22 MHz	MARS/Net Ops on any Swan transceivers, RF gain potentiometer
406	5.173	Intended for mobile Operation, Limited Band Coverage, RF gain pot
406B	5.173	Intended for mobile Operation (partial coverage in HF bands), RF pot
410	5.173	Replacement VFO for the 420, RF gain pot for use with 400 XCVR
410C	5.500	For 350C/, 500C/CX, etc. Two color schemes gray, two-tone
412X/MX		Designed for use with the commercial model 400 series transceivers.
420	5.173	Base station external VFO for 400 transceivers, RF gain pot
508	5.500	Included Adaptor 22/22B circuitry for external/internal VFO
510X	10 Crystals, <22 MHz	MARS/Net Ops, crystal control with ~±5 kHz Freq Tuning
610X	10 Crystals, <22 MHz	MARS/Net Ops, crystal control with ~±5 kHz Freq Tuning

re-adjusted and it will still not be linear across the band unless the band coils are also carefully pruned, not a simple task. In cases where the frequencies are a close match, such as for the 5.5-MHz design frequency of the 410C external VFO when used with the 5.6-MHz IF of the 400E/F/G/H transceiver, the VFO trimmer capacitors can probably be adjusted satisfactorily with an acceptable linearity error. See the Transceiver Signal Processing Section 6.2.7 for more details on the signal mixing process.

4.14.2. Accessory Socket Jumpers

Most Swan transceivers, such as the 350C, 500CX, 270B Cygnet, etc. are equipped with an accessory socket and must be operated with either an external VFO or a jumper plug installed in that socket. Otherwise, there will be no VFO signal and therefore no audio (a white noise static-like audio hiss will be heard, but no signals). The accessory socket provides for the use of an optional external VFO or crystal oscillator. For a discussion on the various voltage levels and signals on this socket, see the VFO (External), XMT/RCV Switch Change modification Section 5.12.

There are two accessory socket pin jumpers required for transceiver operation without an external VFO installed, one between pins 3 and 4 for feeding the –10 V power to the internal or external VFO and the second between pins 1 and 8 for routing the output from the internal or external VFO to the VFO amplifier. Normally these jumpers are installed on a 9-pin plug that was supplied with the transceiver. On some transceivers, it may be found that the accessory plug jumper connections have been hard wired internally at the socket terminals – if this is the case, they must be removed before an external VFO can be installed. A problem might be encountered in finding the 9-pin plugs, which are somewhat scarce.

Models that do not have an accessory socket include the early mono-banders, the 240 tri-bander, the early version 250 and 350 (the accessory socket was offered as an optional installation kit), the Cygnet-like models (350A/B/D), and the 600R/T twins. The 400 series models have a VFO/accessory socket, however since they have no internal VFO, an external VFO is required to operate under all circumstances.

4.14.3. Adaptors, 22 and 22B

In order for the earlier transceiver models (e.g. 350, 400, or 500) to use an external VFO for split-frequency operation, a VFO model 22 or 22B adaptor switch is required. The 22/B adaptor plugs directly into the transceiver's accessory socket and the external VFO(s) then plugs into the adaptor. In December 1965, it sold for $25. Note that for cases where the station equipment are installed in shelves with minimal head-room above the transceiver, the 22/B adaptor's switch location at the rear top of the cabinet can make switch access exceedingly difficult.

The model 22, which has two external VFO or crystal oscillator input sockets, was specifically for use with the 400 transceiver (which has no internal VFO) permitting switching between two external VFOs or crystal oscillators. If can still be used with the 350 or 500 model transceivers, but when used with those models it switches between the internal VFO and one external VFO – the second socket remains unused.

The 22B was intended specifically for use with the 350 or 500 (or later) transceivers – it has only a single external VFO socket that permits switching between the internal VFO and an external VFO. Thus, it is not suitable for use with the 400 transceiver.

The later model 508 external VFO (designed for 5.5 MHz IF transceivers) has the 22/B adaptor's switching circuitry built into it and thus the 22/B adaptor is not needed when that VFO unit is used with a later transceiver model (those with 5.5 MHz IFs) – just plug the VFO into the transceiver's socket and you're ready to go.

4.14.4. 160

This external VFO was made specifically for use with the 160 or 160-X transceiver (160 meters), selling for $95 in 1971. It tunes over the 1.8-MHz through 2.0-MHz frequency band. This VFO model is unusually in that it uses the same model number as that of the 160 transceiver, so Swan advertisements generally specifically list is as a "*160 vfo*."

4.14.5. 210

The model 210 external VFO was made specifically for use with the 250C six-meter transceiver. To use this VFO with the model 250, the VFO adaptor socket needs to be installed, and since there is an IF difference between the 250 and 250C models (10.7 MHz versus 10.9 MHz), if the VFO is to read and track in frequency properly, it will have to be realigned.

4.14.6. 330

This external tuner (VFO) model is designed for use with the 600R receiver twin, to provide HF coverage over the entire 3-MHz to 30-MHz band, except for guard band from 5.4 MHz to 5.6 MHz around the transceiver's IF. The amateur band coverage with the 600R's internal VFO is still retained, with the 330 switched in or out via a front panel control on the front panel of the 330. This unit is similar in general styling to the model 508 VFO, but in addition to the DIAL SET control, it has band switching for the 3-5.4, 5.6-10, 10-16, 16-24, and 24-30-MHz sub-bands.

4.14.7. 405/405X (Crystal Oscillator)

The model 405 was designed for use with the 5.173-MHz IF model 400 and 350 model (with model 22 adaptor) transceivers. It provides five selectable fixed crystal-controlled channels intended for MARS, net, or other fixed-frequency applications in or near the 80, 40, and 20-meter bands. The back panel apron has locking type trimmer capacitors that are used to adjust each crystal to the desired operation frequency (there is 400 to 700-KHz adjustment range, depending on band) and on the front panel, a vernier control that permits of adjustment of about ±4 kHz about the selected crystal's frequency. This model was also marketed as a "*Mars Oscillator*."

The 405X was marketed for use with the 350C, 500, and 500C transceivers; it sold for $45 in October 1967. It provides 10 selectable crystal channels in or near the 80, 40, 20, and 15-meter bands. Like the 405 model, it also has a front panel vernier frequency adjustment control (±4 kHz about the selected crystal's frequency), however it does not include trimmer capacitors to adjust each fundamental crystal's frequency individually.

Since both models were intended to function with the 400 transceiver, they include a RF GAIN control (the 400 does not have a front panel gain control, but rather relies on the off-board control that was included on the required external VFO (406/B, 410, or 420)). The 405/X plugs directly into the VFO socket on the 400 transceiver, or, when used with the 350 transceiver, it plugs into the required Model 22 Adaptor. When used with later model transceivers, there appears to be a minor modification required, since neither of these models include the front panel VFO/XTAL selector switch used on the 510X (in place of the RF GAIN control) that routes both the –10-V power and the transmitter's internal VFO signal back to the transceiver. Each crystal's frequency is selected based on the band of interest, the desired sideband (normal or opposite), and the IF offset, where:

Crystal Freq = Op Freq +/– 5.173 MHz (or 5.175 MHz)

For example, for 40 or 80 Meter Lower Sideband (Normal),

Crystal Freq = Op Freq + 5.173 MHz

And for 20 and 15 Meter Upper Sideband (Normal),

Crystal Freq = Op Freq – 5.176 MHz.

4.14.8. 406/B, 410/C, 412X/MX, 420

All of models are about 5.5" H, 5.5" W, and 11" D in size (expect for the approximately half-height 406/B intended primarily for mobile use). The 406, 406B, 410, 420 external VFOs were all designed for use with the 5.173-MHz IF transceivers. Since all of these models were also designed to be used with the model 400 transceiver, each includes a RF GAIN control (the 400 does not include a front panel RF GAIN control as part of its design, but rather relies on the off-board control that was included in the required external VFO (or 405/X crystal oscillators). The external 410C VFO is the only one of the 400 series designed for use with a 5.5-MHz IF transceiver (e.g. 350C, 500C, etc.).

Despite its higher model number, the 420 preceded the 410 in production, which was the replacement for that unit. The 406B was an evolutionary upgrade and replacement for the 406. All of these 5.173-MHz VFOs will plug directly into transceiver models that use a 5.173-MHz IF (e.g. 400, 350, 500) and the VFO's frequency dial will accurately track the transceiver's operational frequency. However to work with the 350 and 500 model series, the Swan Model 22 or 22B adapter switch is required (along with the optional transceiver accessory socket). This accessory plugs into the back of the transceiver and switches the source of the VFO signal between the internal and external VFO. Note that the model 400 transceiver has no internal VFO and if spilt frequency operation is desired, the model 22 adapter is required (the 22B will not work because it has only one VFO input socket). These VFOs will also operate with later transceiver models (those with 5.5-MHz IFs) but the frequency calibration will be off and it will not track linearly across the band unless the band coils are pruned.

Modification Caution. There was a service bulletin from Swan describing a single wire change to any of these VFOs to offer a slight gain in stability when operating split frequency. If this change has been made to the VFO, it can't be plugged directly into the VFO socket – it must be connected via the model 22 or 22B VFO adaptor.

406/B. The 406 and 406B are half-height and shorter length (all other models are about 5.5" H, 5.5" W, and 11" D) external VFO tuners intended primarily for mobile operation, permitting the transceiver to be placed anywhere in the vehicle, even the trunk. The 406 mobile VFO has no external DIAL SET – users needed to be unbuttoned the cover to get at the frequency-calibration trimmer capacitor. It uses an all light-gray paint scheme and provides only limited frequency coverage on each band (mainly audio sub-bands). They matched the 400's front panel design and in late 1965, sold for $75. In about 1965, the updated 406B was outfitted with a rear apron dial-set. During that time frame, it was also updated to have the two-tone gray panel color scheme.

410. Swan began producing the 410 in mid-1965 as a replacement for the 420 and sold it for $95 in October 1967. Since the 410 uses an 8-position band switch (the 10-M band uses 5 sub-band switch positions), it is considerably less complex and was obviously cheaper to build than the 420 (which has a 20-position band switch). The panel paint and trim were updated in 1967 to match the new two-tone dark gray color scheme of the 400, 350, and the 500 transceivers.

410C. The 410C was originally designed to serve as an external VFO for the 350C transceiver and sold for $115 in April 1968. The early 410C came with a 3-transistor VFO board, similar to the 3-transistor internal VFO board that was incorporated into the 350's circuit at that time in an attempt to correct VFO drift problems. It has the same form-factor and styling as the 350C and will work with other 5.5-MHz IF transceivers (e.g. 500C/CX). It is a full amateur band frequency-coverage VFO, using 8-frequency ranges of 500 kHz each. With the exception of lacking the circuitry for separate dual VFO operation, it is functionally and physically similar to the model 508 that replaced it. The 410C will plug directly into the transceiver, but does not permit split-frequency operation unless the model 22 or 22B VFO adaptor is also used.

412X, 412MX. The 412X and 412MX crystal-controlled oscillators were designed for the commercial Swan 400s. They require a small change to operate with any Swan amateur transceiver models.

420. For fixed station operation of the 1.573-MHz IF model transceivers (400, 350), Swan initially made the full-coverage 420 VFO, which sold for ~$120 in late 1965. The early 420 VFO was very stylish and modern looking; even today, it looks like a fairly recent piece of equipment. It was also very expensive to produce, since there were 20 ranges with 200 kHz per range and therefore a lot going on in the band switch (the 10-M band uses 12 sub-band switch positions!).

Like the 406, the 420 was designed specifically to match and work with the model 400 transceiver, so it has a RF GAIN control and initially had a matching single-tone gray front panel. The 420 VFO received the two-tone gray panel in 1965, but production was discontinued in 1966 when it was replaced by the 410. Only about 200 of the two-tone gray (similar to the 508 color scheme and panel design) 420s were produced.

4.14.9. 508

The 508 full-band (80/40/20/15/10 M) coverage VFO, the successor to the 410C, was introduced in late 1968 and sold for $125 in November of that year. It is fully compatible with any of the later model Swan transceivers (non Cygnet) that use a 5.5-MHz IF (350C, 500C and later). The 508 was dropped from the line at the end of the 700CX transceiver's production run in 1977. This VFO incorporates into its design the Model 22/B adaptor circuitry required for split-frequency operation and therefore no adaptor switch is required; it plugs directly into the transceiver's accessory socket permitting split-frequency operation via a switch on its front panel.

The 508 will also work with the 5.173-MHz IF transceivers (350, 400 and 500), but the frequency calibration and tracking across the band will be off because the 508 frequency determining circuits are calibrated for the 5.5-MHz IF used in later transceivers (270, 350C, 500C and later). Therefore, even after calibrating with the trimmers, the VFO dial scale will not track across the band accurately when used with a 5.173-MHz transceiver. The 508 can be made to track correctly, but requires very patient pruning of the non-adjustable band coils.

4.14.10. 510X (Crystal Controlled Oscillator)

The 510X Crystal-Controlled Oscillator was marketed for use with the 350C, 500C, 500CX, and later transceiver models and sold for $45 in April 1969. It is designed to provide stable frequency control for MARS (it was marketed as a "*MARS*" Oscillator) net or fixed channel applications, providing for 10 switch-selectable crystals with a frequency output of up to 22 MHz. The 510X provides a front panel vernier control that can tune ±2 to ±3 kHz (sometimes as much as ±5 kHz) about the crystal-controlled frequency. Since this model does not contain a RF GAIN control, it is not directly useable with the model 400 series transceivers without modification. Crystal frequencies are calculated in the same manner (using a 5.5-MHz IF) as described in Section 4.14.7.

4.14.11. 610X

This external crystal oscillator performs the same basic function as the 510X model and sold for ~$54 in August 1973. It includes a front panel pilot light indicating when the unit is active, however as with its predecessors, it still draws it operating power from the transceiver. The front panel and case has the same styling as the 700CX transceiver, even though it is intended for use with the all solid-state SS-15, SS-100, SS-200, and SS200A (w or w/o SS-16B filter) transceivers.

4.14.12. TCU (Transmitter Control Unit)

The Model TCU (Transmitter Control Unit) is designed to operate in conjunction with the Swan SW-240 single sideband transceiver and is physically the same size. It provides an external VFO to permit split-frequency operation, a VOX capability, a 100-kHz crystal calibrator, and a number of other capabilities. A minor modification to the SW-240 is required for the TCU installation, as discussed in the TCU instructions. The transceiver's power supply may also be mounted inside the TCU cabinet (because of form-factor constraints, 117X-type power supplies will not necessarily fit). Power for the TCU is supplied via a 12-conductor cable from the transceiver. Also, see the discussion of this accessory in Swan Newsletter, Issue 8, Section A.8.4.

4.15. VOX Units

All Swan VOX units will work without modification with any Swan transceiver that accepts the device. The VX-1 model does not have semi-break-in CW capability like the rest, but it is a very simple modification to include that capability, as discussed and shown below. The VOX unit plugs directly into the VOX socket on the transceiver. The VX-3 model may not have been marketed, or if it was, only for a very short time in a very limited quantity.

The schematic for the VX-2 is shown in Fig. 4-4. There are some minor circuit changes between earlier and later models, but these changes should have no real effect on operation. In 1971, Swan went to –12 V for running the VFO and thought the higher voltage may effect VX-2 operation, so the 470-Ω resistor in the Q5 circuit was changed to 1.5 kΩ. However both values will work. Later versions of the VX-2 (1971 or later) may also include a diode connected from the positive side of the relay coil to ground, which was incorporated to minimize the possibility of relay chatter.

VX-1. The VOX-1 sold for $35 in November 1964. This model provides for only voice activation, but can be easily modified for semi-break-in CW. Just connect a wire from pin 5 of the accessory plug to the base of transistor Q5, as show in Fig. 4-4. Inspection of the schematics for the VX-1 (1965) and VX-2 (1968) show essentially identical circuits, except for this connection. Later versions of the VX-2 include a diode on the relay coil. That diode should not be needed for the VX-1 CW break-in modification to function properly.

VX-2. The VX-2 was produced for nearly a 10-year time span and in March 1968 sold for $35, the same price of the VX-1 in 1964. VX-2 is very similar in circuitry to the VX-1, but includes wiring to permit semi-break-in CW operation. Some versions of this unit were produced with both the crackle black-paint finish like that used on the transceiver cases and an un-textured black semi-gloss paint finish.

VX-4. VX-4 is the final VOX unit design. It's all solid-state (no relays) and is functionally identical to the VX-2. On this model, the three control knobs (delay, anti-trip, and VOX gain) have been replaced with screwdriver adjustment slots directly in the blue-plastic control shaft that are flush with the case body.

4.16. Wattmeters

Swan wattmeters, particularly the earlier models, are a very well designed and built accessory that rivals the capabilities of many current day models. Their rugged construction, high accuracy, and large meter display on the base-station models make them particularly desirable and user friendly. While the initial models and/or versions appear to have been fabricated in the USA, most, if not all of the later ones were of foreign manufacture. For example, the Japanese company that supplied the Swan WM-2000A also appears to have produced the same design for Yaesu (e.g. the Yaesu Model YS-2000 appears to be identical, other than for its logo and paint).

For a given model number you may find distinct concessions made to construction quality and design between early and later manufactured units to maintain a competitive price. These include lighter gauge metal cases (heavy gauge steel to lighter gauge aluminum) and/or redesigned AVG/PEP circuits to utilize fewer calibration adjustment potentiometers – the SW-3000's design changed from 16 potentiometers (with individual calibration adjustments for each forward/reverse, average (RMS)/PEP, and scale sensitivity settings) to only 8 potentiometers (with the same calibration potentiometer used for forward and reverse switch settings).

4.16.1. Accuracy

With any wattmeter, it is probably unwise to put a great deal of faith in the accuracy of the meter reading. Even if the meter is properly calibrated, accuracy is generally only ±7% to ±10% of the full-scale (FS) value and any error will not necessarily be consistent as a function of frequency or display range. Note also that published wattmeter review articles (e.g. QST) on new, commercial amateur-grade equipment frequently show significant measurement errors, well beyond the stated meter's error; however such errors are highly variable dependent on manufacturer, band, operation mode (average or PEP), scale sensitivity, etc.

With a 10% FS accuracy meter (1,000-W display sensitivity selected) and a 900-W RF true power output, it may have an actual error of say only 9 W when measured on 40 meters, but on 10 meters, the same 900-W RF level may have an actual error of 100 W. Recall that a ±10% FS accuracy means that for a 1,000-W display scale, a 900-W reading's true value is anywhere between 800 W and 1,000 W. Therefore, for the 1,000-W display sensitivity, an actual 200-W power level might produce a reading anywhere between 100 and 300 W!

However, this does not mean that multiple readings (minutes, hours, weeks, or even months later) made on the same system using identical test conditions (frequency, RF power level, SWR, etc.), will have sample-to-sample measurement variances equal to the specified full-scale error. For example, if a true 300-W power RF output at 7 MHz on a system with a 1:1 SWR is measured using the 500-W scale on a meter with a 10% FS error (±50-W maximum error), repeated measurements might yield readings of 340, 343, 336, 341 W, etc. In this hypothetical case, while each of the measured values has an absolute error of about +40 W, the measurement data set has a reading-to-reading error variance (due to electrical/meter variation and reading errors such as parallax, scale interpolation, etc.) with a normal distribution that is much smaller than the specified full-scale accuracy. This assumed 40-W error for a given scale sensitivity selection will not necessarily be the same for other significantly different power levels within a given display scale, different display scale ranges, significantly different frequencies within a band, or different bands (e.g. it could be 60 watts in error at 14 MHz). Although for any new measurement set-up, multiple or repeated readings (even hours or days later) should have a consistent average absolute measurement error with a similar much lower reading-to-reading variance.

Effect of SWR on Accuracy. To further complicate the situation, the forward reading meter is only valid for SWR ratios of 1:1. Under that condition, all of the measured forward power is delivered to the load and there is no reflected power reading. However, with any load-impedance mismatch there is a reflected power that increases the forward power reading of a directional wattmeter by an equal amount. Thus, it is ironic to note that with the transmitter properly tuned-up using two different antenna systems, one with a SWR of 1:1 and a second with a SWR of 3:1, the 1:1 system will show a lower measured RF output forward power wattmeter reading than the 3:1 system! If the 1:1 SWR indicates a 300-W RF output, then for a 3:1 SWR the meter should read ~450 W forward power output with a reverse power reading of about 160 W. As the SWR increases, the reflected power becomes a progressively higher percentage of the total forward power measured.

The true power delivered to the antenna is the indicated forward power less any measured reverse power. For this very reason, if an estimate is made of transmitter efficiency without compensating for the reverse power contribution, ridiculously high estimates of transmitter efficiencies will be obtained. For example, efficiency measurements on a 700CX with a 1:1 SWR dummy load might show an estimated dc input power (cathode current times estimated plate voltage) of 500 W with a 300-W RF output, for a very good efficiency of 60%. But, with a 3:1 SWR antenna load, the same 500 W dc input power might show a 450 W forward output power, for an astounding (and unbelievable) efficiency of 90%!

Note also that the reflected power and its contribution to the forward power reading (caused by any SWR mismatch) does not represent any real additional power that is generated by the transmitter and consumed by the load, but rather is associated with the standing wave phenomenon in the transmission line and its influence on the measurement system.

4.16.2. PEP Operation and Calibration

Due to the inertia effects related to a pointer's movement, a typical analog meter will generally display only an average of a time varying signal's value. Thus, while an analog voltmeter may accurately track a slowly varying

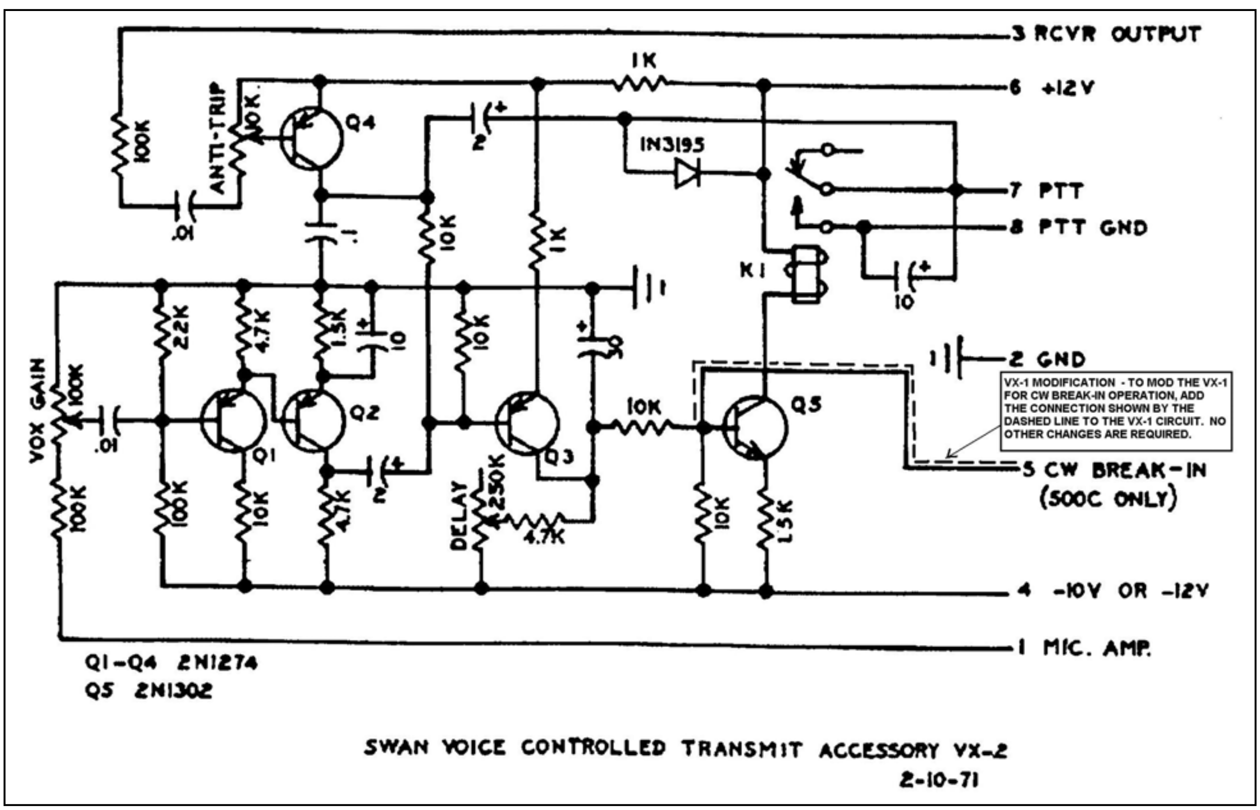


Figure 4-4 VX-2 VOX Schematic

signal, such as the voltage sample that represents the cathode current in a transmitter during tune-up, with variations any greater than a few Hertz, and certainly when used as a wattmeter to measure the RF power of CW or SSB signals, it cannot by itself (without additional circuitry) directly display the maximum or peak value.

RMS Calibration. Root-Mean-Square (RMS) is frequently referred to as average (AVG), although the two are not identical. An AVG measurement of a CW signal's voltage is equal to 0.6366 of its peak value while the RMS voltage is equal to 0.707 of the peak value. A RMS reading wattmeter may be calibrated by feeding a transceiver's steady-state CW signal into a 50-Ω dummy load and adjusting the wattmeter's calibration either directly, relative to a known calibrated reference RMS wattmeter, or indirectly, based on calculations (Power = $V_{rms}^2/R = (V_{peak}/1.414)^2/R$) made from the measured RF voltage (e.g. oscilloscope) or current at the dummy load.

PEP Calibration. Swan's PEP (peak envelop power) wattmeters employ a voltage follower circuit that tracks the slow voltage decay of a capacitor charged by a sampled and rectified dc voltage whose level is proportional to the RF waveform modulation peaks. This slow decay allows the meter's pointer to more closely track the instantaneous RF modulation envelope voltage peaks sensed and processed by the voltage follower circuit. To calibrate a Swan PEP meter, either a calibrated PEP wattmeter or an oscilloscope may be used. With a known calibrated PEP wattmeter reference, any typical SSB signal can be used, and the test meter adjusted accordingly.

If an indirect oscilloscope measurement of instantaneous RF peak voltage at a dummy load is used to calculate RF output power, one might use either a CW or SSB modulating signal and calibrate a wattmeter to coincide with the measured PEP. However because of the radically different time-varying nature of the two signals types, the same calibration settings may be achieved only for an idealized high-speed digital processed wattmeter system that is unconstrained by the meter's pointer inertia and analog sensing circuit's time constants.

CW Calibration Signal. If a steady-state CW signal is used for calibration, a wattmeter's calibration adjustment is straightforward and unambiguous, but it most likely will not yield accurate operational PEP measurements, since the calibration signal does not replicate the sporadic and varying modulation peaks seen during normal SSB operations.

Recall that the FCC's definition of PEP is that it is equal to the modulation envelope voltage peak averaged over one RF carrier signal cycle (Power = $\{V_{peak}/1.414\}^2/R$). The CW signal PEP modulation envelope is really just a special case of a SSB signal. Its peak modulation envelop power is a constant value and its rate of peak occurrence is equal to the RF frequency – its PEP is equal to its RMS power. At 7 MHz, a constant amplitude single-cycle CW signal peak is seen 7,000,000 times a second while a typical maximum amplitude SSB signal peak may be seen perhaps only once every few seconds. Thus, the use of a CW signal is not really consistent with SSB operations in terms of how a PEP circuit/meter must respond.

With a continuous CW signal, the meter's pointer will remain at a fixed, steady-state value and pointer inertia or circuit time constants are not an issue, while during sporadic SSB peaks, it must try to follow the PEP fluctuations from the voltage follower circuit as a function of time. Because of this, if a meter's calibration were adjusted using a CW signal, the PEP measured during a key down CW transmission will accurately measure the CW RMS value, but not necessarily accurately measure the sporadic SSB peaks (dependent on meter design).

SSB Calibration Signal. On the other hand, if a typical SSB signal is used during calibration, it would be unwise to adjust a PEP wattmeter's calibration based on a just a single, isolated, short duration modulation peak or pulse, since this also would not permit the meter's adjustment to accurately reflect the pointer inertia and capacitor/voltage follower effects that occur during typical SSB operation where multiple, variable amplitude peaks occur. If the signal is averaged over a number of SSB RF voltage modulation peaks (eyeball averaged), the adjustment will be both more accurate and realistic, but the calibration adjustment is somewhat subjective. When the meter's calibration is adjusted using a SSB signal, the PEP measured during a key-down CW transmission will most likely not equal the measured CW RMS value.

Examination of a WM-3000 PEP wattmeter's peak readings (RMS/AVG mode were been calibrated separately) showed that when calibrated to a CW signal, the actual measured operational SSB PEP RF output (measured with an oscilloscope) was significantly greater than that indicated by the meter. After recalibration of the PEP mode (200-W scale) to accurately display the actual SSB PEP levels, a comparison was made with a MFJ 969 tuner's wattmeter (300-W scale). When using a ~100-W CW test signal, both units had the same RMS mode reading (103 W versus 105 W), but when switched to the PEP mode, the MFJ indicated a 100-W PEP level while the WM-3000 indicated 140 W. When the signal modulation was switched from steady-state CW to a typical SSB signal, both units indicated near identical PEP levels, in agreement with oscilloscope measurements.

See the additional discussions on peak versus average SSB signals in the Swan transceiver manuals.

4.16.3. SWR Measurement (Fwd/Rev Power)

On Swan directional wattmeters that do not include a SWR function, but have only a forward and reverse RF power measurement capability (such as the WM-1500 and WM-2000), the SWR can easily be determined from a nomogram that relates both of those measurements to SWR, calculated by the formula SWR = $\{1+\sqrt{(P_{ref}/P_{fwd})}\}/\{1-\sqrt{(P_{ref}/P_{fwd})}\}$.

Fig. 4-5 shows this nomogram, similar to the one that is included in some Swan wattmeter manuals. To determine SWR, merely find the intersection on the graph of the measured forward and reverse powers, interpolating as necessary between the linear curves of constant SWR. For example, with a measured forward power of 200 W and a reflected or reverse power of 25 W, the SWR would be approximately 1.8. Recall that on the logarithmic axis scales shown, the power of ten format mathematically is interpreted as $10^1 = 10$, $10^0 = 1$, $10^{-1} = 0.1$, etc. If you look at any cross pointer type wattmeter being sold today, such as those offered by MFJ and Daiwa, this nomogram is in fact printed on the meter face as curvilinear scales.

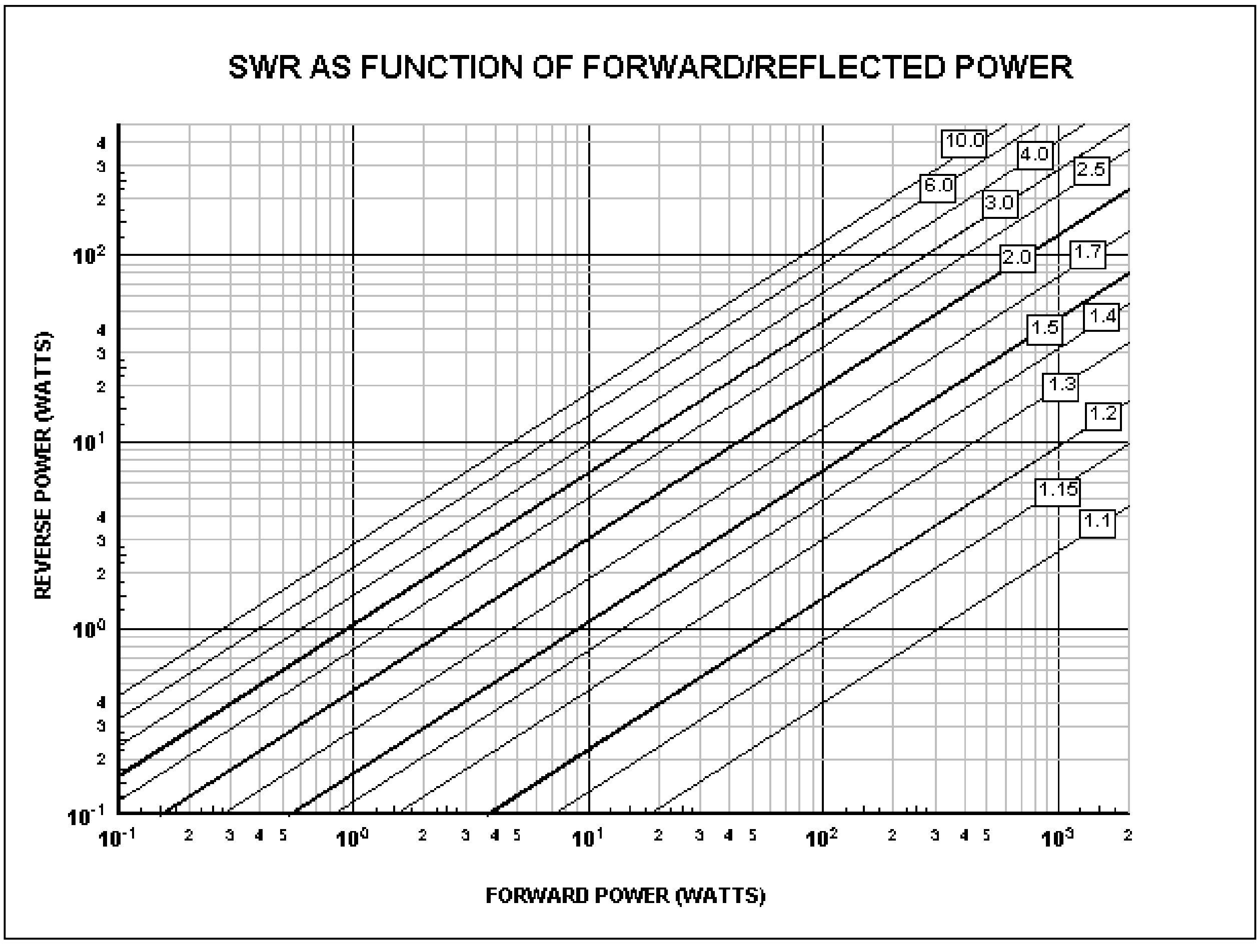


Figure 4-5 SWR as a Function of Forward and Reverse Power

4.16.4. WM-200A

The WM-200A through line VHF wattmeter, introduced in ~1978, is similar to the WM-6200 VHF meter in that it operates over the 50 to 150-MHz frequency range, has two power scales (0-20 and 0-200 W), and includes a direct reading VSWR (1:1 to 1:3) capability, but it also includes additional circuitry to provide both RMS and PEP measurement and has an increased SWR measurement accuracy. The power accuracy is ±10% of full scale and the VSWR accuracy is ±5%. The cabinet size (4" H x 8" W x 5.5" D) and styling are the same as the WM-6200 (and WM-2000/3000).

4.16.5. WMM-200

The WMM-200 SWR and Power Meter, introduced in ~1978, is a small, cosmetically streamlined version of the larger size VHF meter models, designed specifically for mobile operation. However, the unit is considerably smaller (5" x 2" x 1 ¾") and uses a rather small, round format meter. It includes a swivel base so that it can be mounted on a dash, overhead, or center console, etc. Since it has a remote RF sensor, the display can be physically separated from the coax feed line. Like the base station models, in covers the 50-MHz to 150-MHz frequency range, has 0 to 20-W and 0 to 200-W scale ranges, and includes a direct SWR measurement capability, but it only provides RMS power measurements. The VSWR measurement range is 1:1 to 3:1 with a ±3% FS accuracy. Power measurement accuracy is ±10% of full scale. A meter lamp requires an external 12-V power source.

4.16.6. WM-1500

The WM-1500 was Swan's first wattmeter model, which was introduced in ~1973 and continued to be sold through at least the 1978 time frame, even after a number of other models with advanced features (SWR, digital display) were introduced. It provides both QRO and QRP average power measurement capability, with switched full-scale sensitivities of 5, 50, 500, and 1,500 W. Either forward or reverse power can be displayed with another switch selection. Specified accuracy is ±10% or less of full scale for frequencies from 2 MHz to 30 MHz and with reduced accuracy, up to 50 MHz.

It provides an indirect measurement of SWR through its ability to measure both forward and reverse power, if these measurements are used in conjunction with the nomogram shown in Fig. 4.5. This meter, like most other WM series wattmeter, has a large easily read meter, but its cabinet (and meter) is squarer (6" H x 6" W x 4.5" D) as opposed to the rectangular format of the WM-2000 or WM-3000 series meters.

4.16.7. WM-2000/A

The WM-2000 and WM-2000A are identical except that additional circuitry and switching is included for direct PEP measurements in the later model. The meter power measurement accuracy is ±7% of full scale. The cabinet size is 4" H x 8" W x 5.5" D. The units operate over the 3.5-MHz to 30-MHz frequency range, have a very large and easily readable meter, and have full-scale meter display selections of 200, 1,000, and 2,000 W. This is a rather unfortunate choice of scale ranges for use with the higher power dual-tube PA Swan transceiver designs, as most of those transceiver typically exceed 200 W output, forcing the user to use the 1,000 W sensitivity and operate in the less accurate, lower portion of the meter's scale.

The WM-2000A was introduced in ~1978. It provides a direct measure of SWR between 1:1 and 3:1, though a simple meter calibration procedure via a front panel potentiometer is required. The 2000A includes an internal 117-V ac power supply to operate the PEP circuitry, but the meter will operate in the RMS mode (average power) without ac power applied.

The WM-2000 model only provides an indirect measurement of SWR through its ability to measure both forward and reverse power in conjunction with a nomogram that relates these power measurements to SWR, as shown in Fig. 4-5 (one was provided with the WM-2000 manual).

There was an unusual 19" rack mounted (with a 5¼ " height) configuration of this model that was made of this unit, with the WM-2000 positioned on the left hand portion of the panel and the phone patch positioned on the right hand side – the front panel configuration, labeling, and styling is the same as that of the individual units.

This rack version might have been a special build for the federal government/NASA, since on one such rack configuration, the serial numbers of both units were #525 with a *NASA* prefix.

Operational Amplifier Replacement. The WM-2000A and WM-3000 Swan PEP wattmeter circuits use an 8-pin operational amplifier IC (NEC C151C) in the PEP circuit, which functions as a voltage follower that tracks the voltage decay of a capacitor charged by a sampled and rectified dc voltage proportional to the RF waveform peak. The ARRL 1986 handbook lists a number of Op Amp pin layouts, including one that functionally matches the NEC C151C (i.e. same in/out/voltage/dc null balancing pin layout, as per the wattmeter schematic) and lists six equivalent model numbers. Radio Shack carries the LM741CN (and can order the LF356N). It functions well in the wattmeter. If replacing the chip, it is prudent to install a chip holder. It makes any future replacement easy and saves the IC from any potential overheating with a direct solder installation.

4.16.8. WMD-2000

The WMD-2000 digital SWR power meter, introduced in ~1978, provides both a peak and RMS power reading capability over the 3.5-MHz to 30-MHz frequency range, has a large and easily readable 4 digit LCD readout, requires 117-V ac power to operate, and handles power levels up to 2,000 W. The VSWR measurement capability extends from 1:1 to 19.99:1. The power accuracy is ±10% of the reading and VSWR accuracy is ±3% percent of the reading value. Note that for most power readings, this is an improvement in accuracy over the analog meter models, which are typically specified as ±7% or ±10% of the selected full-scale range. The 4¼" by 8" by 5¼" inch form-factor is not the same size as either the WM-1500 or other WM-2000 series wattmeter models.

4.16.9. WM-3000

The WM-3000 provides both Peak and RMS power readings over the 3.5-MHz to 30-MHz range, has a very large and easily readable meter, and full-scale sensitivity scale selections of 200, 500, 1,000 and 2,000 W. The meter measurement accuracy is 7% of full scale. Because of the availability of the 500-W range, this meter is well suited to Swan dual-tube PA transceiver designs since it operates in the higher accuracy portion of the meter's display scale.

The cabinet size is 4" H x 8" W x 5.5" D. The unit includes an internal 117-V ac power supply to operate the PEP circuitry, however the meter will operate in the RMS mode without power. See Section 4.15.7 for information on the IC operational amplifier used in the PEP circuit. This unit has no direct SWR measurement capability, although with its ability to measure both forward and reverse power, it can be easily determined using the nomogram provided with the WM-3000 manual (similar to Fig. 4.5).

At least two version of this meter were produced. One version has internal calibration potentiometers for each of the 4 scale ranges for the RMS forward/reverse and PEP forward/reverse functions (8 potentiometers total). The second has internal calibration potentiometers of each of the 4 scale ranges for the RMS forward, RMS reverse, PEP forward, and PEP reverse, permitting a more accurate calibration (16 potentiometers total).

4.16.10. WM-6200

The WM-6200 through-line VHF wattmeter provides RMS power readings over the 50-MHz through 150-MHz range and direct reading of VSWR over the 1:1 to 3:1 measurement range (±5% accuracy). Power scale selections are 0-20 and 0-200 W with a ±7% FS accuracy. It has the same large analog meter, rectangular case format, and styling similar to that used in the WM-2000/WM-3000 HF wattmeters.

4.16.11. WMD-6200

The WMD-6200 VHF VSWR Power Meter, introduced in ~1978, is a digital version of the WM-6200 VHF wattmeter that operates over the 50 to 150-MHz frequency range. It requires 117-V ac power for operation, has the same form-factor and styling as the WMD-2000 HF digital wattmeter, and uses a 4 digit LED display. Specification changes relative to the WM-6200 include: a power display capability from 2-199.9 W (±10% of reading) and a VSWR display capability from 1:1 to 19.99:1 (±3% of reading).

4.16.12. Meters, Misc. (FS, SWR, Portable)

Most meters listed below provide only a relative measure of RF output power (including via field strength). While a relative measurement provides no indication of actual RF power output, it still can be used for tune-up purposes (tuning to the maximum indicated relative RF output power point) to obtain the proper LOAD and PLATE control positions for near maximum RF output and efficiency. When used for that purpose, they operate just as efficiently and accurately as the other, more elaborate RF wattmeters discussed above.

4.16.12.1. FS1 Field Strength

This was a relatively cheap, portable field strength meter intended primarily to aid in the adjustment of mobile antennas. It operates over a frequency range from 1.5 MHz to 200 MHz and uses a telescoping antenna to sense RF signal strength. Relative signal level is displayed on a meter, whose sensitivity is adjustable.

4.16.12.2. FS2 Field Strength

This small meter provides in-line power (1-kW maximum) and SWR measurements (1 to 1:3) with an accuracy of ±5% of full scale. It also has a built-in whip antenna for RF field strength measurements. It requires about 25-W minimum for SWR measurements on 80 meters, decreasing to lower power levels at higher frequencies (i.e. ~15 W minimum at 40 meters).

4.16.12.3. SWR-1/SWR-1A Operation

This small compact meter is capable of handling 1,000-W RF power and measures SWR between 1:1 to in excess of 3:1 over the 3.5-MHz to 150-MHz frequency range. The SWR1A has two meters and provides simultaneous measurement of both forward and reverse relative RF power (it does not give a measure of absolute power, although it can be calibrated against a known reference and then affixing specific relative sensitivity control adjustment positions correspond to the measured power levels in the various bands) and with a simple calibration/adjustment procedure, SWR. It was intended primarily for portable or mobile use.

To measure SWR, just insert some transmitter carrier to generate a low RF output level (both meters go up scale), turn the potentiometer positioned in the center of the unit (which controls the sensitivity of the left-hand power meter) up until the that power meter reads full scale; then directly read the SWR on the right-hand meter. The right-hand meter may be a little confusing because it shows an upper scale indicating relative reverse power in watts and a lower scale that is applicable during SWR measurements.

4.16.12.4. SWR3

The SWR3 was the smallest meter made by Swan for portable or mobile applications and provides a VSWR measurement capability over the 1.7-MHz to 55-MHz frequency range. Like the SWR-1 and SWR-1A, it does not have a calibrated forward or reverse RF power measurement capability, but only provides a relative measure of forward RF power (just as useful as a calibrated meter for transmitter tune-up purposes).

Through a simple calibration procedure the SWR, with 3% accuracy over a 1:1 to 3:1 range is measured and displayed. To obtain a measurement at a given RF frequency (~20-W minimum RF power is required at 7 MHz and somewhat higher RF levels at lower frequencies and lower RF levels at higher frequencies) the meter's sensitivity potentiometer is first adjusted for full-scale pointer deflection when in the forward mode, then switched to the reference mode to directly display SWR.

5. MODIFICATIONS

***Caution** – when working on tube transceivers and power supplies, lethal ac and dc voltages are present. Under the wrong conditions, even low voltages can be fatal! Always disconnect the ac line, always disconnect the transceiver from power supply, always wait at least a couple of minutes for the bleeder resistors to discharge the high and medium voltage filters, and to be absolutely sure, always discharge all power supply or transceiver filter capacitors and other terminals to ground with an insulated handled too, even if power has not been applied for a long time. The ~–110-V bias and the ~18-V relay supplies have no bleeder resistors and if the supply is disconnected from the transceiver, those capacitors retain a charge for a long, long time, so these must be manually discharged.*

Recognize that the modifications listed in this section represent only some of the more common ones that in general apply to a wide variety of models. There are many other factory service bulletins and modifications not mentioned that expand the capabilities of a specific model (e.g. FSK modification for the Swan 400).

Documentation. Make a working photocopy of the operation manual and schematic to preserve the condition of the original. In addition to purchase price and date, seller, buyer, etc. information, always take the time to thoroughly document any modifications, troubleshooting, and alignment work done on any piece of Ham gear – with the proliferation of digital cameras, a couple of close-up photos is an ideal adjunct to written notes. It is also a good idea to make any modifications in such a way that they can be reversed easily and/or at least easily identified. Wouldn't it be great to have a detailed life history included with a "new" piece of Swan gear you acquire?

5.1. ALC XCVR Modification (Linear Amp)

If you are using one of the powerful dual-tube PA Swan transceiver models with a linear amplifier, a relatively simple ALC modification can be made to permit them to be used more easily with linear amplifiers – see Swan Newsletter, Issue 7, Section A.7.6.

5.2. Balance Mod Conversion, 7360 to 6JH8

If you wish to convert a Swan transceiver's balance modulator to use the lower cost 6JH8 in place of the costly 7360, see the modification discussed in the 7360, 6JH8 Balance Modulator Section 8.6.14.

5.3. CW/Carrier Variable Adjustment

Operation Manual instructions direct the user to always tune-up to near the maximum RF output power point under full carrier conditions. However, any improper implementation (e.g. extended tune-up periods, control maladjustments, etc.) of those steps has the potential to damage the PA tubes. Some transceiver models (e.g. early version 350s) are automatically at full drive whenever the function switch is in the TUNE/CW position. Others require the CAR BAL control to be adjusted to its cw or ccw position to obtain full carrier. With that later capability, an inexperienced user can first tune-up to the approximate settings under lower carrier conditions, limiting the potential tube damage cause by procedure error. For transceiver models that only apply full drive, a very easy modification permits the carrier level used during tune-up or CW operations to be varied via the CAR BAL control when the transceiver is placed in the TUNE or CW mode. Indeed, when 350s were returned to Swan for servicing or upgrade installation, this was one of the modifications that Swan automatically made to the unit prior to returning it to the customer. This modification does not alter the CAR BAL control operation in the SSB mode.

It is interesting to note that this modification was recommended by Swan in service bulletin 9A (also see Herb's comments in Section 6.1), not for tune-up or variable CW RF output level considerations, but because of excessive 15-meter spurious radiation caused by the 2nd harmonic of the carrier frequency mixing with the 2nd harmonic of the VFO in the model 350 and 400 transceivers, when operated in the lower portion of the 15-meter band at full output. For those transceiver models, Swan recommended CW operation using a cathode current level adjusted via the CAR BAL control to 2/3^{rds} of that obtained during full carrier, maximum power/efficiency tune-up (i.e. if 500 mA was obtained during tune-up, the CAR BAL control would be adjusted to ~350 mA for CW operation).

Note that the Cygnet, Cygnet-like, and most early single-tube PA transceiver models, which use full carrier drive during normal tune-up procedures, switch either a cathode resistor or a screen resistor into the circuit when the mode control is in the TUNE position that limits the amplifier power capability during tune-up and helps to protect the PA tube from damage. Thus, the actual RF output power during SSB or CW operations on those models will be significantly higher than the 80 to 90 W or so achieved during tune-up.

Modification Procedure. Remove the bottom cover and locate the balanced modulator tube socket. If the balanced modulator tube is a 6JH8, there will be a wire connected to pin #1 that goes to the function switch. Disconnect that wire at the tube socket, tape the end, and label. If the tube is still the 7360 used prior to 1968, disconnect the wire from pin #9. Sometimes (but very rarely) the wire from the function switch was connected to pin #2 of the 6JH8 socket and pin #7 of the 7360 tube socket, but in both cases it is connected to the function switch – don't disconnect anything but the wire to the function switch.

Remember, with this modification, you will have to manually inject carrier during the normal tune-up procedure when the rig is switched to the TUNE or TUNE/CW position. Section 8.6.14, which discusses balanced modulator tube substitutions, includes this simple modification as a pen and ink notation on a section of the 500C schematic shown in Fig. 8-7. After this modification is made, remember to null the CAR BAL control prior to SSB operations, otherwise carrier will be inserted during the SSB transmissions. See the discussions in Section 5.8.2 related to front panel CAR BAL control adjustments to reduce the CW RF output level and associated efficiency implications.

5.4. CW/Carrier RF Level Adjustment, Fixed Level

While one may desire to convert a transceiver that has a fixed, full-carrier insertion to a variable carrier level insertion capability as discussed above, the converse might also be true for transceivers that came with the variable carrier insertion as part of their standard design. See the Swan Newsletter, Issue 4, Section A.4.4 for a discussion on the merits of converting to fixed, full-carrier tuning.

5.5. CW Side Tone, Improved

In order to change the CW side-tone level, many manuals suggests reducing the value of a resistor in the audio output circuit (i.e. R1202, 47 Ω) to pull the AF transformer secondary signal down closer to ground, dropping the tone in level as well as anything else on the secondary. This seldom produces a satisfactory side tone that does not vary excessively as a function of audio volume control position. A sketch of a modification that should work better is shown in Fig. 5-1. This modification may be installed on the 350C, 500C, and 500CX. It needs only four additional components added to the original side-tone oscillator circuit. To generate the side tone, the AF output tube operates as an oscillator when the function switch is placed in the CW mode position. The modification produces a relatively stable side-tone level, regardless of audio frequency gain-control setting.

5.6. Headphone Jack, External

If a Swan transceiver lacks an external headphone/speaker jack (e.g. 260), one can easily be added. Install a jack directly on the transceiver rear chassis apron or mounted in a small stand-alone external box. Installation on the front panel is also an option, but it will surely decrease the value of the rig from a collector's standpoint, no matter how clean a job is done. Simply locate the wires to the speaker, and identify the ground and signal lines. Connect by affixing the ground wire to the frame of the jack, breaking the signal wire and connecting the speaker side to the normal connection on the jack, while running the transformer side of the signal wire to the phone plug contact that shorts to the normal connection of the jack when no plug is inserted.

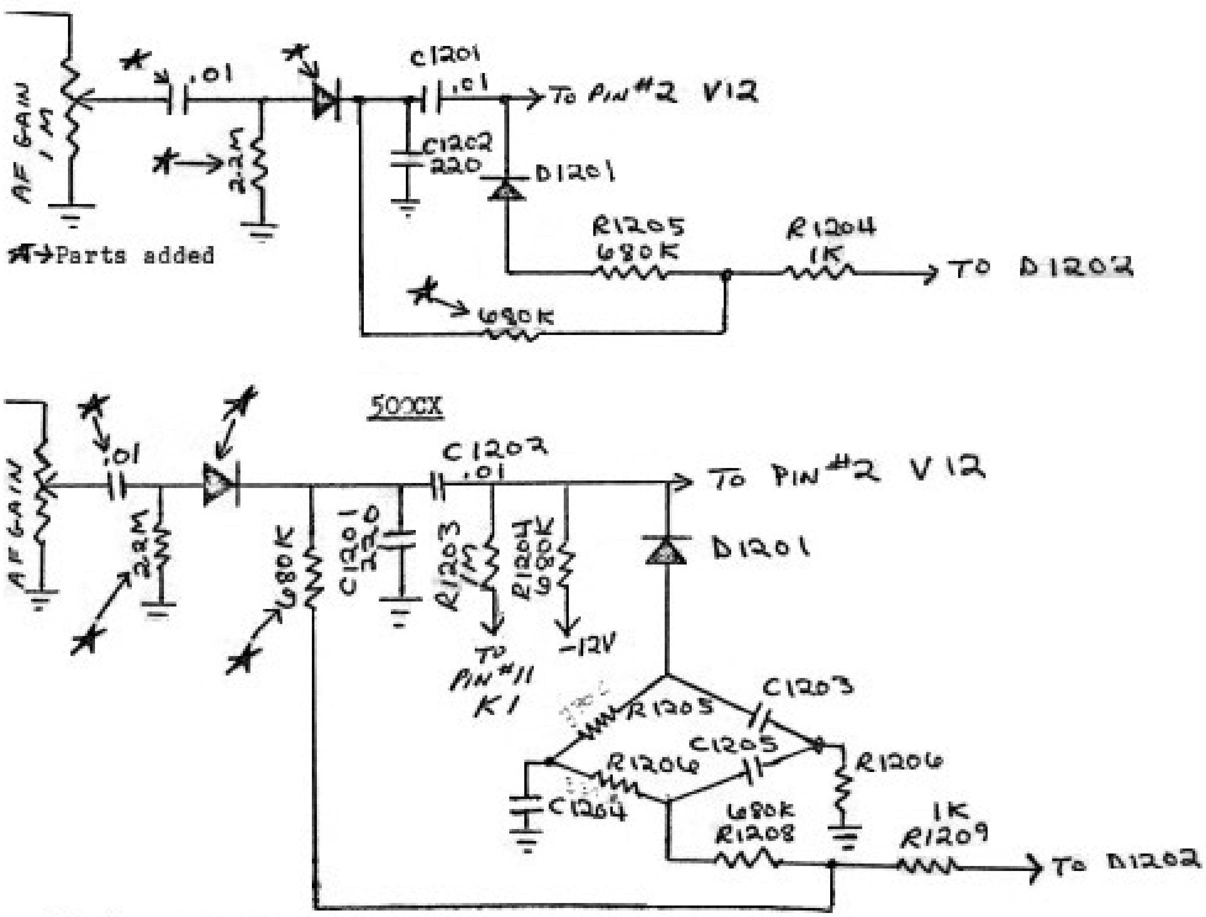
Since the Swan output transformer is designed for a 3 to 4-Ω load, LO-Z headphones with an impedance between 4 and 600 Ω should work fine. Ideally, monaural headphones designed specifically for amateur communications should be used, such as the Kenwood HS-5, which have an 8-Ω impedance and a frequency response from 50 to 3,000 Hz. The limited bandpass of phones will reduce both high and low frequency noise outside the SSB audio signal's bandwidth. If stereo headphones are to be used, just use a stereo-to-mono adapter in line with the headphones.

In some cases, with higher impedance headphones, it may also be desirable to connect a swamping resistor (~10 Ω) across the audio output to flatten out the frequency response from the output transformer. It should be wired so that it is disconnected when the speaker is used, though likely neither you nor the transceiver will be able to tell the difference if it weren't.

CW MONITOR 500C - 350C - 500CX

The following parts can be added in the CW monitor so the A.F. Gain control will not effect the monitor volume or tone.

500C - 350C



Parts required:

1. POWER DIODE 600V PIV,750 ma. #475-018
2. .01 cap. GP DISC. #072-023
3. 2.2 meg. 1/2 watt #042-225
4. 680 k. 1/2 watt #042-684

Figure 5-1 CW Monitor Modification Schematic

See related discussion on audio hum problems in the Power Supply, Common Problems Section 3.4.1.2, and the Swan issued service bulletin shown in Fig. 3-1.

5.7. PA Conversion for Increased Power

A couple of modifications for converting transceivers to a higher dc input PEP capability are listed below, however it should be recognized that the 8950 tube specified in one method is exceedingly expensive. If such a conversion is performed, use of a lower cost substitute tube should be considered (e.g. 6LB6, which would also requires that the filaments be wired in series – see the 8950 Tube Section 8.6.15 for further information).

6LQ6 to 8950/M2067. See Swan Newsletter, Issue 5, Section A.5.2 for a procedure to convert the 6LQ6 PA deck to use either the 8950 or M2067 tubes. This modification should change the minimum dc input power capability for a 350C from ~360-W to ~500-W CW (~700-mA cathode current).

6HF5 to 8950. A procedure for the conversion of the model 350 transceiver (6HF5) to use the 8950 to achieve a higher RF power output is covered in detail in the November 1976, August 1978, and April 1979 issues of *QST* in the "*Hints & Kinks*" column.

EL509. The Russian built EL509 tube has also been used as a PA tube substitute in Swan transceivers. However, while it has been found to work well, the modification is a fairly big job, as it also requires some mechanical work. The primary advantage to the EL509 is that it will operate forever and the Russians are still making them, so the supply is good. If interested in this modification, post a request to the Swan-Net Reflector to obtain first-hand detailed information of users who have performed this change.

5.8. RF Power Reduction Modifications

Often it is desired to reduce the RF power output of Swan dual-tube PA transceivers (non-Cygnet designs) to minimize the stress on circuit components (e.g. wafer switches, power amplifier tubes, etc.), limit power output capability for driving a linear amplifier, or just because of an operator's preference for a lower RF output level. The common methods to reduce the output power fall into two basic categories, namely (1) design modifications that change the PA tube's operating voltage levels and (2) user front panel control adjustments.

5.8.1. Operating Voltage Modifications

The first category of modifications makes circuit voltage changes to reduce the fundamental maximum power the transmitter can achieve and is often done on higher power Swans, such as the 500CX and 700CX. The power output capability of a pentode tube AB_1 class amplifier is a function of both screen and plate voltage, but screen voltage is the dominant controlling variable. Therefore, it is these two variables that are changed to reduce the transmitter's RF output power, namely, (1) significantly decreasing the plate voltage level on the PA tubes, or (2) moderately decreasing the screen grid voltage applied to the PA tubes.

Understanding Effect of Screen Versus Plate Voltage Variations. It is helpful to have a general feel as to what cause and effect occurs when these two parameters are varied. Unfortunately, sweep tube (e.g. 6LQ6, 6MJ6, etc.) specifications and characteristic curve data for the operational voltages used by Swan are very limited (i.e. ~800-V plate and ~275-V screen versus ~300-V plate and ~100-V screen for TV applications), since most manufacturer published tube information give only the typical voltages used for the designed application, that of a TV CRT horizontal deflection (sweep) amplifier.

To conceptually illustrate how these two voltages (screen and plate) influence PA pentode tube performance, example data from a 5881 pentode tube are given in Table 5-1. This data shows that with the plate voltage held constant at 500 V and the screen voltage increased 60% from 250 to 400 volts, the plate (cathode) current increases over 300%, from 105 mA to 320 mA. Whereas, when the screen voltage is held constant at 250 V and the plate voltage is increased 66% from 300 to 500 volts, the cathode current increased only 10%, from about 95 mA to 105 mA. So, one can expect that for the two modifications suggested above smaller proportional changes in the screen voltage will have a more profound effect than larger changes in plate voltages, and indeed that is the case. Also see Table 6-1 and related discussions in the Important Fundamentals Section 6.2, which presents some sweep tube data at voltages approaching those used by Swan. Review of that data also shows a similar ef-

Table 5-1 Example of Relationship Between Screen/Plate Voltage and PA Cathode Current

Plate Current as F'n of Screen Voltage - 5881			
Plate (Volts)	**Grid (Volts)**	**Screen (Volts)**	**Plate (mAmps)**
500	-15	250	105
500	-15	325	195
500	-15	400	320

Plate Current as F'n of Plate Voltage - 5881			
Plate (Volts)	**Grid (Volts)**	**Screen (Volts)**	**Plate (mAmps)**
300	-15	250	95
400	-15	250	100
500	-15	250	105

fect to that illustrated in Table 5-1, although it is not as obvious because neither the screen nor the plate voltage remains fixed as the other varies.

Ideally, for a specific circuit design, the plate, screen, and/or bias voltages should be concurrently altered if a significant change in the designed power capability is desired, since changing only one can cause problems (excessive screen current, signal distortion, etc.). In fact, inspection of the early Swan manuals (e.g. 120, 240, etc.) show minimal, nominal, and maximum recommended operating voltages, each with its own set of plate, screen, and bias voltages (see Table 3-1). Swan also implemented this type of operating voltage change in the 600T transceiver to include a low-power front panel switch that decreased total dc input PEP capability by ~50% (from 600 W) by lowering the 215-volt (nominal) screen voltage by about ~30% in conjunction with increasing the idle current from 50 mA to 80 mA via a separate bias adjustment circuit. Therefore, modifications of this type, where only one of the parameters is changed, generally require care to properly implement.

5.8.1.1. Reduce HV Power Supply Level

See the Power Supply Section 3.6 for modification details and procedures. This modification reduces the fundamental power a transceiver is capable of generating by modification of the external 117X power supply to lower the PA plate voltage from ~800 V to ~600 V. It is desirable when driving a linear amplifier with any of the two-tube PA transceivers, as it brings the maximum power down to the 150-W range, protecting both the transceiver PA tubes and other circuit components during barefoot operation, as well as any linear amplifier being driven by the transmitter. If one desires, it can be made reversible by installing a switch (with proper voltage rating) in the power supply to revert to the original circuit.

5.8.1.2. Reduce Screen Voltage

The early 350, 400 and 500 series transceivers included a screen grid resistor in the PA circuit (typically labeled R407, 10 kΩ, 10 watt) to limit screen voltage. The voltage drop of this resistor, installed in series with the PA screen grids, slightly reduces the voltage on the screen, causing a final output power reduction of 5% to 10%. This power reduction helps to increase PA tube life (perhaps by as much as 50%) and reduces the strain placed on other components, such as the RF driver band wafer switch, a common failure point in the higher power transceivers. This resistor was deleted from the later higher power models employing the 6LQ6/6JE6C/6MJ6 and 8950 tube types (e.g. 500CX, 700CX, 750CW) in order to ensure the transceiver would meet the advertised power claims. These higher power transceivers also use more solid-state circuitry (carrier oscillator, crystal calibrator, etc.) and therefore have fewer tubes to help draw down the +275-V medium voltage from which the screen voltage level is derived. Therefore, rather than having a nominal screen voltage of +215 V or so as suggested in their manuals, the typical screen voltage is much greater, sometimes measuring the full +275 V or more (see Table 3-5).

With earlier Swan transceiver models that have had their PA retrofitted with 8950 tubes or other higher output tubes, this resistor may also have been removed to increase power output. If yours has been retrofitted with 8950s, check to see if this resistor (R407) is installed.

As noted earlier in this section, when significantly reducing the plate voltage, in general the screen and/or bias voltage are also frequently altered to keep from burning-up the screen. However, this is not true for this modification to

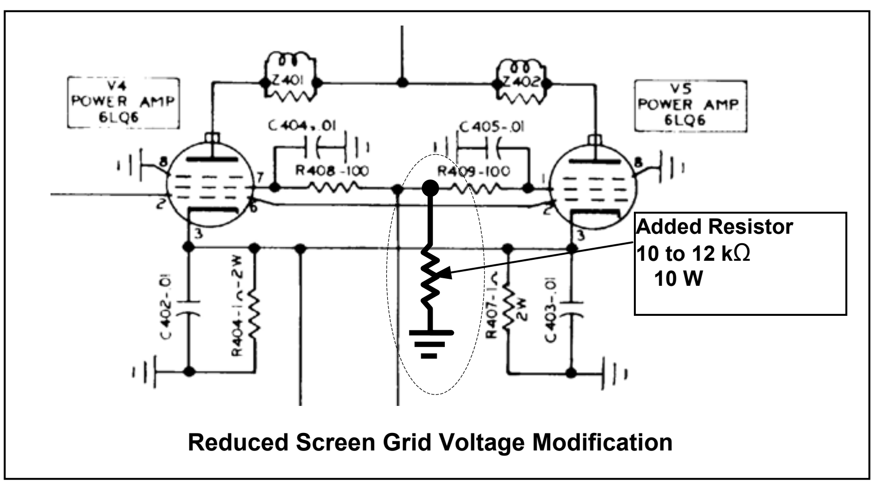


Figure 5-2 PA Screen Voltage Modification Schematic

Swan transceivers because of its limited scope (see related discussion of this issue in the Power Supply, HV Reduction Modification Section 3.6). The dc input HV level reduction with this modification is basically re-adjusting the screen voltage to near that used in the baseline 350 and 500 series transceivers.

Procedure. Simply re-install the 10-kΩ resistor, as depicted in the schematic shown in Fig. 5-2. Use a 10-kΩ to 15-kΩ resistor with a rating of at least 10 W. This modification will typically reduce the screen grid voltage by about ~15 to 25 V. Before and after measurements of this modification report a decrease in screen voltage from +270 V to +245 V. If one desires, this modification can be made reversible by installing a switch with the proper voltage and power ratings in series with the added resistor.

5.8.2. Operating Control Adjustments

The second category of options to reduce output power is to make front panel control adjustments. Preferred methods include: (1) reducing the microphone gain during SSB operation and (2) reducing the CW carrier level insertion for very low-level CW operation.

Other methods that will also achieve a reduced output but should never be used because of severe signal quality deterioration, the potential for dire consequences to driver and/or PA related tubes due to heat damage, or increased risk of other component failure include: (1) decreasing the idle current, (2) detuning the driver, and (3) significantly light loading.

5.8.2.1. Reduce Microphone Gain

This is by far the easiest and safest way to reduce SSB power! Once you have the transmitter tuned-up to near maximum RF output power, reduce SSB operating power output by simply reducing microphone gain. Because the driver is just amplifying whatever signal level it receives, reduction of the MIC GAIN control also reduces the input signal level to the PA. Since this forces the PA to operate over the lower portion of the characteristics curve, there will be some small increase in signal distortion and a reduction in efficiency. See related discussions in the Important Fundamentals Section 6.2 and the Tune-Up Considerations Section 6.3.

SSB Tuning/Loading. It's best not to get too wrapped-round-the-axel about attempting to tuning exactly to the maximum power point, since even after being meticulously tuned-up precisely to its maximum RF output point with a steady-state carrier or CW signal, when switched to the SSB mode the transmitter will not be optimally tuned for the SSB peaks anyway. The SSB peaks are variable in amplitude, having instantaneous grid drive peak levels both significantly higher and lower than that used during full carrier tune-up and the plate voltage levels will also be significantly different due to power supply loading under full carrier or CW tune-up conditions. Since the pentode tube's plate resistance (R_p) is a function of its plate, screen, and grid drive voltage levels, an unavoidable consequence of this is that R_p actually changes somewhat as those parameters vary – thus there is no possible single PLATE and LOAD control position setting that is optimum for matching the R_p to the feed line/antenna load for all signal level conditions.

This really is only of academic interest rather than a practical or operational concern, since this inherent tuning predicament has only a small effect during normal SSB operation. In practice, the best that can be realistically done is to use Swan's recommended tuning method (preferably using an external wattmeter). Maximum RF output power occurs on the highest positive grid voltage SSB audio peaks, so the normal Swan specified procedure of tuning to near the maximum power/efficiency point under full CW carrier level conditions is a good compromise that intuitively makes sense for both normal and moderately reduced SSB microphone gain settings. Reasonable linearity and efficiency is still maintained during the voice peaks that occur even with significantly reduced microphone gain settings.

The only possible exception to tuning to maximum RF output power for SSB operation may be if extremely low SSB RF output levels were desired (i.e. QRP and perhaps even with 10s of watts PEP RF output). Using the same rationale as discussed below for very low RF output level CW operation, tuning-up using to a lower CW carrier level for such reduced power SSB operations may be desirable since is should improve power amplifier efficiency and signal linearity. See the additional discussions of these issues in the Tune-Up Loading and PA Efficiency Section 6.2.9.

5.8.2.2. Reduce Carrier Level – Option 1 (CW)

Option 1. For lower-level RF output CW operations, one option is to simply *reduce the carrier insertion level* (CAR BAL) *after first tuning-up to near the maximum RF power output loading point under full carrier conditions, as is normally done*. On most Swan transceiver models, the CW level is controlled by the CAR BAL control, which determines the carrier signal level that is applied to the control grid of the PA tube(s), thus controlling RF output level. However, on some transceiver models, the CW level might be a fixed full-output level and this adjustment is not an option. See the CW level adjustment modification previously discussed in Section 5.3 if your transceiver applies only full carrier when in the CW mode and you wish to change it.

Unfortunately, operating at a reduced carrier level to lower the CW RF power output results in a significant loss in PA efficiency (RF output/DC power input) and a moderate increase in PA tube power dissipation requirements. See the Tune-Up Loading and PA Efficiency Section 6.2.9 for detailed measurements and discussions of this issue.

Measured Results. When the transmitter is tuned to near the maximum RF power output point with full-carrier insertion (as recommended in nearly all Swan manuals) and then operated at lower CW carrier insertion levels, the reduced CW signal voltage on the grid is below that used during tune-up, resulting not only in lower output, but also much lower efficiencies and correspondingly higher power dissipation requirements. During operations under such conditions, the potential for heat related damage to the PA tubes becomes a very real concern.

This assertion made above is based on the measurements shown in Fig. 6-9 and related discussions in that section. For example, as shown in that data, measured on a 500C transceiver, during full-carrier steady-state CW conditions, the maximum RF power output and peak efficiency occurred at about 260 W, with ~168 W of power dissipation required with an efficiency of 61%. During typical CW operations (standard code element spacing, word spacing, and operator pauses), the average power dissipation required of the PA tubes decreases from the 168 W to ~60 W, the rated plate dissipation limit (30-W per tube).

When the carrier insertion level was decreased from maximum, there is a decrease in efficiency and an increase in dissipation requirements – at 100-W RF output, the efficiency decreased to only 34% and PA tubes' power dissipation required increased to about 195 W, or about 70 W average during typical CW operations. In fact, when the carrier insertion level is adjusted so that the RF output power is anywhere between 80 and 250 W, the power dissipation requirements actually increase relative to the maximum 260-W RF output condition! Only when the RF power output level fell below 75 W did the expected power dissipation requirements fall below the 30-W per tube, however, at those low levels, the efficiency also fell off dramatically to the 20 or 30% range.

So, based on those measurements, the bottom line is that reducing CW insertion level to decrease operating RF power output will not necessarily be easier on the PA tubes, and indeed, even though the output power level is significantly lower, the stress on the PA tubes may even be higher than under full carrier insertion, maximum RF output conditions.

5.8.2.3. Tune-Up at Reduced Carrier – Option 2 (CW)

As discussed above, operating at reduced carrier insertion levels, after first tuning-up the transmitter to near the maximum efficiency and RF power output point, causes a decrease in efficiency and in most cases, an increase in required tube power dissipation.

Option 2. A second option for lower-level RF output CW operations is to again *reduce the carrier insertion level, as is suggested Option 1 (Section 5.8.2.2), but to first tune-up the transmitter for maximum RF output and efficiency at the reduced carrier insertion level* (as opposed to the maximum carrier insertion level as is normally done). When the transmitter is tuned-up at the reduced carrier level, the efficiency is increased relative to Option 1 and more importantly, the power dissipation requirement is drastically decreased. Note that this is not to be confused with intentionally light loading during tune-up, which should never be done (see Fig. 6-8 and related discussions below).

Note that in Section 6.2, Herb Johnson, in quoted correspondence with QST, emphasizes that the transmitter should always be tuned-up under full carrier, however, implicit in that declaration is that any succeeding on-air operations will be conducted at full SSB or CW modulation levels and not with an intentionally reduced carrier level.

Measured Results. The assertion made above is based on the data presented in Figs. 6-9 and 6-10 and the related discussions. Fig. 6-9 shows that, after first tuning a 500C to its 260-W maximum RF power output at full CW insertion level, if the CAR BAL is then decreased to significantly reduced RF output power to say, 50 W, the efficiency falls off to only 24% and the PA tube power dissipation decreases from 168 W to 152 W. While both of these values are just at or under the 60 W total dual-tube PA dissipation capability (when the typical CW duty cycle is factored-in), the tubes are working just about as hard in either case to dissipate heat! However, as indicated in Fig. 6-10, if the transceiver is re-tuned at the reduced CW insertion level that yields a 50-W RF output, the efficiency increases to 34% and the total power dissipation decreases to only 98 W, or about 35 W at a typical CW operation duty cycle.

This behavior holds true for all reduced CW carrier insertion levels. If the transmitter is retuned to the lower insertion level, the PA tube dissipation is always significantly lower and the efficiency significantly higher than if the RF output is just reduced via the CAR BAL after first tuning to near the full-carrier, maximum RF output power loading conditions. If this approach is used, care should be exercised to ensure that the transmitter is re-tuned for full carrier maximum power/efficiency for normal full-power CW or SSB operations.

5.8.2.4. Detuning the Driver

Never reduce power by detuning the driver (GRID). All Swan manuals take great pains to emphasize the need to quickly peak (i.e. simultaneously resonate its plate and mixer output circuits) the GRID control under low carrier level conditions at the very onset of the tuning process. Tuning the GRID off-resonance will certainly reduce the power output level, but it also increases the power dissipation required by the driver tube. Such a condition will shorten tube life and, if severe enough, will quickly cause tube or other component failure (e.g. the choke in the driver tube's plate supply). See also discussions in the Tune-Up Considerations Section 6.3.

5.8.2.5. Light/Excessive Loading During Tune-Up.

Do not significantly light load the transmitter during tune-up. For any given carrier insertion level, intentionally loading to other than near the maximum efficiency and RF power output point will cause a decrease in RF output, however it will also cause a decrease in efficiency, a decrease in signal linearity, and a dramatic increase in PA tube power dissipation requirements.

When lightly loaded, the output load capacitance is higher than it should be, that is, the front panel PA LOAD control is at lower numerical position than it would for maximum output power to be obtained. If this is done either inadvertently or intentionally to reduce output power, in essence the π network (tank) is misadjusted so that the PA's output impedance does not match the coax/antenna system's impedance.

Interestingly, excessive loading significantly beyond the maximum RF output power point is even worse – doing so actually decreases RF output power while dc input power increases and efficiency rapidly falls-off, dramatically increasing PA tube power dissipation requirements!

For the rationale behind these assertions, see the discussion of this issue in the Tune-Up Loading and PA Efficiency Section 6.2.9 and Fig. 6-8 for measured data illustrating the effect of both light and excessive loading.

5.9. S Meter Mod Service Bulletin, Swan 250

The Swan 250 as originally designed and produced did not have a S-meter function. The meter provided only readings of either cathode current or relative power. While many baseline 250s likely have had this modification installed, you should be aware there is a service bulletin available that outlines a procedure to incorporate a S-meter capability. Contact the Swan-Net for this information.

5.10. Sensitivity Service Bulletin, Swan 250

During the original design and pilot production run of the 6-meter model 250 transceiver, it was found that it was necessary to stabilize the receiver R.F. amplifier stage by using a small ferrite inductor in the grid-lead and a 10-Ω series plate resistor. Noise figures and sensitivity suffered very little on the first units built and performance appeared to be entirely adequate. However as often happens when mass-producing a product, these stabilizing measures were not satisfactory in all cases.

Swan issued a service bulletin (July 26, 1967) that outlined some front-end modifications that would improve performance on these early version units. In some cases, the corrective modifications were relatively minor, while in a few cases they were substantial. The modification kit Swan offered was relatively easy to install and corrected the sensitivity problem in most cases. These modifications should have been made at the factory to all 250s that were manufactured after July 1967.

While it's unlikely that you will acquire a 250 that does not have these modifications installed, you should be aware that it is available and check to see if they're installed in your transceiver. If the last two digits of the serial number are higher than 12 or if the last two digits are 12 and followed by the letter B the modifications were included at the factory during fabrication. However, if the last two digits are 12 or less and there is no letter B, the unit should be checked to confirm that the modifications have been made postproduction.

You can also easily see if these modifications has been made by removing the bottom cover and inspecting the V6 tube socket (6HA5 RF amplifier); if there is a horizontally-oriented angled brass shield plate across the center of the socket soldered to pin 3, the center sleeve, and the grounding lug, the modification has been installed.

5.11. Notch Filter, Early Swan 350, 400

A tunable-notch filter can be incorporated into early Swan 350 and 400 transceivers by modifying the discrete shunt crystal circuit (intended to provide additional carrier frequency suppression to that normally accomplished by the balanced modulator) in the IF filter of these earlier models. See Swan Newsletter, Issue 10, Section A.10.7 for information on this modification.

Note that rather than going through this modification, it's much easier and more effective to add an off-board audio filter capability (bandpass, low pass, high pass, and notch), such as an old analog Autek, or even a newer state-of-the-are digital Timewave to the audio output from any transceiver model. See discussion in the External Audio Filter Section 4.4.4.

5.12. VFO (External), XMT/RCV Switch Change.

The 508 external VFO is configured such that the three-position VFO SELECTOR switch on its front panel allows the operator to select: (1) the transmitter's internal VFO (labeled XCV A) to control both the transmit and receive frequency, (2) the transmitter's internal VFO (A) to control the transmit frequency and external VFO (B) to control of the receive frequency (labeled TRANS A/RCV B), or (3) the external VFO (labeled XCV B) to control both the transmit and receive frequency.

Since the frequency stability of the external VFO is generally much better than the transceiver's internal VFO (both in terms of absolute drift and warm-up time), a simple modification that can be made to the external VFO is to rewire the relay in the 508 that controls this switching so that all of the VFO SELECTOR switch's A and B functions are reversed. Thus, when operating split frequency, the transmit frequency will be controlled by the more stable external VFO and the receive frequency will be controlled by the transceiver's internal VFO, which can be retuned by the operator to compensate for any higher drift rate without adversely impacting other QSO participants.

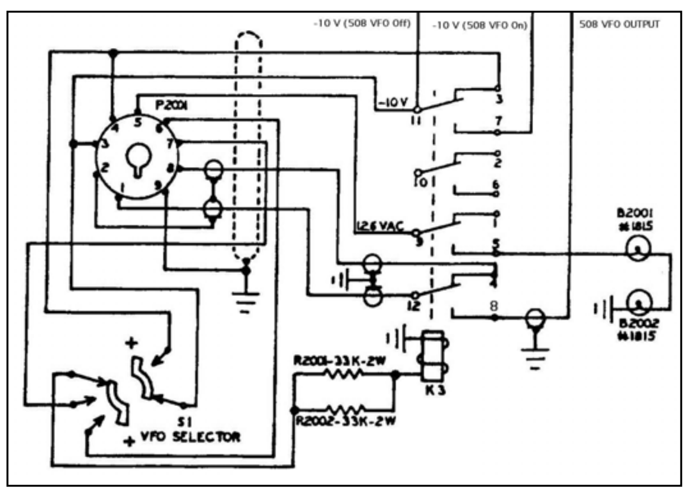


Figure 5-3 Model 508 External VFO Relay Wiring

If this is the case, why would Swan have used the VFOs as they did? The answer is most likely that they were just following the VFO usage convention established when the split-frequency capability was first added to the model 350 transceiver, in late 1966. To add that feature to the 350 transceiver required the installation of the accessory socket and the use of the model 22/B Dual VFO Adaptor, in addition to the external 406/B or 410 VFO. When the 22 adaptor was used with the 350 (it could also be used with the model 400 transceiver that has no internal VFO), a jumper wire was to be installed between pins 3 and 5 of the accessory socket – that jumper wire supplied –10-V power continuously to the transmitter's internal VFO regardless of the 22 adaptor's switch position so that it was operating even when the external VFO was being used for receive (the 508 VFO contains the 22 adaptor's circuitry, but it does not supply power continuously to either the internal or external VFO). The reason for this arrangement is discussed in their *Notes On Use of Model 22 Dual VFO Adaptor with Swan Transceivers* (9/12/66), which states: "*When either of the VFO's* (sic) *has been turned off for a short period, there will be a few cycles shift in frequency when it is turned back on. This shift will take place during the first few seconds. For this reason, VFO-A* (which is also the internal VFO)*, which is the transmitting VFO, is left on at all times when operating dual VFO control so that your transmitting frequency will be on exact frequency when you begin transmitting.*" Apparently Swan subsequently found that such frequency changes are apparently very small and/or of no operational consequence, since in the 508 VFO power is supplied only to the VFO currently in use.

In order to swap the A and B VFO functions on the 508 external VFO, a number of wiring changes have to be made to its internal relay. That relay and the accessory socket portion of the 508's schematic is shown in Figure 5-3. The 9-pin accessory plug shown mates, via the cable, with the accessory socket on the transceiver's rear apron and serves as a input and output interface for the fallowing signals.

- *Pin 1 outputs the VFO signal to the transceiver*. This is true whether or not the transceiver's internal VFO is being used or the 508's VFO is being used – when the transceiver's VFO is being used, its output is routed into the 508 via accessory socket pin 8 and then merely re-routed via the relay back to the transceiver. When an external VFO or crystal oscillator is not used, a jumper plug installed in the transceiver's accessory socket (with a jumper between pins 1 and 8) routes the internal VFO's signal via pin 1 to the VFO amplifier.
- *Pin 2 is a VFO shield ground for the VFO signal input and output (affixed to pins 1 and 8) coaxial cables*. It is interconnected to chassis ground on the transceiver's VFO board and at the VFO amplifier input.
- *Pin 3 inputs the –10 V (or –12 V, depending on transceiver model) DC power voltage to the VFO from the receiver – this is true for both the internal and external VFO*. That voltage is either re-routed back into the transceiver to power the internal VFO or to the external VFO, via the 508's relay. When an external VFO or crystal oscillator is not used, a jumper plug installed in the transceiver's accessory socket (with a jumper between pins 3 and 4) performs this function.
- *Pin 4 outputs the –10 V DC power from 508 (that had been inputted to the 508 VFO via pin 3) to the transceiver's VFO circuit via the 508's relay*. When an external VFO or crystal oscillator is not used, a jumper plug installed in the transceiver's accessory socket (with a jumper between pins 3 and 4) performs this function.
- *Pin 5 inputs the 12.6 V ac to the 508 from the transceiver's filament supply*. It is routed to the 508's relay and is used only to power the pilot lamps when the external VFO is in use.
- *Pin 6 inputs –210 V (–215 V) DC to the 508 from the transceiver's MV supply (through a dropping resistor in the transceiver) via the transceiver's K1 relay – it is only present when the transceiver is in the receive mode*. When the VFO SELECTOR switch is in the XCV A position, it is unused in the 508. When the VFO SELECTOR switch is in the TRANS A/RCV B position, that voltage is fed thru paralleled 33-KΩ, 2-W dropping resistors to the 508's relay coil, which activates the 508's VFO and feeds that signal to the transceiver when in receive mode, but, when the transmitter is keyed, the –210 V is removed from pin 6 via the transceiver's K1 relay and the transceiver's internal VFO is then used for transmit. When the VFO SELECTOR switch is in the XCV B position, the pin 6 voltage is unused in the 508.
- *Pin 7 also inputs to the 508 the same –210 V (–215 V) DC as pin 6, but in this case it comes directly from the transceiver's MV supply (through a dropping resistor in the transceiver) – it is always present, regardless of transceiver mode (transmit or receive)*. When the VFO SELECTOR switch is in position XCV A or position

TRANS A/RCV B, it is unused. When the switch is in position XCV B, that voltage is fed thru paralleled 33-KΩ, 2-W dropping *resistors* to the 508's relay coil, which activates the 508's VFO and feeds that signal to the transceiver during both transmit and receive operations.

- *Pin 8 inputs the transceiver's internal VFO output signal to the 508 – switching within the VFO re-routes that signal back into the transceiver via accessory socket pin 1, but only if the internal VFO is being used*. When an external VFO or crystal oscillator is not used, a jumper plug (with a jumper between pins 1 and 8) performs this function.
- *Pin 9 is connected to chassis ground*.

Inspection of this circuit shows that three poles of the four-pole relay contact sets are used to switch three voltages and signals, namely: –10 V DC power, 12.6 V ac power, and VFO signal routing. The only modification that is required to swap the A and B VFO SELECTOR switch functions listed on the front panel of the 508 is to swap the wiring going to the control contacts of the three relay poles that are used. Namely,

- *Do not make any wiring changes to the selector switch.*
- *Remove the two wires (red, red) going to relay pin 3 and reconnect it to pin 7,*
- *Remove the wire (red/brown strip) going to pin 7 and reconnect to pin 3,*
- *Remove the wire (orange) going to pin 1 and reconnect to unoccupied pin 5.*
- *Remove the coax center conductor going to pin 4 and reconnect to pin 8*
- *Remove the coax center conductor going to pin 8 and reconnect to pin 4*

This is a very straightforward procedure, although the cramped working space can make the job difficult. Use a lower wattage soldering pencil, used solder braid to extract the solder from existing connections, and use care not to apply excessive heat that will melt or burn the insulation!

5.13. VX-1 VOX Mod For CW Break-In

The VX-2 schematic, shown in Fig. 4-4, has a very similar circuit to the VX-1. Appended to that schematic and discussed in Section 4.14, is a very simple modification required to convert the VX-1 for CW break-in operation by just connecting a new wire from pin 5 of the accessory plug to the base of transistor Q5. Inspection of the schematics for the VX-1 (1965) and VX-2 (1968) show essentially identical circuits, except for that connection.

5.14. WARC Band Operation

The WARC bands can be activated in nearly any Swan. All C models or later (350C/500C – those with 5.5-MHz IF) came from the factory with the 17-meter band capability built-in. When Cubic was building later radios covering all bands, they elected not to disseminate the information detailing the activation of WARC bands on earlier equipment since standard business practice is to sell new radios rather than extending the use of older units. The actual addition of a WARC band would require going to a 6-position band switch, but most users choose to relinquish the 15-meter band position for installing 17 meters. While a 6-position band switch can be added to provide for the 17-meter band operation, it requires considerable work.

5***.5-MHz IF Transceivers***. On 5.5-MHz IF transceivers, the model 410C and 508 VFOs are already calibrated for 17 meters. Just plug one of these VFOs into the transceiver with the band switch set to 40 meters and set the transceiver's band switch to 15 meters. Align the mixer and driver (the 15-meter coils have sufficient tuning range so that when rotating the slugs inward, plenty of inductance is available for peaking 17 meters) coil slugs for maximum drive on 17 meters and, using the green scale, read the 17-meter frequency directly on the VFO. If you don't possess an external VFO, a jumper will be required inside the transceiver's VFO compartment to connect the 40-meter VFO tuned circuit to the 15-meter position. The 10-meter band can also be changed to the 12-meter band in a similar manner.

No adjustment of the VFO amplifier is necessary since the 40-meter VFO range provides the correct output frequency for upper sideband operation on 17 meters. If you plan to run 17 meters exclusively in the 15-meter position, you may want to move the tap on the π output coil so that one extra coil turn is added for 17-meter operation. This will improve the matching ability for that band; sometimes you will find that moving the tap two turns will be even more efficient. However, the radio should perform on 17 meters even if no change is made to the π output coil tap, just not quite as efficiently.

5,173 kHz IF Transceivers. There are a number of ways of accomplishing the 17-meter band activation on the Swan 400 (or other 5.173-MHz IF transceivers) transceiver, but it is not as easy as with 5.5-MHz IF transceivers.

One approach is to use the external VFO's 40-meter range for 17 meters. Since the Swan 400 has a 5.173-MHz IF, the 410 external VFO must be recalibrated on 40 meters to cover 17 meters. The other bands are not affected. Then, only the transceiver 15-meter mixer and driver stages must be aligned for 17 meters. No crystals, no coil modifications, etc. are required. However for maximum efficiency, the 15-meter coil tap should be moved down one turn, but this is not absolutely necessary.

A second option that will avoid making it difficult to operate on 40 meters because of the VFO re-calibration is to leave the existing 40-meter circuitry alone and install a new set of components, duplicating the 40-meter tuned circuit (coil, capacitor, and associated wiring) to the switch's X position and then aligning that new circuit for 17 meters. Of course, the downside of this approach is it's a considerable amount of work.

A third option, and perhaps the best method for 17-meter operation on a model 400 transceiver, is to change the IF by installing a 5.5-MHz carrier oscillator crystal(s) and mating the transceiver with a 410C or 508 external VFO. Then realign the 1st and 2nd IF, balanced modulator transformer, plus the 15-meter mixer and driver coils. The VFO amplifier requires no change. This will provide 80, 40, 20, 17, 10-meter operation exactly like the modification for the later C model transceivers.

6. TRANCEIVER BASICS (SIGNAL FLOW, TUNING)

6.1. Herb Johnson's Tuning Comments

An insight into Swan's design, tune-up, and operating philosophy can be obtained from a reply that Herb Johnson wrote to the "*Hints and Kinks"* column in June 1968 issue of *QST*. Concerning tube life and tune-up procedures he wrote:

***ON SWAN 350 MODIFICATION**. "The problem of short tube life with 6HF5s has affected only a relatively small percentage of Swan owners, and the main reason for running full power during tuning is because there is no better way to adjust the final for proper loading. As soon as you reduce power, whether by reducing drive, or screen and plate voltage, you can no longer find the correct setting for the PA LOAD controls. When loading adjustment is not properly set, you lose efficiency, resulting in less output. Also, the final will 'flat-top' sooner, and distortion products are much greater. This is why we have been reluctant to provide for reduced-power tuning, and instead encourage the operator to become accustomed to rapid tuning procedures. Many owners tell us they have run their original tubes for as long as two to three years of regular operating without replacement. Their secret is mainly that they don't tune-up often, and when they do it is done quickly."*

"One of the problems we find is that some operators will dip the plate tuning and adjust the plate loading rather slowly, trying to tune to exactly a certain number of milliamperes. They find 30 seconds rather short, and the tubes find it rather long. The best way for tuning up is to use a field-strength meter or bridge. Simply adjust PA Tune and PA LOAD for maximum output, disregarding the PA cathode current. Tuning up with a plate or cathode current meter is mostly a carryover from the days when it was the only tuning indicator in the transmitter, and r.f. ammeters came rather high. But with so many S.W.R. bridges or field-strength meters around today, tuning for maximum output is simple, fast, and by far a better way."

"Referring to Step (3) of the Swan 350 modification article in January QST, we had actually removed this wire in later 350s and in all of the 500s manufactured through December of '67. This requires then that you have to insert carrier with the CAR. BAL. control every time you tune-up, and then rebalance the carrier to operate. This is not nearly as convenient, and our reason for doing it was not to control power during tune-up, but to reduce a possible spurious problem when operating 15-meter CW. Steps (4) and (5) in the article really don't do anything, because once you have done Step (3) you can control the power level during tune-up with the CAR. BAL. control, if this is the way you wish to tune-up. However as stated before, we don't recommend tuning up at reduced power. Incidentally, by doing Step (5) you no longer have offset transmit frequency when operating CW. This won't bother the phone man, but will make a CW man unhappy."

"One other note regarding PA tube life: the tubes must be fairly well matched for idling current. We supply them in matched pairs on request. Usually a replacement pair picked from a dealer's shelf will not be matched very closely, and when idling current in set for 50 mA, one tube is drawing most of this. Tube life will then be quite limited. If the original tubes fail, and this can sometimes happen through no fault of the owner, they should be replaced by a matched set from the dealer, or from the factory." - Herbert G. Johnson, W6QKI

6.2. Important Fundamentals

A variety of comments relevant to tuning and alternate tune-up methodologies is discussed below. They are presented as a means of gaining a basic understanding of exactly what is happening during the tune-up, transmission, and receiving processes. With this knowledge, it will become obvious why the tune-up adjustments are being made and more importantly, it will permit one to recognize when the transmitter is properly tuned, avoid costly mistakes (destroyed finals), and identify problems. The above quote by Herb Johnson eloquently emphasizes that tuning-up the PA to near the maximum power and efficiency point is necessary for optimal operation. While this is certainly true for full-power operation, measurements clearly show that if significantly reduced RF power output operation is desired, tuning to the maximum power and efficiency point at a reduced carrier insertion level might be desirable and even essential in some cases, as shown by the data in this chapter.

6.2.1. AB_1 Amplifier Class

Swan transceivers operate the final RF power amplifier in the class AB_1 mode. Shown in Fig. 6-1 (Ref: "*Fundamentals of Radio," E. C. Jordan et. al., Prentice-Hall, Inc., New York, 1942*) is a graphic representation of the family of AB class amplifiers that illustrate the generic relationship (i.e. the characteristic curve) between the control grid bias voltage (E_c), signal voltage, and the power amplifier tube plate voltage and cathode current. As shown in this figure, a class AB_1 amplifier is one in which the grid bias plus signal is such that the plate current flows for more than ½ of a sinusoidal signal's cycle but less than a full cycle (denoted by AB) and in which no grid current flows (denoted by the subscript 1). It is operated such that signal voltages applied to the grid of the PA tube are never greater than the negative control grid bias voltage (grid is never positive relative to the cathode) and thus there is no flow of grid current.

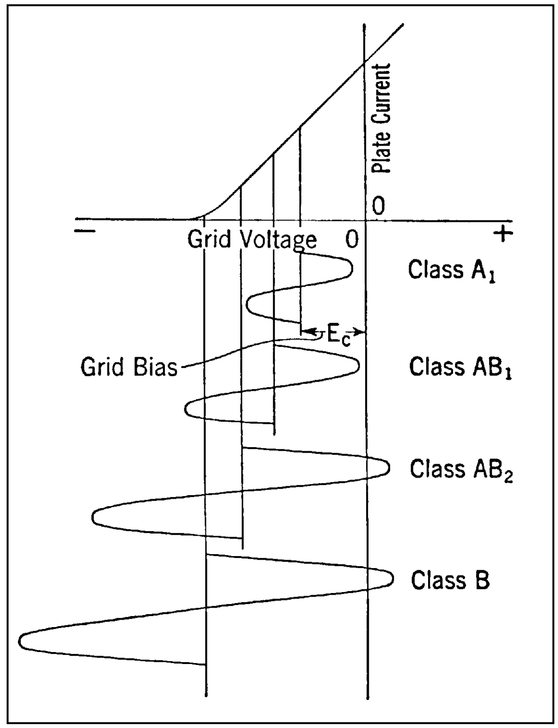


Figure 6-1 Power Amplifier Classifications

The control grid bias voltage for an AB_1 amplifier is not a single fixed value, but a range of values bounded by the A_1 and AB_2 amplifier grid voltage ranges. Selection of a specific grid bias voltage is dependent on the desired performance characteristics within an amplifier's class. Since maximum instantaneous power output (and usually efficiency) occurs during the most positive grid signal levels when maximum plate (or cathode) current flows in the tube, those AB_1 amplifier designs with very negative bias values will have a tendency to have the highest power efficiencies but also a somewhat greater amount of signal distortion. Those with more positive grid voltages will have lower efficiencies but also lower signal distortion.

An AB_1 class amplifier can achieve power efficiencies as much as 65%, but at the expense of some output signal distortion. Inspection of Fig. 6-1 shows that at the most negative grid signal voltages, the amplifier is driven through a non-linear response and into the cut-off region of the operating curve, where no PA cathode current flows during a portion of the signal's cycle. When the signal voltage is in that region, there is a corresponding distortion in the output signal at the tube's plate, since it is truncated (flat-bottomed) in that region. While the A_1 class of amplifier avoids this distortion problem by operating only in the linear portion of the characteristic curve for all grid signal levels, it has much lower efficiency than an AB_1 amplifier. Frequently the AB_1 PA is operated in the push-pull mode which minimizes this distortion problem by using only the linear half cycle portion of the sinusoidal from each of two tubes, one with a phase reversal, thus reconstructing an output signal with little distortion, however in Swan transceivers this is not the case as the dual-tube PAs are operated in a parallel configuration to maximize power output.

The other AB_2 and B classes of amplifiers shown in Fig. 6-1 have even higher power output efficiencies, but also have much more distortion and they permit current flow in the control grid, since it becomes positive relative to the cathode on signal peaks. As illustrated in the figure, the other amplifier classes position the grid bias voltage, E_c, in different ranges along the operating curve to achieve the desired amplification trait.

6.2.2. PA Bias

As discussed above and show in Fig. 6-1, the PA bias refers to the amount of negative voltage from the power supply that is needed on the control grid of the PA tubes to maintain a certain cathode current conduction when no other signal is applied. This is also referred to in Swan manuals as the bias or idle current. Adjusting the BIAS control sets the operating point on the PA sweep tube's characteristic curve. The modulating RF signal is impressed on this negative dc voltage (i.e. the modulating signal varies about this static dc offset value), thereby causing the PA tube's cathode current to vary in unison with the modulating signal voltage over the portion of the operating curve consistent with the AB_1 amplifier class. Prior to tune-up of Swan transceivers, the control grid voltage (the E_c value shown in the figure) is adjusted via the BIAS potentiometer on the rear apron to achieve the specified cathode idle current, typically ~25 mA in single and ~50 mA in the dual-tube PA designs.

When adjusting the PA BIAS control, make sure the microphone gain is minimum (fully counter clock wise) and that the CAR BAL has been adjusted to completely null out the carrier. If the microphone gain has not been minimized (and the transmitter is keyed using the microphone PTT switch) and/or if the CAR BAL had not been completely nulled, the cathode current reading can reflect both the current due to the static bias-voltage level along with any un-nulled carrier or background signals picked up by the open microphone (depending on GRID, PLATE, and LOAD control settings).

As illustrated in Fig. 6-1, setting the bias lower will shift the signal impressed on the grid to the left (approaching an AB_2 class amplifier), causing a larger percentage of the modulating signal to drive the PA tube into cut-off where no signal flows. Signal distortion will increase significantly. Setting the bias too high will shift the modulation signals impressed on the grid to the right (approaching an A_1 class amplifier), more onto the linear portion of the characteristic curve, decreasing signal distortion. However, efficiency is also decreased and the potential for PA tube related damages increased. For example, if the idle were set say at 80 mA, then during idle conditions the tubes would have to dissipate almost 70 W (80 mA x ~870 V), exceeding the rated plate power dissipation (60-W total with 30-W per tube, assuming the tubes are matched).

If there is no carrier RF output power indicated on a sensitive external wattmeter when the CAR BAL is nulled, the cathode current should be constant and the meter reading is the unmodulated, static idle current whose value is dependent only on the BIAS potentiometer adjustment. Under such conditions, the power dissipation required of the PA tubes (i.e. 0.050 A x 900 V = 45 W) is well under the specified maximum and the transmitter can operate for extended periods without risk of heat related damage.

Make sure the transceiver's cathode current meter is correctly mechanically zeroed and that there is no static charge on the meter face to effect the pointer's movement. Check the position of the meter's pointer after the transceiver has been off for an extended time – it should read zero. If not, the mechanical zeroing control should be re-adjusted, however if it's a transceiver model where it's not easily accessible (behind the model number plate), the bias level should be set to compensate for any zeroing error. If it reads below zero and the idle current is then set to 50 mA, the actual current will most likely be somewhat higher and maybe much higher. Likewise, if the meter reads above zero, at a 50-mA setting the actual current will be lower than that indicated.

6.2.3. Bias and Driver/PA Interaction.

Anytime the microphone's PTT switch is depressed (or when the function switch is placed in TRANS or TUNE position), the PA tubes have their screen grid voltage applied through the relay contacts. In fact, it is the only voltage that is switched between the transmit and receive modes. The nominal 215-V screen voltage (actual value is typically 250 V or higher in later models) is what permits the PA tube's current to flow when the PA BIAS control is being adjusted. Prior to depressing the PTT or going to TRANSMIT/TUNE, the PA tubes are in sort of a standby condition with HV (900 V or so) on the plate and bias voltage on the tube's control grid (in a 500CX, about that value is about –65 to –85 V, depending on the setting of the BIAS potentiometer that is required to cause an idle current of ~50 mA. Other than the filament voltage, those are the only voltages applied to the PA tube(s). Without the screen grid voltage, no cathode current flows. As soon as the PTT energizes the relay (in dual-tube PA models, the K1 4-pole relay mounted on top of the chassis) the tube immediately conducts idle current completely independent of anything happening elsewhere in the transceiver. In fact, both the transmit mixer and RF driver tubes can be completely removed from the transceiver and the idle current can still be set properly! If the CAR BAL is completely nulled, the bias idle current is also completely independent of the GRID, PA PLATE, and PA LOAD control positions; resonant tuning (or lack thereof) of the mixer, driver, or PA circuits does not affect the value of the idling current.

As noted previously, the measured cathode current shows the true idle current only if the carrier balance (CAR BAL) has been completely nulled and the microphone gain (MIC GAIN) is adjusted to minimum. If the CAR BAL control has not been nulled, some carrier signal can appear on the PA tube's control grid, depending on the amount of carrier unbalance and the degree of driver/mixer circuit resonance. When the GRID is peaked, the driver circuit's output impedance is tuned to that of the PA's input circuit. The signal voltage level on the PA tube's control grid is maximized and signal related current, in addition to the idle current, flows through the power amplifier's cathode. When un-peaked, even though there may be only a small increase in measure PA cathode current, high current levels will be still be flowing through the driver tube, which then must dissipate all of that power through heat radiation. Therefore, if the carrier (CAR BAL) is not completely nulled, the driver tuning control (GRID) must be immediately peaked to resonate that circuit. After the GRID has been peaked, the CAR BAL still must be completely nulled to correctly read the idle current. Likewise, even with the CAR BAL fully nulled, if the microphone gain is not at minimum, background ambient sound picked up by the open microphone could appear on the grid of PA, causing signal current to flow in addition to the idle current.

6.2.4. Tube Plate Resistance (Impedance).

Plate resistance and its behavior are of interest because it's the PA tube's output impedance that must be matched, via the π network, to that of the antenna load. Since the sweep tubes used in the power amplifier are operated near their maximum operating values (far beyond the 200-V to 250-V plate and 100-V or so screen grid voltages used in TV applications) their characteristic curves can be expected to have wider sample-to-sample variation than when used within the tube manufacturer's specified operational voltage ranges. Very little documentation in the form of characteristic curves or other data is available for these tubes under these higher voltage-operating conditions. Therefore, for illustration purposes, Fig. 6-2 shows a generic family of typical pentode tube characteristic curves. The plate current (≈cathode current) is plotted as a function of plate voltage, while the screen grid voltage is held constant. The shapes of these types of curve families are dependent on all operating parameters (e.g. plate, and control, screen, and suppressor grid voltages), as well as plotting format. The same data could also have been plotted as cathode current as a function of grid voltage with the plate and screen voltages held constant to obtain a different curve set from the same data, similar to that shown in Fig. 6-4.

Table 6-1 shows a few published measurements for specific sweep tube types operated at higher PA voltages approaching those used by Swan, where one or two parameters remain fixed (e.g. plate voltage V_p or screen voltage V_s) while the others vary, that illustrate tube behavior. Obviously these interactions among the cathode current and plate, grid, and screen voltages are very complex; but to even further complicate matters, rarely in actual practice does the plate or screen voltage actually remain constant. For example, as the power supply is loaded down during higher cathode currents caused by higher grid signal levels, the plate voltage level drops and thus, all three vary somewhat from the ideal case described by the characteristics curves.

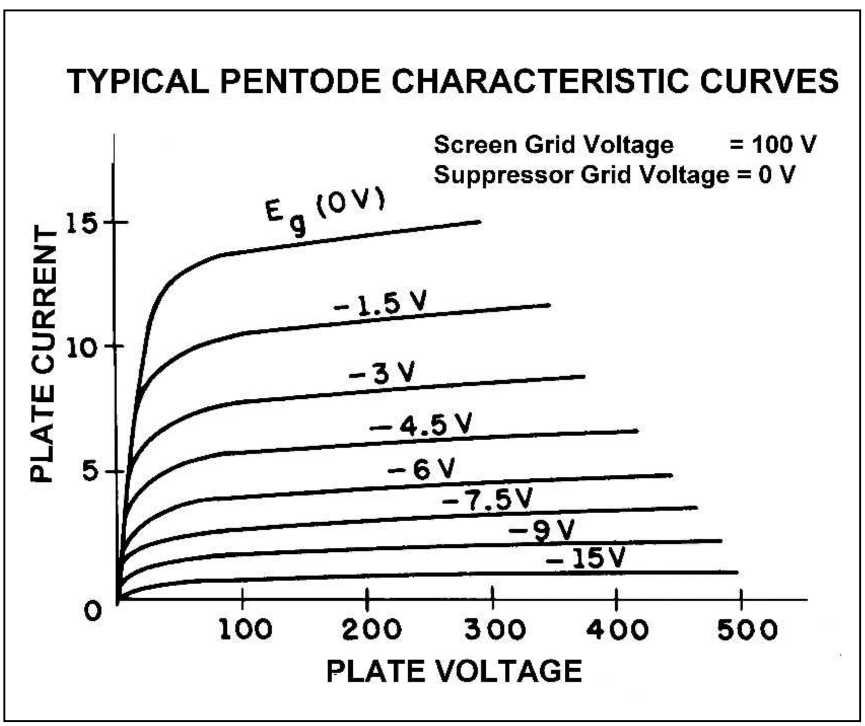


Figure 6-2 Typical Pentode Characteristic Curves

When the transmitter is tuned-up to near the maximum power and efficiency point, the PLATE and LOAD controls are adjusted such that the π network optimally transforms the PA tube(s)'s plate resistance (i.e. ~2,500 Ω for dual-tube PA transceivers) to best match the impedance of the antenna (i.e. ideally 50 Ω, but in practice anything perhaps from ~15 Ω or less to ~300 Ω or more), permitting maximum RF power transfer from the PA to the load. A tube's plate resistance (R_L) is defined as the ratio of the differential change in plate voltage (P_v) to plate current (P_i), or $R_L = \Delta P_v/\Delta P_i$ (i.e. Ohm's law). The plate current is essentially identical to the cathode current shown on the transceiver's meter.

As shown in Fig. 6-2, R_L is actually a somewhat dynamic value. Perusal of this family of curves shows that for plate voltages above about 50 volts, the curve slopes clearly vary with grid voltage. That is, the linear portion of each characteristic curve slope ($\Delta P_v/\Delta P_i$) is flatter at higher negative grid voltages and steeper at move positive voltages. For example, if a single-tube PA's R_L were 5,000 Ω with –1.5 V on the grid, then at a lower grid voltage, say –9 volts, its R_L would be somewhat higher, since with a flatter curve slope the same incremental change in P_i would result in a larger incremental change in P_v. Therefore, during actual operation with a varying signal voltage on the grid, the plate resistance varies substantially – during the highest current (most power output) condition, the R_L is lowest, and during the lowest current conditions (i.e. approaching cut-off) the R_L is highest. This type of plate resistance variation is also clearly illustrated by the limited measured data for sweep tubes under higher voltage conditions in a grid-driven, AB_1 class operation mode shown in Table 6-1 (labeled R_p).

Since a tube's plate resistance R_L is a complex function of plate, screen, and grid drive voltage levels, the unavoidable consequence is that there are no PLATE and LOAD control positions settings that are perfect. Even if a transmitter's tuning is adjusted to the exact maximum RF output power/efficiency point under full carrier (as specified by Swan), as the signal level on the grid varies during normal SSB operation the degree to which the PA tube's output impedance is matched through the π network's PLATE and LOAD controls to the antenna's fixed impedance varies (and hence also the efficiency). That is why you will find that during tune-up the PLATE and LOAD control positions for the maximum power and efficiency point will vary as a function of carrier insertion level – at low carrier levels the PLATE will tend to be rotated more towards the left.

Fortunately, this intrinsic mismatch has little practical impact and is more of academic interest than operational concern. Since maximum RF output power occurs on the positive signal peaks, for typical transceiver operation the best compromise to this inescapable predicament is to just tune to near the maximum RF power point. On the practical side, even if one tunes a transmitter multiple times, the control settings will never be exactly the same and there still would be some matching error, which is both normal, expected, and unavoidable, as is the change in the degree of matching due to the inherent R_L variation with signal level.

Table 6-1 Sweep Tube Operational Data at Higher Operating Voltages

AB_1 Class Linear Amplifier, Grid Driven											
Tube Type	V_p (v)	V_s (v)	V_g (v)	I_p @ V_g (ma)	I_p Max (ma)	$I_{scrn\ Max}$ (ma)	R_p (Ω)	P_{in} (w)	P_{out} (w)	Avg Dis (w)	3rd IMD (dB)
6146	600	200	-46	25	103	9	3570	61	41	16	-25
	750	200	-51	25	118	7	2825	88	55	28	-22
	800	290	-69	30	125	10	3620	100	59	35	-24
	800	290	-77	25	180	13	2300	145	91	45	-19
6DQ5	500	150	-46	48	170	17	1800	85	54	27	-28
	600	150	-46	48	182	13	1625	91	56	29	-26
	700	150	-49	35	182	11	2210	127	78	41	-23
	800	180	-67	30	250	13	1710	200	121	70	-19
6HF5	500	140	-46	40	133	5	1900	67	35	29	-27
	800	125	-45	30	197	7	2170	158	100	48	-21
6JE6A	500	125	-44	40	110	4	2300	55	30	24	-26
	750	175	-63	27	218	15	1850	163	102	51	-20
6LQ6/ 6MJ6	750	175	-60	25	215	9	1850	161	102	49	-18
	800	200	-69	25	242	13	1850	197	124	60	-18

Perhaps an even more important lesson of this discussion is that it is a mistake to become overly concerned with tuning to the exact maximum RF power output point or the exact cathode current null – PLATE and LOAD adjustments near the proper setting will most likely perform just as well as finicky exact tuning and will save a heck of a lot of wear and tear on the PA tubes associated with protracted tuning procedures.

6.2.5. Power Amplifier Tube Performance

The tubes used in the PAs of most Swan transceivers are grid-driven power pentodes originally designed for TV CRT sweep control applications. Swan transceivers use a much higher plate voltage to obtain the highest possible power from the tubes that they are capable of delivering without destroying them through inter-electrode arcing or excessive heat build-up. These operating conditions are at or beyond the manufacturer's published characteristic curve and other operation data.

Typical characteristic curves for sweep tubes are only specified in tube manuals and data sheets to around 250 volts and one could expect that every tube of a particular type will demonstrate a similar response when tested to that voltage level. However, increasing the plate voltage on these tubes is like stretching a rubber band. When slightly taunt, say with 6 oz. of tension, a batch of rubber bands might be nearly the same length. However, when pulled out to 16 oz. of tension, all of them most probably will be at different lengths, because of very small differences in the composition of the rubber that cannot be easily detected under conditions that are more benign. This same analogy applies to PA tubes, which is why it is necessary to employ matched tubes in the final stage of your transmitter when two are used in parallel, or at least tubes that have been determined to behave fairly similar to each other, in terms of having the same (preferably within ±10%, but at least within ±20% of each other) cathode idle current (when the plate, screen, grid, and filament voltages are held constant). Stretching the plate voltage out to 800 V or more exposes the differences in individual tubes that will not be detected when examined under lower voltage potentials or when not operated as a pair.

A tube's amplification performance is defined by its characteristic curves. Depending on how the data is plotted, a tube's performance can be depicted as shown in Fig. 6-1 (cathode current versus grid voltage as a function of a fix screen voltage) or as in Fig. 6-2 (cathode or plate current versus plate voltage as a function of grid voltage) – they both represent the same information.

The operational behavior of a tube over the linear portion of its characteristic curve is primarily controlled by the screen voltage rather than the plate voltage. For example, a screen voltage of 250 V and plate voltage of 800 V may cause a ~200-mA cathode current for a given control-grid bias voltage. Reducing the plate voltage to say 400 V might only reduce cathode current to maybe ~150 mA. Even if the ~900-V plate voltage were reduced to only ~250 V, the same voltage that is used on the screen in many Swan transceivers, it will still result in a significant PA tube cathode current. On the other hand, if screen voltage is cut in half, the cathode current might be reduced to maybe ~50 mA or less. The drastic drop in cathode current with a reduction of screen voltage and the secondary effect of reducing plate voltage is a characteristic of pentode tube operation. This effect is discussed in the following sections and previously illustrated by the data shown in Table 6-1.

Published High Voltage Sweep Tube Data. There is no readily accessible Swan specific measurements or PA tube characteristic curves at these high plate and screen operational conditions. Even so, a limited tabulation is presented in Table 6-1 of data for grid-driven sweep tubes operated as an AB_1 class amplifier with higher voltage conditions approaching those used by Swan, along with those for the 6146 tube as a reference (extracted from data listed in Bill Orr's *Radio Handbook, 21 Edition* – the original data may have been initially published in an article in *Ham Radio* magazine in the 1968 time frame). Unfortunately, neither details of the source of the measurements (which may well have been partially from Swan transceivers) nor complete definitions are given with that data. While the data does not include sufficient information to permit the generation of a family of characteristic curves for a detailed examination of tube performance behavior, it is useful both for illustrating the relative effect of increases in screen versus plate voltage and as a comparison with measured Swan tube performance shown in the following paragraphs and in Section 8.4.8.

As shown in this table for the 6DQ5 tube (used in the early mono-band and 240 transceiver models), when the plate voltage is increased from 500 V to 700 V with the screen voltage held constant at 150 volts, the plate current increases only from 170 to 182 mA; whereas, when the plate voltage is increased from 700 to 800 V and the screen voltage from 150 to 180 volts, the plate current increases from 182 to 250 mA. Notice that the maximum 200-V screen level listed in the table is considerably less than that typically used by Swan (i.e. ~225 V to as much as ~275 V or more). The –60-V to –69-V grid bias voltages listed for the maximum 800-V plate and 200-V screen levels is relatively consistent with the that measured in a Swan transceiver (i.e. –77-V grid bias level for a 900-V plate and 275-V screen on a 500CX, as shown in Fig. 6-3). The table also indicates that, for many sweep tubes (e.g. 6LQ6/6MJ6), the listed 3rd order inter-modulation distortion is only 18-dB down, but in Swan transceivers this is somewhat mitigated by having a tuned circuit on both the PA tube's control grid and plate.

As clearly indicated by this tabular data, significantly increasing or decreasing the plate voltage (often accompanied by a related change in screen and/or bias voltages) will cause an appreciable corresponding change in an amplifier power capability. An example of exploiting this behavior is given in the Operating Voltage Modifications Section 5.8.1, where a reduction of the power supply's high voltage from ~900 to ~600 V is suggested as one means to fundamentally reduce the RF power capability of Swan transceivers. A similar approach is used in the 600T and some other transceiver models to reduce power. Such a change to only the high voltage level does not alter the PA performance in terms of signal quality or efficiency in any real measurable fashion. But, PA tube life should be increased perhaps by a factor of as much as 3 to 5 if all other operational conditions remain the same (i.e. on-air time, mode of operation, etc.).

Another example of a use of similar operating voltages is the Tempo One (notorious as one of the first Oriental radio to place the first couple of nails in the coffins of American amateur radio manufacturers), which employs a pair of 6JS6s in the PA stage with a plate voltage of 600 V and is rated at 300-W dc input PEP. While Swan owners were replacing 6HF5s and 6LQ6s every year or two on average, 6JS6s in the Tempo were used 8 to 10 years before replacement. There probably still are Tempo Ones out there with the original Japanese 6JS6s in place – surely not as capable as they once were, but still providing adequate power.

Characteristic Curve Shape – Plate Voltage Influence. So, what does the actual real-life characteristic curve of a typical dual-tube PA Swan transceiver look like? As discussed in the preceding sections and illustrated generically in Fig. 6-1, Swan transmitters are operated in an AB_1 mode. That graph shows the AB_1 amplifier operating point (grid bias required for a specific idle current) positioned such that it is primarily in the linear portion of the characteristic curve, with only the most negative grid signal voltages (signal plus bias voltages) driving the PA tube a little into cut-off (i.e. no cathode current flow) and therefore the output signal at the plate cap would be only slightly altered, with a small portion of a signal clipped (flat-bottomed) when it's in the cut-off region.

In understanding what happens to the signal in the PA circuit, the generic example given in Fig. 6-1 is a bit misleading in that the bias position of an AB_1 class amplifier is not a fixed point, but is variable (as long as plate current flows for more than ½ cycle but less than a full cycle and in which no grid current flows). Fig. 6-3 shows actual measurements

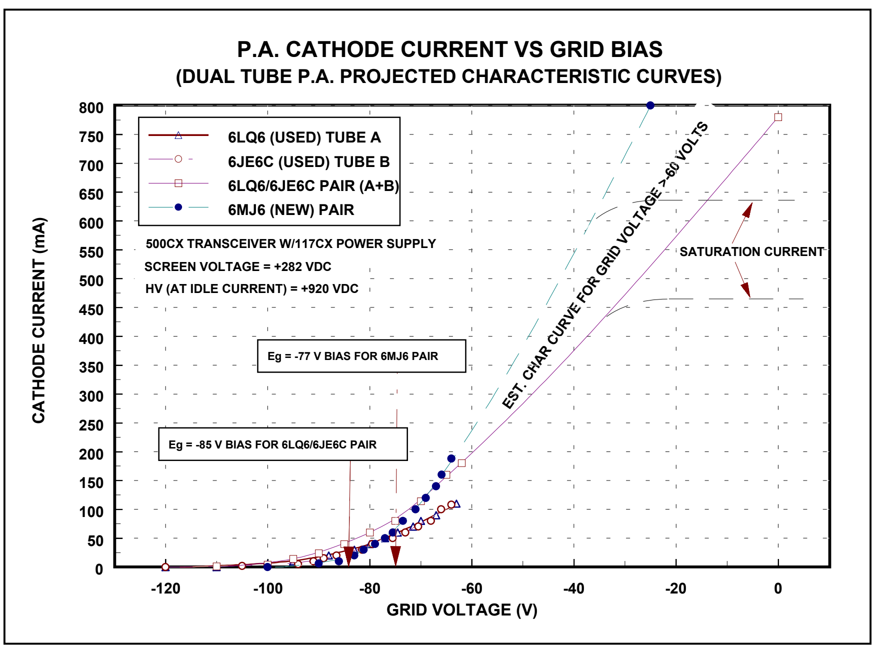


Figure 6-3 Measure PA Tube Characteristic Curves

of the lower portion of the characteristic curve from a Swan transceiver. As demonstrated by those measurements, the Swan design actually positions the bias voltage rather close to the knee of the characteristic curve – that is, towards the lower end of the linear portion of the characteristic curve. Within the AB_1 class amplifier family, this has a tendency to increase power efficiency but it also increases the amount of distortion.

All data shown in Fig. 6-3 were collected on a 500CX, using an 117CX power supply, with a HV level of ~920 V @ idle current conditions (dropping to ~750 V under maximum RF output power conditions) and a screen-grid voltage in all cases of ~280 V. This figure shows the measured control-grid voltage versus cathode current for three tubes; a matched pair of used 6LQ6 and 6JE6C tubes previously installed in the transceiver, and a new-old-stock 6MJ6, a heavy-duty direct substitute for those tubes. The lower portions of the curves (grid voltages of –60 V or less) show actual curve fitted data measurements points; the upper linear portions are projections based on the measured curve slopes (a higher resolution graph of the single-tube data is shown in Fig. 8-5).

As indicated in the legend, in the case of the 6LQ6 and 6JE6C tubes, the characteristic curves were measured individually in addition to both operating as a pair. This pair curve closely agrees with the summation of the individual measured currents (these three curves are denoted by empty symbols). In the case of the 6MJ6, the single-tube characteristic curve (shown only in Fig. 8-5) was measured and the cathode current doubled to obtain the equivalent measure for a perfectly matched dual 6MJ6 tube amplifier characteristic curve (solid circles), which is directly comparable to the 6LQ6/6JE6C pair characteristic curve. Affixed to the plot is the grid bias voltage levels needed for a 50-mA idle current (~–85 V for the 6LQ6/6JE6C pair and ~–77 V for the 6MJ6 pair).

The projected linear portion of the characteristic curve does not continue indefinitely with increasing grid voltage as might be implied by the generic example given in Fig. 6-1. As indicated by the appended upper curve knee portions (labeled saturation current) in Fig. 6-3, at some higher current levels there is a maximum cathode saturation current knee for a given tube design, condition, and operating voltage set (screen, plate, filament, etc.). When at saturation current, increasing the grid voltage will not result in any further increase in cathode/heater current – for the electromagnetic fields generated within the tube by the given plate and screen voltage levels, the maximum number of free electrons from the cathode are flowing to the plate. As a Swan transceiver's amplifier (or any other tube-design transmitter) enters this saturation current region, it flat-tops (or clips) the output signal, generating, in addition to audio information, distortion and higher levels of intermodulation distortion (IMD – generating third and fifth order harmonics), other broad spectrum clipping (flat-topping) related interfering RF components that fall both within and about a transmitted signal's normal RF bandwidth (splatter). Since these distortion components and splatter rapidly increase as the tubes are driven further into saturation, it is important not to overdrive the transmitted signal into this

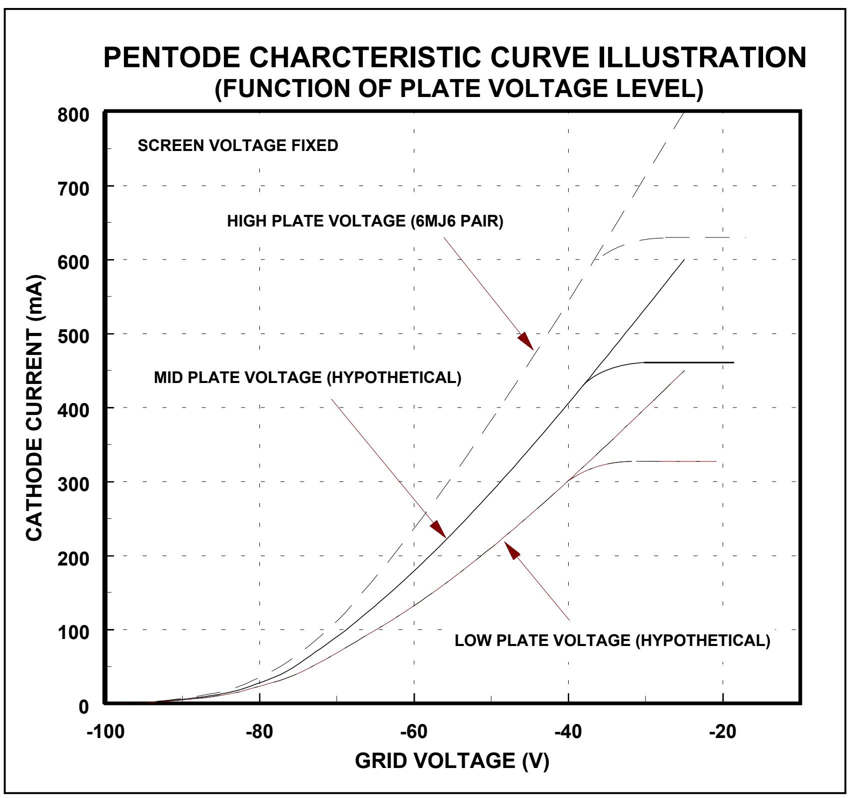


Figure 6-4 Conceptual Characteristic Curve Family

saturation region by having the microphone gain too high.

Both the usable length and slope of the linear portion of the characteristic curve is somewhat dependent on plate voltage, although it is primarily a function of screen voltage as discussed previously. Fig. 6-4 shows a conceptual family of curves of the type that might be obtained with a range of plate voltage levels for a fixed screen voltage. The High Plate Voltage curve is the same one shown in Fig. 6-3 for the 6MJ6 new tube. As illustrated, when the plate voltage is decreased (labeled Mid and Low Plate Voltage), the characteristic curve changes in slope (i.e. the linear portion becomes flatter or steeper, similar to the slope difference shown in Fig. 6-3 between the curves for new and used tubes) when the plate voltage is increased or decreased.

For example, as shown in Fig. 6-4, for the 6MJ6 Pair curve at a –60 V grid voltage the cathode current may decrease from the 230 mA value shown at the High Plate Voltage level to perhaps 180 mA if the plate voltage were reduced to the Mid Plate level. If the plate voltage were further decreased to the Low Plate Voltage, then the cathode current might further drop to perhaps 130 mA, as indicated. The curve with the highest plate voltage has the steepest slope and the longest linear portion before saturation and hence the highest power output capability. Thus, rather than a single fixed characteristic curve there is a family of characteristic curves which define tube performance at a selected screen voltage and various plate voltages. It must be stressed that these are hypothetical rather than actual measurements.

Conclusions/Summary. A number of pertinent conclusions and observations are supported by the data shown in these figures, tables and associated discussions:

- ***Tube matching in dual-tube amplifiers is essential***. As shown by the data, if tubes do not have nearly the same idle current and/or have drastically different characteristic curve slopes, one tube will be required to do the lion's share of the work and power dissipation, reducing the transmitter's maximum dc input power capability and drastically stressing the tube(s) and reducing its life.

- ***New tubes will not necessarily have higher idle currents than used tubes for a given bias level***. The data shows that to achieve a 50-mA cathode current, the 6MJ6 pair requires a control-grid bias voltage of –77 V, while the 6LQ6/6JE6C pair requires a –85 V grid voltage. At the –85 V grid level, the 6MJ6 pair draws only ~18-mA cathode current (9 mA per tube, see Fig. 8.5). Clearly, the new 6MJ6 tube draws significantly less current that either of the used tubes for any given grid voltage level and if it were used with one of the used tubes, it would not be matched.

- ***Matching tubes in terms of idle current does not guarantee they are matched in characteristic curve slope (amplification capability)***. As suggested by the data, even if matched in terms of idle current, two tubes can have radically different characteristic curve slopes and thus not be matched at higher power levels. That is, at low power, the tubes might share the amplification load equally, but at higher power that will not necessarily be true. However matching tubes based on idle current tube is still essential and in most cases the only viable approach, because matching continuously over all portions of the characteristic curves requires specialized equipment or matching at a number of discrete cathode current points. Since the sweep tubes in question are operated under extreme-operating conditions, far beyond that used in the TV applications for which they were designed, characteristic curve sample-to-sample variation may be such that closely matching at all current levels is an impossible dream.

- ***A used tube has less power output capability than a new tube. Even if matched in terms of idle current, they will most not likely be matched in terms of power handling capability***. The linear portion of the characteristic curves for new and used tubes of the same type may have significant differences in characteristic curve slope. The data shows that for the same plate, screen, and signal voltage levels, the 6MJ6 pair will produce a much higher cathode current than the good, but used pair of tubes (after each tube pair's bias voltage is first adjusted for a 50-mA cathode idle current). For a 40 V peak signal, the 6MJ6 pair grid voltage would be –37 V (–77 $V_{bias@50mA}$ + 40 V) with a ~580-mA cathode current, while the 6LQ6/6JE6C pair had a grid voltage of –45 V (–85 $V_{bias@50mA}$ + 40 V) and a ~330-mA cathode current. Or to put it another way, if the 50-mA point of the 6MJ6 pair curve shown in Fig 6-3 was normalized to the same –85-V grid bias voltage of the used tube curve (entire curve shifted to the left), its cathode current for the –45-V signal level would be ~580 mA. Thus, the new 6MJ6s have a higher inherent dc input power and corresponding higher RF output power capability than the used tubes. As illustrated by the data, as tubes age the linear portion of the characteristic curve slope gradually flattens and it dc input power capability progressively decreases.

- ***For a given screen voltage, the fundamental power amplification capability of a tube increases or decreases with higher or lower plate voltages***. However, maximum power (cathode current) is still limited by: plate voltage level that causes inter-electrode arcing, tube power dissipation considerations, the maximum saturation current, and the fundamental tube condition (new versus a used one with some degree of electron depletion).
- ***For a given plate voltage, the fundamental power amplification capability of a tube increases or decreases with higher or lower screen-grid voltages***. Again, as with increasing or decreasing plate voltages, this is limited by a tube's heat dissipation, saturation current, and condition.

6.2.6. PA Self and Parasitic Oscillations.

An inherent problem with vacuum tube power amplifiers is their tendency to go into unwanted, self-sustaining high power oscillation. That is, with no intended signal applied to the grid of the amplifier, it will oscillate on its own, usually at maximum power level. Such oscillations may start spontaneously or they may start when a signal is imposed on the control grid during normal tune-up or on-air operations (possibly even as a function of a specific signal level or PLATE and LOAD control positions required for a particular antenna load), but in any case, they are usually self-sustaining (will continue as long as the transmitter is keyed). These oscillations may be classed into two general types based on their frequency, namely self-oscillation or parasitic oscillation.

Self-Oscillation. Self-oscillation occurs when an amplifier begins a self-sustained high-power CW-type oscillation at or near the desired tuned frequency and in many cases it is induced by normal tuning procedures or operational signal levels. In effect the amplifier is free running at full output power. Under such conditions, while higher levels of RF output power can be seen at the output, the PA will still be required to dissipate high power levels, similar to that experienced during the tune-up process, so extended periods (e.g. tens of seconds or more) of operation under such conditions can seriously damage the power amplifier tubes.

Parasitic Oscillation. Parasitic oscillation occurs when an amplifier begins a self-sustained oscillation at a much lower or a much higher frequency than the one to which the PA it is tuned, although most commonly, it oscillates at higher frequencies (VHF). As with the self-oscillation case, the amplifier is free running at a high power, but in this case little or no RF output power will be seen since it is running at other than the tuned frequency. Under such conditions, all the power must be dissipated by the PA tubes, so the tubes can be quickly destroyed even when operated for only very short time periods (perhaps 5 to 10 seconds or less).

To combat these oscillation problems, Swan and other transceivers include both neutralization capacitors and parasitic chokes (shown in Fig. 6-5, labeled Z401 and Z501), and even then, they may be inadequate or marginal in controlling the problem.

To counter both self and parasitic oscillation problems, a neutralization capacitor (not shown in Fig. 6-5) is included in most designs to directly couple a small sample of the output signal that has been reversed in phase (shifted 180 degrees with respect to the output signal) back to the grid. So, when oscillating, a small amount of the output signal is subtracted from the input signal, whether it's a self-sustaining oscillation or an intended SSB or CW signal. This counteracts the in-phase coupling due to the inter-electrode capacitance, thereby preventing run-away uncontrolled oscillation of the power amplifier. See the discussion on the 700CX transceiver in Section 2.3.14 and the 8950 PA tube in Section 8.6.15.

To combat the parasitic oscillation problem, a parasitic choke is affixed in series with the PA tube plate, adjacent to the cap. It consists of a low value resistor (e.g. typically ~50 Ω, 2 W) and an inductor in parallel (usually directly wound around the resistor and typically 3 to 5 turns of No. 18 enameled wire warped around the resistor).

In the case of an earlier Swan 350 version, a 49-Ω, 2-W carbon composite resistor with a 4-turn coil was often used. For comparison, in the case of the Galaxy V Mark III, an 11-Ω, 2-W resistor with 3 turns is used.

Note that in some cases, the same self and/or parasitic oscillation behavior can occur in the driver tube (which uses a fixed capacitance neutralization capacitor in almost all models) and it will mimic the more common PA self and/or parasitic oscillation condition (see Section 7.7.6) since the driver's self-oscillation signals appear on the PA grid. See additional discussions on neutralization in Section 7.7.

Parasitic Choke Comments. An excellent summary of the purpose and design of the parasitic chokes is given in *Radio Handbook, 21st Edition*, by William Orr. On this topic he summarizes, "*A parallel coil and resistor combination operates on the principle that the resistor loads the VHF circuit* (suppresses the VHF signals above the desired operating frequency) *but is shunted by the coil for the lower fundamental frequency* (permits the operating frequency signals to pass around the resistor with little suppression or attenuation). *The parasitic choke is usually made of a non-inductive resistor of about 25 to 100 ohms, shunted by three or four turns of wire, approximately one-half inch in diameter and frequently wound over the body of the resistor.*" Furthermore, "*. . . for the plate circuit of a small tube such as . . . 6146, 6LQ6, or similar type normally may consist of a 47-ohm composition resistor of 2-watt size wire with 4 turns of No. 18 enameled wire wound around the resistor. However for operation above 30 MHz, special tailoring of the value of the resistor and the size of the coil wound around it will be required in order to attain satisfactory parasitic suppression without excessive power loss in the parasitic suppressor.*"

6.2.7. PA and π Network

Fig. 6-5 shows a simplified generic schematic for a tube transceiver's π output tuning network (tank) and Swan's corresponding design used in the 350C transceiver. The following sub-paragraphs discuss the general theory of the tuning process and the actual electronic performance of the physical components depicted in that figure.

PA Tank Circuit. Assuming there is no self and/or parasitic oscillation problems and the transmitter is operating as intended, what's happening inside a PA tube and how does a typical circuit work? The three basic components of the π output are: (1) the PA PLATE variable capacitor, (2) the output air-core coil that has a tap for each of the bands and (3) the PA LOAD capacitor(s). The combination of these components, as illustrated by the insert in Fig. 6-5, schematically resembles a π-like structure, with the two capacitors forming the legs and the inductor the top bar. This configuration makes up a RF transformer, sort of like an antenna tuner.

The π-output circuit makes it possible to meet the conditions necessary for the optimal transfer of power from one circuit to another. That is, maximum power is transmitted from the source to the load when the source and the load are identical in impedance to each other. This is not just a wild assertion made by some 19th century physicist; it can be proven mathematically and empirically.

This π circuit, also commonly called the tank, is used to place the proper load impedance (plate resistance, R_p) on the PA tube(s) and transform that higher output impedance down to that of the feed line/antenna system, just like a step down transformer. For example, if a particular PA tube has an output impedance of 5,000 Ω (typical in Swan radios) and is placed in parallel with another tube of the same type, the two tubes act just like two resistors in parallel and the resistance is half. That is, two 5,000-Ω tubes in parallel have a total of 2,500-Ω impedance for that PA circuit. These are the approximate values of the PA tube plate resistances in Swan transceivers, however they are really only a nominal tube output impedance values, since the R_p of a tube actually varies somewhat with grid signal, plate, and screen voltage levels. See also the related discussion on tube plate resistance in Section 6.2.4.

Impedance Transformation/Matching. The π-output circuit components must transform that ~2,500-Ω (~5,000 Ω if a single-tube PA) output impedance down to that of the antenna system (ideally about 50 Ω) in order to deliver power efficiently to the antenna. Swan dual-tube PA transceivers have a rather broad matching capability and are able to transform the PA tube impedance down to antenna loads in the range of between 17 to 150 Ω (SWR ≤ 3). Single-tube PA Swan transceivers have less range, mainly due to the higher step-down ratio required and the confined quarters within the PA compartment.

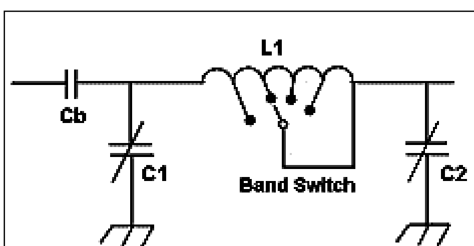
The load or source impedance (Z) is a complex mathematical value representing the combined dc resistance and the net capacitive and inductive reactance of the circuit (represented as $Z = R + jX$). The reactance (X) is a function of frequency, as opposed to dc resistance, which is constant as a function of frequency. Its value is dependent of the relationship between the RF frequency, voltages, and currents (magnitude and phase) in the circuit and its sign is determined by whether the net reactance is capacitive or inductive.

To match the plate and antenna impedance, the transmitter's π-output circuit controls (PLATE and LOAD) are adjusted during tuning so that its reactance is approximately equal in magnitude but opposite in sign from that of the load. That is, if the feed line/antenna's impedance were $\sim\{R_{FL/A} + jX_L\}$ then the π network would be adjusted for $\sim\{R_T - jX_C\}$, which corresponds to the maximum RF power output and efficiency control positions. Doing this cancels the reactance components of the transmission line/antenna load so that maximum power can be transferred to the resistive component of the load and hopefully radiated by the antenna (as opposed by being converted to heat by ground, trap, or other antenna associated losses).

This is exactly what's occurring at resonance when we tune-to-the-dip at the maximum power and efficiency point. While the reactive component has been canceled, the resistive component of the feed-line/antenna's impedance sill remains and the SWR due to that reflection coefficient still exists. We have not canceled or improved the feed-line/antenna's SWR, but we have adjusted the system such that maximum RF power is transferred to the feed-line. The only caveat is that the SWR range over which a π network can function is limited by its design. In the case of Swan transceivers, that is typically SWRs of ~3:1 or less. External tuners enable the transceiver to be matched to loads that have a much higher SWR range and/or other feed-line types.

Antenna Tuner Comments. The tube transceiver's π-network circuitry and tuning procedure are performing a function similar to an antenna tuner used with solid-state transmitters. In order for solid-state equipment to develop full output power, a 50-Ω impedance load is typically required. To protect the solid-state finals from damage and/or excessive signal distortion, the input power of most solid-state transceivers progressively decreases with increasing SWR. The external or internal tuner is commonly used so that the transceiver sees a 50-Ω impedance and therefore a SWR of 1:1, which permits it to deliver its full rated power into the tuner.

It is important to note that this 1:1 SWR is only between the transceiver and antenna tuner; between the tuner and antenna the SWR is still dictated by the load's impedance and associated refection coefficient, similar to the condition after a tube transceiver's π network has been resonated for maximum RF power output. In addition to permitting full-power output from a solid-state transceiver under a much wider range of SWR conditions, most tuners



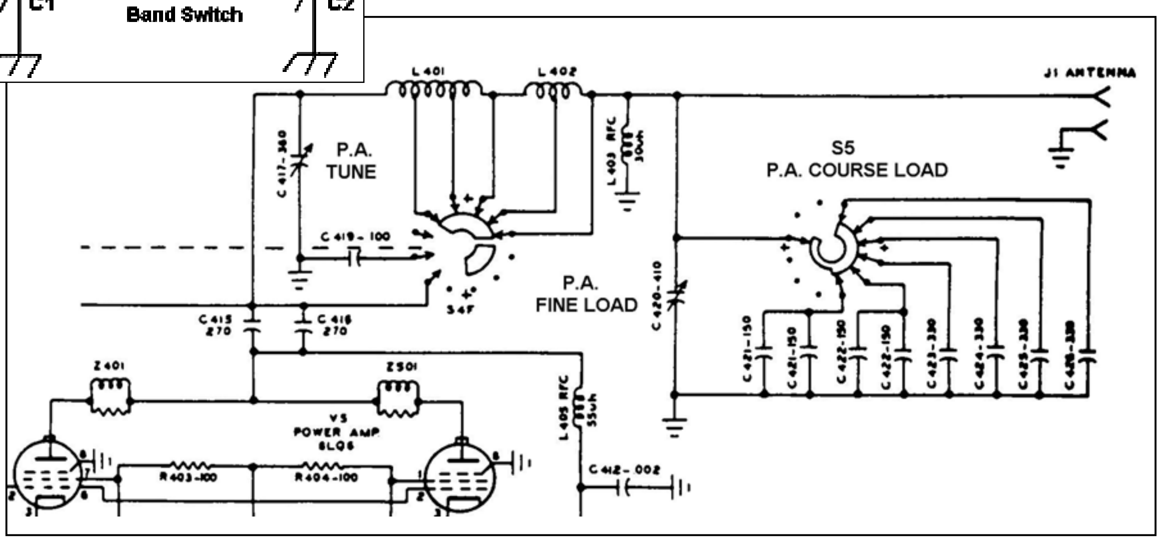


Figure 6-5 π Output Tuning Network Schematics, Simplified and 350C

also provides a capability for matching both balanced and unbalanced transmission feed lines, as well as long wire antennas, which cannot be done with a Swan transceiver without the use of a tuner.

Circuit Example. The simplified π-output tank circuit (impedance matching network) and the corresponding Swan 350C design implementation shown in Fig. 6-5 illustrates the conceptual and the actual components used to interconnect the PA and antenna to ensure the optimum transfer of power.

Capacitor C_b (Swan's C415 and C416) blocks the nominal +800 V dc on the plate caps from the tuning components. The C2 load capacitor (Swan's fixed C421 through C426 COURSE LOAD and variable C420 FINE LOAD capacitors), in conjunction with the band switched inductor L1 (Swan's L401 and L402), is typically adjusted to a high capacitance (i.e. lightly loaded with the LOAD control towards the ccw direction) value for initial tuning. The variable capacitor C1 (Swan's C417 PA TUNE, also call PLATE in some manuals) is then alternately adjusted with each LOAD control increase, to best match or transform the tube's impedance to that of the antenna load through the feed line. Since both the PLATE/TUNE and LOAD adjustments interact with L1 and each other, they are not independent and hence they must be interactively adjusted in the familiar load-and-dip tuning procedure (or load-and-peak for those Swan transceiver models that display the relative RF power output level or when using an external wattmeter) until the maximum power and efficiency control settings are achieved.

6.2.8. Signal Processing

How are the signals manipulated or processed by the transceiver as they pass through the various electronic stages? While almost all Swan manuals give a block diagram describing the signal flow through the various circuit sub-sections (e.g. microphone amplifier to transceiver audio amplifier to the mixer, etc.), such a presentation gives a poor innate feel as to what's actually happening to the signals. Figs. 6-6 and 6-7 are intended to provide a more intuitive understanding of the audio signal flow during the transmission process, in the first case focusing on the mixing and filtering processes for SSB signal generation, and in the second case focusing on a CW signal's flow through the power amplifier.

To all intents and purposes, the receiving signal processing effectively reverses this process so that the SSB information received at radio frequencies is translated down to the audio base-band, with the signal being fed to the product detector rather than to the balanced modulator as when in the transmit mode and the carrier oscillator serving as the beat frequency oscillator.

Signal Mixing. How are the microphone's audio signals in the 300 Hz through 3,000 Hz base-band frequency range translated up through the mixing and filter processes so that it's in the appropriate sideband (LSB or USB) and transmitted at the correct RF frequency?

Fig. 6-6 shows a graphic overview of a SSB signal generating process from the microphone's output to the power amplifier's control grid, illustrating the carrier oscillator and VFO signal mixing processing that results in the translation of the audio information from the acoustic base-band frequencies up to the desired RF frequency. In this case, the signals are presented in terms of their frequency content (i.e. spectral amplitude versus frequency), similar in format to a display from a FFT analyzer, rather than the analog time display (i.e. signal amplitude versus time), such as is seen on an oscilloscope. If the same time segment is displayed, both of these formats are in fact presenting the same information.

These examples assume the transceiver is 350C or later model (i.e. one with a 5.5 MHz intermediate frequency) operated in the LSB mode at a RF frequency of 7.2 MHz. Note that the audio information is graphically depicted as having a lower signal amplitude at 300 Hz than at 3,000 Hz; this is useful since it allows one to easily visually track how the acoustic information is inverted in the sidebands generated by the mixing processes.

At the output of a nonlinear mixing process of two signals, not only are the two original signals present, but most importantly, the sum and difference signals of the two are also generated; specifically the upper sideband (USB) and lower sideband (LSB). Both sidebands contain exactly the same audio information, however the LSB is inverted in frequency. In a Swan transceiver, the balanced modulator provides the nonlinear system that performs the mixing at the IF, while at the RF that function is performed by the RF mixer circuit.

As shown in Fig. 6-6, the balanced modulator inputs the base-band audio information (labeled A) from the microphone audio amplification circuit along with the 5.5-MHz carrier oscillator's (CO) sinusoidal signal. In this case, only the portion of the signal spectrum about the 5.5-MHz CO frequency at the output of the mixing process is shown – the mixed composite output signal still contains the original base-band audio information at the 300 to 3,000-Hz audio frequencies (not shown). Notice that the USB retains the same spectral shape as the original audio base-band signal (300 → 3,000 Hz = 5.5003 → 5.503 MHz), while the LSB is inverted (i.e. 300 → 3,000 Hz = 5.497 ← 5.4997 MHz, that is, the LSB spectral information is inverted in frequency, with the 300 Hz information at a higher IF (5.4997 MHz) than the 3,000-Hz audio information. While an indication of the 5.5 MHz CO signal is depicted in the graphic, the balanced modulator normally suppresses the carrier oscillator frequency by 40 to 50 dB or more.

These IF signals, centered exactly on the CO frequency, are then passed through the IF crystal filter, which has a nominal bandpass (6-dB down bandwidth points) of 5.5003 to 5.503 MHz (2.7-kHz wide). This bandpass exactly matches the USB frequencies of the mixed signal. As shown in the figure, the filter bandpass response effectively eliminates all signal components except the USB containing the audio information. That signal is then passed to the input of the RF mixer. The VFO signal frequency is not the actual RF operational frequency, but on the 40-M amateur band is equal to the intermediate frequency plus the desired RF operational frequency, or 5.5 MHz + 7.2 MHz = 12.7 MHz. This 12.7-MHz signal is also fed to the input of the RF mixer. The output (in this case the full spectrum is shown) of the RF mixer consists of the original output of the IF crystal filter (USB from the audio/CO mixing process), the VFO signal at 12.7 MHz, and the new set of sideband signals, namely: the USB (18.2003 MHz → 18.203 MHz) and the LSB (7.197 MHz ← 7.1997 MHz). These sidebands again contain the same original microphone base-band audio information from 300 Hz to 3,000 Hz, with the LSB audio information again inverted in frequency.

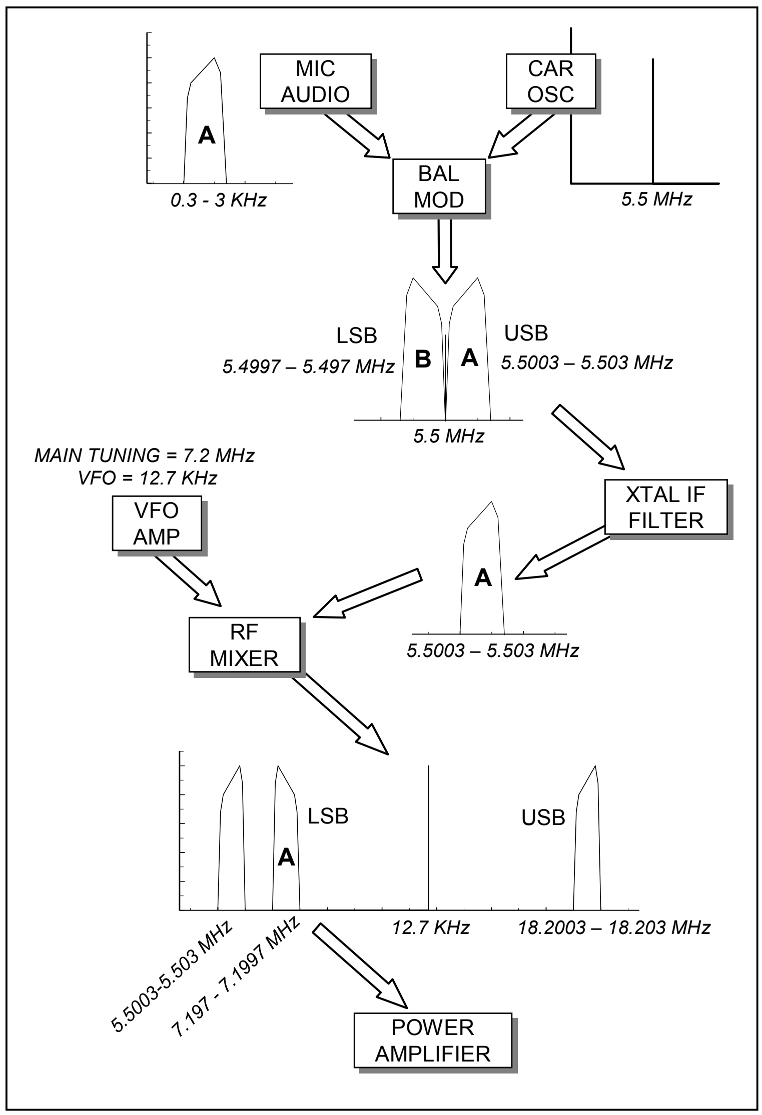


Figure 6-6 SSB Signal Mixing and Filtering

Eureka! The RF mixer's LSB (the sideband labeled A, that was the USB out of the IF mixing process) lies exactly at the 7.2 MHz RF frequency, with the inverted audio information extending 3 kHz down in frequency, exactly where we want it to be (and also the very reason why the FCC is such a stickler about operating frequencies at or near the amateur band edges). Both the mixer and driver output stages contain tuned circuits that have limited band-passes about their operation frequencies, which serve to attenuate all other out-of band signal components from the mixing processes. In addition, as will be illustrated shortly, the tuned PA π network further attenuates the unwanted signals outside the RF bandpass near the 7.2 MHz operation frequency.

Opposite Sideband Selection. What happens when a receiver equipped with both normal and opposite sideband capability is switched to the opposite sideband (USB, in this case)? The only thing that really happens is that the CO frequency is shifted-up in frequency by 3.3 kHz, from 5.5 MHz to 5.50033 MHz. This shifts the IF mixer's output spectrum to the right by 3.3 kHz, so that the LSB (labeled B) is aligned with the IF crystal filter's fixed bandpass. All other aspects of the signal flow remains the same – after passing through the RF mixer, sideband B is then inverted in the RF mixing process. The RF mixer's two sideband outputs shown in Fig. 6-6 have now been transposed or swapped, so that the information contained in the mixer's LSB output at 7.2 MHz transmission frequency is actually the USB non-inverted audio signal information, since the input was the LSB (sideband B) from the balance modulator, rather than the USB (sideband A) as was the case with the normal sideband selection on 40 meters, exactly what we want. The transmitter audio spectral content of this USB is not inverted as it was with the normal sideband selection. Since in the receive mode, this process is essentially reversed, you can see that if the wrong sideband is selected, the base-band audio that appears at the speaker is the frequency inverted information and very unintelligible!

Power Amplification. Given the linearity limitations discussed previously of a power amplifier when operated in the AB_1 mode (i.e. a portion of the output signal lies within the tube's cut-off region of the characteristic curve), why isn't the power amplifier output signal fed to the antenna heavily distorted? In the earlier mixing example discussed in Fig. 6-6, a SSB signal using a spectrum display format was used. In this case, for simplicity, a CW signal is assumed and the conventional analog time-varying signal display format is used. Regardless of which signal or display type is used, the same fundamental signal processing behavior and characteristics still apply.

From the preceding discussions it is obvious that significant distortion must occur in the current (and voltage) waveform at the plate cap of the PA, since the 50-mA idle current point corresponds to a position close to the knee of the characteristic curve, where the tube approaches cut-off. Under such conditions, the most negative signals (i.e. those which drive the grid below the static bias voltage level) impressed on the control grid will drive the tube into the non-linear region of the characteristic curve and into cut-off, where zero cathode current flows. When the signal is positive with respect to the grid, the amplifier is operating on the linear portion of the cathode curve and peak cathode current flows. Therefore, with the steady-state sinusoidal signal used during tune-up (or CW operation), one would expect the most negative portion of the signal cycle to be truncated, resulting in a highly distorted waveform. However examination of the output waveform at a dummy load (or antenna) shows that the full power RF output CW signal is indeed sinusoidal, similar to the control grid signal and without obvious distortions!

How can this be? Fig. 6-7 shows an overview of the signal flow observed on a 500CX. Plot A of this figure portrays an accurate representation of the 7.1 MHz carrier signal observed on the PA control grids with the carrier balance adjusted to yield a 200-mA cathode current reading (after the transmitter had been first tuned to maximum power under full carrier). As indicated, this signal is a 98 V peak-to-peak sinusoidal with a dc offset of –83 V, the grid voltage that was required for the 50-mA idle current. Plot B shows the characteristic curve for the 6LQ6/6JE6C used finals discussed in the Power Amplifier Tube Performance Section 6.2.5 and whose characteristic curves are shown in Figs. 6-3 and 8-3. Mapping this varying grid signal directly onto the measured characteristic curve and plotting the time varying cathode current produces the waveform shown in Plot C, which is the signal that is present on the tube's plate cap (the corresponding voltage variations have a similar waveform, but with a phase offset). This current plot is of the instantaneous signal – the indicated meter reading, a average value, for this signal was 200 mA. As a confirmation that this signal at the plate cap does indeed correspond to the meter reading, the instantaneous cathode current curve (Plot C) was sampled and the average current level numerically computed. The calculated average current was 208 mA; in surprisingly close agreement with the actual meter reading (the meter had no mechanical offset, so no additional errors, other than the inherent meter accuracy should be present). The measured and computed current for what appears to be a highly distorted waveform agree!

So, why isn't the signal at the antenna similar to the cathode current waveform? Recall that the π-tuning network in the PA which adjusts the PA tube's output impedance (~2,500 Ω for Swan's dual parallel tube PA configuration) to that of the antenna (ideally 50 Ω), is a tuned circuit, containing parallel capacitances and inductances that like any other tuned circuit, has a resonant frequency and finite bandpass characteristics. When tuned for maximum power, very coarse measurements of that bandpass at 7.1 MHz are shown appended to Plot D of Fig. 6-7.

This very rough measurement of the π-output circuit's bandpass indicate it had a ~3 dB down bandwidth of ~600 kHz for the given frequency and control adjustments. Therefore, signals that lie significantly outside that bandpass will be attenuated and will not appear (or be significantly attenuated) at the antenna. Likewise, if the spectral content of the distorted cathode current waveform shown in Plot C is numerically analyzed using a FFT (Fast Fourier Transform) algorithm that calculates the constituent sinusoidal frequency components that make-up this repetitive signal waveform, it is found that the actual frequency content consists primarily of only three major components: the fundamental at 7.1 MHz, which contains almost all of the power (~95%), the first harmonic at 14.2 MHz whose power level is ~13 dB down with respect to the fundamental, and the third harmonic at 21.3 MHz, which is ~22 dB down with respect to the fundamental. These spectrum components are shown on Plot D.

Therefore, for this simplistic test case, the signal that appears at the antenna output consists of all frequency components summed after attenuation by the π network frequency response. In this case, the distortion components are far outside the primary bandpass and thus are drastically attenuated – they contribute virtually nothing to the RF signal at the antenna. Note also that that maximum amplifier power is achieved during maximum

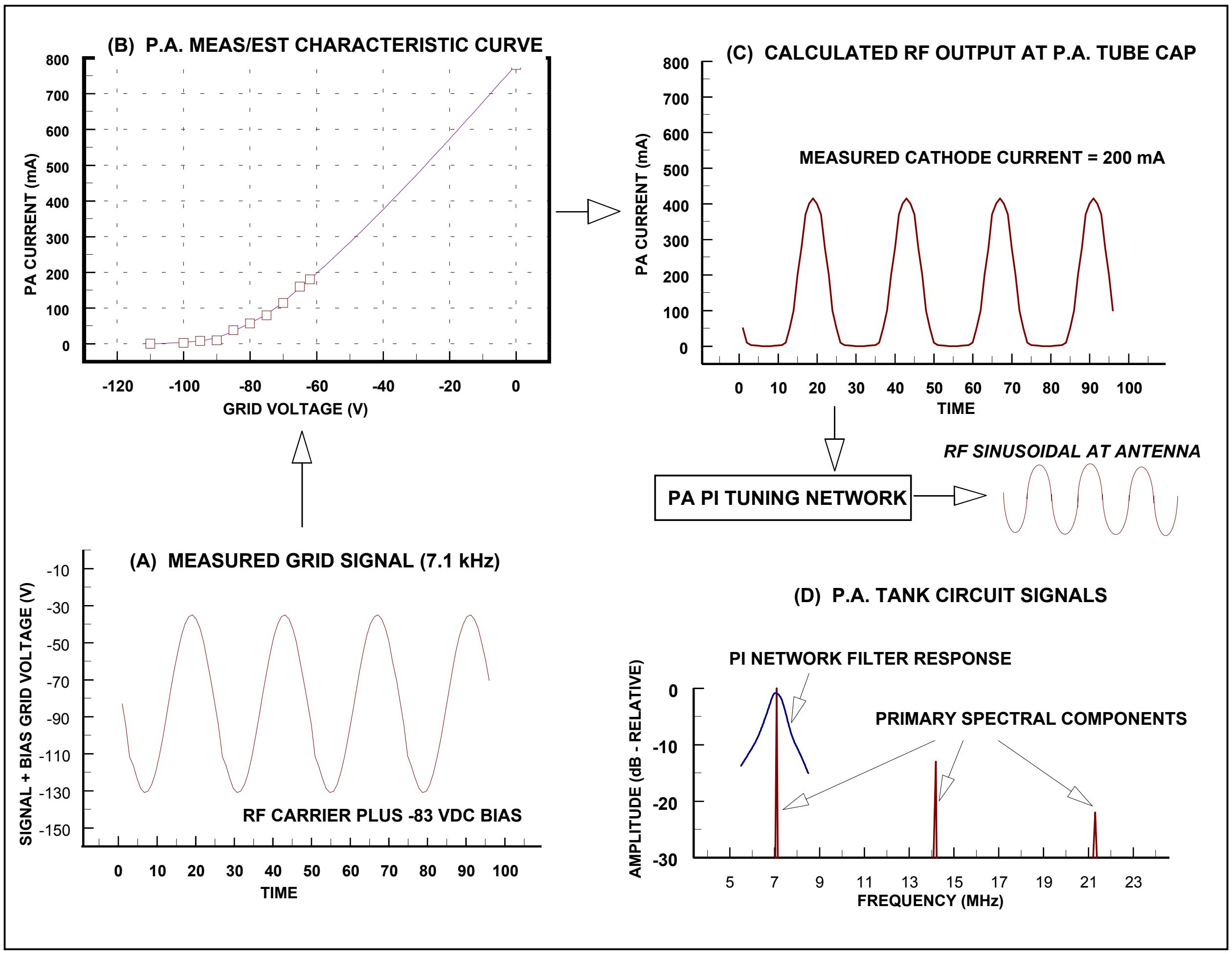


Figure 6-7 Swan PA Signal Processing

cathode current flow on control grid voltage peaks where the signal is undistorted – during periods of low cathode current, where the signal is flat-bottomed, there is very little power output. Thus, distortion in the transmitted signal is minimized. However the linear portion of the characteristic curve does not continue indefinitely as implied in Plot B (see Fig. 6-4) – if the signal level is too high the amplifier is driven into saturation and signal flat-topping occurs during maximum power output, resulting in RF splatter and transmitted signal distortion, hence the concern with adjusting the MIC GAIN too high during SSB or AM operation.

Consequently, as observed in real life and indicated in Fig. 6-7, with normal signal levels, the carrier output signal consists primarily of a relatively distortion-free fundamental that appears nearly identical to that on the control grid. Of course, a SSB signal is much more complex, with a time varying frequency content including transients that produce more wideband spectral distortion products than the simple CW case depicted above, however, they are still filtered out or attenuated in a similar manner to the CW example. In a nutshell, this design works, and works well, producing an audio signal that is relatively distortion free, and, as many on the receiving end of a Swan signal will attest to, of outstanding quality!

6.2.9. Tune-Up Loading and PA Efficiency

As discussed previously, maximum power and efficiency occurs only when the output impedance of a PA stage matches that of the antenna system, with one numerically the complex conjugate of the other. The π-output network of the PA stage is the circuit that performs this matching function. If the LOAD control is adjusted either significantly lower (light-loading) or higher (excessive-loading) than optimal for a given signal level (usually full carrier insertion), then the RF output power will be below maximum, signal linearity will decrease, efficiency will be lower, and generally the PA heat dissipation will be higher. Details on the inter-relationship between RF power output, efficiency, and loading are show in Figs. 6-8, 6-9, 6-10 and discussed below.

When lightly loaded, the output load capacitance is higher than it should be, that is, the front panel PA LOAD control is at lower numerical position (ccw) than it would be when maximum output power is obtained. If this is done either inadvertently or intentionally to reduce output power, the π network is misadjusted so that the output impedance does not best match that of the antenna. The consequence is lower efficiency, with a lower percentage RF power output for a given dc input power. For example, if a transceiver were tuned for maximum output power (say LOAD = 5) into a 50-Ω load with the dc input power of 400 W (e.g. 533 mA x 750 V = 400 W) and the corresponding RF output power as measured on a calibrated wattmeter reads 250 W, then the efficiency would be 250/400 or 63%. With light loading the cathode current might only be 350 mA. That is, the LOAD control might be set to 3 and the PLATE control is adjusted for maximum RF output at that load setting, when you know that maximum power is developed with the PA LOAD control at position 5. In this hypothetical example, the cathode current in the dip might be 350 mA with a corresponding dc input power of 280 W (350 mA x 800 V = 280 W) and a RF output power of 70 W. Now the ratio of input to output power is 70/280 or only a 25% efficiency. A higher percentage of the dc input power is being lost as heat in the final power am-

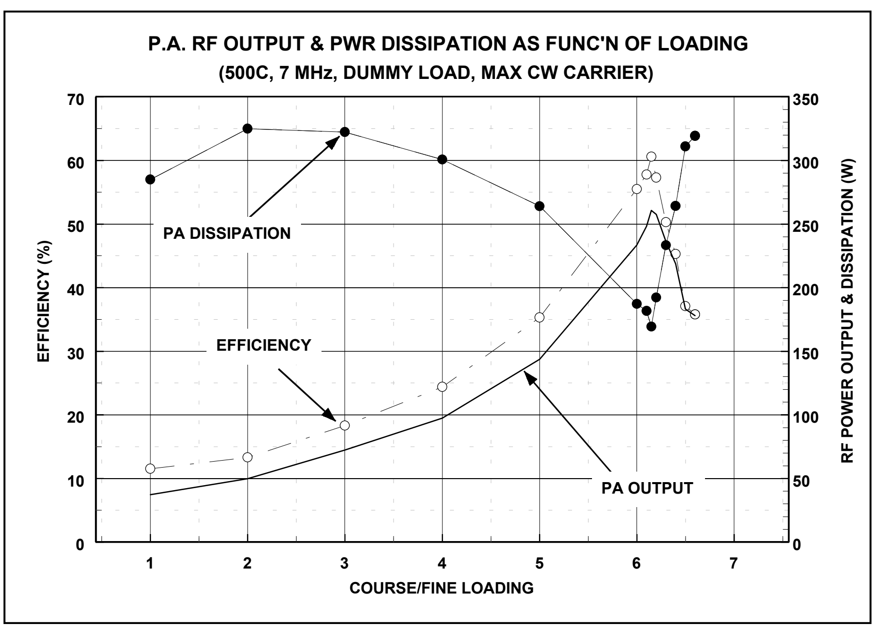


Figure 6-8 Power Output & PA Dissipation Versus Loading

plifier stage than is producing useful RF output power. Notice in the first case, with 63% efficiency, the PA tubes must dissipate 150 W for a steady-state CW signal (much less when operating due to duty cycle factors), but with the lower RF power output at the 25% condition, the power dissipation would be 210 W! As shown by the measurements below, this is indeed the case. The following data were collected after using an external wattmeter-type tune-up procedure – if the cathode current "dip" is used, the results vary somewhat.

6.2.9.1. Light and Excessive Loading

Fig. 6-8 shows measurements illustrating the impact of both light and excessive loading on efficiency and PA tube power dissipation. The data were measured on a 500C at 7 MHz with a 50-Ω dummy load, using a steady state, full-CW carrier insertion at all times. RF output power was calculated indirectly by measuring the RF voltage level at the dummy load. At each LOAD setting the PLATE was adjusted for maximum RF output. The measurements have some error due to tuning inaccuracies at each LOAD position, the plate's HV level estimate, and cathode meter and oscilloscope error. In addition, since the measurements represent a complex interaction among neutralization, tube condition, tuning, alignment, etc., there will be rig-to-rig variability, however the trends should be representative of typical performance.

The abscissa shows the COURSE LOAD and FINE LOAD transceiver control positions (FINE LOAD used only on a COURSE LOAD switch setting of 6). A LOAD setting of 1 corresponds to a fully ccw-control position and a 7 a full cw position. The calculated efficiency (dashed curve with empty circles, referenced to the left-had axis), was calculated as the measured RF power output at the dummy load divided by the total dc input power (cathode current times the estimated HV level, based on the measured data shown in Fig. 3-4). The corresponding RF power output is indicated by the solid curve with no symbols, referenced to the right-hand axis. Also appended to this figure is the corresponding curve of required PA tube power dissipation (solid curve with filled circles), also referenced to the right-hand axis.

Light and Excessive Loading Implications. If ever one picture is worth a thousand words, this is it! At the maximum RF output of 260 W (426-W dc input power), the COURSE LOAD setting was 6.15 and the calculated efficiency was 61%. With light loading using a LOAD setting of 3, output power falls off to 75 W and efficiency decreases dramatically to less than 20%! With excessive loading using a LOAD setting of 6.6, RF power output also falls off to 180 W and efficiency also drops dramatically to less than 40%.

The data tell us a good news, bad news story.

- The ***good news*** – maximum efficiency occurs at near the peak RF output power loading point, as expected. At peak power and efficiency, the PA tubes are required to dissipate about 170 W, but this apparent excessive value is deceptively high due to SSB or CW operational duty cycle factors, which reduce the operational requirements to near or below the dual-tube 60-W total power dissipation specification, as discussed below.
- The ***real bad news*** – either significant light-loading or significant excessive-loading results not only in a lower RF power output but also a dramatically reduced efficiency and corresponding precipitous increase in PA tube power dissipation requirements. While at a LOAD setting of 6.15, the maximum power and efficiency tune-up adjustment point, the RF output power output is 260 W and the power dissipation is 170 W (430-W dc input power), at a LOAD setting of 2, RF output power is only 50 W, but the tube dissipation power is 325 W (375-W dc input power), and at a LOAD setting of 6.7, the output power is 177 W, but the tube dissipation power again increases to almost 325 W (502-W dc input power)!

SSB Duty Cycle. Note that these measurements illustrate the relationship between loading, efficiency, power output, and power dissipation requirements during steady-state CW modulation. Luckily, the PA tube heat dissipation situation is not nearly as bad as it seems, since worse case SSB modulation power is 6 dB (and usually 10 dB or 20 dB) down from the peak power, a reduction by a factor of at least 4 in power. As stated in Swan manuals (e.g. 500CX), with a ~550-W SSB dc input PEP and a best case 65% efficiency, the average SSB input power will only be about 125 W with an average cathode current of 156 mA, requiring a plate dissipation of only ~44 W (125 W_{AVG} - (125 W_{AVG} x $0.65_{EFF)}$)). So, even though the SSB RF peak power output might be

358 W (550 W_{PK} x 65%), with a corresponding 193 W_{PK} heat dissipation, the average PA tube dissipation will be well under the 60 W total dissipation rating of the two 6LQ6 tubes.

Even if we equate the steady-state CW measurements shown in Fig. 6-8 to SSB operation (not really a valid comparison, since average SSB power duty cycle is based on a time varying voice modulated signal), the tubes would have to effectively dissipate at most, only 1/4th or less (since halving the power equals a 3 dB decrease in power, the worse case 6 dB down SSB is 1/4th the steady-state power) of the power indicated. At the measured 61% efficiency point, the 170-W PA tube dissipation shown is reduced by 1/4th to only 42.5 W, well within the 60 W tube rating (30-W per tube). However for a very lightly loaded condition (e.g. 50-W RF output with 14% efficiency) with as much as 325-W power dissipation required for a continuous carrier; when equated to the worse case SSB (6 dB down) condition, the tubes will still have to dissipate 81.25 W!

Morse Code Duty Cycle. Similar calculations for Morse code operation based on the Fig. 6-8 data are more directly applicable to those measurements. With standard Morse code operation using a 3:1 dash to dot ratio with the proper letter and word spacing pauses, the average power is about 40% of the steady-state CW value (actually a little more since the power supply will recover somewhat while idling during spaces). For the worse case 40% duty cycle, during maximum power Morse code operations the 170-W CW power dissipation requirement decreases to 68 W, slightly exceeding the 60 W tube dissipation rating. Remember, this 40% duty cycle in most likely the worse case scenario; with typical operator pauses the duty cycle will be lower and the average power dissipation required will be near or below the 60 W dual-tube PA rating when operating at maximum RF output power.

If one were to operate at reduced power by very lightly loading the transmitter to say 50-W RF output (14% efficiency point) the required steady-state 325-W power dissipation requirement only decreases to 130 W during Morse code sending, grossly exceeding the tubes' dissipation rating.

Summary/Conclusions. Is it any surprise that Herb Johnson in the quote at the beginning of this Chapter stresses tuning to maximum power and using matched tubes? Is it any surprise that experienced Swan users heartily recommend very short tune-up periods and the use of a cooling fan? This data certainly confirms these assertions and also clearly provides a number of additional lessons to be learned, namely:

- Light or excessive loading can be severely detrimental to a transceiver's health, especially if it is used routinely as a means to significantly reduced RF power output during SSB or CW operations.
- Matched PA tubes and short tune-up durations are highly desirable. If unmatched tubes are used, consider the stress on the one tube that carries the majority of the current during extended tune-up periods or if the transmitter is significantly mistuned from its peak RF output (efficiency) control positions – a sure recipe for destroying the tubes.
- To use a tennis analogy, there is a tune-up "sweet spot," in this test case, with the LOAD control setting between ~5.6 and ~6.25. Anywhere within that range the power output remains high and the dissipation remains manageable during extended operations.

  Corollary 1. During tune-up, adjusting the LOAD control close to the maximum power and efficiency point is good enough, compared to the extra wear and tear on the tubes needed to get it exactly perfect.

  Corollary 2. It is far better to be a little light in loading than to use a too much loading during tune-up, as the increases in power dissipation requirements are far more benign when slightly light loading.
- External fan cooling is highly desirable, especially during prolonged tune-up or CW/AM operation.
- Because the steady state heat dissipation is so close to the tube's specified maximum during tuning, short tune-up intervals of 5 seconds or less is essential to maintaining a long PA tube service life.

6.2.9.2. CW Efficiency, PA Dissipation (Max. Power)

Fig. 6-9 shows measurements that examine the impact of reduced CW carrier insertion levels on both efficiency and PA tube power dissipation. After tuning to the maximum power and efficiency point with a full carrier level, the tuning controls remained fixed as the CW carrier insertion level (CAR BAL) was varied. The measurements were made using a 500C at 7 MHz with a dummy load, with the transceiver PA PLATE and PA LOAD initially tuned to maximum power (peak efficiency) with full carrier insertion, as measured at the dummy load. So, the primary difference between this data and the previous data set is that in Fig. 6-8 the transmitter was adjusted to maximum output power with full carrier at a variety of non optimum LOAD control positions (i.e. light and excessive loading), while in Fig. 6-9, the transmitter was only tuned once to the maximum power and efficiency control positions at full carrier.

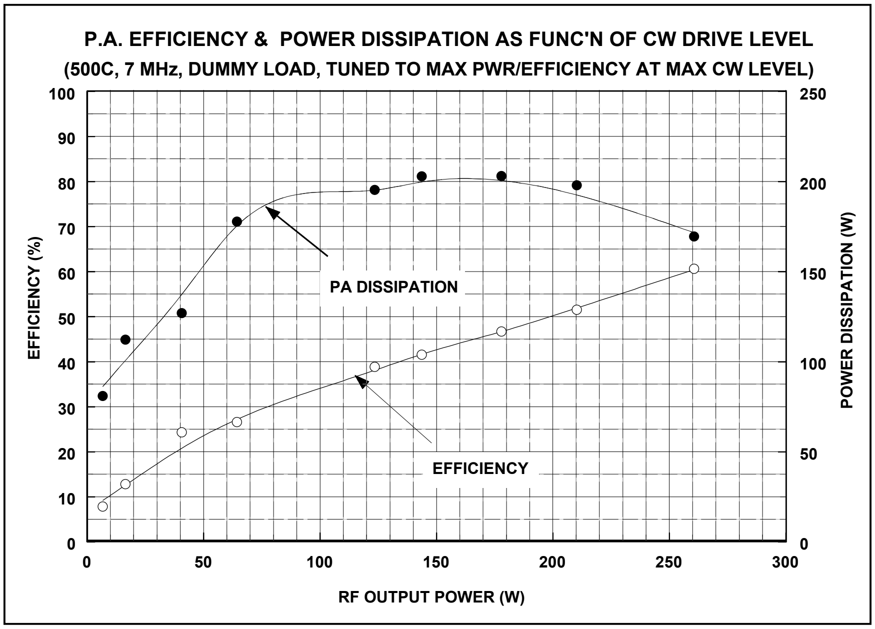


Figure 6-9 CW Eff & PA Pwr Dissipation (Maximum Power)

The values shown may have some error due to inaccuracies in the HV level estimate, cathode meter, oscilloscope, etc. In addition, since the measurements represent a complex interaction between neutralization, tube condition, tuning, alignment, etc., there may be significant rig-to-rig variability; however, the trends should be representative of typical performance. The abscissa shows the CW RF power output as the CAR BAL control was varied – the 500C transceiver had been modified for variable level carrier insertion capability. The efficiency was calculated as the RF power output at the dummy load divided by the total dc input power (cathode current, including bias, times the estimated HV level, based on the HV level versus cathode current power supply loading curves shown in Fig. 3-4).

The measurements in this figure are consistent with the independent data shown in Fig. 6-8 in terms of maximum power and efficiency. Peak efficiency of 61%, consistent with the expected 60% to 65% maximum, occurred at about 260-W RF output power with 167 W of power dissipation required (427-W dc input power, CW). When the CAR BAL control was decreased to lower RF output levels, not only the did the efficiency fall off rapidly as expected, but more importantly, the net amount of power the PA tubes are required to dissipate as the CAR BAL was reduced and CW RF output level falls actually increases from about 167 W at maximum power to about 200 W. Dissipation only drops below 167 W again when the RF output power is reduced to less than 55 W! If the current "dip" tune-up method is used (rather than an external wattmeter), the efficiency at reduced carrier-levels may be somewhat improved from that shown, but should still be excessively high.

Therefore, reducing the BAL CAR carrier insertion level to obtain lower CW RF output levels after the transceiver has first been tuned to maximum efficiency and power is actually a bit harder on the PA tubes than just operating at the maximum RF output level!

Note that, as discussed previously in the Section 6.2.8, these power dissipation levels decrease when the SSB or CW Morse code operational duty cycle is considered. For example, with CW operation, for the maximum 260-W RF output level shown in Fig. 6-9, the 166 W heat dissipation required of the PA tubes can be expected to by reduced to 40% (worse case) or more during CW operation, to 66.4 W or less, just above the typical 60 W dual-tube PA power dissipation rating. Obviously, any increase in the dissipation requirement, as would occur if the CAR BAL control were just decreased to reduce RF output level (as was done in Fig. 6-9), will push the operational dissipation requirements even higher.

6.2.9.3. CW Efficiency, PA Dissipation (Low Power)

If the transmitter is to be operated at lower CW RF output power levels, higher efficiency can be achieved and power dissipation minimized by tuning to the maximum power/efficiency point at the lower CW insertion level rather than using full carrier insertion and tuning as is normally done. Fig. 6-10 shows measurements made on a 500C in the 7-MHz band using a dummy load that illustrate this assertion.

While in Fig. 6-9 the transmitter was tuned to the maximum power/efficiency point and the controls remained fixed while the CW insertion level (CAR BAL) was varied, in this case, at each reduced CW insertion level the PLATE and LOAD controls were re-adjusted for maximum RF output level. At the full CW insertion level, the maximum power/efficiency measurement is consistent with those shown in Figs. 6-8 and 6-9, roughly 60% efficiency, with 250-W RF output and 170 W heat dissipation required. When tuned to and operated at lower CW levels, there is a significant increase in efficiency and a corresponding reduction in PA tube power dissipation compared to the measurements shown in Fig. 6-9.

In Fig. 6-9, at a 75-W CW RF output level (after first being tuned to the maximum full carrier RF power output) the required power dissipation was about 188 W with an efficiency of about 30%. When the transmitter is retuned for maximum RF power at the reduced CW insertion level required for 75 W RF output, as shown in Fig. 6-10 the power dissipation drops to only 112 W and efficiency increases to 41%. The same proportional decrease in required power dissipation and increase in efficiency holds true for all reduced RF power output levels, relative to the full carrier maximum RF output tuning case depicted in Fig 6-9.

Thus tuning to a reduced CW insertion level optimizes efficiency and minimizes power dissipation requirements at the selected carrier insertion level. Again, it must be stressed that this analysis assumes a full duty cycle (continuous carrier/CW) and as discussed earlier, the actual power dissipation requirements will be much less because of the lower Morse code and SSB duty cycles.

Note also that this procedure is distinctly different from light loading, as the transmitter is still tuned to the maximum RF output, but at reduced carrier insertion levels.

SSB Caveat. This benefit is only applicable for reduced CW RF output levels. If this approach of tuning at reduced carrier insertion levels is used for low power CW operations, remember to retune to near the maximum power and efficiency point under full CW insertion conditions for any other operation modes (SSB, AM) at normal power levels.

A possible exception could be if operation at only extremely low SSB RF output levels were desired. If the microphone gain were decreased until only 75-W PEP RF output was achieved, the peak efficiency would be only in the 30% range, as shown in Fig. 6-8. If the transmitter were retuned to the 75 W carrier insertion level prior to SSB operation, the effi-

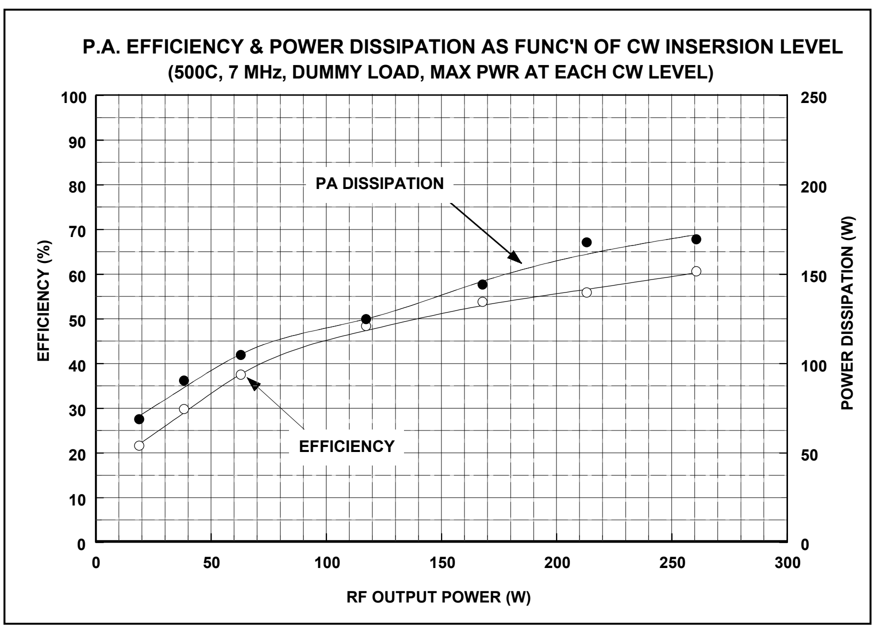


Figure 6-10 CW Eff & PA Pwr Dissipation (Low Power)

ciency should increase to about 40%. While some improvement in distortion could be expected, it is doubtful whether there would be a discernible difference on the receiving end that would merit the extra trouble and hassle.

6.2.10. Expected/Measured RF Power Output

Frequently Swan owners would like to know if their transmitter is functioning properly. High amongst the data of interest is what is the RF power output and is the measured output consistent with what one can expect from a well aligned rig equipped with new, or at least good, tubes.

Antenna Gain. Of course, a companion to transmitter RF power output measurements is the ubiquitous subjective operational signal report, which is a function of both transmitter RF power and antenna design. While theoretically an antenna can have an isotropic or omni-directional radiation pattern (radiates and receives signals of equal strength in all directions), in practice, since the radiating element is never a point source, they all have a non-uniform radiation pattern (directivity). The beam patterns of an antenna can be views as a physical three-dimensional shape. An ideal omni-directional beam pattern is a sphere. A common single-wire antenna of the proper design (length) produces a dipole-like pattern that, in three dimensions, is physically a donut or disk-like shaped and whose main lobe is perpendicular to the wire axis. A rigid aluminum beam array with multiple horizontal or vertical elements placed along a supporting boom has a broad spotlight-like main beam lobe and multiple secondary lower response level lobes.

The contribution to the transmitted signal strength (and improvement in received signal-to-noise ratio) from any antenna beam pattern is characterized by its gain. The radiated power of such beam is described as it's Effective Radiated Power (ERP), which is equal to the transmitter power plus the beam's gain (less any incidental loses (e.g. transmission line)). However, the gain is only applicable for signals within the main-lobe beam-width, generally defined as the 3-dB down sensitivity points – in other directions the radiated power may be less, and in many cases, much less that what would be achieved with just an notional isotropic (or omni-directional) antenna. The narrower the main lobe of beam pattern, the higher the gain.

Antenna gain is commonly referenced in two ways, relative to a theoretical isotropic pattern (dB_i), or relative to an ideal dipole (dB_d) pattern. Since a perfect dipole has 2.14 dB gain over an ideal isotropic (omni-directional) radiator, depending on the reference system, one antenna can be described as having two different gains! Thus, if you have an antenna with a gain of 3 dB_d and a transmitter putting out 400 W, then the ERP is 800 W (400W + 3 dB) relative to a dipole antenna, or 1,306 W (800W + 2.14 dB) relative to a isotropic antenna!

The following paragraphs look at factors involved in the transmitter power output measurement process that can significantly affect the measured results (errors and procedural), the expected minimum RF output based on Swan's specification for a new radio, and detailed measurements under controlled conditions that illustrate what 30+ year old Swans with "good" RF outputs actually put out (e.g. radios that are close to properly aligned, but which do not necessarily have new tubes).

When perusing these data, always bear in mind the practical impact that RF power output measurements, which may seem to be too low, have on actual on-air operations. If a transmitter should put out 400 W, but you measure only 200 W, even if it were an accurate measurement, the operational impact is minimal since it's only about a 3 dB signal decrease. A S-meter unit is typically equal to 6 dB in received signal strength, so the 3 dB signal reduction is only ½ of an S unit! In most cases, this wouldn't even be noticed on the receiving end. So, think a little about the cost and benefits trade-off before replacing PA tubes to increase a transceiver's output.

Power Rating Comments. Recognize that transmitter (and antenna) specifications are areas that frequently fall into the "Black-Arts," with power (and gain) capability advertised in a number of ways, usually such that the highest possible values are claimed. Most Swan transmitters are rated in terms of minimum dc input power (PA cathode or plate current times the plate voltage), not the actual RF output power. So, one has to be careful to understand how the dc input power relates to actual RF output power. However even when directly measuring the output power, care still has to be exercised, as there are a number of methods that might be used and in almost all cases, accurate measurements can only be obtained if the SWR is 1:1 (see SWR Considerations discussion in Section 6.2.9.2). A number of power related definitions include:

Effective Power. This is really an ac power transmission and distribution value, namely the product of the RMS voltage and amperage, (i.e. the apparent power multiplied by the power factor, that is, the cosine of the phase angle between the voltage and the current). The effective or true power is the actual power delivered to or consumed by the load, expressed in watts. Apparent power is properly expressed only in volt-amperes, never watts.

Average Power. The average RF power is equal to 0.637 times the peak voltage when the signal is a steady-state CW. It is of interest because this is the value a typical analog meter displays when measuring a sinusoidal signal's voltage. Frequently amateur wattmeters that measure the average power may be incorrectly labeled as measuring RMS power.

Root-Mean-Square Power. The RMS power is equal to 0.707 times the peak voltage when the signal is a steady-state CW. This RMS power is the root-mean-square value of the signal and is equal to the dc voltage that would cause the same power consumption in a fixed resistive load. Amateur-radio grade wattmeters that actually measure an average value are frequently erroneously labeled as measuring RMS power.

While a high speed digital processing system could accurately compute this value for a SSB RF signal on an instantaneous (or selectable averaging time) basis, with a typical commercial analog meter, accurately measuring modulated signals becomes difficult because of the signal envelope amplitude variations. That is not to say the such meters are not available – even in the tube era, special purpose "true RMS voltmeters" were available, however they were expensive, intended for a laboratory type environment, and generally designed for lower than radio frequencies.

Peak Power Output. The peak power output is the maximum that occurs during a transmission. This differs from the more common PEP measurement in that the power is not averaged over one RF cycle – it is the peak instantaneous power that occurs on the signal's waveform.

Peak Envelope Power (PEP). This is the measurement most often seen in amateur radio usage with regard to SSB signal power and defined by the FCC in their regulations. It is the average power supplied to the antenna transmission line by a transmitter during one radio frequency cycle at the crest (peak) of the modulation envelope taken under normal operating condition. In effect, it treats the peak SSB signal as though it were just one-cycle of a continuous, fixed amplitude CW signal. Therefore, the PEP of a SSB signal is equal to the average power for a CW signal that has the same peak voltage as that of the SSB modulation peak.

Effective SSB Power (Peak to Peak Power). This is just a different (and rarely used) version of peak envelope power expressed in terms of its peak-to-peak power (as opposed to peak envelope power). Practically speaking it is just a doubling of the measured PEP.

6.2.10.1. Power Output Versus PA Tube Condition

The amount of cathode current a tube will load-up to at the maximum power and efficiency point (e.g. 550 mA versus 300 mA) depends on tube condition (driver, power amplifier, and to a lesser extent mixer), power supply voltage levels, and of course, the GRID, PLATE, and LOAD control positions. As tubes age, electron depletion in the chemically treated cathode occurs, limiting the tube's fundamental ability to produce electrons and hence limiting maximum current and therefore RF output power.

Regardless of tube condition, in general the transmitter should always be loaded to near the point where no further increase in the loading will result in an increase in RF output power. One can load to a higher cathode current (excessive loading – see Fig. 6-8), but RF output power actually starts decreasing, despite the fact that cathode current (dc input power) is still increasing – doing so stresses the PA tubes due to excessive heat and could result in arc-over within the tubes.

A quick and dirty check to determine a transmitter's fundamental RF output power potential is to first determine its DC input power capability by very briefly rotating rotate the PLATE control off-resonance (off the cathode current dip) to a non-resonant condition, while under full carrier drive. The off-resonance current reading provides an estimate of the maximum cathode current capacity – when properly loaded, transmitter's cathode current will be about 90% of that value. Assuming the transmitter is properly loaded during tune-up to the maximum RF power output and efficiency point, the highest efficiency achievable is typically ~60% (65% maximum, if you're real lucky, it's a full moon, the planets are aligned, and the wind is blowing from the right direction). Therefore, if the off-resonance cathode current were say, 560 mA, when the transmitter is tuned-up to a maximum RF power point as measured with an external wattmeter, the current should be ~520 mA. Under that condition, one could reasonably expect a maximum RF output level of ~234 watts (520 mA x 750 V x 60%) during a constant carrier condition.

6.2.10.2. Power Measurement Issues

A number measurement (accuracy, methodology, etc.) and related operational (tube condition, tune-up procedure, etc.) issues affect the RF power output achieved by a transmitter. These factors include:

Average Versus PEP. Recognize when operating SSB, CW, or AM, that meter readings are significantly damped, with the pointer's inertia preventing it from following the rapid, short duration modulation peaks. Swan provides a good explanation of this issue in most of their manuals with regard to using the transceiver's cathode current meter to determine dc power input.

With a steady-state (CW) carrier modulation of appreciable duration (1 or 2 seconds or more) the true cathode current is indicated. However this value will not correspond to the transceiver's true SSB PEP output capability because the power supply's capacitors will not have had time to attain full charge under steady-state high power output, as they do during intermittent, varying SSB modulation. Furthermore, during SSB operation, the averaging effect due to pointer inertia will limit the ability of the meter to accurately reflect the true cathode current of signal peaks. If you observe 175 milliamps cathode current on SSB operations you may be achieving upwards of 600-W (assuming a higher power transceiver model) dc input PEP on peaks and not the 157.5 W indicated by a simple current times voltage calculation (0.175A x 900 V).

As with the transceiver's cathode current meter, an external directional wattmeter has the same problem measuring PEP. Swan wattmeters with the PEP feature use a solid-state design voltage follower to sample the RF voltage and hold that value at a slow decay rate, such that the meter movement has sufficient time to track the voltage peaks. Other manufactures use similar active peak sensing circuits or employ a passive (un-powered) designs, however the passive designs frequently have much poorer accuracy.

Current Dip Versus External Wattmeter Power Peak. When tuning a transmitter that is perfectly neutralized, the maximum RF power output into a 50-Ω load will occur simultaneously with the minimum dip in the cathode current. However as discussed in the Neutralization Section 7.7, it is literally impossible to obtain perfect neutralization as a function of frequency within a band, much less between bands. Therefore, some inconsistency between peak output level and cathode current null is both normal and expected. Tuning-up to the current dip rather than to the maximum power using an external wattmeter will not yield the optimal control settings. However, the dip settings are still perfectly acceptable and will be close to the ideal adjustment positions unless the PA tube neutralization is grossly off.

Expected and Measured Power Comments. RF output power should be a direct function of dc input power. The upper limit RF output power possible under ideal conditions for the AB_1 class amplifier used in Swan transceivers is at best 60 to 65% of the dc input power to the transmitter's PA. Using the calculated dc input power and a 60% efficiency serves as a good "sanity check" of what the maximum power one should hope to obtain.

If measurements indicate a significantly higher efficiency, there is some measurement error. For example, if a transmitter can be only loaded to say 200-mA CW at the maximum RF power output point, the dc input power will be about 170 W and the expected RF output is 120-W CW at best. If the CW dc input power on a 350C is 350 W (500 mA X 700 V) and an external wattmeter reads 300 W, the efficiency is 80% – that doesn't pass the sanity test. If power readings look too good to be true, they probably are. There is obviously some measurement error or for some strange reason the fundamental laws of physics are being violated within your 350C's chassis. As discussed below, one should always bear in mind that there are a number of measurement errors. Remember that these errors are cumulative, so RF power output results should be taken with a grain-of-salt unless the equipment is known to be accurately calibrated and/or reliable independent measurement confirmation can be made.

RF power Measurement Issues. While an external wattmeter provides the best methodology to tune-up a transmitter to near its maximum power and efficiency point by using the relative changes in the RF power output indication (peaking), the absolute measure of RF power can frequently be doubtfully due to inherent measurement errors. Fortunately, even if a meter does have humongous absolute errors, for an indication of relative RF power output during tune-up, they as just as accurate as a meter that has absolutely no error.

Measurement Error. Unfortunately, as is illustrated by laboratory measurements of wattmeters (e.g. "*QST Compares HF/VHF Wattmeters*", *QST, July 2002*), the typical measurement accuracy of even today's amateur grade PEP meter designs is frequently atrocious (despite accuracy claims of 10% or less), especially at high power levels (1,000 W) where full-scale (or near full-scale) power measurement errors as great as 200 to 300 W are typically measured! In some cases, even the average (CW) measurements, which are generally much more accurate, are almost as poor.

While similar comparison measurement at lower power levels (e.g. half scale or less) are typically not done in these evaluations because of cost and/or time constraints, there is no reason to suspect that the accuracy percentage would be any better, indeed, at lower scale ranges, it is frequently worse. Based on these types of measurements and the discussions below, it is probably best to take the indicated measured RF output, especially for a 30+ old Swan meter with skepticism, unless its accuracy has been confirmed against a known laboratory standard wattmeter or the power has been measured directly (RF voltage and/or current at the 50-Ω dummy load).

Typical meter specification error tolerances are frequently as great as ±10% of full scale (e.g. Swan WM-1500 = ±10%, WM-2000/3000 = ±7%). This error will not necessarily be linear as a function of power level, frequency, or scale range. A 500-W scale reading may be right on with a 500-W level, but when decreased to 100 W it might be off 50 W when using the same scale range (±50-W error = ±10% of 500-W full scale). In general, maximum accuracy is obtained at or near the full-scale readings (since that is normally the meter's calibration point) and the poorest when measurements fall in the lower portion of the scale, since the same FS error still applies even at the lower scale ranges.

In the case of meters with a PEP function, calibration is highly dependent on both circuit time constants and calibration signal characteristics (steady-state CW, isolated peaks, or multiple signal peaks). If you adjust the meter for an accurate reading of PEP based on a single pulse, you will find that during normal operation the meter is extremely generous; likewise, if you calibrate based on a steady-state CW signal or an average over a number of closely spaced pulses, it will not necessarily provide an accurate measure of isolated higher-level SSB voice peaks.

This calibration issue is clearly highlighted in meter evaluation/comparison measurements that include multiple types of SSB signals, such as two-tone and typical voice SSB signals (for details see "*QST Compares HF/VHF Wattmeters*", *QST, July 2002*), where drastically different measurements are obtained for the same PEP level depending on signal type (e.g. for a 1,000-W RF signal output one meter indicated a 720-W power level for a two-tone signal and 900 W for a voice signal). Based on these data and discussions, one can expect significant errors in PEP reading in excess of the specified error tolerance, even for current-day, brand-new meters.

In the case of cathode current measurements for CW dc input power/efficiency measurement purposes, remember that the cathode current meter is calibrated at the 50-mA current idle current level (dual-tube PA models). This is the inverse of what is normally done on wattmeters, which are calibrated at the full-scale value. In general, the best measurement accuracy is in the vicinity of the calibration point. While no error specification is given for cathode current readings, it is reasonable to expect some possibly significant errors at higher current readings due to, if nothing else, linearity errors (which most likely explain the HV level data spread at high currents shown in Fig. 3-4).

SWR Considerations. Bear in mind that there are many misconceptions with respect to SWR. It is sometimes assumed that a low SWR is necessary for an antenna to transmit efficiently – that is not correct. Why a low SWR is desirable is so that the transmitter can efficiently transmit full power to the antenna with minimal transmission line losses. In the case of modern solid-state transceivers, a low SWR is highly desirable since the output power is automatically reduced to protect circuit components in high SWR conditions.

It is also assumed that a low SWR automatically means you are radiating the maximum RF energy – that also is not true. A simple example clearly proves the point. Consider the case of a 50-Ω dummy load. It has a 1:1 SWR but radiates essentially no energy, converting all the RF energy to heat. Conversely, an antenna that has high SWR at certain frequencies (such as the G5RV) will radiate the power it receives efficiently (when using an antenna tuner and balun/matching network at the antenna to help ensure the transmitter sees a 1:1 SWR, even though the antenna may have a SWR of 3 or 4 or even higher) providing it has a high radiation efficiency in which only a minimal amount of energy is lost in heat. After all, if the energy isn't converted to heat, it has to go somewhere – perhaps not in the desired direction(s), but still radiated. While low SWR is not a prerequisite for efficient RF energy transmission and radiation as discussed above, it is for RF power measurement.

Whenever making any transmitter power or efficiency measurements or estimates, if possible use a dummy load. It is extremely important to note that the power delivered to the load is equal to the forward power only if the SWR is 1:1. Under that condition, all of the indicated measured RF power output is delivered to the antenna (other than coax/feed-line losses). With any load impedance mismatch, the SWR increases and there is a reflected power that increases the forward power reading on a directional wattmeter by an equal amount. As the SWR mismatch increases, the reflected power component becomes a progressively higher proportion of the indicated total forward power. The true transmitter power output (that delivered to the coax/antenna) is the forward power minus the reflected power. Thus if a transceiver tuned to near its maximum power point shows a forward power of 250 W and the SWR is 2.5, then the reflected power would be about 70 W and the true RF output power is only about 180 W, not 250 W (see Fig. 4-5).

Oscilloscope Measurements. A good way to accurately measure PEP RF output is to directly measure the peak RF voltage using an oscilloscope (with sufficient bandwidth) and then compute the power by: Power = V_{avg} x A= $V_{avg}^2/Z = (V_{peak}/1.414)^2/50$). A near 50-Ω impedance must be used; otherwise, the calculation shown will be in error due to SWR mismatch as discussed above.

6.2.10.3. Swan Specified Power Output

Swan typically specifies transceiver power in terms of minimum SSB, CW, or AM dc input power. A reasonable estimate of expected RF output power can made from those values based upon the expected AB_1 power amplifier efficiency. For example, the 500CX transceiver has a specified minimum dc input PEP of 520-W SSB, 360-W CW, and 125-W AM. With a 60 to 65% efficiency (as is frequently suggested in the Operation Manual's discussion of dc input power and PA plate dissipation), the minimum expected RF power output into a 50-Ω load ideally should be at least ~325-W PEP on SSB, ~225-W RMS on CW, and ~78 W on AM, assuming a 62.5% efficiency.

Fig. 6-11 gives a graphical summation of the specified SSB and CW dc input power levels and the expected RF output levels (assuming a 63% efficiency) for a variety of transceiver ranging from the lower power early mono-band models to the 700CX. Graph A shows the SSB data and Graph B the corresponding CW values. Bear in mind when reviewing this information that these values are predicated on a brand new, properly aligned radio. After 30+ years of component aging, various degrees of misalignment and tube weakening, realizable power can be significantly less, especially on 15 and 10 meters.

Review of this data shows minimum expected SSB RF output levels from 150-W PEP for the single-tube PA early mono-band models to 450 W for the 700 CX. The corresponding minimum CW output levels ranged from a little over 100 W to 250 or 300 W for the most powerful models. While most manual specified minimum dc input power levels do not make a distinction between the lower HF bands and the higher bands, it is likely that the 15 and especially the 10-meter bands can have significantly lower power levels with any mis-alignment or tube deterioration.

It is interesting to note that the 350B/D (joint manual) is unusual in that the manual only specified power in terms of minimum RF power output – even more curious is that even though the 350A is quite similar in design, the 350B/D's specified RF outputs of 125 W on SSB and 90 W on CW (10% less on 15 M and 10 M) are significantly less than the 190 and 110-W estimates shown for the 350A. One would suspect that in practice, either input levels of less than 300 W (specified dc input power) or efficiencies of less than 60% were realized on the 350A and the 350B/D's specifications were altered to reflect that reality.

6.2.10.4. Measured Power Output

While theoretical estimates are all well and good, the real question is what range of RF power outputs can typically be expected from these old transceivers? Data presented in this section provide user measurements of RF output power from an assortment of transceiver models. Taken collectively, these measurements give a good idea of the RF power output range one can reasonable expect from a well functioning Swan transceiver. Nevertheless, just because a measured SSB PEP output is perhaps only 200 W when you had hoped to get at least 300 W, that doesn't mean that the tubes are bad or an alignment is required. A 200 W output is still a very respectable output for the dual-tube PA 350 through 500CX model transceivers. As noted at the beginning of this section, the operational difference between 200 W and 300 W, or even 500 W, is not that significant.

In Fig. 6-11, Graphs C and D present RF output measurements as a function of frequency band made on a 350D, 400, 500CX, and 700CX transceiver. The 350D is the only lower power, single-tube (6MJ6) power amplifier transceiver. In all cases, a dummy load was used and the transceivers were tuned-up in each amateur band to near their maximum RF power output point, as indicated by an external wattmeter. All transceivers

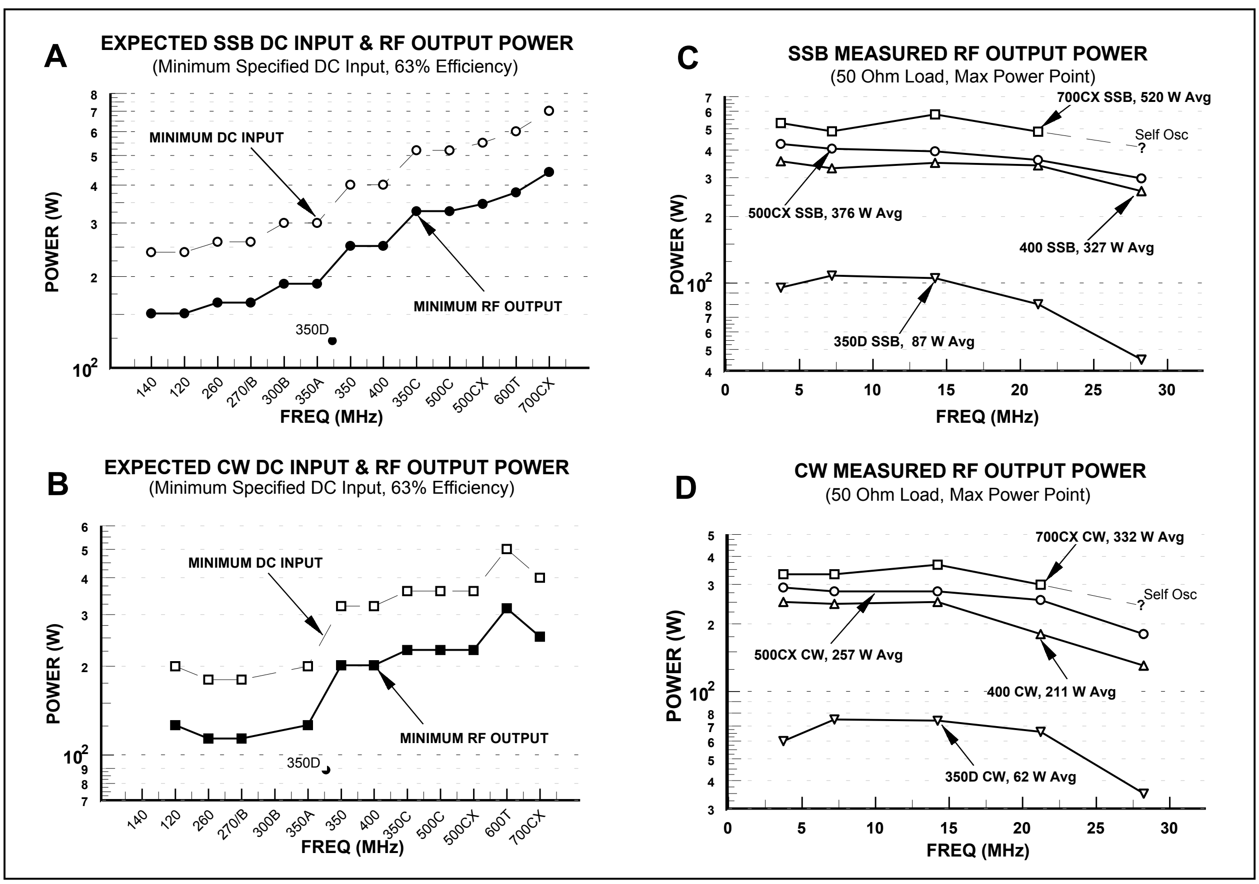


Figure 6-11 Expected and Measured RF Output Levels

were properly aligned (hopefully), but none were equipped with new mixer, driver, or PA tubes. While the tubes were all used, in all cases the power output was known to be respectable. The RF power measurements were made base on oscilloscope RF voltage measurements at the dummy load.

In the case of the CW measurements, the transmitter was tuned-up in the CW mode with full carrier insertion and the reading was taken after about a 2 or 3 second transmit interval (in most cases these CW measurements should be the same as those made in the TUNE mode, but on some transceiver models like the 350D, a cathode resister is switched into the cathode circuit in the TUNE mode to limit RF power during tune-up). In the case of the PEP SSB measurements, they were calculated based upon the peak RF voltage levels at clipping (flat topping) using normal audio modulation as would be generated during a normal QSO.

Bear in mind when perusing the measurements shown in Fig. 6-11 that the maximum RF power achieved will be somewhat dependent of the exact tune-up settings, what frequency is selected within a band, tube stress conditions (duty cycle), etc. For example, the mode 400 transceiver readings (Graph D) show a CW RF output measurement of almost 255 W, taken at 7.100 MHz – when the frequency was changed to 7.280 MHz, the maximum RF output was ~230 W. Since the tune-up process is somewhat subjective, some RF output variability, even if a transmitter is just re-tuned at the same frequency, is both normal and expected. It also should be stressed that these are the maximum RF output levels that were achieved using considerable care in peaking-and-tweaking the controls (GRID, PLATE, LOAD) during tune-up – a quick tune-up to near the maximum power point, even though it may yield perhaps as much as 10% less output, is just as good (if not better because of less tube stress) for reasons discussed in the efficiency and characteristic curve sections.

Measured Results. Graph C shows SSB RF output measurements for the 80 through 10-meter bands. Graph D shows the corresponding CW RF output.

- The 700CX has no data shown for the 10-meter band due parasitic and/or self-oscillation (alas, neutralization difficulties, a common problem on 10 meters with that model). The 700CX achieved between 490 and 600-W PEP RF output (520-W average) on SSB and between 300 and 375 W (332-W average) on CW. These values are greater than the minimum expected 450-W and 260-W outputs shown in Graphs A and B.
- The 500CX achieved between 300 and 430 W (376-W average) on SSB and between 180 and 300 W (257-W average) on CW. In this case, the measured values are more consistent with the minimum expected 350 to 220-W values shown in Graphs A and B.
- The 400 achieved between 260 and 350-W PEP RF output (327-W average) on SSB and between 130 and 255 W (211-W average) on CW. The measured SSB range is significantly higher than the minimum expected specification RF power outputs shown in Graphs A, while the average CW power is only slightly above the expected 200-W RF output minimum shown in Graph B.
- The 350D achieved between 47 to 102-W (87-W average) RF output, quite a bit lower than the 125 W on the lower bands (80, 40, and 20 M) and the 112.5 W on the 15 and 10-M bands specified in the manual. In the CW case, the measured CW RF output was between 36 and 77 W (62 W average), somewhat below the specified 90 W on the low bands and significantly below the manual specified 80 W on the high bands.
- All SSB and CW curves show the expected significant power fall-off in the higher bands inferred early from anecdotal reports. The 500CX shows a 30% SSB and 40% CW power fall off from the low-band maximum RF output to that obtained at 10 meters. The CW measurement data set shows power fall-offs on 10 M ranging from 25% to slightly greater than 50% (for the 400 and 350D).

Other User Measurements. In addition to the controlled test measurements given above, a number of users have reported RF outputs for a variety of models, operation modes, and test conditions. Unfortunately, the reported measurements are not well documented (operation mode, equipment condition, dummy or antenna, measurement methodology, etc.). Nevertheless, even with that caveat, comparisons of these independent data with those shown in Fig. 6-11 still show close agreement in most cases.

- 350 >275-W PEP on 15 to 80 M, 130-W PEP on 10 M
- 350B 90 to 125 W.
- 350C 250-W CW (tubes good).
- 350D 70-W CW (90-W PEP CW), 150-W PEP SSB (tube good).
- 400 250, 250, 225, 100, 75 W on 80 thru 10 meters.
- 500CX 250 to 275 W on 80/40 meters, 80 W on 10 meters.
- 500CX 210, 210, 200, 200, and 120 W on 80/40/20/15/10 meters (used tubes).
- 500CX 285, 285, 290, 208, 107-W SSB PEP on 80/40/20/15/10 meters (Ω load, used tubes)
  200, 210, 230, 160, 62-W CW on 80/40/20/15/10 meters (Ω load, used tubes)
- 700CX 375 to 400-W CW and as much 500 to 600-W PEP on SSB (new finals/alignment).
- 700CX 350-W CW, 600-W PEP SSB on 40 meters (good finals).

6.3. Tune-Up Considerations

6.3.1. Tune-Up Duration

Never tune for more than 5 seconds at a time. Swan manuals are misleading when they state one can hold the transmitter in the TUNE position for 30 seconds (20 seconds in some manuals, such as the 250). Excessive tune-up time durations are the root cause of a number of failures, including: PA tube(s), RF driver tube, PA fixed loading capacitors and associated wafer switches, and on the early versions of the 350 and 400 model transceivers (pre 1966), the π output air-core coil sag. In all cases, immediately peak the GRID as this simultaneously resonates the mixer and driver tuned circuits so that maximum signal drive level to the PA tube(s) is obtained. With the driver circuit out of resonance, excessive plate current flows, causing excessive heat and the potential to burn out the choke in the high voltage plate supply to that tube.

6.3.2. Current Dip Versus Peak Power

The cathode current dip mentioned so often in the manuals is actually only a rough indicator of proper tuning of the PA stage, as the dip minimum will only coincide with maximum power output settings when the PA tubes are perfectly neutralized. However neutralization does not track on the money from band-to-band and in almost all cases, the maximum RF output power PLATE and LOAD control positions will not exactly coincide with the minimum dip.

The most efficient operation is reached when the π network is adjusted for maximum RF output power as indicated by a wattmeter. Another reason for using a wattmeter is that if relying solely on the PA current dip, it is much easier to inadvertently lightly or excessively load, since there is no definitive adjustment point. While some manuals specify a specific cathode current level in the dip, as the PA tube(s) age that level will not necessarily be achievable or might only be only obtained with excessive loading. Other manuals avoid specifying an actual cathode current level in the dip, recommending that it be adjusted so that the cathode current is ~10% down relative to the off-resonance current level.

On some later transceiver models (post 500C) Swan incorporated a meter function to provide a measure of relative RF power output, so tuning on those units involved peaking for maximum power output when in the TUNE mode (although in the CW and SSB operation modes, cathode current is still displayed on the meter), exactly as one would do if using an external wattmeter. So, instead of tuning-up by the familiar loading and dipping of the cathode current, tune-up is accomplished by loading and peaking to the maximum relative RF output level.

6.3.3. Tuning for Maximum Power

As noted in Herb Johnson's quotation in Section 6.1, all Swan radios should be loaded-up to near the maximum power point with maximum carrier insertion in order to have the PA stage operate at optimum power efficiency and signal linearity during normal SSB or full carrier CW operations. This should also generally be done even if your intent is to operate using one of the procedures described in the Operating Control Adjustments Section

5.8.2 to reduce RF output power moderately. A possible exception to this general rule is to load to maximum power at a lower carrier insertion level in cases where a significantly reduced CW or extremely low SSB RF output power level is desired.

A word of caution is in order. It's best not to get too wrapped-around-the-axel about tuning-up exactly to the maximum power point (either RF output power peak or cathode current dip), since even if it were adjusted precisely, ironically it still would not be perfectly adjusted for the range of actual operational control grid signal levels anyway, as discussed in the Tube Plate Resistance Section 6.2.4. Undue concern with getting it just right does nothing more than place excessive wear and tear on the PA tubes. In this case, once one has a feel of the tuning process and has confident in recognizing when it's near the maximum power point, close is good enough!

Note that it is equally bad to significantly light or excessively load to current levels below or above the peak power point, as doing either will decrease the RF output level while actually increasing the amount of power the tube must dissipate (see Fig. 6-8 and related discussion).

It is also useful when tuning-up on often used frequencies to write down the control positions of the transceiver, tuner (if used), and antenna combination used. This list can then be used as a starting place each time you change bands. You might even find that when the controls are adjusted to a new setting they are consistently very close to the final settings and no additional fine-tuning is really required.

6.3.4. Tuning – the FINE LOAD Control

The FINE LOAD control is merely a variable capacitor connected in parallel with the COURSE LOAD. The COURSE LOAD switches lumped/fixed capacitance in the PA LOAD circuit (see Fig. 6-5). The function of the PA LOAD circuit is to match the output impedance of the PA tubes to that of the antenna system. The FINE LOAD permits adjusting the total capacitance to an intermediate value between the fixed capacitor steps in order to get a more precise match than could be obtained using the fixed capacitors alone.

The total capacitance of the FINE LOAD usually is greater than between the COURSE LOAD fixed steps, thus it may be possible to have two setting of these controls that will yield about same maximum RF power output. For example, a COURSE LOAD setting of 5 and a FINE LOAD setting of 6.7 may have the same total capacitance as a COURSE LOAD setting of 6 and a FINE LOAD setting of 1.2.

6.3.5. Inter-Band Retuning

Most Swan two-tube PA radios can tolerate excursions of ±75 or ±100 kHz on 15 meters without needing to be retuned (adjustment of the PLATE and LOAD controls), however the GRID can be more frequency dependent. Moving 100 kHz could require a one full division adjustment of the GRID control. When, for example, a 750CW is tuned-up (assuming it is aligned correctly) for 3,999 kHz, the GRID control might peak the cathode current when fully clockwise (3 O'clock position), at its minimum capacitance. If you were to go down to 3,501 kHz for a little CW work and re-tune, the GRID control could be almost full counterclockwise (9 O'clock), near its maximum capacitance position. Therefore, for this example, only a 100 kHz change of frequency on 80 meters will typically require about one complete division change of the GRID control. One of the reasons the GRID control position is specified along with a frequency during mixer and driver alignment (see Alignment Procedure (Mixer and Driver) Section 7.3) is to ensure that the control will have sufficient adjustment range to permit resonance of the circuit throughout the entire band.

The PA TUNE and PA LOAD adjustments are dependent of both frequency and load impedance (as well as the kind of load impedance – resistive, inductive, capacitive, or a combination of these). As you move up and down any band, the π-output stage sees a complex set of changing impedance conditions that must be met to transfer maximum RF power from the power amplifier tubes to the antenna. As noted previously, the π-output stage (tune capacitor, tank coil and load capacitor) can be viewed as a RF transformer – it steps down the output impedance of the PA tube(s), about ~2,500 Ω for dual-tube PA and ~5,000 Ω for single-tube PA models, down to the 17-Ω to 150-Ω range (SWR ≤3) in order permit maximum power transfer. Obviously, a lot will have to do with the type of antenna (since an antenna's impedance can vary drastically with frequency) as to whether or not a transmitter needs be retuned for 25-kHz or 200-kHz changes from the original tune-up frequency. For example, most mobile whip antennas can be operated only over a 15 or 20-kHz sub-band for a given setting of the tuning controls.

Fortunately, the SSB mode is not too hard on PA tubes when operated somewhat out of resonance, like when moving maybe 100-kHz off frequency on 15 meters. However when employing AM or CW, these modes require adjustment (or at least checking of the tuning conditions) for the specific operating frequency and antenna load. A continuous carrier with the least amount of inefficient operation is very torturous to PA tubes. At the very least, re-peaking the GRID control with any appreciable frequency change is highly desirable.

6.3.6. Using An External Antenna Tuner

As discussed in the PA and π-Network Section 6.2.7, the π network on a Swan transceiver is performing the same function of an external tuner, in that it is best matching the impedance of the PA output to that of the load presented by the transmission line and antenna system so that maximum power transfer occurs. Therefore, a transmatch or antenna tuner may not be especially helpful when used with the typical Swan tube-design transceiver and antenna system.

However there are a number of cases when a separate antenna tuner is desirable or essential. For example, cases where a tuner is needed include: (1) when operated with other than a standard ~50-75 Ω impedance coax transmission cable (e.g. balanced line), (2) when used with a simple long wire antenna, (3) when the antenna system has unusual design characteristics, (e.g. has extremely low or high feed-point resistance (>3 SWR) or uses feed-line radiation as part of its design, such as the G5RV), or (4) when difficult RFI related problems are encountered.

Also, if one were to position a tuner or transmatch at the antenna (between the coax transmission line and antenna, rather than between the transmitter and coax cable), then for antennas with high reflection coefficients (higher SWRs), the SWR in the transmission line will be reduced to ~1:1, eliminating SWR related transmission line losses, although those losses, in the grand scheme of things, are in general relatively minor. See Sections 6.4.6 and 6.4.7 for related discussions.

6.3.7. Grid Detuning, Light Loading (Low Power)

Never detune the GRID or intentionally light-load to keep power down (See discussion in Section 5.8.2). Detuning the GRID will decrease output but it takes the driver and mixer tubes out of resonance, causing excessive heat in the driver tube and signal distortion.

Light loading, that is, adjusting the LOAD control to less than the maximum RF output position, will certainly reduce output power, but will also decrease the efficiency of the PA tubes (Fig. 6-8). While the RF output power will be lower, the amount of power dissipation required by the PA tube(s) actually increases from that required at the maximum RF output power tune-up condition!

6.4. Alternate Tune-Up Methods

When following Swan's tune-up procedure, it at first almost appears that transmitter tuning is an exact science, albeit a complex one – merely follow a series of cookbook steps and voila, it's tuned. However, anyone who has tuned one for the first (or, 2nd, 3rd, . . . nth) time could attest that it's really more of an art, where intuition, experience, and knowledge of a particular transmitter and antenna combination's performance all come into play. So, prior to using any tuning method, take the time to thoroughly review the manual (both technical discussions and procedures) and other sections of this document to gain a basic understanding of what's happening during the tuning process and why.

As with any system that has a number of complex subjective adjustments, users have come up with a number of variants to the basic tune-up procedure. The alternate methods discussed below were reported to have been used with success by Swan users, in many cases for years of operation. Most are, in fact, similar to or variants of procedures that Swan specified or recommended in their various manuals. They have both certain benefits as well as drawbacks and in some cases their utility is dependent on equipment availability (external wattmeter), operation mode, and how comfortable or experienced a Swan user is with the tuning process.

Note that in the late 1960s and early 1970s, a directional external wattmeter was not a common station accessory and therefore the tune-up procedures specified by Swan were predicated on use of only the transceiver's cathode current meter. However tuning by using an external wattmeter is a much better method to adjust the LOAD and PLATE controls to near their proper maximum RF output and efficiency adjustment positions than relying on cathode current – most early Swan manuals even included a line or two recommending use of an external wattmeter as the preferred tune-up method. Later Swan transceiver models (e.g. 700CX) included a relative power output sensing and display circuitry – when tuning-up, the loading was adjusted to the maximum power peak as displayed on the meter rather than the current dip.

So, if an external wattmeter is available, for all tune-up procedures specifying a cathode current dip as a tuning indication, just ignore the transceiver's current meter and tune to an external wattmeter's peak reading, successively increasing the LOAD and peaking the PLATE until you just reach the point where no further increase in power output in noted.. In the case of GRID tuning, a peak in the cathode current also corresponds to a peak in the wattmeter reading, since adjusting the GRID resonates the driver's (and mixer's) tuned circuit, minimizing current flow in that circuit but maximizing signal voltage level on the PA tubes' control grids, which in turn causes an increase in cathode current and RF power output.

Preliminary Tune-Up Steps. Many tune-up procedures listed in the manuals and some that are discussed below share a number of essential preliminary steps, which are repeated for completeness, namely:

(1) *Adjust the GRID, PLATE, and LOAD control for maximum received audio or S-meter level*. Since the PA, mixer and driver tuned circuit are also used during receive, adjusting these controls during receive resonates the circuits and the settings will be near their correct position for transmit. Unfortunately, this procedure is not anywhere near accurate enough for proper transmitter adjustment (particularly for the LOAD and the GRID controls), so some form of additional transmitter tune-up must be done. An exception to this generalization is the 250 six-meter transceiver, in which only the GRID controls the received signal strength (signal path is routed around the PA's π network via a relay).

(2) *Adjust the MIC GAIN ccw (minimum), KEY the microphone, and completely null the CAR BAL.* This adjustment removes all drive signals from the grid of the PA tube(s) so that the current seen when the transmitter is keyed is only the bias or idle current. The MIC GAIN must be minimum so that shack ambient noise does not appear as a signal when the microphone is keyed. In some cases, no meter movement or null indication will be seen when the CAR BAL is varied – this can occur when the GRID is far off resonance. In such cases, just continue on with Steps 3, 4, and 5 – Step 3 will set the bias level, Step 4 will peak (resonate) the GRID, and Step 5 will re-null the CAR BAL and reset the bias level (if required).

(3) *Check the idle current level and adjust the BIAS potentiometer for the specified cathode current, compensating for any meter zeroing error (This step usually need not be done once it has been initially adjusted).* With no ac power applied, the meter's pointer should rest on zero. If it is not and cannot be mechanically zeroed, then might well be a proportional error in the indicated current reading.

The specified idle current positions the operating point on the PA tube's characteristic curve such that the transmitted signal has optimum linearity with a reasonable tube power dissipation requirement. Setting it higher improves linearity but increases tube power-dissipation requirements beyond the ~30 watts per tube capability (e.g. 100 mA requires ~88 watts total dissipation when just idling!). Setting it lower adds to the transmitted signal's distortion.

(4) *With somewhat light loading (LOAD control positioned toward the ccw or lower numeric setting), key the microphone and inject a small amount of carrier with the CAR BAL control, quickly adjust the GRID for cathode current peak, and then quickly adjust PLATE for the cathode current dip.* The GRID control adjustment simultaneously resonates both the mixer and driver stages so that maximum signal is delivered to the PA tubes' grids, thus the increase in PA current. When un-resonated, high plate current levels are flowing in the driver tube and power dissipation requirements are excessive.

If the LOAD control is initially too high, the current dip may be very shallow and not easily found (see Fig. 6-12). This initial PLATE adjustment resonates the π network for this very low carrier level condition and ensures that this control is near resonance for subsequent tuning at higher drive levels. It is normal for the PLATE and LOAD control positions will vary for differing amounts or carrier insertion, so the positions obtained for this very low level of carrier insertion will not be valid for the full-carrier insertion level used when in the TUNE mode.

(5) *Completely null the CAR BAL*. This removes all signals from the PA tube grid so that the transmitter is again idling. The cathode current meter should still read the idle current, if not, reset it. The transmitter can run indefinitely under idle conditions with no danger of heat related damage to the tubes (e.g. 50 mA x 900 V = 45 W).

After the transmitter has been exercised vigorously during tuning, the idle cathode current may be somewhat higher (or lower), but still should be within the adjustment range (i.e. typically 50 mA ±10 mA). Readjustment under such cases should not be needed because it is still within the adjustment range and when the transceiver cools, the idle current will revert to its original setting.

6.4.1. External Wattmeter Tuning

This method is essentially identical to the that outlined in most Swan manuals except for a couple of important changes that minimize potential tube damage and help to ensure the transmitter is tuned to near maximum power and efficiency. Since it permits easy and accurate tuning to the maximum power and efficiency loading point, it is perhaps the preferred tune-up approach.

- *Use an external wattmeter for all tune-up procedures except bias idle current level adjustment*.
- *Limit tune durations to periods of 5 seconds or less*.
- *Follow preliminary tune-up steps as outlined above or in the manual.*
- *Switch to the TUNE position, and tune-up by alternately increasing the LOAD and peaking the PLATE to obtain maximum RF output power. Ignore the cathode current meter and only monitor the wattmeter, tuning to maximum RF output power*. When increasing the LOAD and peaking the PLATE no longer results in a discernable increase in RF output power, you're at (or very near) the maximum power and efficiency tuning point – it doesn't get any better than that.

  Do not try to be too exact, close is good enough. If you continue to increase the LOAD control and peak the PLATE, the RF output power will remain flat and will start to decrease while the cathode current will still continue to increase! If you monitor both the cathode current and wattmeter power, you will observe that the peak wattmeter reading will not necessarily coincide with the current dip – that is normal and expected. When the neutralization is not perfect, peak power output will not correspond to the dip minimum. See Fig. 6-8 and related discussion.

6.4.2. Tuning By Cathode Current Dip

Many earlier manuals direct that tuning be accomplished by loading the π network such that a specific cathode current at the dip minimum is obtained (e.g. 400 mA is specified in the early version 350 manual). While this is applicable when the transceiver is properly aligned and the tubes are new, with the depredations of time, no transceiver maintains this capability indefinitely and there comes a time when the achievable cathode current will be much less than that specified in the manual. So, what does one do during tune-up if the current levels in the dip specified in the manual cannot be achieved?

Some general insight into the relationship between cathode current level, degree of loading, and RF power output can be gained by reviewing the graphic relationships shown in Fig. 6-12, which is similar to information include in some manuals (e.g. 350D and 600T). As indicated in this figure, under full carrier conditions, as the COURSE/FINE LOAD control is increased and the PA PLATE control is adjusted for a cathode current dip (resonance), the percentage of current decrease relative to the off-resonance current (curve portions E) is proportional to the degree of loading. As loading is increased from very light loading conditions (curve A) to the maximum RF output loading point (C), the percentage of current dip decreases, relative to its off-resonance value. When the dip is excessive, the transmitter is too lightly loaded and not operating a maximum efficiency. When the dip is too shallow, the transmitter is excessively loaded and its also operating at reduced efficiency. In both cases, the power dissipation requirements placed on the PA tubes increases dramatically relative to the maximum power and efficiency point.

For some transceiver models, such as the 350D and 600T, the percentage of cathode current dip is specified as the primary tune-up criteria. For both of these models, the percentage of dip at proper loading is specified as ~10%. Therefore, for cases where the DC input power capability is considerably less than when new and properly adjusted, as an alternative to the directions to tune-up to a specific cathode current level is to:

- *Follow preliminary tune-up steps as outlined above or in the manual.*
- *Under full carrier tune-up conditions (mode switch in TUNE with CAR BAL full cw or ccw, if required) alternately adjust the PLATE and LOAD controls such that the depth of the cathode current dip is about 10% of its off-resonant value, rather than at a specific numeric value.* If your transmitter shows a cathode current of say 400 mA when the PLATE control is rotated off-resonance, then the current in the dip should be about 360 mA. Do not be too concerned with precisely adjusting to the desired value. Unfortunately, there is no magic dip percentage that indicates exactly when it is optimally tuned for maximum power and efficiency. Recall that depending on the neutralization adjustment, the cathode current dip will rarely coincide with the actual maximum RF power output point, so it is at best just an approximation anyway.

6.4.3. Keyed CW Tuning

When using the TUNE switch, most users leave the transmitter activated while they alternately load and dip – if one limits tune-up time to 5 seconds at most, this becomes problematic because of the wear and tear on the switch. By using the CW mode with a key, the transmitter can be keyed on for very short durations while tuning adjustment are made. With a little practice, it is possible to complete the entire tuning process for maximum power with as little as 5 or 10 seconds total transmit time!

The TUNE position in many models apply only full carrier while the CW approach permits initial lower carrier drive levels (for transmitters with variable carrier insertion via the CAR BAL control). In cases where a user has difficulty in rapidly tuning under full carrier conditions, initially tuning at low carrier levels protects somewhat against high cathode current conditions while searching for the proper PLATE and LOAD positions.

It is interesting to note that the procedure of initially tuning under a lower carrier level condition is basically the one recommended by Swan after they had routinely made the variable carrier adjustment modifications to 350s that were returned to the factory for a variety of upgrades in the 1960s. This modification was made not to provide a different tune-up methodology (which is basically the one outlined below, less the key), but so that during CW operations the output level could be decreased a little to help solve a spurious radiation problem in the model 350 and 400 transceivers when operated in the lower portion of the 15 meter band at full CW output.

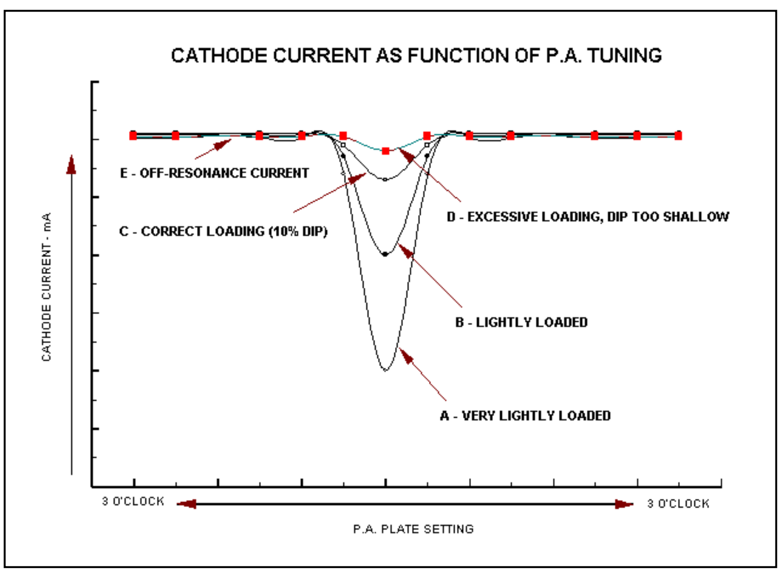


Figure 6-12 PA Cathode Current As Function of PA Loading

- *Follow preliminary tune-up steps as outlined above or in the manual. Use a wattmeter if possible.*
- *It desired, you can also perform the GRID peaking step while in the CW mode, rather than keying the microphone as outlined in the preliminary tune-up steps. After initially keying and nulling the CAR BAL, simply insert a little carrier so that a small increase in cathode current is seen on the meter and peak the GRID control (as you would do if you were keying the microphone and inserting a little carrier and keying the microphone as when following the Operation Manual's instructions).*
- *Place the transmitter in the CW mode. Key the transmitter momentarily, adjusting the CAR BAL to obtain ~150-mA cathode current. Dip the PLATE and adjust the LOAD to approximately resonate the π network for this CW insertion level*. Release the key as required to minimize transmit time while loading to near the maximum power control positions. There is no need to adjust the controls for the exact settings for maximum power at this intermediate carrier insertion level, since the π network will not be properly adjusted for full carrier signal conditions anyway.
- *Rotate CAL BAL to full cc or ccw of obtain full carrier and quickly touch-up the PLATE and LOAD to maximum RF output*. Even during the final adjustment for maximum power, do not be overly concerned with getting the exact maximum power control positions; pretty close is good enough. In some transmitters the CW drive level is higher than that used when in the TUNE mode (Cygnet-like models and the 240), so in those cases, you may wish to switch to the TUNE position to help prevent PA tube damage.
- *Null the CAR BAL after tuning has been completed*, otherwise a high level carrier will be transmitted during SSB operations.

6.4.4. Pre-Recorded Control Settings

This method limits the tune-up time drastically since it relies on pre-recorded control settings obtained using the standard full carrier, high power tuning. Its drawback is that one must already have preformed the tune-up procedure for each antenna system at the desired frequencies. You may even find its possible to forgo any tuning and just use the pre-recorded setting without any further tune-up, except perhaps the GRID control. Since it can be sensitive to small adjustment errors, it's prudent to do a quick re-peak of it, rather than relying solely on the recorded setting.

It's interesting to note that the 500CX "*MARS Special*" was equipped 0 to 100 labeling on the skirts of the COURSE and FINE TUNING loading controls (instead of the typical one through seven numeric or graphic "dot" labeling used on amateur models) for exactly this purpose. Military operators used the 0-100 scales to more accurately log the control positions that were determined to produce the most power on a particular frequency so they could easily reset the controls when returning to that frequency

- *Adjust the GRID, PLATE, and LOAD controls in accordance with previously recorded values.* The recorded settings will only be valid only if you are operating near the frequency at which they were initially made and only if the same antenna system is used.
- *Key the microphone, insert a little carrier with the CAR BAL, and peak the GRID.* Re-null the CAR BAL.
- *If desired, insert full carrier (TUNE or CW with CAR BAL full ccw or cw) and dip the PLATE.* The LOAD control is relatively insensitive to positional errors, so there might be no real need to re-adjust it, as the recorded setting should be very close to the correct position.

6.4.5. Low Power Tuning

This method outlines a procedure used successfully by some Swan users that quickly tunes the transceiver only at very low power levels and therefore has the benefit of diminishing the possibility of damage to the PA tubes. However even with low carrier levels, the transceiver should still not be left in transmit mode for extended times when tuning and the GRID control still must be peaked immediately.

See discussion the Tune-Up Loading and PA Efficiency Section 6.2.9. That data suggests that in general it would be unwise to use a low carrier level tune-up procedure except in special circumstances (e.g. CW operation at very low RF output levels). Low level tuning procedures are extremely unlikely to achieve the maximum power/efficiency control positions for full drive signal conditions and as such, should be used with caution, especially if the rig is used for AM or high power CW operation.

One perhaps might consider using this approach only after confirming that you can reliably obtain control settings that are consistently in close agreement with those achieved using conventional full power tuning methods. A quick comparison between the full carrier maximum power tune-up and this low power tune-up procedure on a 500CX yielded about 100-W RF output differences (~300 W versus ~200 W). This will not make a significant difference in reported signal level (remember, one S unit equals ~6 dB and the power change from 200 to 300 W is only ~1.76 dB), but, since the transmitter is operating at significantly reduced efficiency, it will be actually be much harder on the PA tubes power dissipation-wise than with full power loading.

- *First tune the GRID, PLATE and LOAD controls for maximum receive signal audio and S-meter levels.* This gets you close to the right spot.
- *With an external wattmeter in the forward power mode, turn the microphone gain all the way down, center the carrier balance, and make sure the mode selector is in SSB.*
- *Key the transmitter microphone and while watching the PA Cathode current meter, adjust the CAR BAL for a dip or minimum reading.*
- *Key the transmitter microphone. With the transmitter keyed and while watching the wattmeter, rotate the CAR BAL control a slight bit off center to obtain a couple of watts of output.*
- *At this point first peak the GRID, then the PA PLATE and LOAD for maximum power out.* You can watch the cathode current meter for a dip while tuning the PA PLATE but an external wattmeter is faster and more accurate.
- *Once peaked, reduce the power by turning the carrier CAR BAL control back to the center for minimum carrier output.* Just remember, even at this low power level, do not key the transmitter up for longer than necessary to tune (usually 10-15 seconds is all you need).

6.4.6. Tuning With An External Tuner (#1)

In these days of solid-state no-tune transceivers and automatic antenna tuners, use of an external tuner with a tube-design Swan radio at first may seem daunting, but it's relatively straightforward. One suggested procedure is to:

- *Use a wattmeter if possible. Follow preliminary tune-up steps as outlined above (Section 6.4) or in the manual. Load the radio into a dummy load to the maximum power and efficiency point.* After loading into the dummy load, the GRID, PA PLATE, and PA Load are adjusted for a 50-Ω load, the design load impedance at which best power transfer between the transmitter and load occurs.
- *Switch the transceiver's RF output to the tuner/antenna and adjust the tuner controls for minimum SWR using severely reduced transmitter power (a small amount of carrier insertion with the CAR BAL control).* Just adjust the tuner for minimum SWR with no adjustment of the transceiver's controls. Any lower power level will do, as it is just used to get the tuner adjusted near their correct settings. A SWR meter placed between the transceiver and tuner should read 1:1, a meter placed between the tuner and antenna should read whatever SWR is a result of the resistive portion of the antenna system's load.
- *Increase the transmitter to full RF output (CAR BAL full cw or ccw) and merely touch up the transmitter's PLATE and LOAD controls for maximum output.* This should only take a couple seconds. Record the tuner and transmitter control positions settings for future reference during tune-up.

6.4.7. Tuning With An External Tuner (#2)

This method is a drastic modification to the conventional approach described above. Its benefit is that it will limit potential damage to the PA tubes during tune-up because of its brevity. The downside is that the true peak power point will not be obtained, since the initial receiver noise level adjustment is relatively insensitive to small changes to the PA LOAD position settings and to a lesser extent PLATE and GRID control positions.

However, because of the sensitivity of RF output level to exact GRID position, it would probably be highly desirable to also include step 4 of the preliminary tune-up steps described in Section 6.4. Because of efficiency and power dissipation concerns, this method should be used with caution, especially if either AM or full output CW operations are to be used. It might be a good idea to test a number of other tune-up methodologies for comparison to evaluate its effectiveness (RF power output, efficiency, etc.). See related discussion on tuner usage in the Using an External Antenna Tuner Section 6.3.6.

- *Tune for maximum background noise on receive only (Preliminary Tune-Up Section 6.4, Step 1). Don't touch the function switch (i.e. TUNE or TRANS). Slowly go back and forth to achieve maximum background noise using the PA GRID, PA PLATE, COURSE LOAD, and FINE LOAD controls to achieve the highest background noise.* When you are at maximum static/background noise on receive, you are pretty close to being tuned to that particular frequency in the transmit mode without putting any additional power dissipation burden on the PA tube(s).

- *Adjust the tuner also for the maximum background noise.* This will not be exact, but somewhat close for start-up.

- *Very quickly switch the function switch to TUNE and just adjust the PLATE control for maximum RF output.* Don't follow the instruction manual sequence (LOAD and PLATE) of tuning for a cathode current dip (or RF output power peak). While many may disagree with this procedure, it should save the tubes by not requiring them to dissipate a lot of heat by keeping the tune procedure as short as possible. It's important not to stay in the tune position too long, for this will quickly flatten your PA tubes. Use a short 5-10 second time frame to go through the above procedure, but pay close attention to the RF output meter.

- *Finally, go back and touch-up the antenna tuner and adjust to achieve the lowest possible SWR.* Only a very minor adjustment should be needed here or there for maximum output in the TUNE mode. Tube sets can withstand a much higher SWR than a solid-state final, but you still should keep it as low as possible to avoid damage to the final tubes.

7. ALIGNMENT

Performing a transceiver alignment for the first time as described in the Swan manuals can indeed be a daunting experience, to say the least. Not only are you required to measure internal voltages and adjust a number of coil slugs and trimmer capacitors, but in some cases unsoldering of the PA tube screen voltage is specified – quite an intimidating task for a neophyte! The process is even further exacerbated in some cases by manuals whose instructions are ambiguous or incomplete (e.g. missing GRID control positions). In some cases, the procedures include steps that are not really required unless the transceiver is woefully misadjusted, such as resetting of PA tube neutralizing capacitor and adjustment of the carrier oscillator trimmer capacitor as part of the mixer and driver alignment (e.g. 240 manual).

7.1. General Comments

If you are just doing normal every-day routine maintenance, alignment of all circuits need not necessarily be done. For example, if a receiver audio distortion problem is suspected to be caused by carrier oscillator maladjustment, you may try alignment of just that circuit. Likewise, with the installation of new PA tubes, only the neutralization might be performed (although driver alignment should also be done). If a new driver tube in installed, only that circuit alignment might be done, although since the mixer and driver are simultaneously adjusted via the GRID control and the alignment procedures treat them as an integrated unit, its probably a good idea to do both. Note that in most alignment procedures, the band sequence in which the alignment is performed is important; so review the manual directions for guidance.

Neutralization Considerations. The Pre Alignment Conditions section of many transceiver manuals implies that the neutralization capacitor should be adjusted to a nominal mid-range position prior to the start of alignment. This is typically not required unless the transceiver is undergoing its very first alignment after assembly or new PA tubes have been installed and it's immediately going into parasitic and/or self-oscillation.

Voltage Measurements. If you are adjusting a voltage level for a maximum or minimum reading during alignment, a VOM is fine. If you to adjust something to a specific voltage, then use what Swan used, a VTVM or a modern digital voltmeter (DVM). Although, forget about using a DVM for peaking and nulling, unless it has an ancillary analog bar graph display. The visual effect of a pointer movement is essential for those adjustments.

Meter Orientation. The transceiver's cathode current meter can give somewhat different readings when physically oriented in other than its normal operation position. Thus, if the transceiver is placed on its side, the current reading may be off (i.e. a reading of 50 mA may in fact be 30 or perhaps 80 mA or more). Observed effects of transceiver orientation showed significant error in one radio but only minimal effect in another case, so it may be meter specific. Since some alignment procedures may be performed with the transceiver on its side under moderate PA cathode current conditions, check meter behavior with change of orientation and compensate as required to ensure that excessive current is not inadvertently used.

Trimmer Capacitor and Slug Positions. If you are doing an alignment for the very first time, it is wise to carefully note the position of the trimmer capacitor(s) and coil slug(s) prior to adjustment. Doing so will provide a safety net against making errors in procedure (e.g. adjusting the wrong slug) until you gain confidence and experience. Either mark the capacitor/coil form or carefully note the amount of adjustment made relative to its initial setting (e.g. 45 degrees ccw). While the adjustment sensitivity on some controls is such that even if it's returned to what appears to be the exact initial reference point, the adjusted parameter will not be the same, but at least it will be close.

When making the adjustments, carefully observe cause and effect – rarely on a known working radio should significant changes be required. If you're twisting away and nothing is happening, pause and recheck everything, making absolutely sure you are adjusting the correct control. Only if the control has been totally misadjusted in the past should multi-turn changes be required.

Coil and Transformer Slug Adjustment. Consider purchasing multiple alignment tools of the same size so that one can be inserted in all transformer or coil slugs requiring adjustment at a specific frequency band. Doing so will permit the correct coils to be carefully identified prior to adjustment of a mixer and driver coil set, preventing inadvertent adjustment of the wrong coil as you sequentially align multiple slugs at one frequency – especially if you go back to re-peak the slugs.

Coil Slugs (Frozen/Broken). In the event that during adjustment a coil slug is frozen in place or physically damaged (cracked or damaged slot), application of a single drop of dishwashing detergent (allowed to soak in overnight) may provide sufficient lubrication to permit adjustment or removal. If that doesn't work and the slug is hopelessly frozen or damaged, the only alternative, other than outright replacement of the entire coil assembly, is to carefully drill out the coil slug using successively larger drill bits. Extreme care is necessary to prevent either damaging the coil-form or drilling too deep and damaging the second slug, if the coil is so equipped.

7.2. Alignment Procedure (VFO Amplifier)

The VFO alignment at a mid-band frequency resonates the tuned circuit on the plate of the VFO amplifier such that it delivers maximum signal level to the control grid of the mixer tube. Once aligned at the specified frequency, its resonance bandpass is broad enough so that it also passes the entire range of main tuning VFO frequencies throughout the band with minimal signal level reduction. The use of the exact specified main tuning desire frequency is not essential, anywhere in the immediate vicinity if fine.

7.2.1. Manual VFO Procedures Overview

Single-Tube PAs. The manuals for the various Swan single-tube PA model transceivers specify at least two distinctly different VFO amplifier alignment approaches, depending on model. In all cases, alignment at a mid-band main tuning-dial frequency is specified. For some models (e.g. 120, 140, 175 early mono-band transceivers), the recommended procedure is to first connect a VTVM between pin 1 of the 12BE6 (receiver mixer) and ground. With the transceiver in the receive mode, the VFO amplifier circuit coil is then adjusted for a peak negative meter reading (the VFO signal is sent to both the transmitter and receiver mixer tubes) similar to the procedure outlined by Swan for most, if not all, dual-tube PA designs. This adjustment procedure is independent of the GRID, PLATE, or LOAD control position.

In other single-tube PA model manuals (e.g. Cygnet 260, 270, 300B, etc.), the VFO amplifier plate circuit is aligned with the transmitter operated under low power levels (microphone keyed and CAR BAL adjusted for ~60-mA cathode current), with the PLATE resonated (dipped) at light loading conditions (LOAD control rotated somewhat toward the ccw). These VFO adjustments are not broken-out as a separate subsection of the alignment process, but are treated more as an inherent part the mixer and driver alignment. As cathode current increases during alignment, the CAR BAL is re-adjusted to maintain a cathode current of less than 80 mA at all times.

Dual-Tube PAs. The Swan VFO alignment procedures for most, if not all dual-tube transceiver models specify that the adjustment be made based on the peak voltage level as measured on the control grid pin of the receiver mixer tube with a VTVM. In all cases this is done at a specified mid-band main tuning dial frequency and with the transceiver operated in the receive mode. This adjustment procedure is independent of the GRID, PLATE, or LOAD control position.

7.2.2. Alternate VFO Alignment Procedure

This methodology is basically the one outlined in the Swan Newsletter, Issue 3, Section A.3.1.1. It greatly simplifies the manual's procedure, is relatively non-evasive, and appears to be the most accurate way to align the circuit. Even better yet, it is not necessary to put the rig into the transmit mode nor is it necessary to make direct measurements of circuit voltages.

One of the problems with the manual's VFO procedure that measures the mixer tube's grid voltage with a VTVM is that it is frequently very difficult to obtain a distinct peak. Some of the circuits will not clearly peak or the maximum reading only seems to occur when the slug is totally removed from its form (especially on 40 meters). With this alternate approach, you should see a clear, nicely defined peak when the slug is well within its coil-form.

Remember, on each band to set the main tuning frequency dial to the approximate specified frequency near the middle of the band. The transceiver remains in the receive mode throughout the adjustment process.

- *Turn off transceiver, disconnect the ac, and remove the bottom cover*.
- *Clip a lead from to the insulated body (not the bare wires) of the disc capacitor that comes off pin 1 of the 12BE6 mixer (usually C-702, a 30 pf disc coupling capacitor in dual-tube PA models) and goes to the plate of the VFO amplifier tube*. Make sure the clip is properly insulated and secured to preclude accidental shorting.
- *Attach the lead to either a field strength meter or oscilloscope*. Loosely coupling to the antenna (a short antenna wire) of a general purpose receive should also work, however you will have to tune it to the proper VFO frequency, which is the main tuning dial plus or minus the approximate carrier oscillator frequency, depending on band.
- *Plug in the ac power, place the mode switch in the receive position, and turn on ac power*.
- *Select the band and main tuning dial frequency combination as listed in manual. Leave the transceiver in the receive mode*. The positions of the GRID, PLATE, and LOAD controls are irrelevant.
- *Adjust the VFO amplifier coil slug for maximum reading*. On the field strength meter, this is just the maximum signal strength. On the oscilloscope display, this will be maximum VFO signal amplitude. On a separate receiver tuned to the VFO frequency, it will be maximum S-meter amplitude, although this may be somewhat insensitive due to both the high display compression (6 dB/S unit) and the need to adjust tuning and antenna coupling to maintain mid-display meter reading, but in a pinch, it should work.
- *Repeat the above steps for each band and frequency combination listed in the manual*.

7.3. Alignment Procedure (Mixer and Driver)

The mixer and driver tuned circuits are aligned together at a specific main tuning-dial frequency and GRID control position. The GRID control simultaneously adjusts two ganged variable capacitors, aligning the mixer and driver circuits together, insuring resonance is optimized for both circuits at the same frequency. When in resonance, the mixer output provides maximum signal voltage levels to the control grid of the driver tube, which in turn provides maximum signal level to the PA tube control grid(s). The effective bandpass of each of these tuned circuits is somewhat narrower than the full amateur band and by readjusting the GRID control, the circuits are brought into resonance with little loss of signal level for other main tuning dial frequencies within the band. When properly aligned, the GRID control has a sufficient adjustment range to permit peaking the PA cathode current during tune-up throughout the entire frequency range of a particular band.

The most important front panel settings during mixer and driver alignment are the main tuning dial frequency and the GRID control position, however the exact main tuning dial frequency or precise GRID control setting is not critical. Indeed, any GRID position will do (except as noted below), providing that control maintains the ability to peak the cathode current at any frequency in the band after it has been aligned. However, for alignment procedures where the PA is active, the tank must be in resonance (usually with light loading), the GRID should be at or near resonance (peaked) and the cathode current must to closely monitored. The current must be reduced via the CAR BAL control so that it never exceeds ~80 mA (single-tube PA designs) or ~100 mA (dual-tube PA designs) for any substantial time period as the various circuits are aligned and RF output level increases accordingly (if the alternate alignment procedure is used).

7.3.1. Manual Mixer/Driver Alignment Overview

Single-Tube PAs. The manuals for most, if not all, Swan single-tube PA model transceivers (120, Cygnets, 350D, etc.) specify an alignment approach in which the mixer and driver circuits are adjusted with the PA operated at low power levels and in which the PLATE and LOAD are first adjusted to resonance, usually with light loading (LOAD control toward or at the ccw or 9:00 O'clock position). In all cases, alignment at a mid-band tuning dial frequency is specified. Then the microphone is keyed and the CAR BAL adjusted for ~60 mA of cathode current. As the mixer and driver circuit coils are adjusted and the cathode current (and RF output power) increases, the CAR BAL must be reduced to ensure that the PA cathode current is 80 mA or less at all times to avoid damage to the PA tubes. Both circuits are adjusted to maximum cathode current or maximum RF output if an external wattmeter is used.

Dual-Tube PAs. There is a potential to damage the PA tubes when alignment is performed with the transmitter's PA active, as is done with the single-tube transceiver models. For that reason, Swan probably specified a different dual-tube transceiver alignment methodology to completely avoid any possibility of damage. So, manuals for most, if not all, dual-tube PA transceiver models (e.g. 350, 400, 500CX) specify an alignment approach in which the screen voltage is physically removed from the PA tubes and maximum bias (BIAS control full ccw) is applied so that the those tubes are completely inoperative and there is no danger of PA tube damage. Since the PA is disabled, the position of the PLATE and LOAD controls is irrelevant during this procedure. A field strength meter is then loosely coupled to disc capacitor that couples the driver circuit output to the control grids of the PA tubes (C308 connected to pin 2 of V4 in the 500CX) via an alligator clip affixed to the capacitor's body and a VTVM is used to measure the voltage across the fixed resistor that supplies bias voltage to the control grid of the tubes (R401 a 1-kΩ resistor in the 500CX). Note that this voltage level is dependent on the ccw (maximum bias) position of the BIAS control.

Frequency and GRID Control Positions (350, 400). For alignment of each band's mixer and driver circuits, the main tuning dial is adjusted to a near mid-band frequency. Main tuning dial frequencies typically are: ~3,800 kHz, ~7,150 kHz, ~14,150 kHz, ~21,450 kHz, and ~29,000 kHz, although they vary somewhat depending on transceiver model. The use of the exact frequency specified is not essential.

Most manuals, with the notable exception of the 350 and 400 manuals, list specific GRID control positions in conjunction with the main tuning dial frequencies to be used during alignment. So, if you're attempting alignment on the 350 and 400 models using the manual procedure, what do you do? The specified GRID control positions for other models are all within about ±30° degrees of the 12 O'clock setting. Typically the 40 and 20-meter band settings are toward the 11 or even 10:00 O'clock position, 80 meters at 10:00 O'clock, and 15 and 10 meter bands towards the 2 or even the 2:30 O'clock position. The specified setting varies somewhat depending on transceiver model. Since the 350C and 500 models are the closest kin to the 350 and 400 models, the GRID control settings specified for those models is probably satisfactory, namely: 80 M = 12 O'clock, 40 and 20 M = 11 O'clock, 15 M = 2 O'clock, and 10 M = 2:30 O'clock. These settings are also typical for many other models.

As with the main tuning dial frequency specification, accurate GRID control positioning to the location specified in the manual for alignment is usually not critical. Given the relative crudeness of the scale and knob markings (to say nothing of the knob orientation on the shaft), one would intuitively suspect that the exact knob position specified is not necessary and that probably anything in the general area will yield satisfactory results. As discussed earlier in this section, during alignment, any GRID position will do (unless mixer and driver circuit resonance is required as part of the procedure), providing that after alignment the control maintains its ability to peak the cathode current at any frequency in the band. The manual specified adjustment position merely ensures that is the case.

Carrier Oscillator (CO) Adjustment Caveat. Some manuals for early transceiver models (e.g. 240, 400) include the adjustment of the CO trimmer capacitor as an integral component of the mixer and driver alignment, although they don't tell you that is what your are doing, they just specify the trimmer capacitor part number. The CO is then subsequently readjusted in the CO alignment section. This adjustment is not included in later model manuals as an integral part of the mixer and driver alignment. Most likely this was included in earlier procedures to protect against cases where the CO may have been badly misadjusted and only very low or near zero cathode current levels are obtained because the CO frequency is well outside of the bandpass of the IF filter.

If your receive audio is satisfactory or your carrier oscillator frequency is know to be adjusted properly based on favorable SSB audio reports, consider omitting the adjustment of the trimmer capacitor from the mixer/driver alignment section for these models, otherwise you will have to also do that adjustment procedure, even if you weren't planning to do it. An exception to this may be alignment of radios with a SS-16 intermediate frequency filter installed. In such cases, the filter slopes and CO frequency may be such that little or no carrier is produced when the CO frequency is properly adjusted, even with the CAR BAL control full cc or ccw.

7.3.2. Alternate Mixer/Driver Alignment Procedure

In the opinion of many users, the manual instructions for aligning the mixer and driver coils are fairly useless. The following procedure has been recommended and used with good results. It is similar to the one outlined in the Swan Newsletter, Issue 3, Section A.3.1.3. The major differences between this method and that specified in the manual is that the PA tube's screen voltage isn't disconnected, and an internal voltage levels and signal strengths are not used to peak the coils. Rather, the procedure is performed with the transmitter's PA active under lower power conditions and adjustments made based on maximum RF power output or cathode current level.

- *Do not disconnect the screen voltage, set the BIAS to maximum (full ccw), or use an internal VTVM voltage and signal strength meter*.
- *If possible, use a dummy load. Decrease microphone gain to minimum (full ccw)*.
- *Select the desired band and adjust the main tuning dial to the specified frequency*.
- *Set the LOAD control for somewhat light loading (towards the 9:00 O'clock position)*. Since you will only be operating at very low power levels, that setting will provide both a nice distinct tune-up dip and will be closer to the low carrier level maximum RF power output, tune-up condition than the normal LOAD control position that would be obtained during full power operations.
- *Key the microphone, insert a little carrier with the CAR BAL control, and immediately peak the GRID*. Leave the GRID in that position through the alignment procedure for that band. You will probably find that the GRID control will not be exactly at its manual specified alignment position – that should be OK. See the related discussion below.
- *Immediately resonate the PLATE (dip the cathode current)*.
- *Adjust cathode current for about 60 mA or so via the CAR BAL control*.
- *Then, peak each coil in the mixer and driver circuits for each band as specified in the manual by keying the microphone for short 5 or 10 second time periods. Adjust CAR BAL as necessary so that cathode current always remains below 100 mA so that you do not drive the tubes too hard*. The proper coil slug adjustment position for resonance will be indicated by a cathode current maximum and by an external wattmeter's RF output maximum. You may chose to alternately adjust the mixer and driver coils to confirm you have the exact peak, but this should be unnecessary as there is nil interaction between the circuits, so one adjustment does not appreciable affect the other.

Coil Slug Peaking Problems. If you turn the slug into the coil so far that it is out of range, it may tune to another band. In that case, back the coil out until it is at least flush with the coil-form opening, and start over. In the worst case scenario, with the coils apparently hopelessly maladjusted, set up another receiver nearby tuned to the transmitter's tuning dial frequency, and then peak the coil using the receiver's S meter. That will get it on the right band. Then go back to peaking as described above.

Grid Position Comments. Using the manual's mixer and driver alignment procedure with the GRID positions listed. For dual-tube PA transceivers, when using the manual's procedures there is no time requirement to quickly adjust the coil slugs for resonance at that setting, since the CAR BAL is nulled, drive levels are minimum, and the transmitter PA is disable (screen disconnected, maximum BIAS), so there is no danger of damage to these tubes.

However, with the transmitter active as outlined in this alternative procedure, using the manual specified GRID position become problematic. It is not unlikely that the GRID control position specified in the manual will not coincide with the position needed to resonate (peak) the driver when the PA is tuned-up. If one leaves the GRID control at the position specified in the manual while doing the alternate alignment procedure, then until you are able to align the mixer and driver slugs for resonance at that frequency excessive current will flow in the driver tube, risking damage to it. For this reason, the resonant GRID position is used in the alternative procedure outlined above rather than the manual's specified position. There is really no difference as to what position is used, providing that after alignment the GRID control can still peak the cathode current (resonate the mixer and driver) at all frequencies within the band.

If one were to end up in a situation where the GRID cannot be peaked at all tuning dial frequencies after alignment, or if you're just a purist and insist on aligning with the GRID in the specified position, then you have two choices. The first is to use the manual's procedure to align the mixer and driver circuits. The second is to use the alternate procedure but adjust the GRID to the manual's specified position in a number of steps such that the GRID control is always near resonance, peaking the mixer and driver coils at each step.

For example, suppose the GRID control was in resonance (peaked) at the 9:30 O'clock position and the manual specified position is 11:00 O'clock. Adjust the GRID control slightly off resonance in the direction of the specified setting (e.g. 9:45 O'clock) and quickly peak the coil slugs of the mixer and driver. Reposition the GRID again toward the desired setting so that it is slightly out of resonance (e.g. 10:00 O'clock), and again readjust the coils. Thus, the GRID control position can be walked to the manual's specified alignment specified position in a couple steps. Doing this will avoid the problem just setting the GRID to the specified position and tuning the slugs for extended time periods without the circuit being in resonance.

7.4. VFO Oscillator Adjustment

Alignment of a band's VFO oscillator trimmer capacitor is required if the DIAL SET control (which has approximately ±8 to ±12-kHz adjustment range) is unable to adjust the VFO oscillator's frequency so that the tuning dial reads accurately. Swan's alignment procedure uses the crystal calibrator's output as a reference signal to zero-beat the VFO oscillator's output against. The VFO trimmer is adjusted as the tuning dial is walked to the correct setting, with due care to adjust the VFO oscillator in small increments so as not to jump across two 100-kHz harmonics. Not mentioned in the procedure is the need to adjust the DIAL SET trimmer capacitor so that its plates are in the half-mesh position to ensure that the DIAL SET trimmer will retain the capability to vary the ±8 kHz about the alignment frequency, so that it can compensate for both positive and negative frequency errors as the VFO is tuned across the band or between bands.

If a suitable frequency counter is available, it's much easier to simply directly measure and set the VFO frequency. A simple pick-up loop near the VFO amplifier tube may yield sufficient signal level to trigger the counter. The VFO adjustment frequency is that indicated on the transceiver's tuning dial, plus or minus the carrier oscillator frequency, depending which band is selected.

Another approach to the manual's procedure is to use any state-of-the art receiver to indirectly adjust the VFO frequency by: (1) use the separate transceiver to generate a low power CW (or an unmodulated AM or FM) signal at a know frequency, (2) while listening to the beat frequency tone, walk the Swan's main tuning dial to that frequency as small adjustments are made to the VFO trimmer until the main tuning dial's frequency corresponds to the transmitter's known frequency, (3) if desired, zero-beat when near the desired frequency to obtain an accurate adjustment. If using an unmodulated AM or FM signal the receiver and transmitter frequencies will be identical to that shown on the Swan's tuning dial. If using a CW signal, by convention, the transmitted frequency will be offset from that indicated on the transmitter's display. Thus when at zero-beat using a CW signal, the transmitter's frequency will actually be ~750 Hz lower if on LSB and ~750 Hz higher if on USB, although given the scale accuracy and of the DIAL SET adjustment range, ignoring this offset should still produce satisfactory results.

7.4.1. Zero Beating

This procedure was very common in days of yore, but with the advent of state-of-the-art solid-state equipment with very stable oscillators and digital frequency displays, its usage is now less common. Zero beating merely exploits the phenomenon that occurs when any two signals are mixed (also known as heterodyning), generating a new composite signal consisting of the two fundamentals and the sum and difference frequencies (as well as a whole host of lower level harmonics), similar to what occurs in RF mixer signal generation. The fundamental signals usually consist of a known reference frequency and an un-calibrated signal. When the two signals are close together in frequency (hundreds to a few thousands of Hz apart) the sum and difference frequency component is in the audio range and very easily detectable by ear. As the two frequencies are brought closer together, the sum and difference beat frequency decreases until the point of zero-beat is reached when the two signals are identical and no audio signal is heard.

This is the same process used by Swan to adjust the tuning dial's calibration. The VFO tuning dial is positioned at the 100-kHz frequency increment of interest (using the appropriate USB or LSB dial marker) and the DIAL SET control is adjusted while the main VFO tuning remains fixed. The DIAL SET is slowly adjusted to decrease the audible tone's beat frequency until it totally disappears at zero-beat, at which point the VFO frequency is exactly on one of the 100-kHz (or 50 kHz, or 25 kHz, depending on transceiver model) harmonics generated by the calibration oscillator.

7.5. Carrier Oscillator Adjustment

The carrier oscillator (CO) trimmer capacitor adjustment on some Swan radios can be especially sensitive to very small control adjustments. When adjusting, don't be surprised if only a small fraction of a turn is required. So, while marking the original position of the slug's setting to return it to it's initial location can be useful it you haven't done this alignment before, it most likely will not get the CO back to its original frequency. If a frequency counter with the proper sensitivity is available, it can be used to measure the CO frequency directly via a simple pick-up loop, so that before and after measurements of the frequency can be made. The CO frequency should be close (couple hundred Hertz or less) to the nominal IF of the radio.

7.5.1. Alternate #1

This procedure is similar to that described in the manual, however it uses lower power levels and slightly different audio frequencies (1,400 Hz versus 1,500 Hz). In general, using a 1,400 Hz for the adjustment procedure may provide a more pleasing audio for a male voice – likewise the 1,500 Hz may provide better results for a female operator. The object of this adjustment is to position the audio sideband created in the mixing process so that the 300-Hz through 3,000-Hz (or there about) audio frequencies pass through the IF filter. When properly aligned, the 1,400-Hz audio signal is well within the filter's bandpass while the 300-Hz audio frequency (with the same input signal amplitude) is on the sharply decreasing IF skirt such that its signal power is about 1/4th of the power (6 dB down) measured at 1,400 Hz (i.e. 20-dB versus 5-dB RF output power or 40 dB versus 10 dB, since a doubling of power equals a 3 dB increase). There is nothing magic about using exactly these frequencies; anything close (i.e. within tens of Hz) is fine.

- *Using an external wattmeter, tune-up the transceiver for full power and completely null the carrier.*
- *Insert an ~1,400 Hz (or ~1,500 Hz if the primary operator is female) audio signal into the microphone input and advance the microphone gain until the RF output power is 10 to 15 W.*
- *Adjust the 1st IF transformer for maximum output, keeping output power output to 10 or 15 W by re-adjusting the microphone gain as required.*
- *Adjust the upper and lower slugs of the balanced modulator transformer for maximum RF power output.*
- *Then, with the audio frequency still at ~1,400 Hz (or ~1,500 Hz), increase the microphone gain until the RF output is 20 W, sweep the audio generator down to 300 Hz, and adjust the carrier oscillator crystal trimmer capacitor until the power output is in the 5 to 7-W range. Repeat this sequence until you obtain 20 W at 1,400 Hz and 5 to 7 W at 300 Hz without any need to adjust the trimmer capacitor.* The audio generator's output signal level must remain constant, as the signal is sweep in frequency. Even though the audio signal is constant, you may see some cyclical increase and decrease in RF output as the audio frequency is sweep down or up in frequency between 1,500 and 600 Hz or so – this is the filter's bandpass ripple and is normal and expected. When completed, recheck by sweeping the audio generator to 150 Hz to 175 Hz. When sweeping down in frequency from 300 Hz the RF output power should decrease smoothly and at ~150 Hz the RF power output reading should be nil.

7.5.2. Alternate #2

If the carrier oscillator has significant adjustment errors, the received audio will sound tinny, bassy, distorted, or Donald-Duckish no matter how the receiver is tuned and of course, QSO audio reports of your transmitted audio will likewise indicate an audio problem.

If you lack the test equipment or for some reason cannot successfully complete the normal CO adjustment procedure described above and in the manual, doing a simple quick-and-dirty aural adjustment as outlined below should get you at least in the ballpark. While it's not very scientific, it's certainly quick and easy. One caution though. It's best to try this only if you're absolutely sure the CO adjustment is the problem (e.g. if you've already fiddled with the control either intentionally or accidentally and it seems hopelessly misadjusted), otherwise you might be compounding the situation if it's really due to problem elsewhere in the signal chain.

One quick test is to tune to an AM station and listen to the sidebands with both the normal and opposite SSB switch setting. If the audio sounds normal on one but not the other, maladjustment of the one CO is suggested. If both sidebands are garbled, then either both CO frequencies have been incorrectly adjustment or there is a failure other than a simple CO frequency adjustment. Unfortunately, when using the following approach there is little hope of actually getting the proper CO frequency adjustment as specified in the manual since a aurally judging SSB audio quality is highly subjective and dependent on receiver tuning, to say nothing of audio signal processing used on the transmitting end.

- *Tune to a strong SSB signal on any band for best audio quality*.
- *Adjust the carrier frequency trimmer capacitor for a natural-sounding voice*. Note that with many users, there is a tendency to adjust the tuning so that the received audio has too much bass.
- *Carefully tune a little around the strong signal as you make very small adjustments to ensure that the VFO is not tuned off frequency*.
- *As a final check, obtain a number of critical on-air QSOs audio quality signal reports and readjust as necessary*. If you appear to have success with this method, a good experiment is to use the alternative #1 procedure to check the RF output power ratio between the 1,400-Hz (or 1,500-Hz) and 300-Hz frequencies.

7.6. Crystal Calibrator Adjustment

Many Swan manuals specify the adjustment of the 100-kHz crystal calibrator's frequency by first tuning an external receiver exactly to WWV's frequency, a known stable frequency standard that is a harmonic of 100 kHz. Then, after coupling the transceiver's calibration oscillator output via a pick-up loop around pin 1 of the RF amplifier tube (V6 in the 500CX) to the receiver's antenna, its trimmer capacitor is adjusted to a zero-beat on the receiver's signal.

At first glance, it appears that the 100-kHz oscillator signal, when mixed with 10 or 15-MHz WWV signal, would not generate any audible sum and difference signals because of grossly different calibrator and WWV's frequency. However the oscillator's signal is far from an idyllic sine wave, containing a multitude of harmonics at ~100-kHz intervals, one of which will mix with the receiver's VFO, producing the beat frequency tone.

Alternate Procedures. Swan's instructions were written in the days before highly stable and accurate digital tuning readouts were commonly available on amateur receivers. If a state-of-the-art general coverage receiver with tuning accurate to fractions of a Hertz is available, an alternate alignment procedure is to just: (1) tune the receiver directly to 100 kHz or any multiple thereof, (2) place a pick-up coil/wire around the RF amplifier tube (or calibration oscillator tube on early models) and couple it to the receiver's antenna, (3) select USB or LSB mode on the receiver, and (4) adjust the calibration oscillator's trimmer capacitor so that its signal zero beats. If no beat tone is heard because the oscillator is drastically maladjusted, just tune the receiver about the 100 kHz interval selected until the beat tone is heard and, by alternately adjusting both the receiver and the trimmer capacitor toward the 100 kHz mark in small steps, walk the signal back to the exact 100-kHz frequency increment. It is desirable to zero-beat as accurately as possible, since any error will be compounded at the 100 kHz harmonic that is used during calibration at the transmitter's operational frequency.

Alternately, a frequency counter can be used directly with a pick-up loop around the oscillator tube and the trimmer capacitor adjusted directly to 100 kHz. However, sensitivity and triggering stability maybe a problem, depending on counter design.

7.7. Neutralization

Also, see the related discussion in Section 6.2.6. In the AB_1 grid driven pentode tube PA design, no driver signal current flows in the grids of the PA tubes, since those voltage levels are never positive with respect to the cathode. The driving signal only supervises the control grid voltage, so any signal level coupled to the grid directly effects or controls the amplifier operation. The inherent fixed capacitance between the plate and grid electrodes of any amplifier tube couples or feeds-back some of the amplified high level signal at the plate back onto the control grid, which in-turn further increases the signal output at the plate, etc. in a repeating cycle. This coupling can produce a self-oscillation at or near the operational frequency, but since the coupling effect is more pronounce at higher frequencies, a parasitic oscillation at other than the desired operational frequency is more likely. If the amount of coupling is minimal, the feedback cycle quickly dies out. If the amount of coupling is sufficiently high, the signal will not die out, but rather it will rapidly increase and the amplifier goes into sustained uncontrolled high power self and/or parasitic oscillation. In a properly operating transmitter, such autonomous oscillations should never occur under any normal operational or transmitter control settings.

These oscillations can be induced by operational changes (e.g. signals applied to the grid, changes in π-network control positions, antenna load) or can even occur spontaneously as soon as the screen voltage is applied, either for specific ranges of tune-up control (GRID, PLATE, LOAD, and FINE LOAD) positions or in the worse case, regardless of some or all control positions and operational conditions. It will continue until the transmitter is unkeyed or, in some cases, until the control positions are changed. The situation is conceptually similar to the high frequency feedback squeal heard on an improperly adjusted public address amplifier system, where the audio is acoustically coupled from the speakers to the microphone, inducing a parasitic and/or self-oscillation condition.

When parasitic oscillation occurs the PA stage is essentially turned into a high power oscillator at a significantly different frequency than to that which the transmitter is tuned and whose high cathode currents can quickly damage the PA tube(s), since, under such conditions, all of the power must be dissipated as heat. When parasitic oscillations occur, while cathode current may be very high, an external wattmeter will show very little RF power output.

When self-oscillation occurs the PA stage is again essentially turned into a high power oscillator, but in this case at or near the desired operational frequency. However, the high cathode currents can still quickly damage the PA tube(s) since it is equivalent to leaving it in the TUNE mode under full power. In such cases, a sinusoidal oscillation signal will be transmitted and an external wattmeter will show appreciable RF output power readings.

To combat the parasitic oscillation problem, Swan (and other) transceivers include simple parasitic chokes in series with the PA tube plate cap, composed of a coil (typically 3 to 5 turns) wound on and connected in parallel with a low valued carbon composite resistor (typically about 50 Ω, but value is usually not critical), which serves to help damp out any parasitic oscillations (see discussion in Section 6.2.6).

However, parasitic chokes by themselves are unable to correct this problem. To primarily combat both the self-oscillation and parasitic oscillation problems, a neutralization capacitor is also included in most designs to directly couple a small sample of the output signal that has been reversed in phase (180 degrees out of phase with respect to the output signal) back to the control grid. This counter-acts the in-phase coupling due to the inter-electrode capacitance, thereby preventing run-away uncontrolled oscillation of the power amplifier.

7.7.1. Typical Neutralization Examples

When operating on any band, but especially on 10 or 15 meters, you must be certain that the PA stage is properly neutralized, particularly when loading into some antenna impedance loads (e.g. G5RV). As discussed above, any uncontrolled parasitic and/or self-oscillations that occur due to incorrect neutralization adjustment will mimic normal high power cathode current. If permitted to operate for even a relatively short time under such autonomous oscillation conditions, especially if they are parasitic, the plates will soon redden and the tube(s) will be irreparably damaged (cathode electron depletion). Unfortunately, even if you have a good set of matched PA tubes equipped with grid-lead radiators (which frequently makes it easier to neutralize, see the Screen Grid-Lead Radiator Section 8.4.6), it still may be difficult to neutralize on 10 meters (particularly the higher power transceiver models), as there are dozens of other areas that might cause problems.

Cathode Current Examples. Understanding what actually happens in the PA circuit during tuning and how it's related to the tube's neutralize is helpful. Fig. 7-1 graphically illustrates the range of typical cathode current behaviors as a function of PLATE control position. Most Swan manuals outline a neutralization check procedure with the GRID peaked, the LOAD control in the 1 position (ccw), the PLATE control positioned fully ccw, and the CAR BAL control adjusted for a 200-mA cathode (500CX). Because of this higher current level, it's best not to dawdle when doing such checks. The PLATE control is then rotated through the resonance null (dip) to the clock-wise position. Ideally, with a properly neutralized tube(s), the off-resonance cathode current will be symmetrical about the resonance dip, with the current rising smoothly on each side to a near constant (flat), 200-

mA current level at both cw and ccw PLATE control positions, as depicted in curve A. When the current dips, a corresponding marked increase in RF power output will be seen on an external wattmeter, since the circuit is then in resonance for a light loading condition.

If the PA tube(s) is in need of neutralization, when rotating the PLATE control through resonance (dip), there will be significant asymmetry between the higher cathode current off-resonance conditions at lower PLATE control versus higher PLATE control positions (or visa versa) and there may also be a pronounced peak in the cathode current in the off-resonance area, as illustrated by curve B.

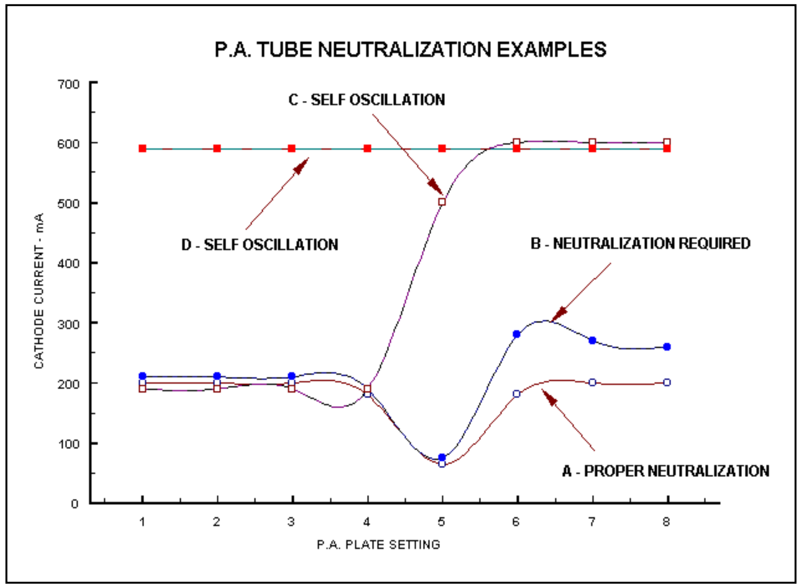


Figure 7-1 PA Cathode Current As Function of Neutralization

Unfortunately, self or parasitic oscillation is one of those problems where there is no one-size-fits-all symptom that characterizes the problem. Self oscillation behavior can appear in a number of ways, such as: (1) in one case, the PA cathode current might abruptly and dramatically rises to very high cathode current levels with a very small change in PA PLATE adjustment (curve C) in only one direction, either during the neutralization check or during normal tune-up operations, (2) under worse case conditions, the circuit might be far enough out of neutralization (particularly on 10 meters) so that the PA circuit goes into self-oscillation immediately whenever the transmitter is keyed (curve D). The cathode current need not be as high as that shown in curves C or D during self-oscillation, it most likely will be some lesser value, (3) or, more likely, you may find the problem is intermittent, dependent on band, load impedance characteristics, and transmitter control settings. All may be well when tuned-up and tested with a dummy load, but the moment a specific antenna is used (or perhaps even for a specific frequency range of a given antenna), erratic behavior occurs. For example, you might find that everything is normal only if the PLATE control is adjusted near resonance at the operational frequency under lower loading conditions. If the PLATE is rotated somewhat off resonance, or if the LOAD control is increased as part of the normal tune-up procedure the PA may again go into oscillation.

For the worse case scenario of continuous self-oscillation upon keying, see the neutralization tips discussed in the following paragraphs. It is important to understand and recognize the difference between the normal, more benign off-resonance condition that occurs on each side of the dip and the uncontrolled self-oscillating condition. Remember, if the power amplifier goes into parasitic oscillation, the cathode current will be excessively high; the CAR BAL control will have no effect when the transmitter is keyed via the microphone, and RF output power will most likely be minimal. With a properly operating transmitter, even when off resonance you should always be able to null the drive signal with the CAR BAL when in the SSB mode and the transmitter should revert to the idle condition regardless of GRID, PLATE, and LOAD control positions.

High Power Transceiver Model Neutralization. A common cause, or at least a main contributor, to neutralization problems with the higher power transceiver models (late version 500Cs, all 500CXs, and all 700CXs) is due to an excessively high screen voltage. The designed screen voltage level was increased in order to meet the advertised power claims. A common tube feature that can help alleviate neutralization problems is the GLR – tubes with that feature can be much easier to neutralize. The somewhat lower power Swan 350, 400, and 500 models did not experience the neutralization problems of later version models because the early 6HF5 tubes all contained grid lead radiators and the screen voltage was only in the 210 to 220 V range, versus the 275 V or more used in the highest power models. See the Reduced Screen Voltage modification in section 5.8.1.2.

10-Meter Issues. Most frequently, self/parasitic oscillations occur on 10 M. When such a problem occurs and the oscillation frequency is significantly different, the LOAD and PLATE controls will either have little effect or their settings at maximum power output or will be significantly different from when operating properly (in addition to most likely a high cathode current with relatively low RF output – in other words, a very low efficiency). For example, if during normal operation, you achieved high RF output power when operating on 10 M with a LOAD setting of 7, but suddenly you are getting some RF output on 10M, but only when in the LOAD setting of 1, your power most likely is going out on a different band. A good first step is to make sure you have the 10 M mixer and driver coils adjusted correctly. A good way to do this is to listen to the signal on a separate receiver to confirm an output peak is present at main dial tuning frequency (e.g. 28.5 MHz). Recall that higher loading occurs at lower capacitance. The 10-position (or 7 position, on post 350C models) load control is switching out capacitance as it is rotated clockwise. Position 10 has the lowest amount of load capacitance and, as with the other switch settings, can be further adjusted with the parallel capacitance of the FINE LOAD control.

Driver Oscillation. Note that in some cases, the same self and/or parasitic oscillation behavior can also occur in the driver tube circuit (which uses a fixed capacitance neutralization capacitor in almost all models) and it will mimic the more common PA self and/or parasitic oscillation condition since the driver's self-oscillation signals appear on the PA grid.

7.7.2. Band Tracking

One fact seldom considered is that neutralization does not track from band-to-band. When neutralization is performed on 20 meters, it may not be perfectly set for 15, 40, or 80 meters, or for that matter, even at the 20-meter band edges. This is true even for transmitters that use PA tubes designed for RF applications such as the 6146. With horizontal output (sweep) tubes, the problem is aggravated, since they were not designed to the same tolerance as RF tubes and they are operated at much higher voltages than their intended service, horizontal sweeping of television CRTs.

Neutralizing the PA stage is a compromise – when set as close as possible on 20 meters, neutralization will be off in varying degrees on 10, 15, 40, and 80 meters. Not all, but some bands might be off significantly because of tube differences as well as some circuit conditions within the transceiver. If the operating bands are primarily 40 and 80 meters, the transceiver probably should be neutralized on 40 meters. If operating primarily on 20 meters and up, it should perhaps be neutralized on 15 meters.

7.7.3. Impact of Tube Grid-Lead Radiators

The neutralizing capacitor is placed in the feedback circuit in such a manner as to apply a small sample of the opposite phased output signal back onto the control grid to counteract the influence of the driving signal that is coupled by inter-electrode capacitance from the plate to the control grid. Even with this neutralization capacitors and the parasitic choke affixed to the plate cap, some tubes will still not neutralize on 10 meters without other conditions being met. Swan had a terrible time with the 8950 tubes when trying to meet production requirements for the Swan 700CX. A good 1/3rd or more of the 8950s had to be pulled and replaced before these units could be satisfactorily neutralized on 10 meters. Seek further assistance on the Swan Reflector if you are unable to achieve proper neutralization on 10 meters (especially for the 700CX with 8950 PA tubes).

If you have neutralization problems, the first thing to do is to examine your PA tubes to make sure there is a grid-lead radiator. It is easily seen inside the top of the envelope (see Fig. 8-3 and related discussions in the Screen Grid-Lead Radiator Section 8.4.6). There has been some confusion about this component. Depending on manufacturer, this structure is about a half inch long, usually has three sides (U-shaped) but sometimes is just a pair of horizontally oriented parallel plates that sort of surrounds the wire coming from the plate cap to the plate. Internally, it is connected to the control grid. Since it is in the proximity of the plate lead carrying the same signal that is controlling the cathode current, this component has the tendency to suppress unwanted high frequency oscillations in the PA tubes (parasitic oscillations). With the high screen voltages Swan has always run to meet the power claims, the grid-lead radiator is an important deterrent to PA tube self-oscillation. Note that the coinshaped rings sometimes seen inside the tube envelopes are getters and not GLRs – they are not a detriment unless they are positioned too close to the grid-lead radiator (see Tube Issues and Problems Section 8.1.4).

7.7.4. Adjustment Comments

Neutralizing Caps, 10 M – HF Interaction. On most transceiver models, the 10-meter neutralizing capacitor is connected in series with the 80 thru 15-meter neutralizing capacitor and is only in the circuit when the band switch is in the 10-meter position. It is not used when in the lower bands. Therefore, once the 10-meter neutralization is set, the lower bands neutralization cannot be changed without disrupting 10 meters. Because of this, Swan directs that 20-meter neutralization is set first, then 10 meters.

Adjustment Hints. When neutralizing the PA tubes, if possible, use a non-conductive screwdriver to avoid any danger of shorting to the chassis and to eliminate any possible capacitance affects that can be associated with a metal screwdriver. A typical non conductive slotted alignment tool probably will not work well because of its flexibility and lack of torque/control due to its small diameter and flexibility – a larger handled, more rigid tool gives much better control when making these adjustments. A metal shaft screwdriver will usually be satisfactory, but if used, carefully wrap the shaft (leave just the metal tip exposed), with a couple layers of tape or shrink tubing to preclude any possibility of shorting to ground the ~250 V present on the neutralization capacitor. After adjustment, recheck the neutralization to confirm that the metal in the screwdriver did not appreciable affect the adjustment.

When adjusting the neutralization capacitor, the following relationship exists between capacitor adjustment and PLATE control position. If the cathode current increases when you are rotating the PLATE capacitor in the direction that increases capacitance (i.e. towards full mesh), you must decrease the capacitance of the neutralizing capacitor. If the cathode current increases when the PLATE is tuned in the direction that is reducing the tuning capacitance, the neutralizing capacitor must be increased in capacitance. This alone can save many random adjustments to any neutralization process.

Neutralizing a 500CX or 700CX models on 10 meters can be exceedingly difficult. Both the 500CX and 700CX did not have a screen grid voltage-dropping resistor in the circuit like earlier Swan radios. Without this resistor, the screen voltage soars higher in order to meet the claimed power level up (see discussion on the re-installation of the resistor in the Reduce Screen Voltage Section 5.8.1.2). This higher screen voltage is hard on tubes and adds another element to the already difficult task of neutralization on 10 meters.

7.7.5. Alternate Alignment Procedure (10 M)

Optimized Neutralization for 10 Meters. For transceivers that are intended primarily to operate on 10 meters and have been successfully neutralized to at least permit tune-up and operation on that band, Swan Newsletter 5, Section A.5.7 suggests an additional neutralization step for optimizing 10-meter operation. After tuning-up to the maximum power point on 10 meters, a readjustment of the neutralization capacitor to obtain peak RF power output is suggested. This will ensure that on 10 meters, the cathode current null will closely coincide with the maximum RF power output point. After doing this procedure, the neutralization on the other bands may be off somewhat more than if it were neutralized on the 40 or 20 M band as is normally done, which equalizes the neutralization error somewhat across the bands.

Worse Case 10-Meter Alignment and Neutralization. For extreme cases where alignment and neutralization cannot be done on 10 meters using the manual procedures because of self/parasitic oscillation, the alternate method outlined below is suggested for first getting the 10-meter mixer and driver coils into sufficient alignment prior to performing the neutralization on 10 meters. There are dozens of circuit defects that can cause unstable 10-meter operation, but let's assume your transceiver is trouble free, other than for improper alignment and neutralization adjustments.

Adjustment Procedure. The following three steps should permit neutralization to be performed on 10 meters in the majority of problem cases.

1. First, if the PA tubes do not contain a grid-lead radiator, if possible, replace them with ones that have this feature.

2. Second, realign 10 meters, but not as outlined in the manuals. Use the following procedure.
   - *Set the GRID at 11 O'clock and the VFO at 28.4 MHz.*
   - *Disconnect the ac power supply and lift the plate cap leads (first short cap to ground with an insulated screwdriver to be sure the power supply capacitors are discharged) so there is no HV on the PA tubes. Reconnect the ac power.*
   - *Tune to 28.4 MHz on a separate receiver or transceiver.*
   - *Start with the mixer and driver coil slugs slightly outside the core.*
   - *Depress the PTT or go to TRANS and rotate the CAR BAL all the way in either direction.*
   - *Then, while turning the mixer slug inward, listen for the signal on the separate receiver and peak the S meter with the signal on that receiver.*
   - *Next, go to the driver; turn the slug inward until a peak is found on the S meter of the separate receiver.*
   - *Go back to the mixer, then to the driver again to make certain you have them right on the money.*
   - *While listening to the signal, null the carrier to confirm the balanced modulator is nulling it properly.*
   - *After all that disconnect the power supply, replace the PA plate caps and reconnect the power supply.*
3. Finally, neutralize on 10 meters as discussed in the manual and below.
   - *Using a non-conductive or insulated shaft screwdriver (to prevent shorting the +250 V on the neutralization capacitor to ground), start the normal, manual outlined, neutralization process over again. Null the carrier; even if you have to go to a lower band to ensure the carrier is completely nulled, although, it should be nulled if you heard it happen on the separate receiver during the preceding test.*
   - *Depress the PTT (or TRANS) – if you see carrier on 10 meters, you must assume it is parasitic oscillations. Carefully, (watch what you are doing) adjust the 10-meter neutralizing capacitor toward the completely compressed position.* If neutralization is possible, as the coil slug goes in, the cathode current will drop to near normal (i.e. idle current). This tells you the capacitor is roughly in the right spot. If nothing happens while compressing, go the other way – the same thing is true here, if the cathode current drops off, you are in the ballpark. Use short transmit intervals.

7.7.6. Driver Tube Neutralization (240)

On the 240 transceiver, there are no instructions issued by Swan for setting the RF Driver neutralization capacitor. This adjustment was set it at the factory and they assumed no one would ever have to change it. Many owners have trashed their 240 after that trimmer was intentionally or inadvertently adjusted, because they did not know its purpose. Once out of adjustment and in self or parasitic oscillation, the driver's output appears on the control grid of the PA tube, mimicking an oscillation problem in the PA due to improper neutralization. Of course, any attempts to correct the perceived PA neutralization problem will be unsuccessful and will only make matters worse! There are several ways to set the drive neutralization. As outlined below, the easiest is to treat it just like the PA circuit.

- *Tune the unit for full power; then, go to either the TRANS position or depress the microphone PTT.*
- *Next, un-null the carrier slightly – just enough to see power on the lowest scale of a wattmeter.*
- *Place a VTVM probe at the driver cathode and observe the cathode voltage. As you rotate the exciter (GRID) control back and forth, a noticeable dip in the voltage should be apparent. The dip in voltage is the same as a dip in cathode current for the driver.* The voltage measured is the voltage drop across the cathode resistor, so it will be a low voltage. By also observing the output of the PA you will be able to compare the dip at the driver cathode with the increase in power output.
- *Adjust the driver neutralization trimmer so that the driver's cathode dip coincides with the peak output power.*

7.7.7. Driver Neutralization, 5-Band Models

For transceiver models produced after the 240, the RF driver (6GK6) stage uses a fixed neutralization capacitor and there is no cathode resistor. Thus, there will be no voltage indication at the cathode to use for measuring the cathode current as described in the above paragraph for the Swan 240. For testing/adjustment purposes, a 4.7-Ω resistor can be placed between the cathode and ground, either temporarily or permanently.

The 5-band transceiver models introduced after the Model 240 use a fixed 3.3-pF neutralization capacitor. It was found, after testing hundreds of 6GK6 pentodes under the operating voltages used by Swan for RF driver circuit, that the 6GK6s consistently required between 2.8 to 3.7 pF for neutralization. Therefore, a standard 3.3-pF feedback capacitor was selected for that circuit. Although the state of RF Driver neutralization can be determined, with this fixed capacitor there is no easy adjustment. If RF Driver neutralization does become a factor in causing unwanted oscillations, merely changing the 6GK6 will frequently solve the problem.

7.8. Filter Trap Alignment, 5,175 kHz and 13 MHz

Both the 350 and 400 models use the same 5,175-kHz and 13-MHz filter trap designs as part of the receiver RF amplifier input circuit. While the manual for the model 350 contains alignment instructions for both traps, the 400 manual only addresses the 5,175-kHz trap adjustment.

5,175 kHz Filter Trap Alignment Comments. Alignment instructions for the 5,175-kHz trap require the adjustment of L602. Unfortunately, the chassis labeling of that coil and the 13-MHz coils (L603/L604) is a bit confusing. The two 13-MHz trap coils are on the bottom and the 5.175-MHz IF trap coil is mounted on top of the chassis.

13 MHz Filter Trap Alignment Comments. The 13 MHz trap system uses a pair of LC tuned circuits. The parallel combination of L604 and C606 is really the trap for 13 MHz – it is in series with the incoming signal and grid of the RF Amplifier. Even though that trap is pretty good, there is a little residual signal energy that gets by to the grid because it needs to be sort of broadband and doesn't zero in on a very narrow frequency segment at 13 MHz. Therefore, a second resonant circuit made up of L603 and C605 is included in the circuit. It's not really a trap at 13 MHz, but rather at that frequency it functions as a low impedance signal path that channels any residual 13-MHz signals reaching the grid of V6 to ground.

The model 350 manual provides the following alignment procedure. "*Tune VFO to 14,325 kHz, insert RF signal to antenna at 13,000 kHz and tune RF generator for beat signal in speaker. Adjust L603 and L604 for minimum beat signal*."

8. SWAN TUBE INFORMATION

8.1. General Tube Information

8.1.1. Tube Replacement

This is one case where the adage "*if it isn't broke, don't fix it*" applies. Think twice before doing a total re-tubing of your Swan transceiver. There are many reported cases of tubes (including the PA tubes) that have been installed in a rig and used not only for years, but for decades. If you replace too many tubes at once, good tubes with years of service will be needlessly replaced and full alignment work will likely be required if the mixer, driver, and PA tubes are all changed. This restrained approach to tube-replacement is further affirmed by guidance Tektronix reportedly provided to repair technicians that advised them not to replace tubes just because they test weak, but rather to only replace tubes that prevent a oscilloscope from meeting its alignment specifications.

In general, those tubes in the AF section typically work or they don't – the same with the voltage regulator (e.g. 0A2). If the received signals sound good and you are getting good audio reports then both the receive and transmit audio chains are most likely operating properly. If the carrier balance control is way off vertical (approximately centered) when the carrier is nulled, first try a spare modulator tube (7360/6JH8) to see if that corrects the problem. However, the most likely cause of this problem is not the tube, but a change of value in one or both of the 100-kΩ, ½-W resistors in the balanced modulator circuit, a very common occurrence.

Where one may get some receiver performance increase is by replacing a weaker tube in the receiver RF and IF amplifiers. Another area where a distinct transmitter performance improvement can be achieved is with the PA driver tube. It is worked pretty hard and the transceiver output power may be increased with a new one. The AF output tube is the same tube type as the driver so they can be swapped to see the effect on power, but remember that the driver circuit should be aligned if that tube is changed. Be sure to check that pin 6 is not internally connected to any other pin (see the discussion in the 6GK6 Section 8.6.5).

8.1.2. Flat or Soft Tubes

The ability of a tube to achieve and maintain its designed power and performance capabilities is highly dependent on the cathode's ability to produce the required electron flow. The cathode is generally indirectly heated by the filament and produces a current flow through thermionic emission (generation of free electrons on the surface of a material through heating).

Depending on tube type and intended operational voltages, the cathode is usually made of tungsten that has been treated with thorium (thoriated tungsten) or a nickel alloy that has been coated with a metal oxide (barium or strontium carbonates, etc.). When initially heated to a very high temperature during manufacture, the thorium or metal oxide forms a very thin layer of metal on the cathode surface that has a much lower electron affinity than the pure cathode metal, and hence a much greater ability to produce free electrons when heated. As the temperature is increased, the cathode's ability to emit electrons increases proportionately. The maximum current that a tube is capable of producing is limited by cathode electron emission, however the amount of current is also controlled by the operational voltage levels (i.e. plate, grid, screen, etc.) applied to the tube elements.

When in operation, oxidation and bombardment of the cathode coating by positive ions (due to gas molecules released from the tube elements or envelope during normal operation) tend to remove the thin surface coating of metal on the cathode, thereby progressively decreasing electron emission capability during the tube's life. Normal operational heating and hot spots that naturally occur at the points on the cathode structure achieving maximum current flow have a tendency to increase the rate of ion bombardment by out-gassing of impurities trapped in the tube's internal structures and by evaporation/oxidation of the cathode coating material. If a tube reaches excessive operational temperatures (i.e. exceeds its power dissipation rating), all the effects cited above will be greatly accelerated, and indeed the tube may be irreparably damaged after only a short period of operation where maximum power dissipation has been exceeded and cathode/plate temperatures have been allowed to build up to excessive levels.

Tubes that have suffered significant removal of the cathode surface coating lose their ability to produce electrons, or have electron depletion. However it must be recognized that such decreases in power can also be associated with other tubes or circuit components that directly control the PA output (screen and plate voltage, driver and mixer tubes, etc.), so if new or substituted PA tubes exhibit the same behavior, other causes should be examined before proclaiming the PA tubes bad. When a PA tube does have this problem, it is frequently referred to as a flat or soft tube. Such tubes can no longer achieve their fundamental designed maximum power output capability and under stress (higher heat/current conditions) will frequently exhibit a progressive decrease in power capability as the duty cycle increases. That is, a new PA tubes may produce a steady-state 300-W RF power output when keyed for say, a 10 second interval (after properly tuning for maximum power of course), but when soft, it may initially produce a maximum of 150 W, decrease to 140 W after 3 seconds of steady-state operation, 130 W after 6 seconds, and 120 W or less after 10 seconds, etc.

8.1.3. Tube Tester Measurements

Testing/Tube Production Variability. Tubes are produced to perform to a physical and electronic performance specification range for each tube type. However, it should not be assumed that all tubes of the same type are created equal and perform exactly the same, since they are mass-produced and vary significantly within the technical specification tolerance. Hence, the use of "weak," "good," "100%," and other such measurement ranges or thresholds used in tube testers. The variability of such tube tester measurements for new tubes of the same type from the same manufacturer is clearly illustrated by the data shown in Fig. 8-1.

No tube tester will provide a definitive indication of whether a tube is good or bad – some tubes that measure as "good" may fail to satisfactorily work in a given circuit, while other tubes that measure as "bad" will still function properly. As stated in the *RCA Receiving Tube Manual, Technical Series RC-21 (1961)*, "*A tube-testing device can only indicate the difference between a given tube's characteristics and those which are standard for that particular type. Since the operating conditions imposed upon a tube of a given type may vary within wide limits, it is impossible for a tube-testing device to evaluate tubes in terms of performance capabilities for all applications. The tube tester, therefore, cannot be looked upon as a final authority in determining whether or not a tube is always satisfactory. Actual operating test in the equipment in which the tube is to be used will give the best possible indication of a tube's worth.*"

Filament Voltage Adjustment. Bear in mind that most tube testers have some method, usually a rheostat that varies line voltage, that permits each tube to be normalized to a zero scale setting. While this permits all tubes' electronic performance to be reference to the same operation condition, it also has a tendency to conceal some differences between tubes. For example, if two sweep tubes of the same type are tested, one might require a 6.1-V filament level to normalize the scale setting to zero and the 2nd requiring a 6.7-V filament level. While both may test as good with identical readings, when powered with the same filament voltage, there most likely will be significant differences in idle current, amplification performance, and other factors between the two for a given set of operational voltages. In many circuits that use a single tube independently, such differences are irrelevant, but when used in a parallel tube configured PA, as in the Swan dual-tube models, the tubes will not be matched and one will be doing most of the work, including heat dissipation.

Tube Structure Variations. Tubes of the same type from the same manufacturer can even have physically different internal structures and may even have slight differences in pin-out assignments that can cause problems in some circuits (see discussion on the 6GK6 pin 6 connections in Section 8.6.5). Indeed, it was common practice for manufacturers to buy and re-label tubes from their competitors, so two tubes with the same brand name could have been fabricated by two different manufacturers. Some tubes can test good but still fail to function properly in a specific electrical circuit; conversely known bad tubes can perform well. To complicate matters, tubes that initially test as good may have temperature or voltage/current related changes (e.g. internal shorts, gassy) that vary the performance as a function of time, load, voltage levels, etc.

Tube Tester Types. Faced with such tube idiosyncrasies, it's still highly desirable to have a tube tester as a simple means to evaluate a tube external to the circuit in question to identify potentially bad tubes. While swapping tubes is an alternative, frequently the condition of the spare is also unknown. Tube testers come in essentially two flavors, the more common (and cheaper) emissions type tester, and the more desirable (and much more expensive) dynamic mutual trans-conductance type tube testers. Both types usually provide an indication of potential shorts and gassy tubes in addition to an estimate of electronic performance. Many tube testers (e.g.

B&K 700 series) also have a “life test” where the filament voltage is reduce by some amount. If the tube is new and/or in excellent condition, emissions reading decrease very little during the life test. If the tube is marginal, emission fall-off significantly. This shows only that the tube is in trouble at a reduced voltage, but can still (for a time) perform satisfactory at the rated filament voltage.

Emission Testers. The emissions type tube-testers apply only low operational voltages and estimates a tube’s condition based on its electron emission capability, a measure more applicable to tubes used in rectifier applications. Having sweep tubes with identical emissions reading does not mean they are a matched set for Swan dual-dual PA applications, since tube testers normalize the performance by adjusting the filament voltage and also because the actual cathode current is a function of circuit operational voltages.

Dynamic Mutual G_m. The dynamic mutual trans-conductance type tester measures trans-conductance (G_m) under higher/additional operation voltages (e.g. either a dc or an ac voltage on the grid). Since the G_m is proportional to gain, it provides a measure of performance more applicable to tubes used in amplifier applications. There of are two basic designs used for this tube-tester type, one applies only a dc voltage to the control grid and a second that applies an ac voltage during measurement. However as with the emissions type tester, a “good” reading by itself still does not provide conclusive information on cathode current matching, a key requirement for matched tubes used in Swan power amplifiers (although some tube equipment users have reported success in matching PA tubes based solely on identical G_m readings).

Calibration and Usage. Therefore, the major benefit of a tube tester is only its ability to identify obviously bad tubes and at a minimum, obtain a quantitative estimate of a tube’s usability. Good indicators of new matched PA tubes are those that test good for emissions and have similar idle cathodes when installed in the transmitter. Tubes that test as similar in G_m and also have similar idle currents are guaranteed to be matched, since both tubes will equally share the workload at all current (power) levels.

There are many tube tester brands available, but bear in mind that these testers are 35-40 years old and the component values have changed, making their quantitative measurements questionable, unless re-calibrated. Most users don’t consider this factor and are misled by measured results. Even later solid-state models will measure good tubes as weak and weak tubes as good unless they are properly calibrated. For example, reported measurements of new 6HF5 tubes on a properly calibrated B&K 747 tube tester typically read 105-115%. Measurement of the same tubes on a second 747 tube tester gave reading of ~65% (weak) before it was calibration and 105% and after calibration. Therefore, the moral of the story is that the tester should be calibrated or the user should have experience with known good tube readings as a reference to properly assess a tube’s usability.

When using a tube tester, be sure to allow sufficient time for a tube to completely warm-up – at least 3 minutes and perhaps 5 minutes is best, particularly with the PA tubes. When doing the condition test (electronics emissions, etc.), be sure to hold the test button/switch in place for a few seconds and observe meter behavior. It should remain stable. If the reading varies or decreases with time, there might well be tube problems, even if it otherwise tests good.

Chart Settings. Since many tube testers will not have up-to-date or complete charts, the settings for a specific tube may not be listed. For those tubes not listed, use the switch settings for a recommended substitute tube (e.g. use 6JE6C settings for the 6MJ6 or 6LQ6; use the 6LF6, 6LB6, or 6JS6 settings with a 12.6-V filament setting for an 8950), or use the settings for the same type that has different filament voltages (e.g. use 6BZ6 a 12BZ6, but with a 12.6-V filament). This should give a good indication of tube condition.

Internal Shorts. Internal shorts, as indicated by tube testers, need not necessarily be low resistance, but may be on the order of thousands of ohms (and may likely be temperature dependent). However, such tubes with higher resistance shorts may still perform satisfactory even though a tube tester indicates a short. Remember to allow the tube to fully come-up to its operational temperature and to tape the envelope gently as it is being tested for shorts.

Tube Performance Variability. Recognize that with any tube tester a variation in measurements for NOS tubes of the same type from the same manufacturer is both normal and expected due to tube-to-tube electronic performance and, to a much, much lesser extent, tube tester adjustment and measurement errors. Repeated measurements on a specific tube with the same tube tester settings and adjustments should be repeatable with excellent consistency. This tube electronic performance variability can make it difficult to determine weather a particular tube is indeed new or used. See also the related discussions in this section and characteristic curve measurements in the Power Amplifier Tube Replacement and Matching Section 8.5.

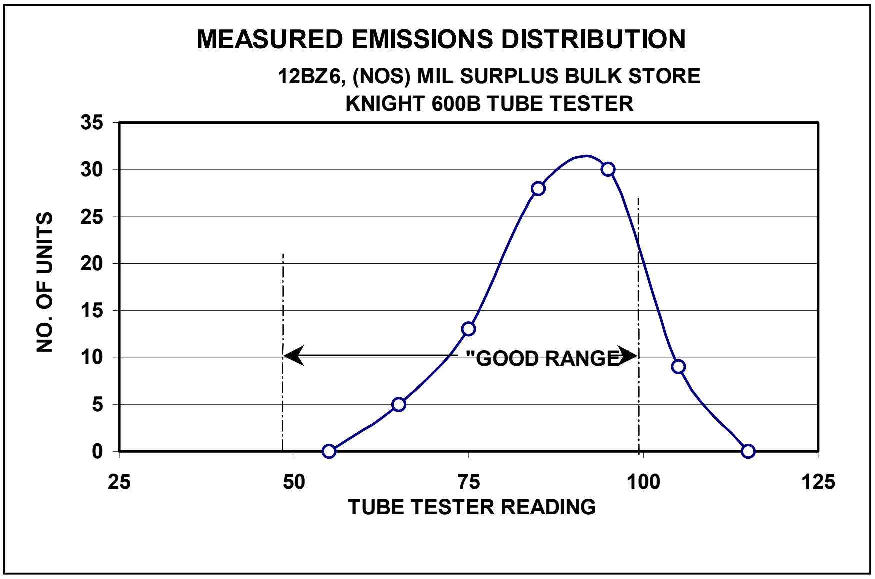


Figure 8-1 Measured NOS Electron Tube Emission Variability

Fig. 8-1 clearly illustrates the dilemma of relying solely on emission type tube tester measurements to determine a tube's condition or to determine matching. That figure shows emission measurements made on 80+ NOS 12BZ6 tubes from bulk stores military surplus. The Knight 600B emissions type tube tester used for the measurements indicates that tubes with emission readings between 50 and 100 are good. The measurement distribution curve shown is similar to the normal bell shaped curve commonly found in nature when making numerous measurements of "identical" products or similar samples. While all tubes tested good, five tubes yielded emissions readings of only 65 or less, which, in the absence of any other information, may suggest that the tube were used. However, in this test case, where the physical condition of all tubes is consistent with NOS and they are from the same source, every one of these tubes would most likely provide satisfactory performance over many years. Thus, it is important to utilize both measured information along with physical condition when evaluating a tube's status as new or used.

8.1.4. Comments, Issues, and Problems

Getters. Any molecules of air or gas of any kind left inside a vacuum tube after it has been evacuated will interfere with the free movement of electrons from the cathode to the anode or any other element in the tube. The manufacturer exhausts most all the gas by mechanical pumping and then seals the outer glass or metal envelope. Inside are all the elements of the tube plus an internal structure called a getter, made of, or coated with a chemically active metal, such as barium, magnesium, strontium, barium, barium berylliate, zirconium, phosphorus etc. or various mixtures of these.

The getter may be as simple as a small button or can be more complex, such as a vertical or horizontal ring-like structure, similar to that shown in Fig. 8-2. The getter is initially heated to a high temperature and the chemically active metal is vaporized or "flashed" using magnetic induction or high voltages applied to the tube elements during manufacture. The vaporized material combines chemically with any molecules of gas that are released by the heating of the metal elements or that are still in the sealed tube, depositing part of itself in combination with the gas molecules on the inside of the envelope. From the outside, this deposit usually appears as either a mirror-like or a darkened circular area. Since this deposit appears directly adjacent to the getter, frequently the getter structure is partially or totally obscured. The getters are positioned such that the vapor condenses in a part of the tube where it will not cause electrical leakage or other undesirable electronic effects.

Most getters are also apparently designed to continuously remove gas as they are heated during normal operation (called keepers in the early days), which in effect maintains a vacuum during the operational life of the tube – it is likely that most tubes function in this manner.

Figure 8-2 Getter Placement Example (6MJ6)

Do not confuse the getter with the control grid-lead radiator (GLR, see discussion in Section 8.4.6), which is a vertically oriented U type or parallel plate structure in the uppermost part of the envelope, included in some tube designs, that is connected to the control grid and surrounds the plate lead from the tube cap. The getters may be placed at various locations within the tube envelope, including in the upper part of the tube – its configuration, orientation, and position is variable. Fig. 8-2, a close up photograph of the top section of a 6MJ6 sweep tube (Radio Shack Realistic brand), shows an example of this structure. Also visible is a heavy gauge dogleg wire connecting the tube cap to the plate. Located just to the immediate right is the horizontally oriented halo-like getter structure with the deposits on the tube envelope directly above, obscuring visibility from the top and right-hand side. This tube does not contain a GLR. A quick comparison of this getter with grid-lead radiators examples depicted in Fig. 8-3 shows easily recognizable differences between the two structures.

Gassy Tubes. If gas gets inside the tube, either from minute amounts of leakage though the glass or pin/glass interface or emissions from the internal structures, and is not able to be removed by the getter, a tube can become gassy. Under such conditions, the tube may glow with a white/blue colored haze of low brightness, usually inside the anode. It is generally only visible when looking down from the top and only in a dark room – it appears as a uniform cloud. When this occurs, the tube is gassy and the electrons going from the cathode to the anode are hitting gas molecules, ionizing them – the recombination of the ions and electrons produce the glow effects. Since the gas ions are much heavier than the electrons, they strike the cathode with a considerable amount of energy, causing both premature cathode wear and secondary electron emissions that can cause erratic tube performance (varying bias currents, signal distortions, increasing plate currents when under load, etc.). This phenomenon is distinctly different from the benign fluorescence glow discussed below.

Fluorescence Glow. A tube that is free of contaminant gas typically has no color during operation, aside from the filament and perhaps of reddening of the plates for power amplifier tubes under high load, except for cases where there is a fluorescence glow occurring. In such cases, a purple-blue (violet) glow is visible on the outside of the anode, on the glass surface inside the envelope, and as spots on other parts inside the tube. This most commonly occurs in power amplifier tubes due to electron bombardment on the glass taking place within the tube – it has no negative effect upon the performance. In fact, tubes displaying this phenomenon are not gassy but rather are particularly good with respect to having a high vacuum. Tubes that exhibit this florescence glow condition are not bad. PA tubes that exhibit other gassy-type glows are going bad or bad and should be replaced.

Regulator Tube Glow/Haze. Some tubes, such as voltage regulator and voltage reference tubes, produce a glow that is associated with its normal operation. In such cases, this glow should be clearly evident and is an indication of proper operation. Depending on the gas used in the tube, the glow may be blue (argon), pink-orange (neon), or blue-violet (mercury vapor).

Tube Burn-In. Some users recommend that NOS power amplifier tubes that are installed in a radio be burned in for 6 to as much as 12 hours (depending on age) prior to the application of RF drive. The rational for doing so is to permit the filament heating to activate the getter and remove any trace gases that have collected in the envelope over time. Another burn-in reason cited is to permit the cathode's emission capability to build up somewhat – while a new tube may maintain the required specification emissions capability over 10,000 hours of more of continuous filament operation (with between perhaps 12,000 to 24,000 hours of actual useful life), it does not reach its peak emission capability until after about a hundred hours of use. After that peak is attained, the emission capability slowly decreases during its life until electron depletion reaches a point where the tube's operation becomes erratic or no longer functions.

Power-on Current Surge. There is no need to limit the initial current inrush to the filament circuit, as tube filament failure, including PA tubes, is almost nonexistent in Swans. However, if one wished to mitigate the initial current and voltage inrush a bit, a quick and easy solution is to installing an inrush current limiter (a negative temperature coefficient (NTC) thermistor) in series with the 120-V ac hot line to the power supply. See Section 3.1.5 for additional comments.

Illegible Numbers. If a tube has no visible or an illegible number imprinted on its surface due to envelope cleaning or just light printing during manufacture and you are uncertain of its type, try placing it in the refrigerator for a few minutes. Upon removal, selective moisture condensation will make the alphanumeric designation readable in almost all cases.

Loose Cap/Base Gluing. The original glue formula used to bond the glass envelope to the base was mostly shellac, with some chalk and rock dust mix included. If the base or cap is loose, try epoxy, crazy glue (cyanoacrylate), etc., whatever will bond to the base or plate connection and has a relatively low viscosity. Any adhesive will have a tough time both coping with the high temperatures and bonding to the smooth glass envelope, so care will have to be taken during removal or installation of any repaired tubes.

Marketing Type Designators. A number of tubes received marketing type designators, that is, they were either identical tubes to those in production with just different type designators, or they were functionally alike with only small physical or electronic changes from existing tubes. With the influx of special communications equipment for CB, fishing industry, aviation, and other commercial applications in the early '60s, many of the existing tube designs were re-labeled with various numeric and alphanumeric designators. Manufacturers held the assumption that non-technical users would be employing such equipment and, knowing no better, would be compelled to replace tubes with exactly what they found in the PA stage, thus creating a reliable and sustaining sales mechanism.

The 8950 was produced by Tung Sol and is one of the tubes that received marketing type designators since the 8950 was identical to their 12JS6. The 8950 capabilities were also already in production with tubes like the 6KD6, 6LX6, etc. The 8950 and M2057 are also examples of tubes that were little different from then existing production tubes. The M2057 has the same electrical characteristics but is about 1/3rd larger in diameter and has 50% higher plate dissipation and power output. The M2057 will fit into Swans without modification. The D-50 is another example. The Dentron GLA1000s employed four D-50 power pentodes in a parallel-grounded grid configuration. That tube is merely a 6LQ6, which Dentron purchased primarily from GE and affixed the D-50 designator in order to preserve sales through the Dentron parts department.

Filament Voltages. The voltage on a tube's filament can drastically affect performance (this is particularly relevant to Swan transceiver models with series/parallel wired filaments – e.g. 240). This concern is nicely summarized in the *RCA Receiving Tube Manual, Technical Series RC-21 (1961)*, which states: "*The design of electron tubes allows for some variation in the voltage and current supplied to the filament or heater, but most satisfactory result are obtained from operation at the rated values. When the voltage is low, the temperature of the cathode is below normal, with the result that electron emission is limited. The limited emission may cause unsatisfactory operation and reduce tube life. On the other hand, high cathode voltage may cause rapid evapo-*

ration of cathode material and shorten tube life. To insure proper tube operation, it is important that the filament or heater voltage be checked at the socket terminals . . . In the case of series operation of heaters or filaments, correct adjustment can be checked by means of an ammeter in the heater or filament circuit."

Table 8-1 Internet Vendor Sources For Vacuum Tubes.

- *www.tubesandmore.com/ Antique Electronics Supply*
- *www.vacuumtubes.com/*
- *tubes_tubes_tubes.tripod.com/tubestubestubes/*
- *home.att.net/~esrc/esrcs3.html*
- *www.hamtubes.com/tubes/*
- *www.radiotubesupply.com/*
- *members.aol.com/etetubes/*
- *doctorroy@radiotubesupply.com (PA tube matching)*

Filament Rejuvenation. While this procedure has minimal utility in the case of Swan transceivers (unless one wants to make some serious modifications), it is interesting to note as a technique used by some in days past. On weak tubes, some old timers perked-up weak tubes by increasing the filament voltage. The normal decline of tube performance is due to electron depletion. Cathode electron depletion is progressive and the rate of depletion depends a lot on operating conditions (cathode current, sustained power levels, power dissipation required, etc.). Increasing the filament voltage of a 6.3 V rated power pentode tube up to around 7 or 8 V forces an otherwise weakened cathode to emit perhaps 25% more electrons and, therefore, brings the tubes back to a more useful level of power. This range of filament voltage variation is consistent with the reported ±10% tolerance allegedly recommended by RCA® in some of their tube manuals.

This will not bring about another full life expectancy and, as filament voltage goes up, a little ac hum can be introduced from the filament into the cathode and mixed in with the intended signal. However, the introduction of ac on the cathode is more prevalent when filament voltage is increased well beyond 125% of its rated value. You can demonstrate for yourself that this rejuvenation behavior occurs by using a simple emissions tube tester and increasing the filament voltage (assuming an ac adjustment rheostat and/switch with sufficiently small voltage steps is available) on a test tube while monitoring the emissions reading.

Note that some Swan transceiver designs (e.g. 240) series wire filaments of two parallel wired 6.3 V tube strings to obtain the nominal 6.3 V voltages while using the 12.6-V ac supply, so an individual filament increase in such cases is not feasible, even if you wanted to go through the trouble. In general, the actual filament voltages in Swan transceivers are higher than the 12.6 or 6.3 nominal voltages since the ac power line level is now higher (i.e. 124 V versus 117 V) and moreover the transformer secondary output voltage will vary as a function of loading. In the case of the 240, the filament voltages can also vary significantly because of the parallel/series-wiring configuration, perhaps from as little as 6 V or less to as much as 7 V or more, depending on how well the filament strings are balanced in terms of sharing equal current. Therefore, moderate filament voltage variations from the nominal are common.

NOS or Used? Use caution when purchasing new-old-stock (NOS) tubes. Examine carefully the tube's exterior printed identification information (which frequently is partially removed when cleaning the envelope of accumulated dust or grime). Check the pins and caps for wear and scratch marks, and the interior structure for discolored areas, etc.

Any NOS tube that has been presumably setting for decades in its original box should have no trace accumulations of grime or dust! Frequently, many tubes that are labeled and sold as NOS have been used for tube substitution (and perhaps many times for that purpose). Some may in fact be used tubes that were swapped out during repair or troubleshooting work done years ago, as is often indicated by its physical condition and suggested by the condition of the box.

Tube Vendors. Besides HamFests, many Internet dealers offer used and NOS tubes for sale. The websites for just a few of these are listed in Table 8-1. Of these, perhaps the most established is Antique Electronics Supply (but also perhaps with the highest prices). Again a word of caution – many of the tubes being sold as NOS, particularly at HamFests, aren't.

Table 8-2 Tube Line-Up For Selected Transceiver Models

	120/140	240	250C	260	270	300B	350	350C	350B/D	400	500	500C	500CX	600R	600T	700CX	700/750
1	***6DQ5***	***6DQ5***	6EW6	12BA6	12AU6	12AU6	6EW6	6EW6	12BA6	6EW6	6EW6	6EW6	6EW6	6BZ6	12BZ6	6EW6	6EW6
2	12BY7	12BY7	12BE6	12BE6	12BE6	12BE6	12BE6	12BE6	12BE6	12BE6	12BE6	12BE6	12BE6	6BZ6	12BE6	12BE6	12BE6
3	12BE6	6BE6	6GK6	6GK6	6GK6	6GK6	6GK6	6GK6	6GK6	6GK6	6GK6	6GK6	6GK6	12BA6	6GK6	6GK6	6GK6
4	12AU6	6AU6	***6146B***	***6LQ6***	***6LQ6***	***8950***	***6HF5***	***6LQ6***	***6MJ6***	**6HF5**	**6LQ6**	**6LQ6**	**6LQ6**	12BA6	***6KD6***	***8950***	***6MJ6***
5	6BA6	6BA6	***6146B***	6BZ6	6BZ6	6CB6A	***6HF5***	***6LQ6***	**6CB6**	**6HF5**	**6LQ6**	**6LQ6**	**6LQ6**	12AX7	***6KD6***	***8950***	***6MJ6***
6	12BE6	12BE6	6CW4	12BE6	12BE6	12BE6	12BZ6	12BZ6	12BE6	12BZ6	12BZ6	12BZ6	6BZ6	12AQ5	12BA6	6BZ6	6CB6A
7	6BZ6	6CB6	6CW4	12BA6	12BA6	12BA6	12BE6	12BE6	12BA6	12BE6	12BE6	12BE6	12BE6	12AV6	6JH8	12BE6	12BE6
8	6BA6	6BA6	6HA5	12BA6	12BA6	12BA6	6EW6	6EW6	12BA6	6EW6	6EW6	6EW6	6EW6		12AX7	12BA6	12BA6
9	7360	7360	6EW6	12AX7	12AX7	12AX7	12BA6	12BA6	12AX7	12BA6	12BA6	12BA6	12BA6		6FG6*	12BA6	12BA6
10	6V6GTA	6V6GTA	12BA6	6AQ5	6AV6	6AV6	12AX7	12AX7	6GW8	12AX7	12AX7	12AX7	12AX7			12AX7	12AX7
11	12AU7	12AU7A	12AX7	6JH8	6AQ5	6AQ5	6BN8	6BN8	12AX7	6BN8	6BN8	6BN8	6BN8			6BN8	6BN8
12	12AX7	12AX7	6BN8	12BA6	12BA6	12BA6	6GK6	6GK6	6AV6	6GK6	6GK6	6GK6	6GK6			6GK6	6GK6
13	6BA6	6U8A	6GK6	6FG6*	6JH8	6JH8	7360	6JH8		12BA6	7360	7360	6JH8			6JH8	12AX7
14	0D3	6AL5	6JH8		12AX7	12AX7	12BA6	12AX7		7360	12AX7	12BA6	12AX7			12AX7	
15	12AV6	0D3	12BA6				12AX7	12BA6		12BA6	12BA6	12AX7					
16			12AX7				0A2			12AX7		0A2					
17			0A2							0A2		12BA6					
18			12BA6														

PA Tubes in Bold Print, * Tuning Eye Tube

8.2. Swan Transceiver Tube Line-Up

Table 8-2 lists a summary of the tube line-ups used in a variety of Swan transceiver models. While there is a considerable degree of consistency among the various models, tube line-up changes were made for a variety of reasons, including functional design changes, such as: PA tubes to meet the higher specified input power requirements (switching to the 8950 in the 700CX model), the inclusion of additional or optional features (e.g. crystal calibrator), or replacement by solid-state components (VFO). Appendix E lists transceiver tube commonality.

The tube line-up was also changed mid-production run on some model due to design changes, availability, and/or cost (e.g. deletion of the 12AV6 in later production units of the 120/140/175 models, replacing the 6CW4 with the 6HA5 in the model 250, the switch from 7360 to the 6JH8 in the 500C, the switch from the 6JH8 to a solid-state modulator in the 750CW, etc.). So, when viewing this table, keep in mind that such changes made during production sometimes altered the tube line-up for a particular model from those listed in the table.

8.3. Tube Substitution Chart

Substitution information on many of the tubes used by the various Swan models, derived from hard copy tube substitution books and on-line website substitution data bases (Nostalgia Air and Hereford Amplifier), is shown in Table 8-3. All sources are not always in total agreement, so be sure to cross check to ensure compatibility. Additional information on basic pin-out assignments, characteristics curves for some tubes, and other technical information can be found at *hereford.ampr.org/cgi-bin/tube*, as well as other websites. For Swan applications, some additional power amplifier tubes not listed as substitutes can be used – see specific information on PA tubes discussed in the following paragraphs. A very useful summary of information Swan PA tubes and potential substitutes is provided on the Swan-Net website. A copy of that data is shown in Appendix C.

Do not be too surprised when examining a transceiver if it includes a tube that is not on any recommended direct substitution list. In days past, when many users had in-depth experience with tube circuit design and performance,

Table 8-3 Tube Substitution Recommendations from Internet Data Bases

	Nostalgia Air	**hereford.ampr.org/**
0A2	0A2WA, 6073, 6626	**150C2**, **6073**, **662**, 150C
6AL5	D27, 7631, 6097, 6058, 6AL5W, 6EB5, 6663, 5726	**5726**, **6663**, 6EB5
6AU6	6BA6, 6HR6, 6AH6, 6CG6, 6AU6A, 7543, 6136, 6HS6	**6136**, **6HS6**, 6BA6, 6HR6, 6AH6, 6CG6
6AV6	6AT6, 6BK6, 6BT6, 6AQ6*, 6066	**6BK6**, 6AT6,6BT6,6AQ6
6BA6	7543, 7496, 6BZ6§, 6AU6A, 6AU6, 6CG6, 6HR6, 6660, 5749, 6BD6	**6BD6**, **5749**, **6660**, 6HR6,6CG6
6BE6	7502*, 6CS6, 6BE6W, 6BY6, 7036, 5915, 5750	**5750**, 5915, 7036, 6BY6
6BN8	6BJ8§	6BJ8
6BZ6	6DC6, 6HQ6, 6JH6, 6BA6§	**6GM6**, **6HQ6**, **6JH6**, 6JK6
6CB6	*6CB6A, 6AW6, 6CF6, 6DC6, 6DE6, 6DK6, 6HQ6, 6AG5§, 6AU6§, 6BC5§, 6CE5§, 6BH6§, 6HS6*§, 6676, 7732*	*NA*
6DQ5	NA	6CD6, 6EX6
6EW6	6GM6, 6HS6*§	**6GM6**, 6BJ6, 6BZ6, 6CB6, 6CF6, 6DE6,6DK6,6JH6,6HQ6
6GK6	NA	6HB6
6GW8	NA	NA
6HA5	6HQ5, 6HQ5, 6HM5, 6HK5	**6HK5**, 6HM5, 6HQ5
6HF5	NA	6GV5.
6JE6A	6JE6B, 6JE6C	NA
6JH8	NA	**6AR8**
6KD6	NA	NA
6LB6	NA	6JS6
6LQ6	6JE6B, 6JE6C, 6LZ6, 6ME6, 6MJ6	**6JE6**
6ME6	6JE6B, 6JE6C, 6MJ6, 6LZ6	**6JF6**, 6JU6
6MJ6	NA	NA
6V6	7408, 7184, 5871, 6V6Y, 6V6GX, 6V6GT/G, 6V6GTA, 6V6GT, 6V6G	NA
12AU6	12AW6*, 12BA6A, 12AU6A, 12AW6, 12BA6	**12BA6**, **12AW6**
12AU7	7730, 7489, 7316, 6680, 6189, 6067, 5963, 12AU7WA, 12AU7W	**12AT7**, 12AZ7, 12BH7
12AV6	12BT6, 12BK6, 12AT6A, 12AV6A, 12AT6, 12BX6	12BX6, 12AT6
12AX7	12AX7A, 12AX7WA, 12DF7, 12DT7, 7025, 7025A, 12AD7*, 12AU7§, 12AU7A§, 12BZ7*, 12DM7*, 5751*, 5751WA*, 6057, 6681, 7494, 7729	**12DF7**, **12DM7**, 12AD7, 12AX7A
12BA6	12AU6, 12AU6A, 12BA6A, 12BZ6§	**12AU6** (6AU6)
12BE6	12BE6A, 12CS6	12CS6 (6BE6)
12BY7	8448, 7733, 12DQ7, 12BV7, 12BY7A	**12DQ7**, 12GN7
12BZ6	12BA6§, 12BA6A§	**12DX6** (6BZ6)
6146B	8298A	NA
7360	NA	NA
8950	NA	NA
	*Parallel filaments § May not work in all circuits	**Bold indicates preferred.** Not Available, () Lower Voltage Filament

many chose to intentionally use a tube type that was quite similar, but not a direct substitute. When such a situation is found, it is prudent to cross check available tube information (e.g. pin-out assignments) and to carefully inspect the circuit to ensure that additional component changes were not made that would adversely affect the performance if the manual's specified tube were reinserted.

8.4. General Power Amplifier Tube Information

8.4.1. Why Sweep Tubes?

Why were sweep tubes used? The answer is lower cost and as much as three times the power compared to tubes designed specifically for RF applications, during an era when power sold transceivers like power sold cars in the 1950s and 1960s. While Galaxy preceded Swan in their use of sweep tubes in commercial amateur transmitter and transceiver designs, Swan certainly carried forth that application to the its full potential in both quantity of production units and variety of models.

When the Swan 400, 350 and 500 were new, they would run a minimum of 500-W dc input PEP on 80 thru 15 meters and 400-W PEP input on 10 meters. This reduced power on the higher frequency bands was a minor penalty to pay for using sweep tubes, given all that low frequency power. In addition, sweep tubes, with their

Table 8-4 Summary of PA Tubes Used in Swan Transceivers

Model	Tube Type
115	6DQ5
120	6DQ5
140	6DQ5
175	6DQ5
240	6DQ5 (6CB5A will sub for 6DQ5s after rewiring PA tube socket)
250	6146B
250C	6146B
260	6LQ6/6JE6
270	6LQ6/6JE6
270B	6LQ6/6JE6
300B	8950 (12JS6C will sub for 8950 - some require single wire change)
350	6HF5
350C	6LQ6/6JE6
400	6HF5
500	6HF5
500C	6LQ6/6JE6
500CX	6LQ6
600T	6KD6
700CX	8950 (12JS6C and 6LB6 will sub following a wiring change)
750CW	6MJ6/6LQ6/6JE6
HF700S	6MJ6/6LQ6/6JE6
1011	6LF6
ASTRO-102BX	100% Solid State
ASTRO-150	100% Solid State
	(All of these tubes have substitutes.)

ubiquitous use in TVs, had a significantly lower cost. So, the decision to use PA tube was based on both cost and maximum LF power, with very little sacrifice of power output on 10 meters.

As the quality of available tubes began to erode over the years and components aged, very few transceivers continue to meet those specifications on 10 meters. Even 15-meter operation usually has a decline in dc input and RF output power. However an older, properly tuned rig with a good set of tubes will still do very well on 10 meters compared to the lower bands – a typical 500CX will still do about 150-W CW RF output on 10 meters into a 50-Ω load and 200 W or more on the lower bands. The output achieved is highly dependent of the power amplifier, mixer, and driver tube condition as well as the proper alignment of all of those stages, so the actual output you obtain can vary widely.

8.4.2. Swan Transceiver PA Tube Lineup

The PA tubes used in Swan production transceivers for most models are summarized in Table 8-4. See also the Swan Newsletter, Issue 6, Section A.6.5.

A list of tubes used in the final PA for hundreds of tube transmitters and transceivers (including Swans) going back to the 1930's can be found at: the following web-link: http://members.cox.net/n7rk/xmit_Tube_list.pdf. This is a PDF file, so you will need Adobe Acrobat Reader® to view it either on-line or after downloading.

8.4.3. PA Tube Replacement or Substitution

Replacement of the PA tubes involves: (1) obtaining a matched set (for dual-tube PA transceivers), (2) neutralizing the tubes, and (3) ideally aligning the driver and mixer stages, although many skip this last step unless the power output improvement is poor. See Section A.10.4 for additional options on PA tube substitution.

In cases where PA tubes are replaced or substituted with ones having the same general electrical characteristics, other than for the power or plate dissipation rating, it should be noted that any tubes will only generate as much power as they're capable of producing. Your transceiver won't make them work any harder than their fundamental power capability. Also, note that trace gas in large pentodes sometimes causes a purple-blue glow – this is not necessarily indicative of tube failure.

When replacing or substituting dual-tube power amplifier tubes, they should be matched to ensure that each tube is handling ~50% of the indicated cathode current (and therefore power) and they must be neutralized. Ideally, replacement tubes should both be NOS (new old stock) to have some assurance that when matched in idle current they will also be reasonably well matched in characteristic curve behavior at higher power levels.

In the case of used tubes, in addition to idle current matching, it is highly desirable that both have a similar gain (trans-conductance, G_m), as measured by a dynamic mutual trans-conductance type tube tester. Used tubes may have had considerably different usage and hence amplification capability at high power levels, even though they might have an identical idle current (see Section 8.5).

8.4.4. Tune-Up Duration

Swan manuals imply that damage to power amplifier finals due to excessive heat build-up will not occur if no more than 30 second tune-up intervals are used for the PLATE and LOAD control adjustments, but only after the GRID drive has been quickly adjusted for peak current under low carrier conditions and the PA **π** network is rapidly adjusted to near resonance. Many Swan transceivers (e.g. early 350s) are at full drive during tune-up. Under full, or even reduced carrier level conditions, the 30 seconds tuning period is much too long. Tuning should be limited to a maximum of 5 seconds intervals.

8.4.5. Power Output and Plate Dissipation Ratings

The average per-tube RF power outputs for the PA tube types used in the various transceivers range from 75 W to 145 W, but the PEP SSB RF output power on modulation peaks will be substantially greater, ~250 W per-tube on the higher power tubes/models (see Fig 6-11). Average outputs are: 6146B = 75 W, 6DQ5 = 95 W, 6HF5 = 120 W, 6JE6C = 125 W, 6LQ6 = 125 W, 6MJ6 = 125 W, 6KD6 = 135 W, 8950 = 130 W, 6LF6 = 145 W.

The plate power dissipation ratings for PA tubes used in the various transceiver models range from 24 W to 40 W, but most models used tubes in the 24 to 30 W range. The 6DQ5 and 6JE6 are rated at 24 W; the 6HF5 at 28 W; the 6JE6B/C and 6MJ6 at 30 W; the 6KD6 (model 600T only) and 8950 at 33 W; the 6146B (model 250 only) at 35 W; and the 6LF6 (model 1011 only) is rated at 40 W.

With all of these tubes, including the 8950 and other higher dissipation rated tubes, there is a significant increase in the likelihood of surpassing the screen grid dissipation rating, because the circuit designs and operating voltages aggressively push the tubes toward their upper specification limits (power and heat dissipation). With a modification of the power supply to lower the HV level and/or the installation of a screen grid resistor (for the higher powered models, such as the 700CX), the power can be somewhat reduced, extending the life of the PA tubes and other transceiver components (see Section 3.6).

8.4.6. Control Grid-Lead Radiator (GLR)

When searching for PA tubes to be used on the high frequency bands (i.e. 15 and 10 meters), try to make sure a control grid-lead radiator (GLR) is installed. While tubes without the GLR will function and most likely can be neutralized on 10 meters, one can save a great deal of potential neutralization trouble by making sure it's there. On lower frequencies, where neutralization is not such a problem, tubes without the grid-lead radiator should work fine. The GLR is a horizontally-oriented, U-shaped, or parallel-plate configuration (flat or chevron shaped) partially surrounding

Figure 8-3 Examples of Grid-Lead Radiator Configurations

the plate lead in the upper envelope of the tube. It is affixed to the control grid to provide additional heat radiation capability.

Fig. 8-3 shows a close-up photograph that clearly illustrates tubes with and without GLRs. The leftmost tube is a GE 6LB6 that contains only the heavy dogleg lead going from the plate to the plate cap. The middle tube is a United Electronics 6HF5 tube that shows the same type of plate lead, but has a GLR structure in the form of a pair of horizontally-oriented parallel plates. The rightmost tube is a GE 6LB6 tube, which also contains a dogleg plate lead, similar to that of the first 6LF6 tube, but in this case, it is surrounded on three sides by a U-shaped GLR structure.

Be aware that in many cases, when the getter is also placed in the upper potion of the tube, because of associated deposits on the inside of the envelop, it may be partially obscured and difficult to see. In Fig. 8-4, tubes A and C have such deposits, while the others have the getters (and deposits) positioned mid tube. Be sure not to confuse the GLR structure with the getter. See the discussion and example shown in Section 8.1.4 (Fig. 8-2), which shows a halo shaped getter located in the upper portion of the envelope.

You may well fine two tubes from the same manufacturer with and without the GLR or with different GLR designs. For example, shortly after going to a sort of standardized 33-W plate for many of their horizontal output tubes, GE engineering, in coordination with cost analysts, determined that there was no need for the GLR at the 15.75 kHz operating frequency of TV horizontal output stages. To save manufacturing costs it was dropped from the design and, beginning in 1980, GE sweep tubes began coming off the line without the GLR installed.

8.4.7. Tube Comparison

So, what do some of the tubes used by Swan for the PA and common substitutes look like and how do they compare physically? Fig. 8-4 shows seven popular 12-pin tubes used in Swan equipment – left to right they are:

(A) 6LF6 with Westinghouse label - built by GE.
(B) 8950 with GE label - built by GE.
(C) 6LB6 with GE label - built by GE.
(D) 6KD6 with GE label - built by GE.
(E) 6JS6C with GE label - built by Sylvania.
(F) 6LB6 with Realistic (Radio Shack) label – built by GE.
(G) 6HF5 with Dumont label - built by GE.

A B C D E F G

Figure 8-4 PA Tube Comparison

(A) Westinghouse sold TV/radio tubes for 12 years after they discontinued building tubes. Most were bought from GE, the rest from offshore manufacturers to which they merely affixed their label. The 6LF6 pictured is the best GE built. It was rated for 40-W plate dissipation but under testing, was found to be capable of 45 W due to the steel radiators (seen on either side of the plate). Earlier 6LF6s and other manufacturers did not have the steel plate radiators. Note also that the 6LF6 contains a getter ring inside the top of the tube. It also contains a grid-lead radiator, but it is not visible in the picture.

(B, C, D) These three tubes are the 8950, 6LB6 and 6KD6 and all have the same 33-W plate. The 8950 has no getter ring or grid-lead radiator in the upper portion of the tube. The getter is on the side. Early 6LB6s by all manufacturers were rated at 30-W plate dissipation. However during the last 5 years that GE built tubes, they simplified the construction and component requirements by using the same plate for 6 of their horizontal output amplifier tubes. The 6LB6 was one that started using the 33-W plates. The GE tube manual does not reflect this because the last manual was printed in 1973 and the uniformity practice started in the late 70s. Note the smaller size plate cap on the 6KD6.

(E) This tube is an early 6JS6C. Note the shorter plate. It is rated at 30-W plate dissipation. Later ones built by GE contained the larger 33-W plate.

(F) The tube labeled 6LB6 is actually an early 30-W plate 6JS6C similar to the 6JS6C next to it. Since the two tubes are usually interchangeable, Radio Shack relabeled the 6JS6C to 6LB6. The C is still visible on the tube just under the 6LB6 print. These 30-W plates are exactly the same as those used in the 9-pin 6LQ6, 6JE6C, 6ME6, and 6MJ6 tubes.

(G) As a comparison, the 6HF5 is shown. You cannot tell any difference in the plate from the early 6JS6C and 6LB6, but it is only rated at 28 W. Again, for parts uniformity during production, some later 6HF5s were outfitted with 30-W plates.

(C, D) The 6LB6 and 6KD6 both have a grid-lead radiator (GLR) – the U-shaped metal piece that cups the plate lead wire, although it can't be clearly seen. This reduces the tendency of the tube to go into oscillation and makes it easier to neutralize, especially on 10 and 15 meters. The getter is near the center of the plate in the 6LB6 and inside the top of the 6KD6.

(E, F, G) Neither the 6JS6C nor Realistic 6LB6 have grid-lead radiators, but the 6HF5 does.

8.4.8. Measured PA Tube Characteristic Curve

Fig. 8-5 illustrates the type of matching in terms of characteristic curve variations that can be encountered (see additional related discussions is Section 6.2 and characteristic curve data in Figs. 6-2, 6-3, and 6-4). All measurements were made on a 500CX, using an 117XC power supply. During idle current conditions the measured HV level was +920 V (±20-V error) and the screen voltage was 282 V. The tube's behavior in the linear portion of the characteristic curve (i.e. slope) is a function of tube condition and operating voltage levels (screen and plate). This behavior is primarily controlled by the screen rather than plate voltage, so it is important to be aware of the operating voltage affects when relating the appended measurements to other transceivers. This figure shows only the lower portion of the characteristic curve for each of three separate tubes, that is, the measured cathode current as a function of grid voltage. The 6LQ6 and the 6JE6C were a matched set of used tubes that had been installed in the transceiver. With these tubes, the measured RF out-

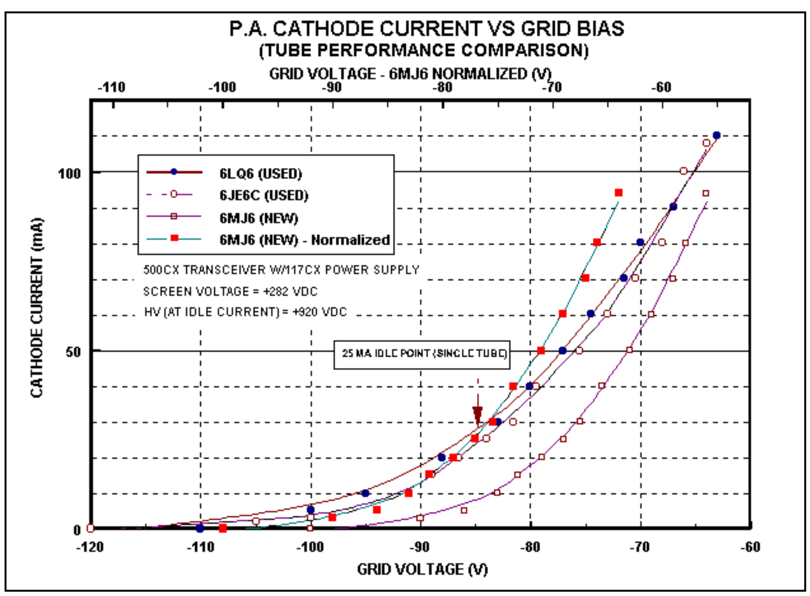


Figure 8-5 PA Tube Matching Measurements

put on 40 meters into a dummy load was 210-W CW and 290-W PEP SSB, so while used, they were obviously still in fairly good condition.

Examination of the curves from these tubes (solid and empty circle symbol curves labeled 6LQ6 and the 6JE6C), show that they are indeed quite well matched, with very similar curve shapes, well within measurement error. The differential between the two at the 25-mA current point is only 3 or 4 mA (see tube matching criteria discussed in the Matching Procedure Section 8.5.3). Also appended to this figure is the curve for a NOS 6MJ6 tube (curve with empty square symbols). Comparison of this curve with the two used 6LQ6 or 6JE6C curves for any given grid voltage shows gross differences in cathode current for any selected grid voltage. At a grid voltage of –85 V, the 6MJ6 has a cathode current of only ~9 mA, while the other two tubes each have ~25-mA current – the 6MJ6 is obviously not a match for either of the other tubes on a cathode current basis.

If the 6MJ6 curve (empty square symbols) is normalized with respect to the either the 6LQ6 or 6JE6C curves at the 25-mA current point (that is, shifted to the left), as shown by the solid square symbol curve (this is equivalent to separately adjusting the bias on the 6MJ6 tube so that it would have a 25-mA idle current), then it becomes obvious that not only does the 6MJ6 have a significant mismatch in current at the 6LQ6/6JE6C idle current grid voltage, but it also has a much steeper curve slope in the linear portion of the characteristic curve at higher grid signal voltages (i.e. those that are more positive), where the class AB_1 amplifiers achieve their maximum power amplification. If the 6MJ6 were mated with either of the other two tubes in a dual-tube PA transceiver with both using the same grid bias voltage, ironically the used tube would be doing most of the work, since for any given grid voltage, the used tube would handle the bulk of the cathode current (25-mA bias idle point plus signal current).

If one were to modify a Swan transmitter so that each tube has its own bias control and the 6MJ6 were paired with one of the other tubes, then the situation is depicted in the figure by comparing either of the two used tubes with the normalized 6MJ6 curve would apply. Each tube would have the same 25-mA idle current (50 mA total), but when more positive signal voltages are applied to the control grids, say –70 V, the dc input power would be ~66 W (78 mA x 850 V) for the 6LQ6 or 6JE6C, but ~94 W (110 mA x 850 V) for the 6MJ6. This difference in input powers illustrates the inter-tube characteristic curve variability that can occur and would be even more pronounced at even higher grid voltage levels, where the 6MJ6 would be forced to do most of the work.. It also illustrates the increased maximum power handling capability that a new tube can have relative to a used one where electron depletion and other changed has decreased a tube's power output capability. Clearly the 6MJ6, in addition to being a poor match to the either of the other tubes in terms of idle current at a given grid voltage, it is also a poor match in terms of characteristic curve shape!

As discussed in the Power Amplifier Tube Performance Section 6.2.5 and as suggested by the data shown in Figs. 6-2 and 6-3, the PA characteristic curve shape at more positive grid signal voltages is linear. This linear portion extends at a near constant slope until the tube reaches a saturation point where further increases in plate or screen voltage levels will not cause any further increase in cathode current. In addition, as suggested by this data, the curve slope in the linear portion of the characteristic curve changes as the tube ages. When a tube is new, the slope is at its steepest and produces the highest cathode current for a given grid signal voltage. As the tube ages, the linear portion of the curve flattens, reflecting the decrease in the amount of power that the tube can produce (i.e. for a given grid voltage, the cathode current decreases).

Summary. Note that as discussed earlier, neither emissions nor dynamic mutual trans-conductance type tube testers by themselves provide a true indication of tube matching. The above data supports that assertion. While two NOS tubes should have nearly the same characteristic curve, used tubes may well have dissimilar characteristic curves. If two tubes have identical emissions readings, they still may have grossly different idle currents. Likewise, even if two tubes have identical trans-conductance (G_m) measurements, their curve slopes should be similar, but they still may have significantly different idle currents, forcing one tube to do most of the work.

So if using a mixed pair of a NOS and a good, but used tube, consider that there may also be hidden effects, even if tubes are found to be matched based only on similar cathode currents at a fixed grid voltage. Because of this, when tubes are replaced, a set of two new matched tubes is preferable. When using two used tubes, ideally, in addition to being matched in idle current, they should also be matched in G_m, so that both tubes have the same amplification capability at higher power levers.

8.5. Power Amplifier Tube Replacement/Matching

For additional information on tube matching, also see the discussion in Swan Newsletter, Issue 7, Section A.7.4. As discussed above, neither the common emissions nor the mutual trans-conductance type tube testers by themselves provide an accurately indication of matching for Swan dual-tube PA applications. Neither provides an absolute measure of cathode current at transmitter idle conditions (the emissions type just confirms electron emission capability while the trans-conductance tester provides a measure of the tube's gain or amplification at higher operating voltages), an essential requirement for matching.

One of the primary differences between television horizontal output tubes and pentode RF transmitting tubes is in the area of characteristic curve tolerance. The sweep tubes do not have a high degree of sample-to-sample uniformity, whereas the RF tubes should be much closer in operating characteristics. Another difference is their intended design application. TV horizontal sweep output tubes function with screen and plate voltages of less than 300 V and at the horizontal sweep rate (frequency) of 15.75 kHz. Therefore, any tube randomly selected from a stock of say 100 tubes and plugged into any TV horizontal output stage circuit that was designed around that tube would work perfectly. No matching or idle current adjustment is required even though those types of tubes are not held to the strict construction or characteristic curve tolerances of one designed for RF applications, like a 6146B. One can usually get by using unmatched NOS 6146B's due to more precise internal component placement which keeps each tube fairly close to each other in conduction values, whereas TV horizontal output tubes, especially when operating at plate voltages of 600 V to 900 V, need to be analyzed to identify matched pairs.

Matched PA tubes are necessary for proper operation and tube life in dual-tube PA transceivers because these PA stages are grid driven as opposed to cathode driven. A cathode driven (also called grounded-grid) design, is essentially a 10 to 1 amplifier. That is, 1-W in and 10-W out. Whereas the sweep tubes are grid driven power pentodes and transmitters circuit designs typically permit 25 to sometimes over 100 to 1 amplification. Because horizontal sweep tubes were designed for TV service at lower B+ voltages than found in amateur transmitters, there is little difficulty encountered when replacing a single tube in the horizontal output stage. However, when the B+ goes from 250 V to 800 V or more, it starts to expose the frailties and wide variations in operating characteristic curve differences among tubes of the same type. Comparing pentodes by plate color in a dark room is a poor and inaccurate method of matching TV service pentodes. This might be a rough gauge for matching determination in industrial tubes like a 3-500Z in grounded grid applications, but certainly not sweep tubes. Your options to ensure that each tube carriers ~50% of the power load are to either install matched tubes or to add a second bias control in order to individually place each of the PA tubes at its proper idle current.

Replacing the two PA tubes involves finding a matched pair and neutralizing them, preferable with a realignment of the RF driver. While intuitively one would think that matched tubes ideally should be from the same manufacturer and have the identical physical design, in reality they can be tubes from different manufacturers or even tubes of mixed direct substitutable types (e.g. a 6LQ6 and a 6JE6C, 6JE6C and a 6MJ6, 6LQ6 and a 6ME6, etc.), providing they meet the matching criteria discussed herein. Tube distributors that offer genuine matched tubes should have tested them on a specialized apparatus that places all the intended operating voltage levels (plate, screen, bias and filament) on the tubes and measure cathode current as a function of bias level. Tubes that behave similar to each other are considered matched. This means each tube will share the load equally. If the cathode current meter of your 350 shows 50 mA of idle current, each tube is conducting 25 mA. With say, a Drake TR3, which employs three PA tubes with a total cathode current of 75 mA, each of the 12JB6s will be conducting 25 mA. Matching all 6LQ6s in the four sweep tube amplifiers is usually not as critical since they are operated in a grounded grid mode.

8.5.1. Using Unmatched Tubes

Unmatched tubes will force one tube to do the bulk of the work and as a consequence, maximum output power will be reduced and undue stress will be placed on the one tube. There will be an imbalance in idle currents and one tube will be have excessive idle current – while the meter will read 50 mA, one tube may be conducting only 15 mA and the other 35 mA. Under that condition, the tube working hardest will have to dissipate 31.5 watts (900 V x 35 mA), exceeding the plate power dissipation rating for many tubes while only under idle conditions!

Unmatched tubes will also increase the tendency to arc-through when tuning or modulating because of this unequal burden. Under such conditions, you may hear a snap or crack as an arc occurs in one or both of the PA tubes and momentary shorts out the HV/MV section of the power supply. This is never a good sign.

If uncertain about the matching of the PA tubes, set the PA BIAS to at least 50 mA to ensure one tube is not being biased close to cut-off. See Section 6.2.2 for a discussion on bias and Fig. 6-1 for a graphical representation of grid bias voltage relative to amplifier class versus the tube's operational characteristic curve. Always run a fan on tubes, especially if they are not known to be matched. Even at 25 mA each, the tubes will still benefit from external cooling.

8.5.2. Linear Amp Tube Matching Comments

The grounded grid sweep tube linear amplifiers (e.g. Swan 1200X) are essentially 10 to 1 type amplifiers. In rough terms, 100 W of drive will produce 1,000 W of amplified signal. Under that operating configuration, the small electrical differences among tubes are usually not so pronounced that idle current will vary too much from tube-to-tube. Thus, you can attempt to run a set of unmatched PA tubes. However, in grid drive linear amplifiers such as the PA stage of any Swan transceiver and linear amplifiers such as the SBE SB1LA and SB2LA, the gain is much higher. Because small differences among tubes are magnified considerably in these high gain applications, they must be matched to ensure each tube is carrying a nearly identical current.

8.5.3. Matching Procedure

When performing the matching procedure outlined below, both PA tubes must be installed. No two-tube PA transceivers will operate with only one tube in place, except for the Swan 700CX. That is because the PA tubes in that transceiver have 12.6-V ac filaments wired in parallel and thus can run one at a time, while all other dual-tube PA transceivers use 6.3-V ac filament tubes wired in series. On the 700CX, with the filament of one tube out the PA control tuning will be a little off normal, but will still produce power from the one tube. The following procedure can be used to obtain a very good indication of how well any number of new old stock (NOS) tubes are matched to one another in terms an idle current.

- There is a small possibility that either the bias level and/or the precise carrier nulling might change while the transceiver comes up to a fully temperature stabilized condition (one-half to an hour warm-up time) during the matching procedure, altering the initial BIAS current and CAR BAL null settings. So, it might we wise to initially bring the transceiver up to normal operation temperature prior to starting the matching procedure outlined below. Note that when the tube used during the initial bias current reference adjustment is re-installed, the current should be the same. In order to preclude a carrier insertion related current change, you can monitor the RF output level with a QRP wattmeter to ensure the RF output power remains near zero. Conversely, another approach that absolutely ensures there is no carrier related cathode current is to simply remove the driver tube.
- *Unplug the power supply and wait at least a minute or two for the HV capacitors to discharge. Short the HV (tube's plate cap) to ground with a well-insulated screwdriver to be absolutely sure. Place both tubes in the transceiver, leave one of the plate cap connectors off and clear of the HV cage and other electrical components.*
- *Turn on the transceiver and warm-up the tube for 5 minutes*.
- *Press the PTT and completely null the carrier*. At full carrier null, corresponding to the minimum in the cathode meter current reading, no RF output should be indicated on your wattmeter or SWR bridge – under that condition the current reading represents the bias idle current. *Adjust the bias voltage potentiometer to ~50 mA (one tube with a plate cap on). Carefully note the exact meter reading.*
- *Turn the transceiver off, pull the power supply plug, wait a few minutes. Short the HV to ground with a well-insulated screwdriver to be absolutely sure there is no voltage on the plate cap. Then disconnect the plate cap from the first tube and connect the second plate cap to the second tube. Plug in the power supply and again warm-up the transceiver for 5 minutes.*
- *Do not change any control setting*.
- *After warm-up, hit the PTT again and observe the cathode current of the second tube. Note the exact PA cathode current reading on the meter.*

- Ideally the current reading should be ~50 mA, the same as the first tube. A reasonable tolerance for the second tube to be considered matched is a current reading anywhere between 40 and 60 mA (within ~20% of each other), however, the closer the better.
- You may check any number of tubes this way. *However, don't change the bias voltage pot after setting the first tube to 50 mA and make sure that the tubes are allowed to warm-up for at least 5 minutes. All of the additional tubes will be referenced to the initial bias voltage setting.*
- If you have several tubes and notice two of them are say 75 mA each, somewhat higher than the original tube, then the two 75 mA tubes are also a matched pair that can be used together.

Once you have a matched pair, install them in the unit, set idle current to 50 mA and start the neutralization process. Remember that neutralization on the 10-meter band can sometimes be a problem requiring careful adjustment or even the use of different PA tubes. Never hold the transceiver in the transmit mode for more than about five seconds at a time while trying to neutralize or tune-up.

Caveats. This procedure guarantees that the tubes are matched at idle current conditions, but not necessarily at high current, high power conditions. However, since NOS tubes conform to a technical specification, they will hopefully also match at other, higher current conditions. Measurements with a dynamic mutual trans-conductance tester will confirm such matching. Conversely, an extension of the same procedure outlined above could be done to obtain additional measures at higher current levels. A second (or even third or fourth) step could be considered in which the bias potentiometer setting is increased (say from the 50 mA to 100 mA or more) and each of the tubes is then again measured at this higher bias cathode current level. True matched tubes will both have similar cathode current levels at all bias setting. For example, if the tubes A and B measure 45 mA and 54 mA respectively at the normal bias setting and 92 mA and 107 mA at the higher bias setting, they would be fairly closely matched. However the potential usefulness of this second step is questionable, given the trouble involved, the danger of tube damage (remember, the tube must dissipate all the power as heat – 200 mA x ~840 V = 168 W!), and the simple fact that with the expected sweep characteristic curve variation at extreme voltages operating conditions, it may be exceedingly difficult to get perfectly matched tubes anyway. Therefore, such additional measurements are probably may be more of academic interest than practical utility.

Matching Used Tubes. When attempting to obtain a matched set of used tubes (or if the status of supposedly NOS tubes is questionable), there is an additional problem in that there is lower confidence that the two used tubes will have similar characteristic curve slopes, since they most likely have had varying amounts of usage and the curve slopes might well be significantly different. As shown in Fig. 8-5, obtaining a higher cathode current during tube matching at a fixed bias level does not necessarily mean that a tube is better or newer than the one with the lower reading. NOS tubes with different bias currents could still have the exact same characteristic curve shape and power handling capability but would just require a different bias level to achieve the design performance in a specific circuit. For used tubes, the procedure outlined above to match tubes at 50-mA cathode current is still essential, even if mutual trans-conductance tube tester measurements are not available, as this is a vast improvement over merely inserting the two used tubes and hoping for the best.

8.6. Specific Tube Information

8.6.1. 0A2 Voltage Regulator Comments

The 0A2 Voltage Regulator (VR) tube is used in the Swan 250 six-meter transceiver as well as early HF models like the 350, 400, 500, 350C and 500C. The 0A2 was removed from the basic circuit design when the solid-state carrier oscillator was introduced during production of the 350C, 500C, and later versions.

It is employed to regulate the plate and screen voltage to the carrier oscillator tube (e.g. 12BA6). Since any free wheeling tube oscillator is sensitive to voltage changes, regulation is vital to keep it on frequency. However, in the case of the Swan carrier oscillator, it is also crystal controlled, so it is inherently much effected by small voltage variations. Therefore, the 0A2's 150-V (plus or minus a few volts) regulated output just provides added security to ensure a stable voltage is applied to the carrier oscillator tube to keep the screen voltage constant. In fact, the 0A2 can be pulled out of any of those radios and you probably wouldn't know it was missing except for a rise in screen and plate voltage at the carrier oscillator. Problems with the VR circuit are usually not terribly difficult to identify. If there are serious problems with the 0A2, the voltage at that tube will vary quite a bit. Proper operation of the tube can be confirmed if you measure roughly 150 V at the plate of the 0A2 and it is a steady voltage, even when going from receive to transmit and back.

8.6.2. 6BN8

It has been reported that 6BN8s employed in the AGC/AVC circuit of many transceiver models may have a propensity for going gassy with usage. Such gassy conditions have been reported to cause, or contribute to, distortion, garbled audio, and improper S-meter performance (too high, too low, variable sensitivity). If a tube tester is available, make sure you carefully test this tube for gas, especially if audio problems are encountered.

8.6.3. 6DQ5

The 6DQ5 is rated at 24-watts screen dissipation with a typical average RF power output of about 95 W. GE and perhaps other tube manufacturers were reported to have produced identically marked versions of the 6DQ5, one of which ran the filament at lower temperatures, requiring less filament current. Since GE tubes with this "dark-heater" version of the filament have a lower filament current, the voltage division in the series/parallel wired filament string used in the model 240 is upset, causing improper heater voltage. At least some tubes manufactured by GE that exhibit this behavior have filament currents of only about 1.25 A versus the 2.5 amperes nominally specified for the tube. See further discussion in the model 240 transceiver discussion Section 2.3.3. There are no obvious differences in the appearance or markings on the version that works in the model 240 transceiver type filament wiring versus the dark heater version that does not. At least some Sylvania brand tubes also exhibit similar behavior.

In the 240, a series-parallel filament circuit is used to establish the correct filament voltage levels, with nine miniature tubes filaments paralleled and connected in series with the 6DQ5 to obtain the 6.3-V ac filament voltage. Usually pin 7 is connected to the 12.6-V ac voltage filament supply, while pin 2 is connected to the nine paralleled miniature tube filaments. This arrangement should result in a ~6.3-V ac reading between pin 7 and 2 on the 6DQ5 and 12.6-V ac from pin 7 to ground. Without these proper filament voltages, electron depletion can be accelerated if the resultant filament voltages are too high or low, the PA tube can be difficult to neutralize, or other operational problems can occur. Because of this, it is advisable to be suspicious of any improper or erratic operation when the 6DQ6 is replaced, especially with a GE or Sylvania tube.

Note that the 6.3-V ac and 12.6-V ac are nominal filament voltages that were based on a 117-V ac line voltage feeding the power supply. With today's voltages on the order of as much as 123 or 124-V ac, the 12.6-V ac will be more like 13.8-V ac and all other power supply voltages will also be proportionally higher. Therefore, the 12.6-V ac and 6.3-V ac reading specified in the 240 manual voltage charts for the various filaments are also just nominal values, especially since the nominal current of the 6DQ5 tube is 2.5 A, while the total nominal currents of the paralleled tube string is 3.05 A. Thus, there will be some additional imbalance across the two filaments. Assuming all tubes are drawing at their nominal current levels, and with a 12.6-V ac filament supply voltage, the filament voltage across the 6DQ5 would be 5.7-V ac and 6.9-V ac across the other paralleled tubes (with a 13.8-V ac filament supply, the voltages would be 6.2-V ac and 7.6-V ac respectively)

The 6DQ5 tube was mounted horizontally and while this presents no problems under normal circumstances, it might increase the potential for inter-electrode shorting with electrode sagging if the tube is abused. With such a failure, it is possible for the HV to be shorted and the power supply fuse to blow. Some users judge the RCA brand to be superior.

6DQ5 Substitutes

6CD6G, 6CD6GA, 6EX6. The 6CD6 and 6EX6 are listed in tube substitution data bases as direct substitutes for the 6DQ5. However, they have a somewhat lower plate dissipation (15 and 20 W for the 6CD6G and 6DC6GA and 22 W for the 6EX6) and both the rated maximum plate and the screen voltage are lower than that specified for the 6DQ6.

8236. The 8236 is a direct substitute (unlike the 6DQ5, it uses the 6146 tube type packaging) for the 6DQ5 that was only built by Tung-Sol and marketed as an ultra-replacement for the 6DQ5 back in the 1960s. With a whopping 50-W plate dissipation and 1,000-V maximum plate rating, it is indeed a robust replacement, to say the least. They are very rare and expensive these days, since the total number of 8236s produced didn't match the demand. During the 1980s and 1990s, most of those sold were found to be re-boxed used ones.

8.6.4. 6EW6/6GM6

The 6GM6 is not used in any transceiver model tube line-up, however it is discussed in a 250 transceiver Sensitivity Bulletin (July 26, 1967) as a substitute for the 6EW6 (1^{st} IF). As noted by Swan, " . . . *a number of owners have tried different tube types in the I.F. stages. The 6GM6 is a 6EW6 except with semi-remote cut-off characteristic. It will provide an apparent increase in overall receiver gain because of different AGC control. There is not harm in trying the change, but it is our feeling that no advantage is to be gained*."

The 6GM6 has also been found in at lease one instance to be substituted in the 500CX in place of the 12BA6s used in the 1^{st} and 2^{nd} IFs. This substitution/modification rewired the two-tube socket filaments in series to use the 12.6-V ac filament supply and also added a 500-Ω, 10-W resistor in parallel with the 750-Ω, 10-W resistor (used to drop the nominal 275-V MV supplied to the IF tube screen), decreasing that voltage drop and increasing the screen voltage on the 6GM6, which is consistent with tube-manual voltage specification differences between the 12BA6 and 6GM6 tubes. The source of this modification (possibly one-of-a-kind) is unknown; it may have been a magazine recommended modification, a word-of-mouth change, or perhaps just based loosely on the tube substitution discussed in the 250 Service Bulletin.

8.6.5. 6GK6

The 6GK6 is used as the audio power amplifier and the RF driver in most transceiver models (exceptions include the early mono-banders and 240 tri-bander, which used the 12BY7 as a driver). The tube in the driver circuit can show some cherry red color during long transmissions, especially when using AM modulation, however it is capable of dissipating heat very well as long as it's within the plate's power dissipation rating. This is typical of many power amplifier tubes during normal operation.

The 6GK6 PA driver tube socket used on most Swan models frequently have a flange that permits a tube shield to be placed over the tube, however it is generally not required or installed. It is not clear if all radios automatically left the factory with or without a shield installed, however it has been reported that it is advisable to remove the shield to help the tube run cooler. Of course, if you experience any transmitter problems (e.g. a driver tube self oscillation that mimics a power amplifier oscillation, since those signals appear on the PA tube grids) try re-installing the shield to see if it corrects the problem.

Pin 6 Internal Connection Caveat. In earlier transceiver models, Swan used pin 6 of this driver tube's socket as a sort of terminal strip connected to ground, since the early 6GK6 tubes had no internal connections going to pin 6. Unfortunately, later versions of the 6GK6 tube (reportedly some that were imported from Asian manufacturers) internally tied that pin to the screen grid. If you replace the older style with a newer style 6GK6 tube (those that are only about 25 years old) and pin 6 is tied to ground, it will burn out a 100-Ω resistor, a RF choke, and the new tube. About 5% of the tubes made have that internal connection.

Therefore, if you have one of these tubes with the internal connection, your options are to: (1) disconnect any wires/ground connected to pin #6 of the tube socket and terminate at any other convenient open tie point, (2) physically clip pin #6 from the tube (although then you will have to be extra careful to insure that the tube is inserted correctly in the socket), or (3) to only use tubes that have no internal connection (measure the continuity between pin 6 and all other pins to ensure that is the case). Note that tubes with the internal connection can be used in the audio amplifier circuit without a problem.

8.6.6. 6HF5

The 12-pin 6HF5, rated at 28-watts plate dissipation with a typical average RF power output of about 120 W, was the most popular sweep tubes used in SSB transmitters during the mid 1960s. All Galaxy 300, Galaxy III, Galaxy V, and V MkII, Galaxy 2000, Swan 350, 400 and 500, WRL Duo-Bander and some Hallicrafters and Drake units employed them. Some owners had rewired their 350 to use 8950s, but are now reverting back to the 6HF5 since they cost less than $1/4^{th}$ of the price of a NOS 8950. The 6HF5 is capable of roughly 250-W dc input PEP on SSB modulation per tube. Thus, a Swan 350, when new and with fresh tubes could do about 450-W dc input PEP on the lower 3 bands and a little less on 15 and 10 meters. The 6HF5 tube cannot be run in a grounded grid configuration because the cathode is internally connected to the suppressor grid.

Swan's Service Bulletin #10, February 1967, recommended that the GE brand tubes be used for replacement, since "*It has been our experience that some of the other brands are extremely difficult to neutralize*." It has also been reported that the Galaxy V manual also explicitly specifies the use of GE brand 6HF5 tubes. Some users have also reported that RCA tubes are easier to neutralize. Brands reported to be more difficult to neutralization include Zenith and Sylvania.

6HF5 Substitutes

6LG6. The 6LG6 is a direct substitute for the 6HF5, but it had an extremely low production rate and is very difficult to find.

6LF6/6MH6. The 6LF6/6MH6 tube can be used to replace the 6HF5, but is not a direct substitute. It is a much more capable than the 6HF5, with all manufacturer versions specified to have at least 40-W plate dissipation. The most desirable are those with the steel grid-lead radiators, which have a huge 45-W plate dissipation capability. Substitution will probably require at least alignment of the mixer and driver stages and the driver coil inductance may be borderline in meeting resonance requirements on 10 M, so that stage may sometimes need modification. The RCA brand tubes are the same height as the 6HF5, but other brands may be higher and will not fit into the rig without modification by lowering the socket platform by about ¼" or so.

8.6.7. 6KD6

The 6KD6, rated at 33-watts plate dissipation with a typical average RF power output of about 135 W, is used in the model 600T transmitter. For replacements, Swan specified RCA tubes.

6KD6 Substitutes

6LF6. The 6LF6 is a direct replacement for the 6KD6. It has a higher peak plate voltage and current rating, and a 40-W plate dissipation versus the 33-W of the 6KD6. About 15 to 20 W or more RF power output has been reported with the 6LF6 compared to the 6KD6. When used as a substitute, the driver stage must be aligned and the plate cap needs to be changed to the smaller size.

8.6.8. 6LQ6/6JE6C

The 9-pin 6JE6 was introduced in 1963 and is rated at 24-W plate dissipation with a typical average PEP RF power output of about 125 W. The 6JE6A has a plate power dissipation of 28 W, unless it is a GE brand, which is 30 W. By the time it evolved into the 6JE6C, the specs were nearly identical to the newly introduced 6LQ6. Both were rated at 30-W plate dissipation. The 9-pin 6LQ6, which has similar plate and power ratings to the 6JE6C, was introduced in 1968 and was used in Swan 350C, 500C, 500CX and Cygnet models.

The 6LQ6, like some other sweep tubes, has a short-term dissipation rating of up to 200 W and some manufacturers even used a Pyrex glass envelope, equaling or even exceeding some real RF tubes in ruggedness in some aspects. The 6MJ6 is essential the same tube except it has a stronger envelope and better heat distribution.

During the final days of tube building in the USA, several manufacturers would intermittently, depending on production runs in progress, place 6LQ6/6JE6C and in some cases 6MJ6/6LQ6/6JE6C labeling on the boxes, when the tube inside may have had any one or any combination of those designators imprinted on it.

6LQ6/6JE6C Substitutes

6JE6A/B, 6KM6, 6LZ6, 6ME6, 6MJ6. In any dual-tube or single-tube PA design Swan transceiver, anyplace the 6LQ6/6JE6C is used a 6JE6A/B, 6LZ6, 6ME6, or 6MJ6 can be directly substituted; that is, no wiring or other changes are required, other than perhaps the normal driver alignment and neutralization. Perusal of the PA tube specification chart given in Appendix C shows that all of these tubes essentially have the same electrical characteristics. In dual-tube PAs, these tubes may be mixed-and-matched in a pinch, combining any two tubes, regardless of manufacture or number type, providing they are a matched set. The 6MJ6 is desirable because it is a heavy-duty version of the 6JE6C/6LQ6, although later production 6JE6C or 6LQ6 tubes may if fact be the same.

6MC6, 6KM6. The 6MC6 and 6KM6 are a special category of direct substitutes since they can only be used in dual-tube PA transceiver models and only if both tubes are of the same type (e.g. a pair of 6MB6s or a pair of 6KM6s – do not mix-and-match as can be done with other directly substitutable tubes). Using tubes in pairs of the same type is required because of significantly different filament currents from the other directly substitutable tubes. The 6LQ6 (et. al.) has a 2.5-A filament current, while the 6KM6 has only 1.6 A and the 6MC6 has 2.9 A. Since the filaments of dual-tube PA are wired in series (the only exception is for the 700CX which uses 8950 12.6-V filament tubes wired in parallel), they must have the same current draws to obtain the proper 6.3-V ac voltage across each tube's filament. The 6MC6 is capable of 10% higher output power (130 versus 125 W for the 6JE6C) and for this reason is a desirable substitute. The 6KM6 is less desirable because the achievable output power will be significantly reduced (75 versus 125 W).

Because of this filament current difference, neither the 6MC6 nor 6KM6 is viable for use in single-tube PA Cygnet-design transceivers. It is possible to use these tubes, but a change is required to obtain the proper filament currents. The Cygnet models (except the 300B with the 8950) are wired so that the filaments of a number of other mini tubes are first wired in parallel and that group is then wired in series with the filament of the PA tube. This is a somewhat precise setup where the combined currents of this parallel mini tubes series is such that it equals the current required for the filament of the PA tube. This permits the 12.6-V ac winding of the power supply to be used. As noted above, the 1.6-A filament draw of the 6MC6 is significantly less current than a 6LQ6 (2.5 A) and would upset this delicate balance of voltage across the PA tube and the parallel/series connected filament arrangement. The 6KM6, in addition to having a reduce output power capability, also would similarly upset the voltage balance with its higher filament current (2.9 A).

M2057, 8950. Procedures for substituting M2057s or 8950s for the 6LQ6s in a Swan 500 are given in the Swan Newsletter, Issue 5, Section A.5.2.

8.6.9. 6MJ6

The 6MJ6 was produced as a heavy-duty version of the 6LQ6 and 6JE6C. It is more forgiving of abuse and more expensive than the standard 6LQ6/6JE6C. The 6MJ6 is rated at 30-W plate dissipation with an average RF power output of about 125W; however there are some electrical characteristics and structural differences that make it more robust than the original 6LQ6/6JE6 types. The GE 6MJ6 promotion sheet outlining these improvements is shown in Fig. 8-6.

6MJ6 Substitutes. As noted in the 6JE6C/6LQ6 paragraph, towards the end of the tube production era, the 6MJ6, 6LQ6, and 6JE6C tubes were essentially identical and were frequently labeled with all three designations on the tubes and/or boxes. You can use a 6LQ6 or a 6JE6A/B/C in place of the 6MJ6 without any problem, providing care is taken, as with all tubes, to ensure high

GE

6MJ6

T12 Novar Type

Beam Power Pentode

TUBES

Features: *Integral Envelope-Top-Cap Assembly
*Rugged Construction
*200 Watt Overload Rating
*Sharp High-Voltage Cutoff

The General Electric 6MJ6 is a double-ended, high-perveance, beam power tube of the novar type having a T-12 envelope. This type is specifically designed to be an ultra-reliable field replacement for The 6LQ6 and 6JE6C in amplifier services.

The 6MJ6 features an integral envelope-top-cap assembly which eliminates loose top caps and minimizes glass dome failures. The ruggedness of this design also assures reduced microphonics and the ability to withstand unusual shock and vibration.

The 6MJ6 has improvements to lower screen and control grid emissions with life. A unique plate connection cools the plate by conduction, resulting in lower plate operating temperatures and longer tube life. Other improvements allow this type to endure the excessive plate dissipations encountered during out-of-resonance tuning. Control testing ensures that the tube can withstand a 200 watt plate dissipation for a continuous or accumulated exposure time not exceeding 40 seconds, sufficient time to permit conventional tuning or for protective devices to function.

Figure 8-6 GE 6MJ6 Promotion Literature

power transmission level durations do not exceed the rated plate dissipation.

As described in GE's promotion literature, the 6MJ6 has an edge in its ability to withstand higher peak plate dissipations for a longer period (200 W for 40 seconds!) than the others do, so it is perhaps advisable when using a substitute to ensure that it is one of the triple labeled tubes to meet the higher stress conditions, particularly when used in the single-tube PA transceiver models.

8.6.10. 12AU6/12BA6

Both of these tubes are used in various transceiver model tube line-ups. The 12BA6 is a remote cut-off tube and the 12AU6 is a sharp cut-off. In the 250 transceiver model Sensitivity Service Bulletin, the substitution of the 12AU6 in place of the 12BA6 is suggested as a possible modification (along with the substitution of the 6GM6 for the 6EW6) to alter the receiver's AGC/sensitivity characteristics. The bulletin states "*Likewise, a 12AU6 many be substituted for the 12BA6 second I.F. stage. . . . the AGC control characteristics will be altered and the experimenter may enjoy trying it. Our own laboratory tests indicated the best all around performance with the 6EW6 – 12BA6 combination. This is one of the many decisions which must be made when moving a piece of electronic gear from the prototype stage into production. . . .*"

8.6.11. 12BE6

It has been reported that 12BE6s frequently become gassy with age/usage, loading down its circuit. So, if the circuit using this tube (AVC, etc.) or any stage connected to that circuit is malfunctioning, this tube should be suspected. If a tube tester is available, make sure you carefully test these tubes for gas, especially if audio problems are encountered.

8.6.12. 12BZ6

12BZ6 Substitutes

12BA6. You may find some Swan earlier model transceivers (such as the 350C, 400, and 500C) with a 12BA6 substituted in place of the more expensive and scarcer 12BZ6 used in the 1st IF amplifier. As noted in Table 8-3, the 12BA6 is listed as a substitution for the 12BZ6, with a notation that it may not work in all circuits. For Swan transceivers, substituting a 12BA6 for the 12BZ6, when it is used in the 1st IF, should work, however the 12BA6 will be working a little harder to achieve the same performance. The major difference is that the cathode and the suppressor grid pin outs of the 12BA6 are switched with respect to the 12BZ6 and there is also some difference in transconductance.

Since the suppressor grid and cathode connections are reversed, substitution could be a serious problem in some circuits, as well as just not working properly. However, in most circuits where there is little or no resistance to ground at both the cathode and suppressor grid, those tubes can be substituted without much worry. If used in the Swan's 1st IF, the 12BA6's cathode will be connected to ground and there will be no external cathode resistance, as it then be in the suppressor grid circuit. This results in a little higher cathode current.

8.6.13. 6146/A/B/W

The 6146 is a beam tetrode tube designed for RF applications and achieves an average RF power output of about 75 W. Surprisingly, it was reportedly first produced by RCA in early 1952 and was advertised as a "big brother" to the 2E26, which had been available since about 1946. While there are significant differences between the 6146A and 6146B tubes, as long as they are used in pairs of the same type, either type can be used in the model 250 six-meter transceiver. It has also been reported that the 6146 and 6146A have been successfully inter-mixed with no problem in non-Swan radios. Only in the most critical design of a piece of equipment would direct substitution of one tube for the other be considered risky. There are a few applications in some transmitters where the PLATE and LOAD controls will be in a slightly different position for maximum output depending on tube type and, of course, the idle current must be reset to the proper level.

When the 6146B was introduced, the manufacturer suggested that the only change for maximum power and efficiency was to increase the screen voltage a bit over what was normal for the earlier 6146/A type tubes. That statement in itself gives an indication of what little concern the manufacturer gave to swapping the 6146B for earlier tubes. If it is not feasible to increase the screen voltage, that is no big deal. As with any substitution of tubes not having the exact electrical characteristics of the original, it is a good policy to check the alignment of the RF mixer and driver to ensure maximum operation efficiency of those stages.

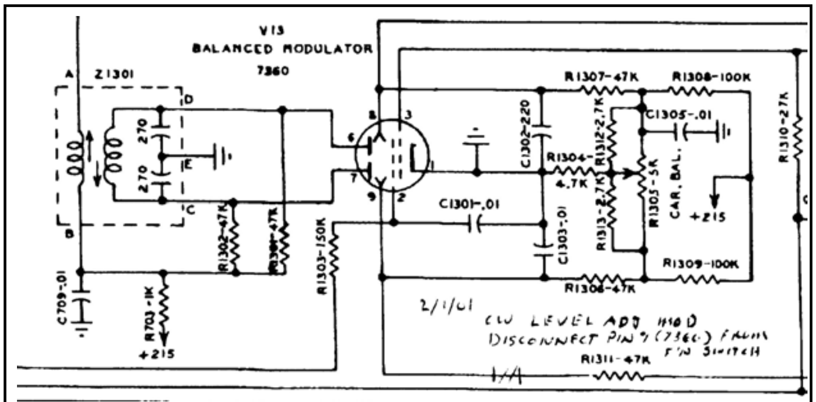
Tubes labeled 6146W probably should not be used since they might actually be either a 6146A or a 6146B. If a 6146W was made prior to 1964, it's a 6146A; if was made after 1964 it's a 6146B. With a 1964 date, it depends on which company manufactured it and the month of manufacture, so you usually can't determine which it is.

8.6.14. 7360, 6JH8 Balance Modulator

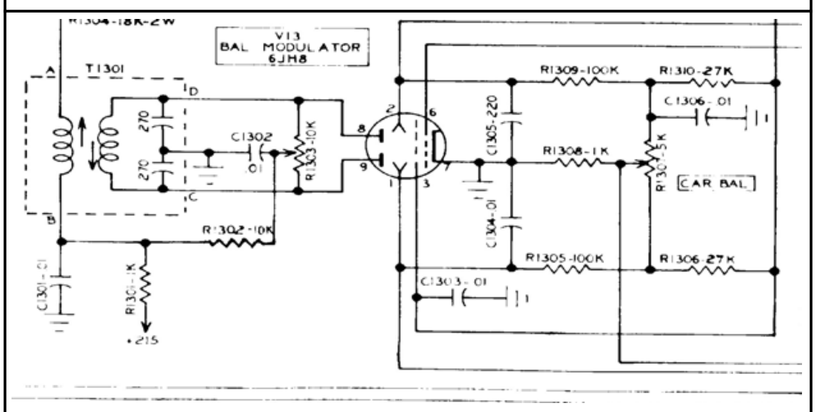
The balanced modulator tube should have a metal shield installed to prevent interaction with stray electromagnetic fields within the cabinet. RCA was the only producer of the 7360, an industrial receiving tube that has not been produced in over 25 years. As with many other tubes, it was sold to other producers and relabeled, so tubes may be found imprinted with other manufacturer's names and logos. All early Swan transceiver models (e.g. 140, 350, 500C) used the 7360 tube for the balanced modulator, however beginning in 1968 it was replaced by the 6JH8. The 250C, 350C, 500CX (and the last 25 of the 500Cs), and all subsequent models used this tube. At that time, the 6JH8 sold for about 1/5th the cost of a 7360 so Swan saw not only a cost saving and availability opportunity, but also found that the 6JH8 worked better. However, some users feel that the audio quality from transceiver models using the 7360 is somewhat superior to those that use the 6JH8. The 6JH8 can be retrofitted into any transceiver employing the 7360. There are no circuit changes other than the tube socket pin wiring discussed below; all other components remain the same.

Different production versions of the 7360 tube are reported to have significantly different filament current draws than the 0.35 A specified in the general tube characteristics. While this has no impact on radios that apply filament voltage directly from the transformer, it can become a problem for special cases like the 240 transceiver, where its filament is wired in parallel and series with other tubes. Because of the series-wiring configuration, the design depends on each tube drawing near its nominal filament current; otherwise, the actual voltage across the tubes can be incorrect. For example with a 12.6-V ac filament supply and with one tube drawing 0.3 A and a second in series drawing 0.2 A instead of 0.3 A, the filament voltages will be 5.4 V and 7.2 V rather than equal. In the case of the 240, any 7360 deviation from the nominal 0.35 is minimized by the 7 or 8 other tubes wired in parallel with it, so any such filament

7360	Function	6JH8
1	cathode	7
2	sup grid	3
3	con grid	6
4	filament	4
5	filament	5
6	plate #1	8
7	plate #2	9
8	deflector #1	2
9	deflector #2	1



500C 7360 Balanced Modulator Wiring



500CX 6JH8 Balanced Modulator Wiring

Figure 8-7 Bal Mod Tube Substitution Schematic (7360 to 6JH8)

current draw variance should not be a problem.

7360 Tube Substitutes

6JH8, 6AR8. The 6JH8 or 6AR8 is not a direct replacement for the 7360. While there are several tubes that will replace the 7360 in varying degrees of effectiveness (which has to do with the amount of voltage required to switch from one deflector to the other for proper modulation and power handling), the best replacement is the 6JH8, because of its low switching voltage requirements and higher power handling capability than the 6AR8. Although the 6ME8 and 6HW8 will also work, the circuit needs some modification to operate well. There are two approaches suggested for implementing this 6JH8 modification as listed below.

6JH8 Adaptor Plug. Rather than rewiring the wires and components going to the tube socket already mounted on the chassis, an option is to just make up an adaptor plug out of an old 9-pin socket or whatever else shows up in the junk box and wiring it with the correct pin assignments as shown in Fig. 8-7. Such homebrew plugs could include just cutting some pins from a bad tube and heat fitting or gluing them into a piece of plastic to make a 9-pin plug, or for a real inelegant solution, just sticking hookup wire directly into the old socket. However, there are potential problems with this adaptor plug modification. The balanced modulator tube is sensitive to stray electromagnetic fields and without proper shielding, instability in carrier null adjustment may occur because of the exposed socket adaptor leads. If problems are encountered the only other option is to re-wired the new pin assignments directly on the chassis installed tube socket.

Rewire Tube Socket. To convert the 7360 socket for 6JH8 (or 6AR8) use, the wires and components currently attached to it must be rewired to the corresponding socket pins shown in the schematics for any later Swan equipment that employs the 6JH8 (e.g. the 500C, 500CX, or 700CX models). As indicated in the schematic excerpt shown in Fig. 8-7, this requires all pins, except the filament, to be rewired. After rewiring for the 6JH8, the 6AR8 also becomes a direct plug-in and will work, but will have slightly lower power handling capabilities than the 6JH8. When doing such rewiring (or any other parts removal and replacement), it is a good idea to first remove as much of the existing solder about the pins and wires by using the thin copper braid that is sold for such purposes. It is much easier than attempting to use a solder sucker or just heating the connection and yanking at the wire. If you are lucky, enough solder is removed so that the wire can be simply unwrapped from the pin!

8.6.15. 8950

The 8950 is a compactron beam power pentode primarily designed for RF applications. The 12-pin, 1.4 A peak current (1.1 A typical), 8950 tube has a 33-W plate dissipation rating and achieves an average RF output of about 130 W. Is rather hard to find and is now extremely expensive (new old stock 2003 price range of $75 to $90 per tube, unmatched). Interestingly, a GE data sheet specifies a maximum plate and screen ratings of only 800 V and 250 V respectively, so, like the sweep tubes used in most Swan PAs, it too is operating at or beyond its design ratings. It's rated at a 400 mA DC cathode current with a 1,400 mA peak rating, so it is very capable of handling the high peak SSB outputs. Nevertheless, as with the sweep tubes, care should be exercised to limit tune-up durations, where DC cathode currents of 600 mA or more can occur, to periods of 5 seconds or less.

The 8950 is a special 12.6-V filament version of the 6LB6 TV sweep tube and is used in the Swan 700CX and 300B transceivers, and the 1200X linear amplifier. Do not be surprised if you have difficulty in neutralizing the 700CX on 10 meters. Even the Swan production line had great difficulty in satisfactorily neutralizing the 700CX on that band, resulting in 30% to 50% of the units requiring re-tubing during manufacture before neutralization was achieved. This problem continued on-and-off throughout the production of the 700CX and resulted in the dropping of the 8950 from the transceiver design. Swan reverted to the 6MJ6 for the later Swan 750CW and the HF700S models.

8950 Substitutes

6JS6C, 12JS6. Most 12JS6 pentodes are the only direct plug-ins for the 8950. However, you do have to make sure that in your application, pins 2 and 6 are connected together and pins 5 and 9 are connected together at the sockets. Some tube manufacturers did not have an internal connection between pin 6 and the cathode and some did not have an internal connection between pin 9 and the control grid. As long as those pins are connected together at the socket in your application, any 12JS6 will replace the 8950. Earlier versions of this tube had 28 and 30-W plates and slightly lower screen voltage ratings. However, during the final years that GE made tubes, the same plate for several horizontal output tubes in order to cut costs – later versions of these two tubes have a 33-W plate. The 6JS6 may also be used, providing the tube socket is rewired for a filament voltage of 6.3 volts. However, some of the Japanese 6JS6s differ slightly in inter-electrode capacitance, which in some cases makes neutralization a little touchy on the higher frequency bands (15 meters and 10 meters).

6LB6. The GE 6LB6 tube is near identical electronically (slight differences in input/output capacitances, filament current, envelope temperature, etc.) to the GE 8950, but with a 6.3-V instead of a 12.6-V heater filament. During the last 5 years that GE produced the 8950, they were able to cut costs by making several of the larger horizontal output tubes with the same plate. Later production units were rated at 33-W plate dissipation even though most manuals and manufacturers data only claimed the 30 W specified for the earliest production units. On GE tubes there is a dither code (a Braille-like dot pattern) printed on the envelope that identify the vintage. Or, you can compare the plate dimensions to determine if you have the later 6LB6 (see Fig. 8-4).

To use the 6LB6s in place of the 8950s, the only modification needed is to connect the filaments for the two tubes in series, instead of parallel, which on the 700CX involves two connections. That way, if one heater burns out, the other one also quits. With the heaters in parallel, as with the standard 8950s, if one goes bad, you can over-drive and ruin the other tube. Check the replacement tubes for clearance, as some variance in height may be encountered. If the 6LB6 is used as a substitute, it is desirable to obtain GE tubes that have the screen grid-lead radiator installed (see Fig. 8-3). The GLR structure generally permits much easier neutralization of the Swan transceiver on the 15 and 10-meter bands.

6LF6. Swan never employed the 6LF6 tube as part of the standard transceiver tube line-up, however it can be used to replace the 6HF5 and 8950 (after rewiring the socket filaments in series to use the 12.6-V ac filament). It is are a much more capable tube than either the 6HF5 or 8950, with all manufacturer versions specified to have at least a 40-W plate dissipation with an average RF power output of about 145 W. For Swan application, the most desirable are those with the steel radiators along either side, which have a 45-W plate dissipation capability. Like the 6LB6, substitution will probably require at least alignment of the mixer and driver stages and, because the driver coil inductance is borderline in meeting resonance requirements on 15 and 10 M, that stage may sometimes requires a small change in the RF driver circuits to better match the output of the driver to the input of the 6LF6. Occasionally, you will find some of the 6LF6s are too tall for your PA compartment. In this case, the socket platform can be lowered a ¼" or so to permit installation.

6KD6. The 6KD6 will work in place of the 8950 as well, but it is a little more taxing on the transformer because it draws more filament current (5 A). See Appendix C, the PA Tube parameter comparison table.

6MB6. In 8950 type linear amplifiers, the 6MB6 type tubes are good substitutes after the socket filament wiring changes are made to connect them in series in order to use the 12.6-V ac filament supply.

M2057. The M2057 has the same electrical characteristics but is about 1/3rd larger in diameter and has 50% higher plate dissipation and power output. The M2057 will fit into Swan transceivers without modification.

8.6.16. Pilot Lamps

While a rather mundane subject area, there are a number of relevant points to consider when replacing these lamps, especially since some types may not be readily available and users may desire to use a substitute with a somewhat different current or voltage rating. Swan used an assortment a miniature lamps in their various transceiver models, as shown in the partial listing below. Note that on some schematics, both the part number (preceded with a letter, such as B1601 or B1701) and lamp type are listed (e.g. #47), on others just the lamp type (e.g. 500/C), while on others (e.g. 260 and 270) just the part number is used. Likewise, the manual parts list is also inconsistent – the bulb type is not even specified or referenced in some manuals.

Excessive Heat. Think twice before using a lamp rated at a higher current. It will generate more light, but also more heat that can cause discoloring or even dark burn marks on the off-white plastic light diffusion panel behind the main dial used on many transceiver models. For example, the type 44 lamp has the same voltage rating as the type 47, but its 250-mA current draw has ~1.6-W versus ~1-W power dissipation. In any case, regardless of the lamp used, make sure it is installed with as much space as possible between the bulb and the white plastic panel to preclude any discoloration or burn marks.

Life Rating. If you use a substitute lamp, in addition to considering current rating, be sure to check that the average life is in the thousands of hours range. You may find lamps that have the same voltage and current rating but do not conform to the type standard with respect to operating life. Some are intended for flashlight use and, as such, have a very low average life, on the order of tens of hours (e.g. at least some Radio Shack type 53 and 1815 lamps are rated at only 30 hours!).

Lamps in Series. On some transceiver models the dial and meter miniature lamps are wired in series (e.g. the 250C and 500CX transceivers use 6 V lamps in series across the 12-V ac filament supply), rather than parallel. If so, don't mix types with different current or voltage ratings since that will result in excessive voltage across one filament and premature failure.

Table 8-5 Pilot Lamp Data

LAMP Type	VOLTAGE (V)	CURRENT (mA)	LIFE (Hrs)	TRANCEIVER Models
47	6.3	150	3K	250, 260, 270. 350C, 500/C/CX, 700CX
N/A	12	40	N/A	350D
53	14.4	120	1K	240
756	14.0	80	15K	350, 400
1815	14.0	200	3K	120, 140, 175, 300A/B, 350B, 600R/T

9. TRANCEIVER PROBLEMS AND FAILURE MODES

This section summarizes a variety of common failure modes that have been observed with Swan transceivers and a number of case studies of actual reported problems, causes, and solutions. In many of these case studies, the problems are similar to those described in the General Failure Sections, while others are unique. Review of this information will hopefully provide some insight into problems experienced with Swan transceivers that will aid in both the routine care-and-feeding of your rig as well as any elective or required emergency surgery.

With any failure, it's best to start with a review of the troubleshooting guide provided in the Swan Operation and Maintenance manuals. These list many of the more common causes, including operator error. Make absolutely sure you're not repairing or sending out for repair a rig that isn't broken. Everybody, even those with years or decades of experience, occasionally slips-up and assumes there is a problem, when in fact it's a simple operational procedure or non-transceiver failure. Such slip-ups could include things like: (1) troubleshooting a VX-2, only to find out that you have forgotten to switch the PTT/VOX switch into the VOX position, (2) forgotten headphones (buried beneath paraphernalia) plugged into the power supply audio jack that sounds like no or low audio, (3) a good microphone that suddenly goes bad that's interpreted as a modulation problem, (4) no antenna or an intermittent connection to the radio, or (5) intermittently shorts caused by a poorly soldered connector on a microphone or key that make received audio sound awfully low and transmitter tune-up down right unusual. Unfortunately, there are times when there is indeed an electronic problem and these fall into basically two categories.

There are a number of generic, but easy to repair, failure modes frequently reported by Swan owners that fall into the "*yep, that's a real common problem, happens to them all*." Some of these are summarized below and discussed in the specific case studies. Rather than spending hours trouble shooting only to re-discover fire, it's best to read-through these areas to ensure the problem you're having doesn't fall into this category.

There are also much more difficult, esoteric problems that fall into the "*gosh, I've never seen that before*" category, where some in-depth component level circuit troubleshooting is required. In such cases it is extremely helpful to have a voltage and/or resistance reference chart(s) (see immediately below and Swan Newsletters, Issue 8, Section A.8.1 and Issue 9, Section A.9.2 for additional information) measured on that specific transceiver when it was known to be in working order to help isolate the problem area. Some of these types of problems are also included in the case studies discussed later in this section.

Document. Always take the time and care to document any modification, troubleshooting, and alignment work done on any piece of Ham gear. With the widespread availability of high-resolution digital cameras, it's also a good idea to photograph the circuit area (before and after modification) as another means of documenting work done. Maintaining an overall shack equipment diary (purchase date, cost, known equipment history, measurements, modifications, etc.) is also an excellent idea.

9.1. Troubleshooting/Repair Aids/Hints

9.1.1. Safety

Always use extreme caution when working on any rig, especially if the HV and MV are exposed. Double and triple check that power is actually off or disconnected, even if you are absolutely positive that it is! If it is not necessary for the unit to be plugged in, unplug it, disconnect the power supply, and wait awhile for all capacitors to discharge – do not rely only on the on/off switch as a means of removing ac power. Rigorously adhere to these rules! Once some experience is gained with working on this type equipment, the adage "familiarity breads contempt (or at least carelessness)" comes into play. Many "experienced" users violate these and other basic rules (working with the rig powered up with PA cage uncovered and exposed), only to realize to their horror that they had inadvertently though the power was off or that they just had carelessly reaching across the rig within an inch of deadly exposed HV!!!!!

It is a good idea to use a Ground Fault Interrupter (GFI) in every electronics workshop. This device is inexpensive and looks almost identical to a regular 120-volt outlet. It is designed to shut off the power off if abnormal current to ground is detected (e.g. a ground leak through you body). If you use old test equipment such as a tube tester or an oscilloscope, you may find that the GFI switches your power off for no apparent reason. The likely cause off this is leaky ac line filter/bypass capacitors (i.e. too much electrical current is flowing through them).

If you are using old test equipment, be sure to replace any such capacitors with new ac rated safety-approved units.

9.1.2. Voltage and Resistance Charts

Swan's approach to voltage and/or resistance charts changed over the years. In the very earliest models (e.g. 120/140/175) only a chart of tube-pin voltages during receive and transmit conditions is given. This evolved to the inclusion of both resistance and voltage measurements in the early mid-term transceivers manuals and then back to only the voltage measurements in most of the later transceivers (post 350) manuals.

If your transceiver is known to be in good working order, it is extremely valuable to make either a resistance or voltage chart (preferably both) for all tube pins, accessory socket pins, and VFO socket pins. When making such a chart, make sure that all control and switch settings are carefully recorded. This will serve as a good baseline for troubleshooting any future component failures. While it will be essentially a duplication of the chart(s) given in the Swan Operation and Maintenance Manual, it will be much more useful in that it will be specific to your transceiver and therefore will reflect all the effects of component tolerance variations, circuit modifications, and normal aging. If you are inexperienced or uncomfortable working with the high voltages in a tube transceiver, the resistance chart should be your approach.

In either case, recognize that the manual listed values are only nominal. If actual ac line operational voltage is higher (most likely in the 120-124 V range) than the nominal 117-ac line voltage, then the measured voltage levels will be proportionately higher. Likewise, whether measuring resistance or voltage, meter measurement error can be significant, particularity if the lower portion of the scale range is used. For example, if the 1,000-Ω sensitivity is used and a known 80-Ω resistance value is measured, with a 3% FS meter accuracy (i.e. ±30 Ω), the actual measurement will be anywhere between 50 and 110 Ω! Using the 100-Ω sensitivity scale, that measured value should be between 77 and 83 Ω.

Also, with the aging of transceiver components, coupled with the normal tolerance ranges when new, the actual normal operating voltages might will be 10% and even as much as 20% higher or lower than the listed nominal value. Of course, if you had made up a resistance or measurement chart for you specific transceiver when it was known to be in a good operating condition, then measurements made during later troubleshooting should certainly be well within 10%.

9.1.3. VTVM, VOM, Oscilloscope Calibration

If you are working with test equipment of dubious calibration accuracy, you can get a fairly good high voltage scale calibration reference from the 150-V voltage regulator tube output employed in older model Swan transceivers. Likewise, the 10 or 12-V Zener output can be used as a good calibration source for lower test equipment measurement ranges.

To assist in quickly calibrating a VOM or VTVM ohmmeter function, assemble a simple matrix on a perforated PC board of 1% precision resistors spanning perhaps the 1 Ω to 1 MΩ or more range. It can be used when making a resistance chart for a transceiver or diagnostic measurements during troubleshooting as a quick accuracy calibration check of your VOM or VTVM.

9.1.4. Parts Placement Sketch

When replacing parts, especially when multiple components are removed, it is wise to draw a rough parts placement sketch that illustrates the component positions, connection points, and polarity (if applicable). This will help ensure that a part isn't erroneously wired due to a faulty memory or inadvertent polarity reversal. This will save a great deal of time compared to trying to confirm the accuracy of the re-installed components against the schematic. Even Swan, in many of their service and upgrade bulletins, included a physical parts layout graphic along with or in place of an actual schematic.

9.1.5. Schematic Comments

Component Location. When tracing a signal or voltage path on a schematic, frequently multiple connections are indicated to a particular point, however a component's position relative to the schematic's common connection point is not necessarily at the implied physical location. For example, pin 7 of a tube could be shown connected to both a capacitor (whose other side is connected to ground) and a wire the goes to a wafer switch contact that in turn has a resistor connected to it (whose other side may go to a dc supply voltage). In such cases, the capacitor might be inserted at the wafer switch, rather than at tube pin 7 as suggested by its position on the schematic.

Wafer Switch Position. Note that not all schematics explicitly specify the mode switch position. On almost all schematics, the wafer switch position shown is often shown in the counter-clockwise switch position (often the CAL or REC position) and clockwise rotation on the schematic corresponds to the other switch positions (REC, XMIT, etc.).

9.1.6. Tools

While a good selection of small box, socket, and Allen wrenches, non-metallic alignment tools, and an assortment of small slotted and Phillips head screw drivers is essential, a few other less common, but highly useful tools are desirable (also see A.4.1 and A.5.3) and will make life a lot easier, including:

Forceps – locking medical type forceps are idea for handling small parts (nuts, washers, etc.), retrieving dropped items in tight spaces, and can be used as heat sinks on the leads of components that might be damaged by excessive heat while soldering.

Dental Pick – this strong, sharp pointed probe is perfect for re-arranging wires, making wire insertion holes in existing soldered pins (while heating the solder) for wire/lead insertion, removal of debris from tight spots, etc.

Tweezers – a couple pair of self-closing tweezers are useful for handling small parts and can serve as a heat sinks when soldering delicate components.

Cleaning "Eraser." Another simple but useful tool is a pin/connector-cleaning device that comes in the form of a thick mechanical type pencil. It consists of hundreds of strands of glass/fiberglass. As the mechanical screw drive is turned, the bundle extends or re-tracks into the pencil barrel. The bundle of fibers rapidly and effectively abrades any surface corrosion of Cinch-Jones connector pins, tube pins, tube socket and terminal strip connectors, etc. It leaves a very clean, scratch free (at least to the naked eye) surface – ideal for use in conjunction with one of the cleaning/conductivity enhancing products (e.g. De-Oxit, etc.). One of this type of cleaning pen is make by Faber-Castell, Germany (No. 30103), marketed as a glass/rust eraser, however this particular brand does not appear to be readily available in the US.

De-soldering Braid. When replacing parts or doing other rewiring of an existing solder connection, it is a good idea to first remove as much of the existing solder about the pins and wires by using the thin copper braid that is sold for such purposes. It is much easier and much less messy than attempting to use a solder sucker or just heating the connection and yanking at the wire. Simply apply the braid between the well-heated soldering iron and the joint and the solder will be sucked into the braid. If you are lucky, enough solder is removed so that the wire can be simply unwrapped from the pin!

9.1.7. Failure Identification

Prior to assuming there is an exotic, difficult to find failure of a subcomponent in the circuit (capacitor, resistor, choke, coil etc.), be sure to check the more common and easy to fix problems that are the root cause of the vast majority of failures. This includes dirty and corroded relay contacts, dirty and corroded Cinch-Jones connectors (including those on the ac power cord), poor tube pin contact, bad tubes, and misalignment.

When working on any unit, always carefully visually inspect all wires, connections, and components in the immediate area of interest for unsoldered or cold solder joints, indications of component overheating, or component leads/wires that have been inadvertently pushed or placed perilously close to adjacent connections. Also look for parts that have been previously replaced, an obvious indication of past problems and perhaps the cause of problems with a previously repaired "*working the last time I used it*" unit.

Sometimes you can temporarily accentuate or correct a failure by just taping or gently flexing (with a completely non-conducting insulated tool) Cinch-Jones connectors, tubes, or components, to assist in identifying loose/intermittent connections, cracked or cold solder joints, shock sensitive tubes, etc. Even with close visual inspection, cracked solder joints can be invisible to the eye.

Problem Example. A real life anecdote that highlights this issue involves the refurbishment of an 117XC power supply. The power supply had been reportedly used within the last year and was working. Initially power-up tests with a Variac prior to refurbishment showed that it was outputting the correct no-load voltages. However, upon opening the patient up, it was found that minor and major surgery had been repeatedly performed.

Two of the 100-µF, 350-V HV filter capacitors had been replaced in the distant past (replacement units were 450 V, but of similar large size and construction of the originals). The relay supply filter capacitor (250 µF, 15 V) had been replaced with a newer style 100-µF, 15-volt unit – it had been soldered to the terminal on one side, but on the other, it was merely pressed into the connector slot and was unsoldered. The medium voltage diode bridge had been replaced in the distant past (leads fragments from the original diodes were still in the connection terminals and the replacement old style diodes were installed). The high voltage rectifier bride had also been replaced at least once, with newer vintage diodes used.

Finally, the relay rectifier diode had also been replaced, with its leads merely tacked onto the top of the terminals. Upon checking in-circuit capacitor ESR (see Section 10.3.1), it was found that one of the other original HV filter capacitors was failing. Obviously this power supply had some recurring problem(s) in its past. In this case, refurbishment included replacement of all diodes and all electrolytic capacitors, as well as two of the bleeder resistors which had 300-KΩ resistance readings versus 150-KΩ specified, and the relay resistor which measured 9.8 Ω versus the 4.7 Ω.

When replacing the capacitors, what might well have been the root cause of the dismal repair history of this power supply was finally discovered. One lead of an original factory installed HV electrolytic filter capacitor had never been soldered and worse yet, it had never even been wrapped around the connection terminal. Since these were the old, very large capacitors that barely fit within the available space, it was firmly wedged between the two terminal strips with the one capacitor lead just barely making contact with the terminal. That particular terminal was very difficult to see clearly. Such a situation could clearly have been the cause of an intermittent problem with any equipment movement (e.g. desk vibration) or perhaps even with temperature changes. Moral of the story – always visually check all components!

9.1.8. CPS to Hz Conversion

Swan manuals, as well as much of the technical information from the Swan-Net written by old-timers, often express frequency information in the archaic units of cps (cycles-per-second), kc, or Mc. While all of these references contained herein have been converted to Hertz (Hz), kHz and MHz respectively, for the convenience of the reader, it is often helpful when working on your transceiver to have either a chart or nomograph to aid in rapid conversion without the use of a calculator or computer. Fig. 9-1 shows a semi-logarithmic chart of such a conversion, expressing CPS on a linear scale and Hz as a logarithmic value. The information is based on exhaustive amounts of empirical data collected, analyzed, modeled, and published 1967 time frame by government and commercial laboratories. Strangely, this chart is of most use annually on April 1.

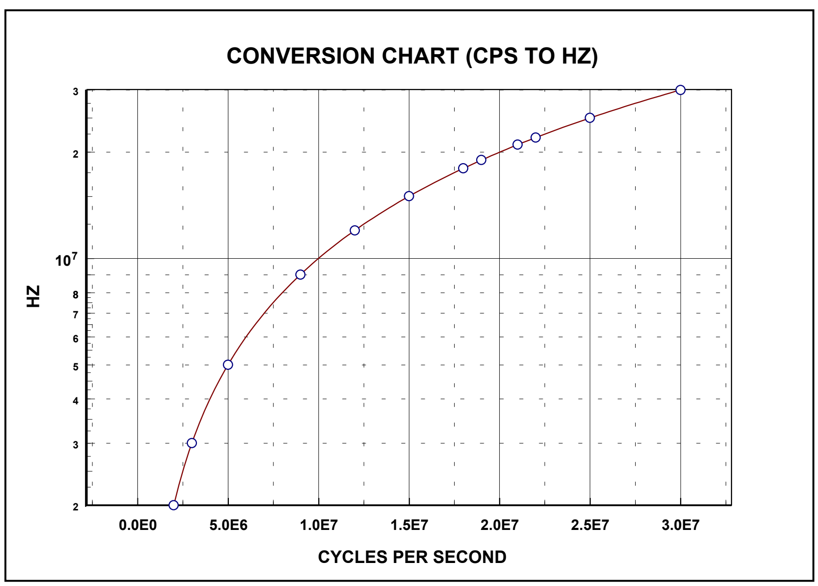


Figure 9-1 Conversion Chart, CPS to Hz

9.2. Drift Problems and Solutions

While some drifting problems can occur in any transceiver model due to a variety of causes, the most endemic problems were perhaps with the 350 and 350C era transceivers, due to a specific band wafer switch problem that turned up after a year or so of use in roughly 50% or less of the rigs. Hence the derogatory monikers, "*3-drifty*," "*drifty-fifty,*" and "*drifty-350*." Likewise, with its higher operation frequency, owners of the model 250 six-meter transceiver frequently reported drift problem with some units.

After reviewing the following paragraphs and other sections dealing with drift, it becomes clear that correction of this problem certainly partially falls into the category of an art as well as a science, or even perhaps Voodoo electronics. Excessive drift problems frequently do not lend themselves to simple, concise causes and in some cases, even contradictory solutions are suggested (i.e. too much ventilation, too little ventilation, etc.).

Other difficult problem areas on specific models have resulted in unconventional solutions. In private correspondence to a Swan 240 owner experiencing driver or final amplifier self oscillation problems, Swan Customer Service representatives suggested a number of bizarre sounding solutions, including "*snapping*" the beryllium copper ground straps, "*prying*" the supporting shafts of the band change switch inward, etc., which they admit " . . . *sounds like it borders on sorcery, but after tracing the problem on several rigs, it appears to be the best answer.*" Some drift problems and solutions certainly fall into this category, where "*sorcery,*" or at the very least, multiple, unconventional corrective actions are required.

Without a doubt Swan and many past and current day transceiver users have spent a great deal of time investigating this problem and it's equally clear that the solution(s) of such a problem can be exceedingly difficult. Drift is a function of temperature, is affected by both measurement instruments and physical proximity of hands, probes, or tools, and has a whole multitude of potential causes, many of them inter-related. Fixing such a problem is kind of like shooting at a moving target, easier said than done. So, remember when reviewing the information that there will not necessarily be one solution for all cases, but most likely one or more of the corrective actions discussed may be required. A synoptic list of recommended causes and solutions is given below – read the appropriate following paragraphs for details. Also, review the Swan Newsletter, Issue 7, Section A.7.3.

- Defective wafer switch contacts (clean contacts, replace switch)
- Corroded wafer switch contacts (clean contacts)
- Poor mechanical VFO enclosure integrity (tighten all enclosure and lid screws)
- Poor mechanical VFO coil/trimmer capacitor mounting (tighten mounting nuts and bolts)
- Bad VFO temperature compensation disc capacitor (replace capacitor)
- VFO band coil inductance changed with coil deformation. (replace temperature compensating capacitor or coil)
- Bad or poor VFO voltage stability (replace –10/12 V Zener diode)
- Improper temperature stabilization due to VFO enclosure ventilation holes (close any holes on VFO enclosure cover)
- Improper ventilation (use fan to cool and minimize temperature equalization time)
- Improper VFO transistor heat dispersion (use heavy duty heat sink on VFO transistor)
- Mechanical stress on component leads and/or poor solder joints within the VFO compartment that are not PC board connections (re-solder all connections)

A great deal of notoriety has been associated with the Swan frequency drift problems, some warranted and perhaps some due to a combination of past reputation and unreasonable expectations because of improved technical standards associated with newer state-of-the-art equipment. Before condemning a particular Swan transceiver with the drift label and attempting a fix, make sure that its excessive drift is indeed beyond what would normally be expected on tube-era equipment.

Discussed in the following paragraphs of this section are the Swan's advertised drift specification, Swan Service Bulletins, examples of typical expected warm-up drift, examples of a true drift problem, and various reported causes and corrective actions. First, be sure that what is being perceived as a drift problem is in fact electronic rather than operational. Without the extremely tight drift specification and high resolution receiver incremental tuning (RIT) common on today's transceivers, it is all too easy with a Swan or other tube-design radios to make minor tuning corrections to the initial QSO frequency, causing appreciable changes from that frequency. To a listener with a digital readout and high resolution tuning and/or RIT, this can easily be interpreted as drift, for which he may readjust his own transmit frequency, causing a cycle of frequency readjustment. It may be best in many cases to just leave well enough alone and listen to Donald Duck for the remainder of the QSO. Remember, in most cases your contact may have never used or even seen a transceiver without a digital display, may be using RIT or XIT (or both) and may be even using aggressive signal processing (compression), altering the audio characteristics and quality!

Swan's VFO Design Comments. The earliest Swan transceivers used a tube design for the VFO oscillator while later units had this function transistorized. Swan's VFO design approach in the early 350 design days was that both capacitance and inductance must be adjustable in order to properly control VFO tracking over the transceiver's frequency dial. In the VFO circuit used on those early designs, the physical stability of the coil's adjustable slug to stay-put was a primary issue, particularly when users where going back and forth with the coil slug to calibrate the VFO. Because of this concern, tests were conducted by both the coil manufacturer and Swan to evaluate the inductance stability of fixed coils under varying temperatures to determine if it could be successfully used. They found the fixed coil's stability to be stable enough to keep the coil side of the tuned circuit within 1 kHz of a desired frequency. Therefore, in 1965 Swan modified the circuit design and began employing a fixed VFO coil.

The extreme accuracy requirements of these fixed-type coils dictated the necessity for absolute precision in forming, laying, and tapping the coil. Since coil inductance is critical to frequency tracking, the coil had to present an exact stable value to the tuned circuit so that tuning linearity could be maintained. That is, with the correct capacitance setting of the VFO tuning capacitor and trimmers, the frequency dial should read, for example, 7,000 kHz when the actual frequency is 7,000 kHz and when the VFO is spun up to 7,300 kHz on the dial, the actual frequency should also be 7,300 kHz. If, on the other hand, if the frequency dial reads 7,300 kHz, but the actual frequency is say 7,295 kHz or 7,305 kHz, the only way to correct that tracking error (assuming the VFO main tuning capacitor is running true) is to adjust the inductance and then recalibrate with the VFO band trimmer.

Thus, the fixed coil design approach has to be right the first time – there is no way to change it without physical modification. That is why extensive testing of these coils was necessary before bolting them in. Also, as noted above, the search for perfect tracking does not stop completely with the coil, as the VFO tuning capacitor must also deliver the correct capacitance at each position on the dial to adequately track throughout the band's frequency range.

Past analysis of Swan drift problems have attributed the problem to a wide variety of causes, including physical VFO coil flexing and deformation or coil winding de-lamination with heat extremes. While that is certainly a possibility in a specific case, it is unlikely to be the root cause of most Swan drift or frequency jumping problems, since similar behavior would also then be expected in nearly all other tube-era receivers, transceivers and transmitters, because many employed a similar VFO tuner design.

9.2.1. Drift Specification and Characteristics

At least a 15-minute warm-up period with significant drift is both realistic and expected, as most early tube transceivers did not have ovens, feedback or PLL systems to keep oscillators perfectly steady – only passive temperature compensating components.

For most later transceiver models (i.e. post 240), Swan specified a drift tolerance during the first hour of operation of less than ±1 kHz in the 80, 40, and 20-meter bands, and less than ±2 kHz when operated in the 15 or 10-meter bands. The 6-meter Swan 250 transceiver also specifies ±2 kHz drift within the first hour.

With the 240, drift rates of less than 500 Hz in the first half hour and 200 Hz/Hr thereafter are suggested as attainable, but only with proper adjustment of temperature compensation trimmer capacitors. Beyond the initial one hour warm-up time, drift is not specified in most other manuals, however independent measurements suggest that drift rates of less than 200 Hz per hour are indeed reasonable (most likely dependent on ambient temperature variations and transceiver temperature variations associated with transmitter duty cycle and power output).

9.2.2. Measured Drift Case Study

How much do Swans really drift and what does the typical drift look like? While each case is going to be unique, an idea of the type and magnitude of drift that can be expected is shown in the examples of drift measured on a 500CX equipped with a 508 VFO and a 350D are shown in Figs. 9-2 and 9-3.

Keep in mind when examining the data that the measurements do not have a high degree of repeatability: switching back and forth between bands during measurements will cause discrete frequency jumps. Even finger pressure on the switch and final wafer contact position when the switch is returned to a band setting can and does affect both absolute frequency and relative drift rate. Likewise, ambient room temperature and the use of external fans will also influence stabilization rates. Note that when higher VFO drift rates are occurring during warm-up, they mostly affect CW operation – in the SSB mode, after a 15 or 20 minutes warm-up period, careful read-justment of the dial frequency permits reasonable operation in all but the most severe drift rate conditions during warm-up to full temperature stabilization.

All data were collected with the equipment at room temperature (68° F), no external cooling (fans) and with initial power turned on 30 seconds prior to the first measurement. Fig. 9-2 shows a comparison of normal drift on the 20-meter band as a function of time from a 500CX's internal VFO and an installed external 508 VFO. In both cases, the measurements are in agreement with the Swan specification of less than 1 kHz in one hour. The 500CX is fully stabilized after only 30 minutes (drift rate of less than ~5 Hz/Min), while the 508 fully stabilized after about 50 minutes. However, both the 508's maximum drift rate and its total magnitude are much less than the 500CX's internal VFO (20 Hz/Min. versus 80 Hz/Min. and 700 Hz versus 1,330 Hz).

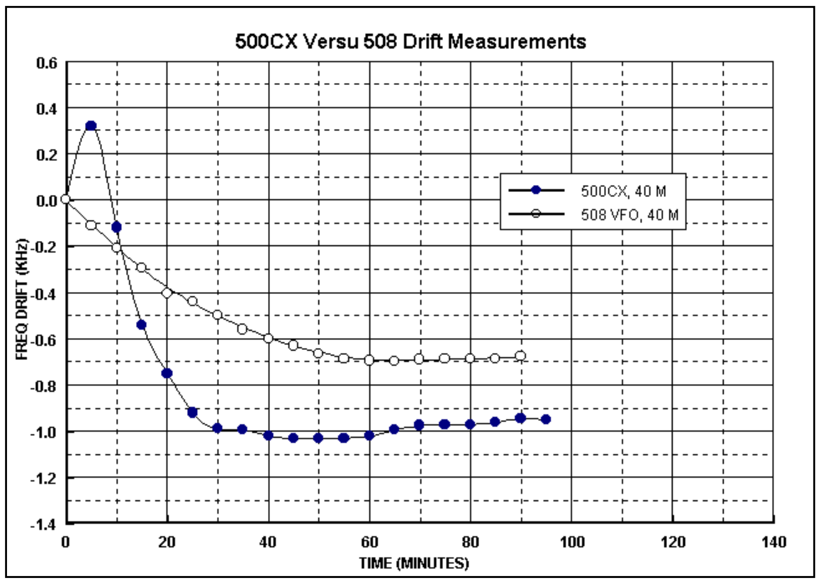


Figure 9-2 Drift Measurements, 350D

In Fig. 9-3, examples of both normal and abnormal drift are illustrated. This figure shows drift data measured on each band of a 350D as a function of time without the use of an external fan cooling. Note the drift rate scale change from the previous figure. In this case, three of the five bands are relatively well behaved, with drift rates of less than ~5 Hz/Min after only 10 to 20 minutes on the 20-meter and 80-meter bands. The 10-meter band has greater than a 7-kHz total drift but is relatively stabilize after 40 minutes. The 40-meter band is also in a bit of trouble, having a total drift of over 4 kHz and requiring 90 to 100 minutes before it settles down! Possible causes of this type of drift, where only select bands are affected, include bad or changed values of the temperature compensation capacitors in the VFO circuitry associated with that band or possible corrosion on the specific band's wafer switch contacts. In this case, one would suspect the problem is most likely due to more switch or other problems, rather than temperature compensation capacitors, since multiple bands are affected.

9.2.3. Drift Causes

As discussed in the introduction of this section, a number of potential causes of drift have been identified, including dirty or corroded band/VFO switches, inferior OEM wafer switches, poor and/or excessive ventilation, poor mechanical integrity, bad temperature compensation capacitors, etc. Additional information on these drift causes and corrections are discussed below and in the Swan Newsletters, Issue 1, Section A.1.1 and Issue 7, Section A.7.3. Other possible causes for VFO instability are also identified by Swan in their January 1970 Special Notes bulletin issued for the 500C (and other), as shown in Fig. 9-4.

It is interesting to note that Kenwood also issued a service bulletin on excessive drift of their TS-140S transceiver in the late 1970s, with recommendations similar in many respects with those covered in Swan service bulletins and those recommended herein (mechanical integrity, etc.).

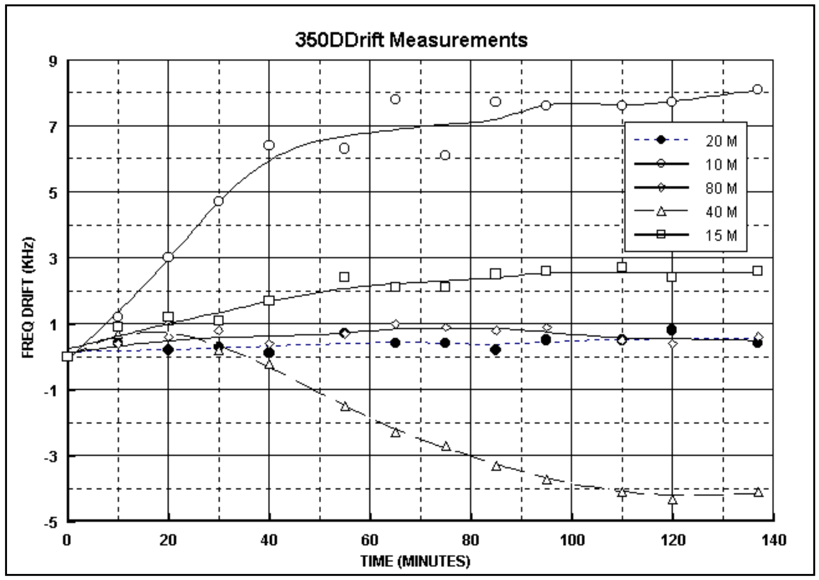


Figure 9-3 Drift Measurements, 500CX vs. 508 VFO

Defective Switches. For transceivers manufactured in the 350/C era, drifting and/or intermittent jumping off frequency after warm-up (i.e. ½ hour) and even audio warbling has been associated with the VFO band switch located inside the VFO compartment. Such problems can be highly dependent of the exact position of the wafer switch contacts after a band change, so just resetting the band switch might correct the problem for a while.

Swan bought switches from two different suppliers off-and-on over the years and, since they were all placed in a common bin, there was no way to tell which one went into which transceiver. Unfortunately, one vender's switch performance deteriorated with usage. Approximately 50% of the early 350 production units had the inferior wafer switches installed that wore prematurely, while perhaps only about 15% of later units had this problem. Some units took only a year or so before the annoying frequency instability started appearing. Swan implemented many design changes and corrective steps to cure this nuisance before they finally focused in on the VFO switch. Later transceivers, such as the 500C and later models, have a more robust, longer lasting switch.

Model 350 VFO Background. In mid 1965, many Swan 350s were closing in on a year's worth of operation and were beginning to develop drift problems in varying degrees. Swan reasoned the VFO transistor Q1 may be going thru some warm-up changes that slowly caused the frequency to vary. On a mid-production design version, to reduce any effect caused by heat, they decided to move Q1 from the VFO circuit board to a small metal box protruding from the bottom plate. This is a somewhat kludge arrangement in which long transistor leads are used to position it on its own little circuit board within a small square bottom panel cut-out. Since the board protrudes below the level of the bottom panel, the small metal cover affixed to both the board and the bottom panel protects it from damage.

About a year later they determined that heat and the under chassis mounting had nothing to do with the kind of drift they were experiencing, so they put the Q1 transistor back on the original circuit board underneath the chassis on later versions. It's quite a nuisance removing and replacing that small square cover when one needs to get into the belly of the radio, especially since one of the transistor leads could get broken or shorted along with losing one or two of the small nuts and washers that fasten the box. So, for owners of one of these 350 units who want to avoid this problem, Q1 can be repositioned back onto the VFO circuit board if desired.

9.2.4. Drift Correction Methods

9.2.4.1. Wafer Band Switch Cleaning

As noted above, a primary cause of excessive, non warm-up drift in Swan transceivers is attributed to wafer switch failure due to wear, corrosion, contact tension changes, etc. Cleaning of the VFO band wafer switch contacts is an obvious first step in refurbishing a transceiver or in attempting to correct an excessive drift problem. A number of commercial tuner and contact cleaners, such as DeoxIT are available and are reported to work very well.

It has also been recommended that wafer switches can be cleaned just as effectively by using a petroleum solvent, such as carburetor cleaner. Do not spray directly, but rather apply in small amounts directly to the switch contacts (use the very thin diameter plastic coffee mixing stirrer straw found at many fast food restaurants as a pipette) and rotate the switch through its various positions a few times. Be sure to allow the components to dry completely before any use. The solvent can change the VFO frequency by as much as 100 kHz or more until it is completely evaporated.

9.2.4.2. VFO Capacitor/Inductor Replacement

Capacitors that are used in VFO tuned circuits often need to have a temperature coefficient (change in value as a function of temperature) that will compensate for the effects caused by the temperature coefficients of the other components in that circuit. Since the tendency of inductive components is toward a positive temperature coefficient, a capacitor with a negative temperature coefficient is usually required to keep a LC circuit constant and hence the VFO frequency stable as components warm-up.

There are families of ceramics capacitors with temperature coefficients that are both linear and negative, denoted by a rating such as N750 (referred to herein as N-type), meaning that the capacitor has a negative

VFO FREQUENCY INSTABILITY

If the frequency jump problem is evident on all bands, the problem could be caused by improper voltage regulation of D-1601 (the minus 10 V Zener diode). This diode is mounted in the chassis adjacent to the Audio Output transformer. This voltage can range from –9.6 V to –10.4 V and still provide satisfactory operation. But there should not be any variation of this regulated voltage. If any variation is noted (when the frequency changes) the Zener diode should be replaced.

Frequency instability (on all bands) could also be caused by any component that would be common to all bands; that is, the VFO printed circuit board, the tuning VFO tuning capacitor, the dial set capacitor, VFO Switch, and the VFO Coupling Capacitor (C-1709 on Swan 500C). These items should be checked for proper solder connections and proper mechanical mounting. The mounting nuts on the VFO printed circuit board should also be checked.

Frequency instability on one or two bands could be caused by poor mechanical mounting on the VFO Trimmer Capacitor, or VFO Coils. Check mounting nuts to make sure a good mechanical ground is being made. Also the solder connections should be checked (for those bands effected and any questionable connections should be re-soldered).

The VFO is the most critical circuitry in the transceiver, and if any problems are encountered that are not easily corrected in the field, (we) recommend returning the unit to the factory for service with a note attached detailing the problem, bands effected, and the amount of operating time required before the defect is evident.

SWAN ELECTRONICS CORPORATION **January, 1970**
OCEANSIDE, CALIFORNIA 92054

SPECIAL NOTES

Figure 9-4 Swan VFO Frequency Instability Bulletin

temperature coefficient of 750 ppm (parts per million) per degree Celsius. Depending on the amount of compensation required, different N-type capacitor values are used to obtain the needed temperature coefficient (or can be obtained by paralleling with appropriately selected NP0 (Negative Positive Zero) capacitance values, as Swan did in many cases). NP0 capacitors have a temperature coefficient near zero. This nomenclature is the same as, and has been superseded by, the COG designation (see discussion in Temperature Coefficient Calculation paragraph below).

In addition to the causes enumerated in Fig. 9-4, yet another potential cause of VFO drift identified by Swan was the failure of a VFO temperature compensation capacitor (or a change in coil inductance) on a specific band's VFO coil (indicated by excessive drift on only one band) or on the capacitor common to all bands (indicated by similar excessive drift on all or most bands). Fig. 9-5 shows a service bulletin issued outlining the procedure for replacement of such a failed capacitor on the Swan 350, 400, and 500 models, however the same approach is applicable to other Swan models.

Don't be surprised if you find it exceedingly difficult to locate N-type temperature capacitors, as they are no longer a readily available item. Most of the major commercial vendors (Digikey, Mouser, etc.) list only NP0s (a.k.a. COGs) and no or only a very limited selection of N-types (e.g. N750 was the only listed temperature co-

VFO TEMPERATURE COMPENSATION

Swan 350, 400, 500

The VFO on the model* 350 is individually compensated on each of the bands. The disc temperature compensating capacitors are mounted on the individual VFO coil for each band. The VFO coils are identified on the VFO cover.

In the VFO drift requires the VFO dial to be tuned higher in frequency, this means that a capacitor with a higher negative temperature co-efficient should be used. If the VFO dial has to be tuned lower in frequency, a temperature compensating capacitor with a lower negative temperature co-efficient should be used.

The negative temperature co-efficient of the capacitors used can vary with the production runs, since these are "selected-in-test" for proper compensation. Typical values are as follows:

80 meters: 5NP0 + 10N75
40 meters: 10N150 + 30NP0 + 10NP0
15 meters: 39NP0 + 10N75 + 10N150
10 meters: 5N150

Example: If it is necessary to tune the VFO up frequency 2 kC during 40 meter warm-up, change the 10NP0 to 10N75. Re-check stability and re-compensate as required.

If it is necessary to turn the VFO down frequency 2 kC during warm-up, change the 10N150 to 10N75. Re-check and re-compensate as required.

This same procedure to re-compensating would be required for any of the bands effected. If it is necessary, the equipment may be returned to the factory for service, with a note attached detailing problems, bands effected, etc.

A selection of capacitors is provided with this letter.

Cubic Communications
305 Airport Rd.
Oceanside, Calif. 92054

***The information on this sheet is for our 350, 400, & 500.**

Figure 9-5 Swan VFO Temperature Compensation Service Bulletin

efficient from one vendor). If replacement N-type capacitors are needed, a parts rig may be the best component source.

VFO Coil Deformation. A related VFO drift problem was also addressed in an article on a model 350 transceiver drift repair that appeared in the August 1979 issue of *Ham Magazine*. The article emphasized: (1) the importance on mechanical integrity (e.g. tightening coil mounting bolts and VFO enclosure screws – see also Fig. 9-4, Swan service bulletin on VFO instability) and (2) the importance of confirming (for designs using the transistorized VFO oscillator rather than the voltage regulator tube) that the output voltage from the Zener diode supplying the transistorized VFO oscillator remains stable.

However the article attributes the cause of most drift problems in Swan 350s to VFO coil deformation based on the following rationale " *. . . changes in coil dimensions with temperature. Drift in the Swan 350 is likely aggravated by the seven tubes clustered around the VFO box. Lack of ventilation traps the heat inside, thus extending the time before drift levels off. On-off cycling over a period of years will gradually stretch the coil wire to the point where it will not return to normal . . . Compensation originally found adequate will no longer keep the drift within reason*."

While the drift problem addressed in the article was corrected using a VFO associated temperature compensation capacitor replacement procedure similar to that outlined in Swans Service Bulletin in Fig. 9-5, the VFO coil was not directly demonstrated to be the cause (as opposed to the capacitor itself). Indeed, since the capacitor replaced was one common to all bands, if the VFO coil were indeed the culprit, then all coils would likely have similar degrees of failure otherwise, replacement of the common temperature compensation capacitor would have corrected one band while causing excessive drift on those bands whose coils were not deformed. The failure mode suggested by the article seems to be an unlikely root cause most excessive drift problems.

Temperature Coefficient Calculation. The Ham Magazine article highlighted a method of capacitor selection only indirectly addressed in Swan's procedure (Fig. 9-5) for calculating the effective temperature coefficient when a N-type temperature compensation capacitor is used in parallel with a NP0 capacitor. To calculate the effective temperature coefficient ($T_{C\ (EFF)}$) of two or more NP0 capacitors in parallel with a N type capacitor:

$$T_{C\ (EFF)} = (C_{NType}/C_{TOT}) \times T_C$$

For example, for the 40-meter VFO compensation capacitors (10N150 + 30NP0 + 10NP0) listed in Fig. 9-5 for the 350, 400, and 500 transceivers, the effective temperature coefficient is:

$$T_{(C\ (EFF)} = [10pF/ (10pF + 30pF + 10pF)] \times 150ppm = 30ppm.$$

Thus, as suggested in the article, by combining the more commonly available NP0 capacitors with a small variety of the more difficult to find N-type capacitors, a wide variety of effective temperature coefficients can be obtained by paralleling appropriate capacitors.

9.2.4.3. VFO Compartment Access Holes (350)

On the model 350 (and other designs that have access holes in the top of the VFO compartment for coil adjustment), it has been found that the VFO enclosure must be nearly airtight in order to reduce drift. Air flow through the enclosure may cause VFO drift and indeed the early versions of the 350 had open VFO trimmer adjustment access holes while later production units had a factory installed plate affixed to the top of the VFO enclosure over these holes. Some owners of the earlier "*Drifty-350s*" would put vinyl electrical tape over these holes, a cheap and dirty fix. Those users with a transceiver having drift problems and uncovered adjustment holes in the VFO compartment may want to try this to see if it has any effect. See the additional discussions in the Swan Newsletters Issue 1, Section A.1.1 and Issue 7, Section A.7.2.

9.2.4.4. VFO Enclosure Mechanical Integrity

One possible source of VFO stability problems on all Swans (and external VFOs) is the structural and mechanical integrity of the VFO compartment, especially in the case of the 250 six-meter transceiver. Make sure the screws on the VFO cover are in place and tight. Since drift has been a problem over the years, many VFO covers have been on and off dozens of times or more and the screw holes become weak or stripped. Slightly oversized screws can be used where threads have been stripped to ensure solid contact is made. In addition, VFO covers should be installed in a manner similar to putting a cylinder head on your engine; tighten the screws until they are just snug, then go around again for a final torque, being careful not to strip the threads.

9.2.4.5. Transistor Heat Sink (250)

A user case study attributed drift in the 250 to the VFO board located under the bottom cover and its two transistors, Q1 and Q2. The report suggested that Q1 is very heat sensitive and it causes temperature related frequency changes that are the source of most if not all of the drift problems on this model rig.

A fix suggested involves mounting a heat sink on the Q1 transistor to stabilize its heating and cooling. A free-standing heat sink, one that is insulated from ground, is needed to be sure that the transistor isn't grounded or shorted. It appears that the bigger the heat sink, the better the frequency stabilization. There is still a slight warm-up period but not nearly as long as previously required – after installing the heat sink, the rig should seem more stable after only 5 or 6 minutes. Once it warms-up completely it should run reasonably drift free and be extremely stable when at temperature. The 250 manual (page 10) shows a picture of the rig with the bottom cover removed and what appears to be a factory installed a heat sink on Q1. Not all of the 250 versions apparently had one installed, but those that have excessive drift may not have it.

The Siltronix 1011B and the 1011D both have the same type of VFO enclosure as the 350. However, in those units everything is mounted inside a VFO enclosure (variable caps, VFO board, etc.), while on the 250, Swan built a VFO box only for the main tuning capacitor and coil. The VFO circuit board is mounted in the open on the bottom of the chassis with no box, just a partial shield.

9.2.4.6. External Cooling

If all else fails or even if one of the solutions described above corrects the problem, consider adding an external cooling fan, if nothing else – it should at a minimum decrease normal warm-up drift duration and will provide a benefit to the life of the PA tubes. See Accessories Section 4.3 for a discussion on cooling fans.

9.2.4.7. Drift Stabilizer

An add-on circuit board, called the DPK VFO Stabilizer is available for about $70. It has been reportedly successfully installed and used on the Swan 300B, 350, and 500CX, as well as other boat-anchor era radios. It includes a 2" by 4" circuit board containing five ICs and additional components. Details of this modification can be found at: *http://home.comcast.net/~k4dpk/pep_adapter.htm*. Functional it compares the frequency of a highly stable on-board oscillator with that from the VFO and when a difference is sensed, it creates a control voltage that is applied to a varactor network across the tuned circuit of the VFO. The control voltage is used in such a way so that its value change is inverse to the direction of drift, so there is no net overall change in frequency. It is fully assembled, requires four connections to the existing transceiver circuits, and should take about an hour to install.

9.3. Power Supply Failure Problems

See the Power Supply Section 3.

9.4. Receiver Problems – General

When working on any tube-design radio, use extreme care, especially if you open the PA cage. Always disconnect the ac power and power supply, wait a couple of minutes for the capacitors to discharge, and just to be absolutely sure, manually discharge high voltage points to ground with a well insulated tool.

For more difficult receiver audio problems (no signals, static only, no audio), a good procedure is to work backward or forward along the audio circuit chain. If an audible hiss is heard, the speaker and audio output transformer are probably working, but the other audio stages are still suspect. A good point to start on a receiver audio problem is at the audio gain pot wiper contact. With the receiver on, touch a small, insulated screwdriver to the middle lug of the audio pot. This will inject a 60-cycle hum into the audio, especially if one lightly touches the driver metal. If you get a growl, the circuit is probably good from that point back to the speaker. Therefore, you have just cut the set in half and have a strong indication that the problem is in the upstream half of the receiver. If there is no growl, at least part of your problem is somewhere from that audio pot wiper lug to the speaker. If the audio is good forward of the pot wiper, trace the problem backwards towards the RF input, one stage at a time.

An alternate approach is to inject a RF signal at some receivable frequency, for example 14.300 kHz, and then trace that signal through from the antenna toward the speaker. In the problem is in the RF section, one might first suspect a local oscillator defect. Possible problems in that area include: (1) the crystal not seated firmly, (2) pins dirty on the crystal, (3) an inactive crystal, (4) a bad coupling capacitor, (5) or maybe just a loose wire.

There are a number of tube-era trouble-shooting books for receivers, including old military training manuals, which frequently contain step-by-step procedures for troubleshooting. The following items are either common receiver failure modes or operation characteristics that have been frequently reported to cause problems by Swan users.

9.4.1. Meter Pegs on Power Application

Upon ac power application, the meter immediately pegs itself with considerable force on all transceiver models made after 1967. As the 2nd IF tube warms-up, the meter movement comes slowly come off the stop and returns to the left, stopping at a point determined by the received signal level and the S-meter Zero adjustment potentiometer. This behavior is not due to a circuit malfunction or maladjustment, but is rather a consequence of the S-meter circuit design. See the detailed discussion in the Meter Issues and Problems Section 9.8.7.

9.4.2. S Meter Readings Low

Eighty percent of Swan meter behavior during receive is controlled by the 2nd IF (e.g. 12BA6) amplifier circuit. The rest has to do with how much signal level the receiver RF amplifier and mixer stages pass to the IF amplifiers. If you are satisfied that incoming signals are genuinely strong, the RF and mixer stages can generally be dismissed as the cause of a weak or low S-meter reading problem. If there is good power output from the transmitter, the 1st IF can also generally be eliminated as defective and the source of the problem.

2nd IF Tube. Problems with S-meter readings that appear too low are usually associated with a weak 2nd IF tube or problems in the voltage divider network in the cathode circuit that adjusts the sensitivity of the S meter. This is especially true for the HF700S meter, whose meter is more fragile and a lot less accurate than the earlier types.

If you have problems in this area, examine the 2nd IF stage thoroughly. With the power supply disconnected measure the resistance at each pin and compare the readings with your resistance chart. Make sure the two cathode resistor values are still what they should be, a 100-Ω resistor in series with a 150-Ω resistor connected from the cathode to ground.

After that, reconnect the power supply and energize. Carefully measure the voltage present at the plate, screen, and the cathode tube pins. The Swan/Cubic people changed that circuit around a little after the Herb Johnson days. The meter is balanced between two slightly higher voltages in the later designs, about 1.5 V instead of the 1 V or less typical in earlier models. The zero potentiometer is located in the middle of the voltage divider in order to provide the higher offset voltage required for adjusting the meter to zero.

The 12BE6s used in the IFs of some models are also reported to be notorious for going gassy and loading down the AVC/AGC circuit and associated components, causing problems with the S-meter function (too high, too low, inability of S-meter zero control to maintain setting). With such problems, be sure when testing these tubes to carefully check for excessively high gas test readings.

MV Filter Capacitor Leakage. Another area that has been reported to cause low S-meter reading and other related problems is a high leakage condition in the large multi-section electrolytic can capacitor mounted on the transceiver's chassis (C202B on early transceiver models). C202 is in the +215 V supply line to the screen of the transmit mixer, etc., so that triple section can electrolytic capacitor is involved in multiple functions, including the AGC amplifier (i.e. 6BN8) and the 2nd IF performance (i.e. 12BA6). Note that if a replacement is unavailable, either gutting the can and inserting smaller new manufacture axial or radial replacement capacitors inside or installing individual capacitors beneath the chassis are viable alternatives. This capacitor is also listed in Section 9.4.5 as a common cause of audio problems such as audio distortion, crackling, etc. Note that the ESR in-circuit testing (see Section 10.3) should be assistance in identifying high leakage conditions.

S Unit/RF Power Relationship. While, by convention, one unit on an S meter is nominally equated to a 6 dB received signal power level change, this is at best just a general guideline. In the 1940s, the S meter was typically designed to register S9 with a 50-µV signal level into a 50-Ω load. Thus, the S9 meter reading actually represents a received RF power level ($P = V^2/R$).

The decibel is often used in scientific fields where huge changes in parameter values occur, as in the case of RF power, signal propagation, and received signal levels. The decibel (dB) is a logarithmic expression of the ratio between two power levels ($10 \times \text{Log}\{P_2/P_1\}$), where P_1 defines the reference value and both power levels use the same units. These values could also simply be expressed in linear decimal format (e.g. 0.005 watts), but doing so would be exceedingly cumbersome because of large decimal values required, or if confusing scientific notation (e.g. 5×10^{-3} watts) is used (due to user unfamiliarity). In addition, the logarithmic form (dB) also has the extremely useful property that a simple addition of two decibel values is equivalent to a multiplication of those linear values and a simple subtraction is equivalent to a division – a great boon to those of us who have lost their ability to do anything but the simplest of mathematics operations (adding and subtracting) without the use of a computer spreadsheet or an advanced calculator!

In RF work, dB levels are usually expressed as dB//m, or dB relative to one milliwatt (with a 50-Ω load), however regardless which reference is used, once a received power level is converted to dB units, a 3 dB increase always equals a doubling in power, therefore a 6 dB change equals a fourfold increase, a 10 dB change is a 10 times increase, a 20 dB change a 100 times increase, etc. The relative received RF power level can be calculated from: $dB//P_1 = 10 \times \text{Log}(P_2/P_1) = 10 \times \text{Log}(\{V_2^2/R\}/\{V_1^2/R\}) = 10 \times \text{Log}(V_2^2/V_1^2) = 20 \times \text{Log}(V_2/V_1)$, or a 6 dB change for each voltage doubling. Therefore, the received RF power level can be calculated directly from the voltage levels at the 50-Ω load. This means that if S9 equals 50 µV, then S8 (a 6-dB decrease) would be 25 µV, S7 (a 12-dB decrease) would be 12.5 µV, etc.

However, this was not and is not an industry-wide standard. Manufacturers decided independently on the value of an S unit (e.g. Collins Radio decided that the S units should be 5 dB) and calibrated their meters accordingly. Nevertheless, even for a specific design, S meters do not give accurate readings anyway due to differences in receiver gain, component aging, and S-meter circuit design and performance. The typical S meter was never meant to provide an accurate measurement of signal strength, but only a rough estimate of relative signal levels.

The bottom line is that the signal strength, as indicated on the S meter on different receivers, will not necessarily agree. Remember, there is no direct quantitative relationship between the S-meter reading and the S1 through S9 RST signal report system used by amateurs, which is only a qualitative assessment of signal strength. A S9 report represents "*extremely strong signals*," it does not necessarily represent a S9 meter reading. Indeed, a S9 meter reading on one receiver could just as well be a S9+20 meter reading or a S8 reading, depending on the receiver! On the other hand, reporting in terms of S-meter units that one signal is S9 and a second is S9 + 10 dB certainly conveys the pertinent information that the second signal is significantly stronger.

9.4.3. Receiver Noise Level – GRID (350)

If the adjustment of the GRID control makes no difference in the intensity of the received signal, there likely is a problem. Swan receiver stages rely on the GRID, PLATE, and LOAD variable capacitors of the transmit stages (mixer, driver, and PA) to tune the path from the antenna connector to the receiver (except 250/C which only uses the GRID capacitors). If the tuning of the GRID control appears to work on other bands, but not on a specific band (e.g. 20 meters), you may have a problem in one of those stages.

However, since some 350C versions are equipped with separate receiver tuned circuits, it is possible to see little or no change in receiver sensitivity when adjusting the GRID control on those units. Look on the bottom chassis cover and see if separate receiver coils are included and so marked (REC COILS). If so, align them as per the simple manual procedure for maximum signal strength.

9.4.4. No/Low/Int. Audio, Common Causes

Some of the more common causes and solutions associated with low, intermittent, or no audio output are listed below. If there is no audio at all, the receiver operation (other than audio output) may be still confirmed by checking for S-meter movement, namely the ability to peak the GRID to obtain a S-meter maximum and the detection of meter fluctuations indicating strong or varying signals as the transceiver is tuned. If you see meter movement, the receive mixer and IF stages are most likely working. Check the obvious failure causes, such as a bad speaker or speaker line connection in the Cinch-Jones connector by placing a known working spare (or headphones) on the speaker line output at the transceiver. Many Swans have terminal connections with the audio output on the topside of the chassis that were intended as a convenient point for installing an optional loudspeaker directly inside the transceiver. That is a good place to check for audio output signals.

- ***Side-Tone Issue***. If your transceiver model is one of those that includes the side-tone circuit, you may notice a slight decrease in AF output when the key is pressed while the transceiver is in the receive mode, sort of like switching on the ANL. This is normal behavior and does not indicate a problem.
- ***Relays***. This is a major cause of many problems. It cannot be stressed enough that K1 (relay on top of chassis with plastic cover) and K2 relay (beneath the chassis) contacts must be clean, corrosion free, and unpitted. The K2 three pole relay under the chassis uses two contact sets for the receiver. One opens and closes the signal line to the receiver RF amplifier while the other opens and closes the ground return at the secondary winding of the AF transformer. As soon as the PTT energizes K1, the 4-pole relay supplies screen voltage (~215 V) to the PA tubes, which immediately conduct idle current completely independent with anything happening elsewhere in the transceiver.

  Dirty contacts on K1 can cause the meter reading to be erratic or incorrectly indicated bias current. Likewise, problems of erratic behavior when switched from receive mode to transmit mode or visa versa (i.e. does not consistently go into transmit mode or switch back to receive mode when un-keyed) are frequently due to dirty relay contacts. The contacts on the K1 relay will often appear clean and un-pitted despite years of use, however there may be a surface film of corrosion, so cleaning with a contact cleaner or petroleum solvent (applied via a thick piece of heavy stock paper wiped repeatedly between the contact surfaces) and/or cleaning with a contact burnishing tool or a strip of very fine emery cloth/paper (for heavy pitting) should be done if receiver problems are evident. See Parts Section 9.9 for K1 relay replacement information.
- ***Cinch-Jones Connector***. Make certain the connectors are clean and making good mechanical contact. Burnish and clean all male and female Cinch-Jones-Cinch connectors on both the 12-pin and 15-pin Cinch-Jones plug with contact cleaner or petroleum solvent and examine the pins carefully, burnishing the sides of the pins as required in order to brighten them. If the connector appears loose or is still intermittent, carefully twist the pins slightly on the male connector. The female and male connector contacts are "*snapped*" into the plastic connector slots. One can become dislodged and pushed back into the connector so that contact cannot be made or worse yet, it can short against the other terminals. So, carefully inspect them and if one appears to be missing or abnormal, remove the cover to ensure all are securely in place.
- ***Ground Strap***. Improper ground between the power supply, transceiver, and earth ground can cause or exacerbate many noise related problems. Install a short ground strap directly between the transceiver and power supply chassis. Even though there is a ground wire internal to the power supply cable, a separate 12 to 18 inch braided ground strap should always be used. Since most Swan transceivers and/or power supplies use a non-polarized two-prong ac power plug with no ac GROUND wire, always install a separate wire or braid to the ac electrical system's earth GROUND for safety.
- ***Audio Output Tube***. With weak or other audio problems, as a good first step, always try replacing the audio output tube, as it may be weak or bad.
- ***S Meter Erratic, Audio Level Varies***. A number of similar reports on the failure of the 1-µfd, 50-V electrolytic capacitor that is affixed to the RF gain potentiometer on many models (e.g. 500) have been noted. Failure manifests itself in a number of ways. In one case the failure was heat sensitive, with the audio level slowly decreasing over minutes with a corresponding S-meter movement, as though the RF gain potentiometer was being decreased. In a second, RF GAIN control behavior was abnormal and inverse of what would be expected, that is as the RF gain is increased, S-meter reading behaves as though gain is being decreased. Other similar odd S-meter behavior or audio variation may possibly occur depending on how the capacitor is failing.

Similar type behavior has also been associated with failure of the D1603 AGC diode (500), failing either independently or in conjunction with the capacitor cited above.

- ***No Accessory Socket Jumper Plug Installed***. Many transceiver models (e.g. 350C, 500CX, 700CX, Cygnets, etc.) have an accessory plug on the rear panel apron for use of an external VFO or crystal oscillator. The early mono-banders, 240, baseline 350, and Cygnet-like models (350A/B/D) do not have this accessory plug. If an external VFO signal source is not used, a jumper plug must be installed that connects pin 3 to pin 4 and another connecting pin 1 to pin 8. If no jumper plug is installed, make certain that a previous owner had not internally hardwired the pins of the accessory socket with these jumper connections. If so, they will have to be removed if the transceiver is to be used with an external VFO. If no jumpers are installed and an external VFO is not used the transceiver will not have a VFO signal and will be inoperative (low level white noise type static hiss on receive).
- ***No VFO Signal***. The VFO signal may not be applied due to a bad external VFO/connection (e.g. pin corrosion, etc.) or the internal VFO is not jumpered at the accessory socket. Clean VFO plug pins and check wire connections. Pull back the cover on the 9-pin VFO plug to make certain no wire has come loose.
- ***External VFO***. If the external VFO inoperative, check the receiver operation by reinstalling jumper plug in accessory socket.
- ***External VFO Relay***. The external 508 VFO has a built-in switching relay (not included on the earlier external 400 series VFOs). If that relay has dirty contacts, you might lose the oscillator signal.

9.4.5. Audio Crackling, Audio Birdies, Causes

Audio noise and crackling, etc. has a multitude of causes, some of the more common ones are summarized below. In addition to these causes, also make sure the Cinch-Jones connectors and K1 and K2 relay are clean and corrosion free, as previously discussed in this section.

- ***External Signal Source***. External interfering signal sources (computer, HP Laserjet printers) can cause audio problems that appear to be transceiver related, especially on 6 meters. Remember to turn off both your computer and printer, as many printers also generate RFI, particularly HP Laserjets.
- ***Rotary Switches***. All rotary switches and potentiometers must be clean and unworn. Check connection integrity. Cracked solder joints and unsoldered connections that are factory assembly errors occasionally have been found, even after decades of service.
- ***Audio Tube***. Replace or substitute the audio output tube to confirm that it is not the cause of the problem.
- ***Tube Pins***. Tap tubes and examine for pin corrosion. To clean, place tube pins in a little petroleum solvent in small container. The solvent should be about a ¼" deep (length of the tube pins). Stand each tube in the solvent for a few seconds, then push each into its socket 2 or 3 times. DeoxIT type cleaner also works well.
- ***CW Side-Tone Oscillator***. On an AF problem, if you are certain the audio stages are functioning and the tubes are good, check all the components in the CW side-tone oscillator circuit. The 500C was the first unit to come outfitted with the side-tone feature. All components are located in AF output stage.
- ***AGC Capacitors***. With S-meter or audio problems, be sure to check the capacitors in the AGC circuit.
- ***AF Transformer***. Check for AF transformer overheating due to excessive current on the primary winding. This can be a result of a problem in the AF output stage tube or a short in the transformer. This may cause crackling in the audio (see discussion on the audio transformer in the following section).
- ***Multi-Section Can Capacitor***. Audio problems are occasionally caused by the large can capacitor located towards the back of the transceiver chassis. Lightly tap this capacitor and listen for a correlation with audio crackle and pop with each tap. The audio may pop-out almost completely. This capacitor failure has also been attributed to a very loud chirping that was constantly present in a rig when the ANL was off.

  This multi-section capacitor can be replaced with single units if a suitable replacement cannot be found or is cost prohibitive. Just use replacements with the same or greater voltage rating and similar capacitance value (generally equal or as much as 2 times greater than the value being replaced), and connect using the polarity shown on the schematic or that used in the existing circuit.

Note that this multi-section can electrolytic capacitor (C202 in early models) is also reported to cause of low S-meter readings as discussed in Section 9.4.2. ESR in-circuit testing (see Section 10.3) should be of assistance in identifying high leakage conditions. Information on replacing capacitors (especially electrolytics) can be found in the Power Supply Section and at the following web page*: antiqueradio.org/recap.htm*.

9.4.6. Audio Distortion.

Audio distortion or gurgling noise on the receiver has been reported to frequently be caused by: (A) bad bypass and filter capacitors in and around the product detector and the AVC (AGC) circuits (e.g. in the early 350, the 20-μF capacitor from the cathode (pin 2 of V11), which is a big part of the AVC circuit), or (B) the 6BN8 becoming gassy, causing a lot of distortion.

9.4.7. Headphone/Speaker Audio Hum

Virtually all Swans have moderate to severe ac hum at the power supply's headphone jack. This is the result of ac induced pickup due to the speaker/headphone audio line being cabled parallel to the ac and filament lines from the power supply to the transceiver and the audio sharing a common ground with them.

A recommended solution reported to work well is to lift the headphone jack from ground with shoulder washers and replace the speaker/headphone line with shielded cable run outside and parallel with the power cable. The original audio line inside the power cable is abandoned, and the entire audio circuit is isolated from ground at the power supply end, grounded only at the transceiver end. This is similar to the procedure recommend by Swan (see Service Bulletin shown in Fig. 3-1 and related discussion) to correct this problem. Also, see comments in the Modification Section 5.6 and in the Swan Newsletters, Issue 2, Section A.2.4 and Issue 3, Section A.3.1.

Some users have reported that excessive 117X speaker and headphone hum has been reduced or eliminated by connecting a short ground braid directly between the transceiver and power supply.

9.5. Receiver Failure Case Studies

Besides the generic causes listed above and in the operation manual, a variety of other receiver failure modes can occur. Listed below, as succinctly as possible, are case studies of actual problems and solutions that have been reported by Swan users.

9.5.1. No, Low, or Intermittent Audio

9.5.1.1. Audio Output Gain Pot Defective (500C)

Problem. As stated. The measured AF gain potentiometer's resistance on a 500C was 78 kΩ versus the specified 100 kΩ.

Cause. Unknown, but probably component aging.

Solution. Not reported. The output control on the Swan 500C and all CXs is a 100-kΩ linear potentiometer. If the existing potentiometer that measured 78 kΩ was the cause, it was probably also changing in value as a function of time, since that value should still be usable.

9.5.1.2. Inoperative (240)

Problem. A Swan 240 receiver is barely operable with incorrect voltages measured on the 6DQ5 filament.

Cause. The 240 uses a series-parallel arrangement for running the 6.3-volt filaments from the 12.6-volt ac supply. Most of the tubes used on transmit (except for the final) have 12.6-V filaments and run in parallel directly off the 12.6-V supply. Most of the tubes used on receive have 6.3-V filaments, and 9 of these are all wired in parallel, as if they were connected to a 6.3-V supply, except they are fed in series with the single 6DQ5 final's filament. According to tube manual data, the 6DQ5's filament draws 2.5 A and the paralleled 6.3-V tubes draw a total of 2.9 A, so they should roughly split the 12.6-V ac supply voltage.

The cause of this problem was incorrect current draw by the 6DQ5 tube. Evidently, some tube companies produced an identically marked version of the 6DQ5, which ran the filament at lower temperatures, requiring less filament current. Thus, such tubes have a lower current draw, which upsets the voltage division in the filament string. There is no obvious difference in the appearance or marking of the version that works in the 240 versus the dark heater version that does not. See additional discussion in Sections 2.3.3 and 8.6.3.

Solution. Replace the 6DQ5 tube with one having the correct filament current draw. Another solution is to re-balance the voltages by rewiring some paralleled tube filaments to use the 12.6 V rather than 6.3 V as described in Section 2.3.3.

9.5.1.3. Inoperative, No Display (350D)

Problem. A Swan 350D digital frequency display is inoperative, reading a constant 000000.

Cause. This was caused by an apparent ground problem, since when pressure is applied to the VFO compartment top to which the VFO display electronics are affixed, the frequency reading was restored, although occasional the wrong frequency was displayed.

Solution. A copper braid was run from all four corners of the top of the VFO section to ground and that seemed to solve the problem for the most part. However occasionally when the rig was cold it still showed 000000, but quickly came back to a proper display reading once it's warmed-up

9.5.1.4. No Audio (Static Hiss)

Problem. Radio powers up, but no audio and tuning produces no signals, just a near constant level static hiss.

Cause. The accessory jumper plug was missing (500CX, etc.).

Solution. Insert plug, install an external VFO, or install hardwire jumpers internally on plug directly on the socket (must be removed if transceiver is to be later operated with and an external VFO) – see Section 4.14.2 for plug jumpers required.

9.5.1.5. No Audio

Problem. No audio or signals when main tuning dial is varied.

Cause. No VFO signal. Bad solder connection in plug coming from external VFO.

Solution. Re-soldered connector.

9.5.1.6. No Audio (350)

Problem. As stated.

Cause. No VFO signal. Problem traced to a broken lead on Q1, the VFO 2N706 oscillator.

Solution. Repaired lead. After this was repaired, the receiver worked fine and was very selective and sensitive.

9.5.1.7. No Audio (500C)

Problem. No signal audio heard on a 500C unless a CW key is inserted in the jack and keyed. The receiver appears to be working, since the S-meter shows signals are being detected. The audio output stage similarly appears to be working since the calibration signal is audible when in the CAL mode. The problem may be in the area of D1201, which is associated with the biasing-off of the AF output tube (V12) on transmit. Touching a meter probe to the junction of D1201 and R1205 (analog meter with positive probe grounded) brought the audio back partially, probably because the test meter is pulling down the voltage on the grid just enough to allow V12 to start working.

Cause. Bad D1201 diode. The D1201 and R1205 components are both in the side-tone circuit. The AF output should work with or without that circuit, so if you disconnect D1201 and the audio comes alive, there is a problem in the side-tone circuitry. The voltages on the AF output tube socket were checked and looked normal.

Solution. The side-tone diode D1201 was replaced with a 1N4004, which restored the audio and did not affect the side-tone frequency or level. There is a slight decrease in AF out when the key is pressed whilst on receive, but it is normal to hear such a change in audio tone when depressing the CW key on radios with the factory installed side-tone circuit. It sort of sounds like the ANL is being switching on.

9.5.1.8. No/Muted Audio (500CX)

Problem. No audio on a 500CX when it was initially power-up after years of storage.

Cause. Audio (headphones and speaker) worked after inserting headphone plug into 117XC jack. Dirt/corrosion on ¼" headphone jack interrupted audio signals to the speaker.

Solution. Cleaned jack with DeoxIT.

9.5.1.9. No Audio, Transformer Problems

Problem. No audio.

Cause. Audio transformer failure.

Solution. A couple of different suppliers provided audio transformers to Swan over the years, but they were all very similar impedance matching transformers. It is a simple step down transformer that matches the high plate impedance of the AF output tube to that of the low impedance speaker or headphone. All Swan transceivers run plate and screen voltages on the AF output tube that keep the output impedance around 5,000 Ω. Therefore, the AF transformer is stepping that impedance down to the speaker's 3 to 4-Ω impedance.

The transformer's primary (red and blue) should have a dc resistance of ~350 Ω. This can vary a little among manufacturers, but not outside the 300 to 400-Ω range. The secondary (black and green) appears to be shorted to many who test it but it's just a very low resistance, less than ~1 Ω, due to the fewer turns compared to the primary and, in some cases, larger gauge wire. The secondary seldom fails whereas the primary, which carries the plate current for the 6GK6 (or 6AQ5 in Cygnets and 6V6 in older mono-band transceivers and Swan 240) usually fails via an open condition and to a lesser extent, due to shorts.

If a parts radio replacement isn't available, substitute AF transformers should work that have: (1) roughly the same physical size (to ensure wattage capability) and (2) a primary that measures about 300 to 400-Ω (that is the dc series resistance that passes plate current). It is possible to come across an AF transformer that steps down to something other than 3-4 Ω, like maybe 8 or 16 Ω – these will work with less efficiency but have the danger of loading the output tube too much with such a poor match. Unless you have nothing else, keep looking for the correct item.

9.5.1.10. No/Low Audio (500C)

Problem. As stated (500C).

Cause. Bad capacitor (i.e. leaky, low resistance) in the A.F. GAIN adjustment circuit was holding signal level fixed. To troubleshoot such problems, try injecting an audio signal onto the control grid of the AF amplifier to verify that it produces an audio output with a good input signal. If the cap is leaky then the negative bias voltage could be off. Measure bias voltage (or resistance) on the control grid (pin 2 of the 6GK6 audio output tube) and compare to the voltage chart (or resistance chart). Excessive negative voltage will effectively shut down the tube. The diode (D1201, side-tone circuit) at pin 2 of that tube is also reported to sometimes go bad.

Solution. Replace capacitor and/or diode.

9.5.1.11. No/Intermittent Audio

Problem. As stated.

Cause. Cinch-Jones connector(s) making inconsistent contact.

Solution. Cleaned and slightly bent pins (to make better mechanical contact) on Cinch-Jones connector.

9.5.1.12. Very Low Audio (350C)

Problem. Audio and signal levels on a 350C are very low, similar to no antenna conditions.

Cause. Bad 12BA6 tube (V8), which had a completely open filament.

Solution. Replaced the tube.

9.5.1.13. Very Low Audio

Problem. As stated.

Cause. Bad audio amplifier tube pin/socket connection. Wiggling the tube restored operation.

Solution. Sprayed DeoxIT on tube pins and insertion/extract from socket a few times to remove any corrosion.

9.5.1.14. Very Low/Poor Audio (500C)

Problem. The audio level on a 500C is low and other problems as stated (see also 10-M Dead, Spurs on 40 M case study listed in the distorted audio section, which was part of a this multi-failure problem).

Cause. Bad audio transformer primary was the cause of very low audio. Modifications had also been previously made to the socket of V11 and unit was grossly misaligned.

Solutions. Replaced V11 and re-installed original specified components, which resulted in some audio improvement. Replacement of the audio transformer fully corrected the audio problem.

9.5.1.15. Intermittent Audio (350C)

Problem. Audio level on a 350C intermittently changes.

Cause. Bad Tube. V11 on a 350C (6BN8) was identified as the culprit by taping the tube. Tube tester readings indicated intermittent and time varying emissions readings.

Solution. Replaced the tube.

9.5.1.16. RF GAIN control Inoperative (500C)

Problem. 500C receiver works, but RF gain control has little effect, S-meter deflects negative when RF gain is decreased, opposite of its normal behavior. See also the immediately following case study.

Cause. Improper bias voltage on the IF amplifier tube control grid. It varied only from –0.9 V to –0.2 V as the RF GAIN control was varied. A 2-µF, 50-V cap (C1604) was bad, measuring 200-Ω dc resistance, limiting available voltage at control grid. This capacitor failure may be a somewhat common problem as it has been reported by multiple users. In a similar case, not only was C1604 bad, but another similar capacitor (Mallory 50 V with white plastic casing) was also found to be bad.

Solution. Replaced capacitor. Control grid voltage varied from –14.0 V to –0.2 V with the capacitor replaced.

9.5.1.17. Varying/No Audio (500)

Problem. There appears to be a heat related problem. After 15 to 20 minutes, the S-meter drifts to the right and pegs while the audio decreases and disappears. With movement of the RF GAIN control, the receiver again became functional, only to have a similar failure behavior repeated over a few minutes. See also immediately proceeding case study.

Cause. This may be a case where multiple failures were apparently contributing to the problem. The electrolytic cap (1-µfd, 50-V) across the RF gain potentiometer was bad, with a measured dc resistance of 4.5 Ω. However when it was changed, the problem still occurred, but the initial failure occurred over a 10 minute period.

Upon further examination, it was found that the 6BN8 tube's (AGC circuit) negative bias level slowly increased during failure to an excessively high level. D1603 in the 6BN8 AGC circuit appeared that it could be a cause of such behavior. While it tested OK, when one lead of the diode was lifted from the circuit, the radio function perfectly. It appears that it might be breaking down when it heats up.

Solution. The capacitor was first replaced. Note that this is an apparently relatively common failure mode and has been reported by a number of users (see immediate preceding subsection). The D1603 AGC diode was then changed. After diode replacement, the receiver function properly.

9.5.2. Audio Distorted, Noisy, Crackly, Spurs

9.5.2.1. AC Hum (750CW/PSU-3)

Problem. Constant amplitude audio hum is heard on the speaker at all audio gain volume settings on a 750CW powered by a PSU-3 power supply. New audio and IF amp tubes were installed with no effect.

Cause. There was a 100-V ac ripple on the 850-V HV supply going to the finals (which were known to be bad). This resulted on about 30 mV of ac on the 200-V MV line in the audio and IF stages.

Note that if the audio hum was present only when using the speaker's headphone jack, then the problem is an extremely common one due to ac pick-up in the cabling between the transceiver and power supply unit. See the Power Supply Section and Power Supply Failure Sections, which discuss the installation of a phone jack on the rear apron of the transceiver or new separate speaker wiring between the power supply and speaker to clear up the hum originating from the unshielded audio line in the power cord.

Solution. Replaced all power supply electrolytic capacitors corrected the problem.

9.5.2.2. Birdies and Warbling (250)

Problem. In receive and calibrate mode, a 250 transceiver has tonal signals at distinct intervals (birdies) similar to calibration signal. Problem occurred both with and without the tube for the calibrator installed.

Cause. A possible cause is front-end neutralization. The manual cautions that if the receiver front-end amplifier is not properly neutralized, you can hear birdies. Try unplugging the 6EW6 (receiver RF amplifier) and see if the birdies go away as you vary the main tuning dial. If so, the front end is most likely going into oscillation. The manual describes a procedure to neutralize the front end. Don't forget that under certain antenna SWR conditions, a front end that seems to be well neutralized when a dummy load is attached may have self and/or parasitic oscillations when the antenna is connected.

Solution. Final solution not reported.

9.5.2.3. Distorted Audio (500CX SS-16)

Problem. On a 500CX equipped with a SS-16 filter, the received USB audio sounds distorted, with too much emphasis on the low audio frequencies.

Cause. Improper adjustment of the carrier oscillator. This problem can occur on any transceiver model. When mixed with the receiver mixer, the resultant IF signals were improperly positioned, due to CO drift with age or improper adjustment, at the IF crystal filter such that perhaps 150 Hz to 2550 Hz versus the nominal 300 Hz to 3,000-Hz audio frequency range is passed through the filter. With the SS-16 IF filter's steeper skirt slopes, significant maladjustments of the CO have a tendency to be more apparent.

Solution. Re-adjusted the USB carrier oscillator trimmer to a slightly lower frequency. See related discussions in SS-16 Section 4.5.

9.5.2.4. Distorted Audio (350)

Problem. Distorted audio on a 350 during high signal-level conditions.

Cause. Defective 2nd IF transformer (Z-901) winding.

Solution. Replaced transformer.

9.5.2.5. Distorted Audio on Strong Signals (500CX)

Problem. Stronger sideband signals (i.e. anything over S9) the sound is distorted on a 500CX. The distortion appears to be IF related since, if the RF gain is significantly reduced, then all is well but the RF gain must be reduced to such an extent that S-meter functionality is lost.

Cause. Not reported.

Solution. Not reported. Suggested troubleshooting recommendations included checking to make sure that all electrolytic capacitors in the MV and BIAS are working (both in the power supply and in the transceiver).

A similar problem had been reported in the AVC (automatic volume control) circuit of a 600R, which uses a 6AV6 for the AGC rectifier. It that case, it was found the screen grid dropping resistor was way out of tolerance. Other suggested areas to focus on were the resistors and capacitors in the time constant portion of the circuit.

9.5.2.6. Distorted or Noisy Audio (500C)

Problem. As stated.

Cause. The 12BE6 is a pentagrid converter, employed as a mixer in both the receive and transmit modes on the 500C and other transceiver models. These tubes are more prone to abruptly becoming defective as opposed to having a long life and slowly weakening. Such noise can appear when the vacuum space barriers between grid elements start breaking down with high resistance shorts. The tube will still work with this type of short, but it will not be distortion free and it can cause damage to other circuit components. A root cause is that frequently R702, a 22-kΩ, 1-W resistor's change in value causes too high of a potential on the grid (pin 6). This R702 resistor is one of the components having the highest failure rate in Swan transceivers, other than tubes.

Solution. Replace the tube and resistor R702 with one rated at 2 W. If the exact value cannot be found, any value within the 20-kΩ to 25-kΩ range is acceptable.

9.5.2.7. Noise and Crackling (500C)

Problem. 500C has very low received audio with crackling sounds. When T1201 was adjusted during alignment to maximum noise level during alignment, it started smoking (always a bad sign!).

Cause. Overheating or smoking clearly indicates a defect in the AF output stage. The smoking of the AF transformer was most likely due to excessive current on the primary winding. This can be a result of a problem in the AF output stage, a bad tube, or a short in the transformer. This would also account for the crackling heard. Under this failure condition, the alignment of the 2nd IF stage in no way causes the abnormal operation of the AF output stage. The output stage is already at fault with the problem just becoming more pronounced with the adjustment of the IF transformers, particularly the 2nd IF.

Solution. Final solution not reported, most likely transformer was replaced.

9.5.2.8. Ringing and Motorboating (700CX/508)

Problem. Using an external 508 VFO, the audio from a 700CX had a ringing sound after warm-up and high-level audio signals periodically broke up, similar to an occasional momentary short in the voltage supply.

Cause. Bad capacitor in 117XC MV filter with a measured 100-kΩ dc resistance under VOM check.

Solution. Replaced all power supply filter capacitors.

9.5.2.9. Snap, Crackle, and Popping

Problem. As stated.

Cause. The multi-section electrolytic can capacitor in MV power distribution in the transceiver was bad. Another potential cause of this problem is a bad or leaky input coupling capacitor (or poor solder joint) to the audio amplifier's grid or a bad audio transformer (discussed elsewhere).

Solution. Replaced electrolytic capacitor.

9.5.2.10. Scratchy (350D)

Problem. On strong signals, audio is scratchy on a 350D. The 12AX7 had been replaced with no improvement.

Cause. The cause of the problem was not reported. A recommended area to investigate is the speaker, which could have a frozen, loose, or cracked cone. Check the cone cement along the frame and in the middle of the speaker to ensure that it is cemented firmly to voice coil. There could also be dirt in the voice coil suspension or magnetic gap area. Troubleshoot to identify problem by substituting an alternate speaker our use headphones. If either of these two tests works, the original speaker is the problem.

Solution. Not Reported.

9.5.2.11. Warbling (500)

Problem. When ac power is applied to a 500 transceiver, background noise is initially present but as the radio warms up, it begins to self/parasitic oscillate, with the frequency of oscillation varying as the PA $\boldsymbol{\pi}$ network is adjusted. Transceiver had previously functioned properly.

Cause. Measurement of the voltages within the transceiver showed that –110 V was not present in the receiver, due to a wire breaking at the soldered terminal on the power supply's Cinch-Jones connector.

Solution. The wire was re-soldered and problem was corrected.

9.5.2.12. Oscillation/Howling (250C)

Problem. When a 250C's GRID control is tuned for peak receiver signal output, the receiver audio breaks into oscillation/howling. When the finals are removed the problem goes away, as it does if the plate supply to the driver stage is disconnected.

Cause. There was an open or changed value resistor in the screen circuit of the 6GK6 driver tube – when running the receiver with the driver plate disconnected this resistor physically burned out.

Solution. Replaced resistor. It was confirmed that the resistor in question was the cause of the problem by disconnecting the resistor – oscillation/howling returned.

9.6. Transmitter Problems – General

When working on any tube-design radio, use extreme care, especially if you open the PA cage. Always disconnect the ac power and power supply, wait a couple of minutes for the capacitors to discharge, and just to be absolutely sure, manually discharge high voltage points to ground with a well insulated tool.

Perhaps highest on the list of common transmitter complaints is low output power and the most common solution is replacement of the PA, mixer, and driver tubes and/or alignment of those circuits. That is certainly an obvious first place to start for low RF power output problems. Recognize that many transceivers can not longer met the original specification power rating, especially on the 10-M band, due to component aging and deterioration. So even with NOS tube replacement and proper alignment, RF output sill may be down somewhat from Swan's original specification. See the discussion in the Expected and Measured Output Power Section 6.2.10.

Unfortunately, they are a whole host of additional problems other than tubes or alignment that can cause transmitter problems. Peruse through the more common problems listed in the Owner's Manual troubleshooting section, and the generic problems and case studies discussed in this section to assist in failure identification and correction.

If possible, when doing any transmitter repair, use a dummy load to minimize any possible antenna related tuning complications and an external wattmeter in conjunction with the cathode current meter so that you have a firm grasp transmitter behavior.

9.6.1. Carrier Oscillator SS-16 IF Filter Issue

If a transceiver is equipped with the SS-16 filter, you may see very little or no cathode current when attempting the peak the GRID as the first step in the tune-up process. Indeed, even if the CAR BAL is rotated fully cw or ccw you may still see no appreciable increase in cathode current. This is due to the much steeper SS-6 IF filter skirt slopes, which suppresses signals at the carrier oscillator (CO) frequency by an additional ~20 dB or more than the standard filter. In such cases, you may have to switch to the TUNE or CW position, which shifts the carrier frequency about 700 Hz higher, well into the bandpass of the IF.

With the standard filter, the CO frequency is suppressed by 15 dB or so by the filter skirt, but you should still see ~150 mA or more cathode current with full BAL CAR signal insertion when the GRID is peaked, even if the PLATE and LOAD haven't been fully resonated. With the SS-16 and its additional ~20 dB of attenuation at the CO frequency, little signal will be obtained. Indeed, the operating instructions included with the SS-16 warn that this behavior is normal for transceivers with that filter installed. Additional instructions included with the SS-16B installation kit provide alternate alignment instructions that allow sufficient carrier insertion to permit AM operation. See the SS-16 Filter Section 4.5, for additional information.

9.6.2. Cygnet Fuse Blowing On Transmit

Swan Cygnet (e.g. 260) radios can have a tendency to blow fuses during tune-up or long transmissions. This problem is frequently in part due to an idle current that is set too high in conjunction with the normal operating load on the power transformer being very close to its maximum capacity. The root cause of the idle current problem is that most Cygnet manuals state that 20 to 30 mA is the required idle current, however 30 mA is a bit too high. It should be a maximum of 25 mA, which is consistent with the 25 mA per tube specified for two-tube (50 mA total) PA transceiver designs. If the idle current is set to the higher value and if the meter accuracy is off a bit, the idle current could be even higher. In this case, it is better to err on the low side than the high side.

9.6.3. Cathode Current Meter Calibration

Meter Calibration Check. To check the meter calibration, use a calibrated voltmeter and, with the CAR BAL set for minimum carrier (perfectly nulled), depress the microphone PTT and measure the voltage at the cathode of the 6LQ6 PA tube (pin 3). In the case of parallel 4.7-Ω cathode resistors, set the bias potentiometer for a voltage drop of 0.06-V across the cathode resister. That equates to about 25 mA or so (0.025 x {4.7}/2). If you replace the cathode resistors with resistors other than the 4.7-Ω values (e.g. a couple of 2.7, 3.3, 3.9 or 4.7-Ω, 2-W carbon resistors can be placed in parallel for a total 4-W rating), merely calculate the combined resistance and use Ohm's law to determine the voltage you want to see at the cathode for 25-mA idle current. In any case, you will be working with some pretty low voltage measurements, less than $1/10^{th}$ of a volt, so a sensitive and accurate voltmeter is necessary. See related discussion below and in the Meter Issues and Problem Section 9.8.7.

Meter Calibration. In order to accurately measure cathode current, the meter must sample the current level indirectly though a resistor network limits both meter current and provides a means of calibrating the meter, so that the cathode current is accurately displayed. The following discussions refer specifically to the model 350 design, however it's conceptually applicable to most other models (resistor values may differ).

Calibration procedure. In the meter sensing circuit, a 470-Ω resistor is connected in parallel with a second resistor and identified in the manual's parts list and on the schematic only as "*selected*." These two meter sensing/calibration resistors are in series with the meter and they are essential in that they prevent the full wrath of cathode voltage from being impressed on the meter while at the same time, accurately measuring cathode current. The combination of these two resistors (R405 and R406 on the 350 schematic) provides the proper resistance needed for the meter to accurately sense the voltage drop across the PA tube's cathode resistors and translate it into the appropriate current reading on the meter.

That is, when say 800 mA is flowing through the cathode resistors and the meter (which is also labeled 800 mA full scale, although it might actually be only a 1-mA movement), in series with a paralleled pair of current limiting resistors, is placed across the cathode resistors, the meter will read full scale. A fixed value cannot be used for the second paralleled resistor since its value must compensation for sample-to-sample variance in cathode resistor and meter resistances. The cathode resistors are connected from ground to the cathodes; they are two parallel 4.7-Ω resistors in early Swan 350s or two 1-Ω resistors in late version Swan 350s. The idle current is, of course, dc; so the inductive properties of a low resistance wire wound resistor in that circuit will not harm PA tube operation, however it is probably still best to use 2-W non-inductive carbon-type resistors.

To determine the correct value of the *selected* resistor, the following procedure is used. Assume the true cathode current is 400 mA when a transmitter is loaded-up to full power. When 400-mA conducts through the parallel-connected 1-Ω cathode resistors (combined resistance is ~0.5 Ω), the voltage drop across these resistors will be 0.2 V. Disregarding for a moment the resistance of the meter coil (a 1-mA full-scale movement), all that need be done is calculate the necessary resistance in series with the meter that will limit the current to a half milliampere (half scale on the 1 mA meter movement corresponds to 400 mA on the affixed meter 0 to 800 mA scale) when the cathode resistor voltage drop is 0.2 V.

Thus, using Ohm's Law, 0.2 V divided by 0.5 mA (.0005 ampere) equals 400-Ω total. Therefore, the limiting resistance is going to be something less than 400 Ω because that total resistance also includes the series resistance of the meter itself. Since nothing is perfect (coil resistance variations, cathode resistor tolerance ranges, etc.), the meter circuit must be individually calibrated by adjusting the value of the parallel *selected* resistor. After subtracting the coil resistance from the 400 Ω, the needed R405 and R406 parallel network resistance will usually fall between 300 and 350 Ω. So, calculate what resistance placed in parallel with a 470 Ω resistor will give 300 to 350 Ω as a starting point (with a 1000 Ω resistor the parallel resistance is ~320 Ω).

With the "*selected*" and 470-Ω two resistor network in place, power up the radio somewhere on the 80 or 40 meter band with the carrier perfectly nulled, hit the PTT and quickly run the idle current to 200 mA. Check with a couple clicks to make sure the idle current is stable at 200 mA – don't hold it more than a second or two. Then, with a voltmeter in its lowest range, click the PTT and read the voltage across the cathode resistors of the PA tubes. It should read 0.1 V, a pretty low voltage but that is what it should be. A 0.1 V voltage drop across the 0.5-Ω cathode resistance equals 200 mA.

If the cathode voltage reads less than 0.1 V, the *selected* resistor must be changed to a slightly higher value or reduced in value if the cathode voltage measures higher than 0.1 V. After making any resistance change, go through the same routine again. Quickly set the idle current to 200 mA, holding it only long enough to read and confirm that it is set at 200 mA. Then, with voltmeter probes across the cathode resistors, click the PTT again and see if it now reads the required 0.1 V. When, satisfied the meter is reading correctly, return the idle current to 50 mA. That, in summary, is how to select the "*selected*" resistor and calibrate a Swan meter.

9.6.4. No, Low, Variable Power, Common Causes

Ideally, once a transmitter is tuned-up to its maximum power point, its output should remain relatively stable under maximum output conditions (key down CW or high duty cycle AM). That is, if held in the tune mode or keyed CW mode for say 5 seconds (longer periods, such as 20 or 30 seconds or more, risk destroying the PA tubes due to excessive heat) the cathode current and RF power output will remain stable. Unfortunately, it is not unusual to occasionally have problems during transmit, especially one of the more common ones, including RF output that decreases with time (e.g. soft tubes), cathode current that increases with time (e.g. gassy tubes), intermittent transmit/receive change over (e.g. relays), etc. as discussed below.

Bias Problems.

- ***No or Low Bias Current***. No bias (idle) current can be caused by: (1) no or a low HV level, (2) no or excessively high (negative) bias voltage, (3) no or a low screen voltage level, (4) bad or value change of the PA cathode resistors, or (5) bad PA tubes. The bias is adjusted independent of the driver tube if the carrier (CAR BAL) has been totally nulled. Indeed, you should be able to adjust the bias to the proper level even if the driver tube is completely removed from the unit. If the HV were missing from the plate, but the other tube voltages were still applied, current will still flow between the cathode and screen, although it should not be a high value, such as 100 mA, at maximum bias and of course, there will be zero output power.
- ***Improper Bias Current***. Check the bias setting, being sure to compensate for any mechanical zeroing error of the meter's pointer that exists when the unit is off. PA idling current (plate voltage is applied with only the static dc bias voltage on the control grid – no signals) should be on the order of 50 mA for most dual-tube PA models. Your manual specifics the correct value for your transmitter.

  If you want to mechanically reset the meter to zero, on most dual-tube PA models it will have to be removed from the unit to gain access to the mechanical zeroing adjustment screw below the meter face (or the model label removed to gain access to the adjustment hole in the front panel). IF you can raise and lower the idle current with the bias pot from between 0 to a least 100 mA, this is a strong indication that the PA stage is properly operating.
- ***Erratic Bias***. Dirty or corroded relay contacts can cause inconsistent bias readings. Likewise, gassy PA tubes can cause a wandering or variable bias current.

No/Erratic Output.

- ***Relay***. Make sure K2 and K1, the 2 or 3 and 4-pole relays (Swan 250 and 400 models use a 2 rather than a 3-pole K2 relay), are clean and un-pitted.
- ***Relay Inoperative or Chatters***. If the 12-V (nominal) relay supply voltage is too low or absent, the relay will not function, its operation may be inconsistent, or it might chatter. A frequent cause of a decreased relay supply voltage is the carbon composite 4.7-Ω series resistor used in the 117XC (117B and later) type power supply relay circuits increasing in value with time to the 10 to 15-Ω range. Its voltage drop will increase and the voltage at the relay coils may decrease to such an extent that relay problems occur.

  With the model 117AC power supplies, this resistor is 15 Ω, since only a single relay is employed in the earliest transceiver models (e.g. 240 or earlier). See the Power Supply Commonality Section 3.2 for modifications required to use a 117AC with the later transceiver models and the 117X-type power supplies with the earliest model transceivers.

Low or Erratic Output Power. It should be noted that a separate receiver should always be able detect a very low level RF signals at the transceiver's VFO and tuned main tuning-dial frequency, even if the PA tubes are removed or the plate caps are disconnected. Just by keying the microphone and fully unbalancing the carrier, the low level signal produced by the driver, VFO, and carrier oscillator circuits should be detectable on the audio of the separate receiver. In cases where no RF output is suspected, this method can be used to confirm the absence of any RF energy output from the PA circuit or (with the PA tubes removed) from the driver, VFO, and carrier oscillator circuits. The inability to detect any such signals on a separate receiver indicates a problem in that circuit.

- ***Flat Finals***. Power amplifier tubes degrade with age or can be damaged relatively easily during tune-up when running an excessive power output for long durations, prematurely shortening their useful lives. Such tube are often referred to as "flat" – since these tubes have a significantly diminished fundamental output capability due to electron depletion, the can achieve only a lower dc input power and therefore low RF output power. Frequently, with tubes in this condition, under key-down CW or high duty cycle (AM) conditions for longer than only a few seconds, the initially measured power and cathode current will progressively and appreciably decrease.
- ***Gassy Tubes***. A "gassy" tube may cause a number of problems. Its power output can exhibit a number of abnormal behaviors, including: (1) an idle current that wanders or varies, and (2) a cathode current that increases when the transmitter is under a key-down high dc input power condition for any length of time – under such operations, the high energy ionized gas molecules collide with the cathode, releasing additional electrons.

  Another problem that is frequently attributed the gassy tubes in both the transmitter and receiver chain is distorted audio. Gassy tubes may exhibit a diffuse white/blue colored haze of low brightness, usually inside the anode. Note that this is different and distinct from the fluorescence glow sometime seen in perfectly operating PA tubes. See the related discussion in the discussion in Section 8.1.4.
- ***Driver Tube Weak or Bad***. Make sure the driver tube is good, that it is properly aligned, and that the GRID control is peaked. If the driver tube is weak, the drive voltage on the PA control grids will be low and the finals will not draw their maximum current of which they are capable. Replace with a substitute tube to check, even if the original tube tests good. Cases have been noted of tubes that test very good but still do not function properly – mixer/driver alignment may be necessary when tubes are changed.
- ***Alignment***. Low output is very frequently caused by poor alignment of the mixer and driver circuits due to either component aging or errors during previous alignment attempts. If one or two bands have near the expected RF output, alignment problems are the most likely causes for excessively low output on the other bands. Recall that the 10 and 15-M bands frequency have significantly lower output than the other bands.
- ***Driver Plate Choke Open***. Check the plate RF choke on the RF driver tube (L306 and 6GK6 on the 700CX), as it can go bad from excessive driver plate current during tune-up. This is a somewhat common failure mode. If the radio is held in the TUNE position too long with the GRID not peaked, that RFC will be damaged or burnt-out and disable the driver stage
- ***Bad Cathode Resistor***. No output in the TUNE or CW mode can be caused by a bad PA tube cathode resistor, since either an open or excessively high value (changed with age or heat) will limit cathode current and hence power output. Check the resistor's value. In the dual-tube PA designs, this is usually either a pair of 4.7-Ω or 1-Ω resistors. In most Cygnet and Cygnet-like designs, a 100-Ω resistor is switched in when in the TUNE or CW mode. When holding the TUNE position too long, perhaps 10 seconds or longer, this 5-W resistor in the Cygnet designs gets very hot and can burn open. It is there to protect the PA tube during tune-up and CW operations, but sometimes the beating is too much for even this protective device.
- ***Balanced Modulator Malfunction***. See Service Bulletin in Fig. 9-6 and bulleted item in next section.
- ***No Power Output on One Band***. If you cannot transmit on a specific band and signals are heard at the correct main tuning dial frequency, you can assume the mixer stage is functioning correctly. However, you will still hear signals even if the driver coil is incorrectly set, the driver load circuit is defective, or the switch tabs on either the driver or PA stage band switch are not making proper connection. The incoming signal will not be nearly as strong as they could be, but with any of these circuits out, it might still be strong enough to make one think the band in question is receiving properly. Check those stages and components as well as the wires to and from the π-network output coil.

9.6.5. Audio Problems, Common Causes

- ***No Modulation***. No SSB carrier modulation is frequently caused by an incorrectly wired microphone or a bad or weak microphone amplifier tube (12AX7) and/or component failure in the associated circuitry.

- ***Raspy audio or audio Hum***. If you receive reports of muffled, distorted, raspy, or audio hum on your signal, before trouble-shooting be sure to check the microphone gain. If it is adjusted too high, it can certainly be the cause of reports of muffled audio, signal splatter, etc. Make sure the microphone gain is adjusted such that on voice peaks, the cathode current is no high than ~1/3rd the value obtained during tune-up. Dramatic meter deflections are not needed to achieve the rated PEP rating and the audio signal will sound much better at lower microphone gain settings.
- ***RF Audio Distortion/RF "Bite."*** Muffled or distorted audio reports (often accompanied by a noticeable RF "bite") are frequently due to "*RF in the shack*." This problem generally has nothing to do with the transmitter, but rather, is usually an antenna/feed-line matching problem associated with RF radiating from the coax feed line (undesirable RF currents are flowing on and radiating from the outside of the coax shield) when it is used to directly feed an antenna. Such conditions not only can cause audio distortion/RF bite problems, but also degrade your antenna radiation pattern (especially for vertical dipole-like systems).

  First, always ensure that the transceiver system is properly grounded (both RF and DC), since poor grounding can contribute to such behavior. If the problem still persists, try either a commercial balun (or make one from a design in the *ARRL Handbook* or other instructions) or even better yet, make your own simple RF choke (this is also called a balun by some since it effectively is a 1:1 balun transitioning the unbalanced coaxial feed-line to the balanced antenna).

  A simple coaxial RF choke is made by merely placing a coil in the coax feed-line of six to eight turns (even a couple more won't hurt), 6" to 8" in diameter, as close to the antenna's feed-point as possible (a suggested alternate coil configuration is to use 15 to 20 turns with a 2 to 3 inch diameter). It has been asserted that such coils are more effective if they are uniformly wound on a cylindrical form (e.g. two-liter plastic container), rather than just coiled randomly. The coil creates a high impedance for any HF RF currents flowing on the outside of the shield, thus acting as an RF choke. Use adhesive, tape, etc. to maintain the coil form (or, if randomly coiled, just tie the loops together with cable ties) and see if the problem goes away or decreases significantly.

  If it diminishes, the problem is antenna or feed-line related. It has been suggested that such a choke also provides some protection from lightning strikes, although that certainly seems to be a dubious claim at best. A similar or variant of these types of coax RF choke coil arrangements is frequently specified by various large antenna manufacturers as part of their installation procedure.
- ***Bias Adjustment***. Make sure that the idle current bias is properly adjusted. Having the bias current excessively low places the PA operating point near or even in the cut-off region of the characteristic curve, causing excessive signal and audio distortion.
- ***Carrier Oscillator Adjustment Incorrect***. The carrier oscillator (CO) frequency is positioned on the low frequency side of the crystal filter skirt so that when it's mixed with the audio signal, the ~300 to ~3,000-Hz audio-frequency sideband lies precisely in the filter's 6-dB down bandpass. If it is positioned, say 300-Hz low in frequency, the microphone audio signals that passes through the intermediate filter will be from the 600-Hz to 3300-Hz band (assuming a 2.7-kHz IF bandwidth) and the transmitted and received signals will have too much treble. If it is positioned 300-Hz too high, then the 0 to 2700-Hz audio band will pass through the filter and the signals will have too much bass. If the CO frequency is even further off, the transmitted and received signals will be heavily garbled or unintelligible.

  Also, if the CO is adjusted too high in frequency, you may find that even with the CAR BAL fully nulled the CO signal will be far enough up the IF filter's slope so that its level is sufficient enough to put out a few watts or RF power. In addition to the balanced modulator CO nulling, additional signal reduction is contributed by the IF filter slope in order to achieve the specified 50 to 60-dB down carrier suppression in the transmitted SSB signal.
- ***Balanced Modulator Problems***. A lack of carrier, erratic carry insertion, or inability to null the carrier with the CAR BAL control can be due to balance modulator circuit failure. Balanced modulator nulling is sensitive to the condition of the tube, associated circuit resistors, and the nulling potentiometer. If it nulls between 10 and 2 O'clock, that is normal – the CAR BAL potentiometer compensates for any small Ohmic

SERVICE NOTE: BALANCED MODULATOR

Symptoms: Inability to balance carrier at midrange of carrier balance potentiometer. Carrier balance occurs at maximum clockwise or maximum counterclockwise rotation of carrier balance control.

Remedy: This problem is normally caused by R1308 or R1309, 100k ½ W resistors in the balanced modulator circuitry. The resistors will change value over a period of time. Replacement with resistors of the proper value (100k 1/2 W 5%) will normally correct the problem.

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Figure 9-6 Balanced Modulator Service Bulletin

differences between the resistors feeding the beam deflectors. When it gets outside the 9 to 3 O'clock range or when you cannot achieve a null within its adjustment range, you should do some preventive maintenance.

A good first step is to try a replacement tube to see if the corrects the problem. If not, focus on the matched 100-kΩ deflector plate resistors, the most common fault with the balanced modulator circuit. These resistors frequently change value and Swan even issued a service note (shown in Fig. 9-6) on this problem, but it only recommended replacement with ½-W, 5% tolerance resistors, however as discussed below, it is prudent to use 5% tolerance resistors with an 1-W power dissipation ratings. Users have reported that even value changes from 100-kΩ to 130-kΩ is enough to cause the loss of ability to null the carrier –failure need not be gradual, but can sometimes occur abruptly. These resistors have one of the highest (if not the highest) failure rates of any circuit component for any transceiver model.

The switching voltage needed of the deflector is actually quite low, less than 30 volts, so the voltage is dropped by these two resistors from the nominal +215 V supply voltage indicated on the circuit schematics to the lower potential. The deflector plates of the balanced modulator tube should have a near equal dc voltages on both of them when the CAR BAL control is nulled. Rotating that control full cw or full ccw should cause the deflector voltages rise or fall.

If only one plate has voltage, check the resistor on the opposite side. If the AM mode is used, the voltage drop is even greater on one or the other resistor. However, the actual supply voltage is always somewhat higher than the nominal +215 V, typically between +220 to +240 V. The ½-W resistors are therefore asked to drop between 200 to 220 V every time the transceiver is turned on. Simple Ohm's Law calculations show that 200-V voltage drop across a 100-kΩ resistor produces 4 tenths of a watts. At 240 V, the resistor produces almost a full ½ watt. These resistors soon start changing value due to constant overheating. This is evidenced by the CAR BAL control needing to be set way to the left or right of center in order to obtain a null, or even an inability to obtain a null at all. Always replace these resistors with one-watt values.

Another approach is to change R1605 to a 750-Ω, 10-W resistor if a lower value is used in your radio. That voltage-dropping resistor in the nominal +215 V power supply circuit of many early and mid-term transceiver models ranges from a 400-Ω to a 600-Ω, 10-W resistor. Making this change of R1605 will bring the feed voltage seen by the balance modulator resistors down by 10 to 15 V. Later transceiver models, such as the 250C, use the 750-Ω, 10-W resistor and they have fewer balanced modulator problems.

9.7. Transmitter Failure Case Studies

Listed below, as succinctly as possible, are case studies of problems and solutions that have been reported by Swan transceiver users.

9.7.1. Operation and Alignment Problems.

9.7.1.1. Bias Current Erratic, No Transmit

Problem. The bias levels are inconsistent when the microphone is keyed or transceiver is switched into the transmit mode, with sporadic/variable readings (wanders) or behaving as if it were still in receive mode.

Cause. The cause was pitted dirty contacts on the K1 and K2 relays.

Solution. The relay contacts were cleaned and burnished.

9.7.1.2. Erratic Idle Current

Problem. Unable to set the PA final tube's idle current properly. The current jumps from 20 milliamps to near full scale (>500 mA) with very small adjustments to the bias potentiometer. Faint squeal heard every time FINE LOAD control turned.

Cause. New finals and driver were substituted with no effect. This symptom suggests that self or parasitic oscillations are causing the tubes to go into uncontrolled oscillation with very slight changes to bias control. However, in this case, close inspection of the vanes of the air capacitor showed they were touching each other!

Solution. The vanes were realigned clear of each other and the final bias voltage then adjusted normally.

9.7.1.3. Transmit Mode Not Activated by PTT

Problem. As stated.

Cause. If the microphone PTT function will not key the relay when the transceiver is in the RECIEVE mode, check the 12-V relay voltage at the relay and power supply (of course first make sure the PTT/VOX switch is in the PTT position, if equipped with this option). Missing 12 V from a Heathkit power supply caused this problem in one case and a bad slide PTT switch was noted on another unit. Dirty or corroded relay contacts are also a common cause of such behavior.

Solution. Restore 12-V relay power. Replaced slide switch. Clean relay contacts.

9.7.1.4. Does Not Return To Receive Mode

Problem. After the transmitter is activated, when un-keyed, it occasionally remains in transmit mode until ac power is turned off. Operates normal when ac power reapplied.

Cause. Inspection of the K2 showed that the relay arm, which had been removed for contact cleaning, was improperly installed and binding. In a second case with a similar problem, it was found that the K1 relay (plastic case relay on top of chassis) was binding due to obstruction from an internal wire that had been moved during case re-installation).

Solution. Re-installed relay arm properly. Repositioned K1 wire.

9.7.1.5. Carrier Balance Malfunction (350, 500)

Problem. When the CAR BAL is adjusted (350 and 500), cathode current remains high and no null is observed, primarily on 10 meters.

Cause. Most likely the neutralization if off on 10 meters. If the carrier will not null and cathode current levels are high, self or parasitic oscillations are likely causing the PA stage to go into autonomous oscillation.

Solution. Not Reported. PA tube neutralization adjustment and/or replacement of PA tubes with a matched set that have grid-lead radiators usually solves such problems.

9.7.1.6. Carrier Output in SSB Mode (270)

Problem. When a Swan 270's microphone is keyed in the receive position on the 40-meter band, the transmitter puts out a CW signal or carrier – all other bands work OK.

Cause. Assuming the carrier is nulled on the other bands, most likely the transmit mixer, RF driver or PA tube is going into oscillation on 40 meters. This could be caused by an incorrect antenna load or a sensitive neutralization alignment problem. In addition, one of the first two stages mentioned above could be out of alignment or have a defective 40-M component causing the oscillation. One quick check for mixer/driver problems is to press the PTT to see if the driver stage tuning appears to be working properly. While observing the cathode current and/or power out, rotate the GRID slowly in either direction to see if the PA cathode current (or RF power out) drops abruptly to normal idle current range (and zero RF power output).

Solution. The tubes were pulled and reseated and problem disappeared, new driver and finals were subsequently installed and neutralized. The cause of problem not specifically identified.

9.7.1.7. CAR BAL Null Position (700CX)

Problem 1. On a 700CX, the CAR BAL control's position at full null is significantly off the 12 O'clock position (near 3 O'clock). The 100-kΩ resistors in the balance modulator tube circuit both are the correct value.

Cause 1. Balance modulator tube related.

Solution 1. Replaced the 6JH8 tube with 6AR8, a substitute with similar specification (see discussion in the 6JH8 Tube Section 8.6.14).

Problem 2. CAR BAL control position at 9 O'clock position when at or near null.

Cause 2. One 100-kΩ resistor in the balance modulator tube circuit had changed value, measuring about 1 MΩ,

Solution 2. Both 100-kΩ resistors were replaced with new 2-watt resistors; the CAR BAL was then positioned at ~12 O'clock when nulled.

9.7.1.8. Cannot Adjust Carrier Oscillator (700CX)

Problem. When adjusting the USB carrier oscillator trimmer as per manual adjustment procedure, output power with a 300-Hz audio oscillator signal is only 4 to 5-W maximum, with trimmer capacitor (C1502) fully open (after first adjusting power output to 40 W at 1,500 Hz). LSB trimmer capacitor adjusts OK.

Cause. The 5,500-kHz carrier oscillator crystal was off frequency.

Solution. A 50-pF silver mica capacitor was added in series with the 15-pF capacitor that's used to pull the carrier up in frequency for CW operation. After this modification, the carrier trimmer adjusted properly. This will have some affect on the CW offset, but shouldn't be too much (effectively, the 15-pF capacitor is changed to a 11.5-pF, assuming it was right on to begin with).

9.7.1.9. Self-Oscillation on 40 M (240)

Problem. An early version 240 transceiver tunes up as specified on all bands, but with low SSB modulation signal levels on the PA control grid, the RF output breaks into damped self-oscillation (on the same operational frequency indicated on the main tuning dial).

Cause. PA neutralization was checked on 20 M as per manual and was found to be off a little. Driver tube neutralization was check and appeared OK.

Solution. The PA neutralization was readjusted as per the manual. Oscillation no longer occurred. Note that self-oscillation may also occur to some unusual reasons, as indicated in the correspondence from Swan to a owner on a PA oscillation problem occurring in a late version 240 (Section 9.2).

9.7.2. Tuning Problems.

9.7.2.1. Arcing in PA Finals

Problem. During tune-up there is arcing in the final(s), unit was previously running well.

Cause. Tube testing of finals shows one with drastically reduced emissions readings and an intermittent short under vibration.

Solution. Replaced PA tubes.

9.7.2.2. Dip Grid/Tune-Up Problems (HS700)

Problem. On a HS700, bias sets normally, but grid only dips to a 100 to 150-mA level with minimum loading. Any change in loading causes the cathode current to increase to 400 mA.

Cause. Most likely, the PA stage (or possibly the drive or mixer) stage is going into oscillation. Check the PA neutralization.

Solution. Final solution not reported.

9.7.2.3. Will Not Load On All Bands (700CX)

Problem. A 700CX transceiver that had previously been converted to 6LB6 PA final tubes will only load-up on the 20 and 40-meter bands (180 and 110 W respectively). Tubes were checked and finals seem properly neutralized. Arcing in the finals.

Cause. Not reported, although cause should not be intrinsically related to the 6LB6 modification, since it was functioning properly beforehand.

Solution. Not reported. Possible solutions suggested include: Replace finals, driver, mixer, and VFO amplifier tubes and realign as per the manual. Also, check screen resistor on V2 (transmitter mixer). A reported failure, which exhibited similar behavior, was due to R203 and a leaking C1804B (80-μF cap), both in the screen of the transmitter mixer (12BE6) – this was in addition to a very weak driver (6GK5) and finals. While you're at it, check the plate choke on the driver tube (L306), as they will go bad from excessive driver plate current.

9.7.2.4. 10 M Dead, Spurs on 40 M (500C)

Problem. On a 500C, problems as stated, in addition to low receiver audio problems listed in previous section.

Cause. Modifications were previously made to the V11 tube socket. A broken 40-M coil slug was the cause of spurs on 40 M. Unit was grossly misaligned.

Solution. Replaced V11 socket and changed back to original circuit components, which resulted in improvement in the audio problem. After replacing a broken 40 M slug, the unit was realigned. Both 10 M and 40 M were then operational on the transmitter.

9.7.2.5. Self Oscillation/High Current (250C)

Problem(s).

Case A. A 250C goes into PA self oscillation when the carrier balance insertion causes cathode currents in excess of 40 mA. Unit had previously been functioning well. Neutralization and new PA, driver, and balanced modulator tubes, along with the 100-KΩ resistors, were tried with no success.

Case B. A second 250C is able to be set to 40 mA idle current, but it is extremely touchy – with adjustment even slightly higher, the cathode current abruptly increase to 350 Ma. During neutralization checks, the carrier balance control has no effect and the idle current could not be adjusted down to the 100 Ma specified in the manual. At the higher current level (~300 Ma) only about 25 W RF output (SSB) was obtained, despite good final PA tubes.

Cause. Case A & B. Unknown. Possible problems suggested that might cause this problem include: (1) a bad disc coupling capacitor between the driver and PA tubes, (2) use of incorrect 6146 tube types (avoid the 6146A/Ws), and (3) the failure of the electrolytic capacitor on the bias pot. It is also a good idea to check the RF signal path for proper connectivity (corrosion, oxidation, or improper soldering, including the plate connector and the associated choke on the plate cap). One possibility to further troubleshoot is to try removing the driver tube to see if it still happens – it could be the driver tube breaking into self-oscillation, rather than the PA tubes.

Solution. Case A & B. A 0.002-μF cap was placed from the junction of L404 and the wiper wire from the bias pot to ground and the unit functioned properly. That capacitor will help remove any tiny amounts of RF from that line. There is a handy terminal strip to do this between V4 and V5. Since the units were previously working, it was assumed that something has drifted or changed with time, such as the RF choke performance due to age/heating. Similar type failure behavior has also been reportedly caused by failure of the parasitic chokes on the plate caps of the 6146 tube due to high heat/aging of the resistors.

9.7.3. No, Low RF Output and Signal Problems.

9.7.3.1. No RF Power Output (240)

Problem. No transmitter RF output. Transceiver receives normally, has all power supply voltages present, and bias current level is present and adjustable when microphone is keyed, but CAR BAL control has no effect and there is no RF output.

Cause. Since the bias current is adjustable within its normal range, the PA is functional and has all the necessary operating voltages. Since the CAR BAL has no effect, no modulation is evident, and no hint of RF output power is evident, the problem is most likely associated with the driver tube and/or associated circuitry, since there is obviously no signal level other than the bias voltage level on the PA tube. Close inspection of the driver circuit showed that the C212 coupling capacitor feeding the signal to pin 3 (control grid) of the driver had broken loose and no signal levels were being fed to the driver.

Solution. Re-soldered capacitor to pin 3.

9.7.3.2. No RF Output (240).

Problem. When in transmit mode (microphone keyed), idle current is intermittent with zero RF output. Idle current can be adjusted to from 25 mA up to 60 mA, but the measured voltage on the control grid is only –40 V versus the expected –70 V as per the manual's voltage chart. The carrier balance can be nulled and inserted current increases to 100 mA, but PLATE and LOAD controls have no effect. Inspection of grid signal shows PA control grid bias voltage and carrier signal are intermittent when microphone is keyed.

Cause. In the past the relay contacts had been physically bent, probably in an attempt to improve contact. After relay repair, idle current was stable in transmit mode, but still zero RF output. Inspection of 6DQ5 tube pin voltage shows all normal in both receive and transmit, except for the much higher bias level required for 25-mA idle current reading, as noted above.

Measurement of the HV on the plate shows no voltage and subsequent continuity measurements show that the large RF choke in the PA cage supplying HV to the plate cap was open. The thin wire from the lower choke coil had become detached from the bottom connection. A poor solder connection on the RF output connector within the cage indicates that the PA had been previous reworked in the area, although no component or other changes were noted. It's possible the re-soldering might have been an earlier attempt to repair the no RF output problem. Obvious the idle current initially observed without the HV applied was due to current flowing through the screen rather than the plate!

Solution. Re-adjusted the relay contact which had been bent and cleaned with fine Emory paper and DeOxit – keyed bias current afterwards was consistently present and constant. Repaired choke by re-soldering coil wire. Unit then tuned-up normally and yielded ~100 watts output on 40 M (not re-aligned).

9.7.3.3. No RF Power Output (270)

Problem. No transmitter RF output when in CW mode. SSB works with full power.

Cause. The Cygnet and Cygnet-like models switch-in a cathode resistor to limit power during CW or tune-up operations to protect the 6LQL PA tube. R406, a 100-Ω, 5-W resistor is switched into the cathode circuit when in the CW/Tune mode; R405, 3-Ω, 5-W resistor is used during SSB operations. Both two resistors are located in the power amp cage. The 100-Ω resistor was open.

Solution. Replaced bad resistor.

9.7.3.4. No RF Power Output (700CX)

Problem. No transmitter RF output. The 700CX transceiver was a new acquisition. Receiver functioned fine. Transceiver was advertised as working, however it was missing the accessory socket jumper plug and two tubes.

Cause. Upon closer inspection, it was found that while the transmitter mixer's (V2, 12BE6) tube shield was in place, there was also no tube installed.

Solution. Installed 12BE6 and unit worked. Always check for the obvious, many problems end up being easily solvable by a close visual inspection.

9.7.3.5. Low Power Output (350D)

Problem. Low RF output power on a 350D.

Cause. Power supply HV level somewhat low with very high ripple (17%). Cause was bad 100-μF HV filter capacitor. Testing of the 6MJ6 PA final tube indicated it was weak/soft.

Solution. Replacement of tube and capacitor yielded full, stable power output.

9.7.3.6. Low RF Output (750CW, SS-16 Filter)

Problem. Very low carrier RF output level when CAR BAL is at maximum (ccw or cw); low SSB RF output PEP levels when the MIC GAIN is at maximum.

Cause. Multiple problems: (1) Resistor blown in PA the cathode circuit, (2) A very low carrier level is normal when a SS-16 filter is installed due to steep IF filter slopes which attenuated the carrier much more than the stock IF filter (See SS-16 Filter Section 4.5), (3) A resistor in the solid-state balance modulator circuit had changed value over time from 27 kΩ to 180 kΩ. The 750CW and later transceiver models used a solid-state modulator (as opposed to the 6JH8/7360 tubes used on earlier units) that has a much higher failure rate than the tube design.

Solution. (1) Replaced the resistors in PA (cathode resistors). (2) No action required. The low carrier level can be compensated somewhat by adjusting the carrier oscillator frequency, however this will change audio characteristics. See a Swan recommended procedure in SS-16 Section 4.5 for adjusting the carrier oscillator for AM operation, (3) Replaced bad in the balanced modulator circuit. After replacing the resistor, same SSB problem was present until a new balanced modulator chip was installed. The resistor value change probably also caused the previously replaced balanced modulator chip (mc1496) to also fail.

9.7.3.7. Low Power Output

Problem. Transmitter can achieve only 20-W output before and after alignment.

Cause. Driver tube was not functioning correctly, even though original tube tested good.

Solution. The 6GK6 driver tube was replaced and the driver circuit was realigned with new tube. The power output was then normal.

9.7.3.8. Very Low Output Power (500C)

Problem. As stated.

Cause. Examination showed that the final PA tubes were both bad. If you inadvertently destroy the finals by improper tune-up procedures or on-air operations with excessively high current levels and transmit durations, on a 500C (and other similar dual-tube PA units), L-306 (RF choke in series with the driver tube's B+ supply) can also be overheated/damaged in the process, so it's a good idea to also check that component.

Solution. Replaced PA finals.

9.7.3.9. Erratic Power, Plate Current, Part 1 (350)

Problem. On transmit with a 350, all is normal for the first 2 minutes during warm-up. Tune-up is normal, meter functions normally, and the cathode current level dips to 250 ma at maximum power, with a power output of 100+ W achieved. However, after 2 minutes, the meters pegs on transmit and the power decreases to around 30 W. This behavior was repeatable and occurred on both 20 meters and 10 meters. There was initially a little arcing when rig first tuned-up on transmit, but did not re-occur after the cover on the finals was removed and accumulated dust cleaned off of the capacitors, tubes, etc.

Cause. One possibility is that something in the PA tuning is shorting or opening after warm-up, which throws the resonance point away from where the PLATE and LOAD controls were set during tune-up. This would show up exactly as described – the cathode current goes up and power goes down because it is out of resonance. A short in one of the PA tubes can also cause this behavior.

Solution. See Part 2 below.

9.7.3.10. Erratic Power Plate Current, Part 2 (350)

Problem. After inspection, one of the cathode resistors (sic) was found to be burned and was replaced, (R406 shown as a 470 Ω, 5%, 1/2 W. and R405 in parallel with R406 is shown as "*selected*," with no value listed on the schematic or the parts list). Someone had previously replaced the selected resistor. After replacement, the same problem described in Part 1 still existed, so the PA tubes were swapped, but again, problem remained. Controls were all in the normal positions with a LOAD control position of 8 or 9 for 20 meters and 9 or 10 for 10 meters.

Cause. It appears that the resistors being referred to are in the meter sensing circuit, rather than the cathode resistors. That 470 Ω resistor is connected in parallel with a second resistor identified as "*selected*" in the parts list and the combination of the two set-up the proper resistance needed between the meter and cathode in order to translate the cathode resistor voltage drop into equivalent cathode current on the meter. The cathode resistors, on the other hand, are connected from ground to the cathodes – they are two parallel-connected 4.7-Ω resistors in early version Swan 350s or two 1-Ω resistors in late Swan 350s.

Solution. Not reported, however it appears the problem may have been partially associated with the failure of the meter sensing circuit resistor as discussed above. See discussion in Cathode Current Sensing Resistor and Meter Calibration Section 9.6.3 for a detailed discussion on the meter sensing resistors and the value that should be used if the selected resistor needs to be replaced.

9.7.3.11. Distorted Audio (500CX SS-16)

Problem. The USB transmitted audio sounds muffled or distorted, with too much emphasis on the low audio frequencies.

Cause. Improper adjustment of the USB carrier oscillator. This problem can occur on any transceiver model. When mixed with the transmitter mixer, the resultant IF signals were improperly positioned (due to component drift with age or improper adjustment of the carrier oscillator) at the IF crystal filter so that the incorrect portion of the base-band audio spectrum was passing through the IF filter (i.e. perhaps 50 Hz to 2350 Hz versus the nominal 300 Hz to 3,000-Hz audio frequency range).

Solution. Perform the carrier oscillator adjustment procedure or readjusted USB carrier oscillator trimmer to a slightly lower frequency. The trimmer capacitor is generally very sensitive to small adjustment changes.

9.7.3.12. Transmitted Audio Distortion (700CX)

Problem. Some distortion has been suddenly acquired on a 700CX's transmitted signal.

Cause. It was determined that the bias was out of adjustment (while the meter was inoperative).

Solution. Bias was reset and transmitter functioned fine.

9.7.3.13. Gravely Audio (350, 500)

Problem. Reports of gravely sounding audio (350 and 500).

Cause. While there are many causes of audio problems internal to the transceiver, it's always best to first look for the obvious. In these cases, a bad microphone and bad antenna coax connector (with high resistance) were found to be the causes of the problems. Also remember to check for poor RF grounds or signal paths back along the coax shield that frequently are the cause RF to get into the transceiver and microphone.

Solution. Replaced microphone and repaired coax connector.

9.7.3.14. Warbly Transmitted Audio (500CX)

Problem. Reports of warbly or somewhat distorted transmitted audio from a 500CX, which was confirmed by listening on another receiver. The transceiver's received audio sounded good. The filter capacitors in the power supply were replaced and C1804 (dual 40-40-μF multi-section can transmitter in the transceiver) in the 275-V line checked good and also when replacement capacitors were temporarily bridged across it. Minimal ac ripple on the 275-V line. Problem does not correlate with an increase or decrease of MIC GAIN control setting. It does not sound like FMing but rather like something wrong in the audio chain.

Possible Causes. (1) Make sure both the bias supply capacitor in the power supply and the bias filter capacitor in the transceiver are OK. Listen to the carrier, either by un-nulling the CAR BAL when in SSB mode or in the CW mode to see if there is an ac hum on the carrier. (2) Check to ensure the problem is not RF pickup related from the microphone cable, feed line, power supplies, etc. If RF related, use capacitor bypassing, baluns, and/or better grounding. (3) Check the value or the resistors (R1404, R1405, R1401) in the microphone amplifier stages (500CX); a similar problem on a different transceiver with out-of-value resistors caused the stages to be nonlinear and produce 'warbly' audio, (4) Check the carrier oscillator adjustment – a similar problem (500C) was corrected by readjusting it.

Solution. Replaced a capacitor with high leakage (C1803 – its value was a 150 μF vice 80 μF as per manual). The transmitted audio seems better at lower levels of mike gain when no movement of cathode current was noted on modulation peaks, but as soon as the gain was increased to yield cathode current peaks of around 100 mA, then the transmitted audio started to sound like it was flat-topping or being overdriven. Resistors were checked and all are within 10% of proper value. No final solution reported.

9.8. Other Problems

9.8.1. Crystal Inoperative

Problem. As stated.

Cause. Unknown.

Solution. If a crystal has quit oscillating, you can try heating the pins with a soldering iron to see if that makes it start up again. No guarantee, but it has been reported to work.

9.8.2. Frequency Counter DD-76 Display

Problem. Display segment inoperative.

Cause. Bad DD-76 display segment.

Solution. The DD-76 manual identifies it as a FND507 common anode seven-segment display. A source for inexpensive replacement displays is Jameco Electronics (*www.jameco.com*), who carries the FND507 display for $0.99 per display in small quantities.

9.8.3. Front Panel Replacement

Problem. Front panel is badly damaged and needs replacement.

Cause. NA.

Solution. Before finding a replacement, make sure the candidate is indeed a true form-fix replacement. Swan changed the number of mode switch functions and even some control positions during the production runs of some transceiver models.

For example, the Swan 350 front panel went through quite a few changes throughout production. The early units did not have a hole drilled for the DIAL SET, there were front panel control labeling differences, and the final design in 1967 had the PA TUNE and PACOARSE LOAD control holes drilled in slightly different positions. If serial numbers of the both the parts rig and refurbishment rig are available, a query to one of the on-air Swan-Nets or via email to *SwanRadio@Angelfire.com* can confirm that the panel from a specific parts rig is identical.

The good news is that the removal and replacement of a front panel, while it appears somewhat daunting, is surprisingly easy. Just remove all the control knobs, the hex nuts holding the various controls to the panel, and the Jackson drive tuning assembly by removing the small nuts holding the Jackson drive assembly to the panel and loosening the shaft set screws (accessible through the hole in the Jackson drive assembly). Disconnecting the wiring to the meter allows it to be removed with the panel, avoiding the need to remove the difficult to access small hex nuts affixing it to the panel. Lift off the old panel, replace with the new one and reverse the procedure. Take this opportunity to mechanically zero the meter if required.

9.8.4. Cinch-Jones Connector Cover Removal

Problem. As stated.

Cause. Not applicable.

Solution. There is no quick way to remove the Cinch-Jones connector cover inside the radio chassis, removal requires just patience, heat, and prying. It's actually a little easier than it at first appears to be.

9.8.5. Key Voltage

Problem. The voltage across the key jack on the back panel is about –110 V. Key closures may sometimes produce key arcs.

Cause. The Swan transmitters use grid-block keying for CW operation. While the voltages on the hot key contact are considerably less and substantially safer than those present used with cathode keying, there will still be an appreciable voltage. The key voltage on the hot contact will be approximately –100 V, but it is fed through 100-kΩ resistor.

Solution. There is no problem. This is an inherent characteristic of the design and the penalty paid for grid-block keying. This key voltage shock hazard is minimized since it is fed through a 100-kΩ resistor, however caution should still be use, especially in adverse conditions (e.g. dampness). To reduce or eliminate arcing, add a 0.5-µF or so capacitor across the key terminals or on the jack inside of the radio, as recommended in a Swan Service Bulletin and earlier model transceiver Operation Manuals.

9.8.6. Meter Commonality/Interchangeability

Early Model Direct Reading Meters. The 100 series early mono-banders (120, 140, 175) and on at least the earliest version of the 240 tri-bander use a direct reading cathode current meter (amp meter). These meters are off-the-shelf commercial versions without the rounded plastic bezel/faceplate that matches the tuning dial.

Mid-Term Model Meters. A larger size, low current (probably 0 to 1 mA full scale) indirect current sensing meter movement was used in at least the last (of three) version of the model 240 (early versions used a direct reading 0-300 mA or 0-400 mA amp meter). That meter is probably interchangeable with the later mid-term models. All mid-term Swan dual-tube PA transceiver models, from the 350 and 400 up to and including the 700CX (and even the Mark II Linear amplifier), use the same larger size 0 to 1 mA full-scale meter. Any of those meters salvaged from a parts radio can be used as replacement. They are all indirect reading. That is, a resistive network is used to sense the low voltage drop across the PA cathode resistor and, through a pair of calibration resistor in series with the meter, to display the correct current reading on the 1-800 mA scale affixed to the 0-1 mA FS meter.

For a 600R (and 600T) and the 400, 350 and early 500 models, where the S-meter reads in reverse, it is still the same meter used in the mid-term dual-tube PA models, just the sensing circuitry and plastic scale backdrops are different. Just remove the old meter's scale and slip it into the replacement meter. Once installed, the meter accuracy should be checked to confirm that the cathode current readings are correct and the calibration resistor changed as required (see discussion in Section 9.6.3).

Late-Term Model Meters. The meters used on the later term dual-tube PA transceiver models (e.g. 750CX, HS700S) is not the same one used in the mid-term dual-tube PA models. While still rectangular in size, it is considerably smaller, less accurate, and much more cheaply constructed.

Cygnet Model Meters. The small rectangular format meters used in the Cygnet (e.g. 270, 300B) model transceivers are interchangeable (it should also be the same meter that is used in the Siltronix 1101). However, note that this Cygnet meter is not the same one used in the Cygnet-like models (e.g. 350A/B/D).

9.8.7. Meter Issues and Problems

9.8.7.1. Meter Static Charge

Problem. Difficulty in removing static charge built-up on meter face.

Cause. Cleaning the plastic meter face with some cloth materials can produce a high static charge. The more you wipe it off, the bigger the static charge grows, significantly affecting the pointer's position.

Solution. Eventually, the charge will dissipates on its own, but it can seem to take forever. First, try wiping the meter with a damp cloth. If this doesn't do it, try some of the anti-static spray that is used on clothing. Remember to test the effect of the spray on some other piece of similar plastic to make sure it won't destroy the plastic face. If it survives, spray a piece of cloth and wipe the meter face with the cloth. Also, the anti-static sheets that are used in the clothes dryer, such as Bounce, should also work.

9.8.7.2. Meter Pointer Repair

Problem. Meter pointer bent or paint delaminating.

Cause. Under momentary short conditions, the meter's pointer can become severely bend or deformed. The Swan meter pointers were initially painted black, and then a year later it was changed to red. Flaking of the red paint from the meter pointers used in the early transceiver models is fairly common.

Solution. If the meter's pointer is bend and the movement's coil has not been destroyed, the pointer can be straightened. Remove the meter from the radio and carefully pry off the plastic face cover. Since the pointer is very fragile, use extreme care, merely holding the meter in place with one probe (toothpicks, etc.) and gently pressing the deformed section in the right direction. Note that the circular lower barrel of the pointer is just a very fragile hollow tube and any clamping pressure whatsoever with deform it. Only as a last resort try using forceps, needle nose pliers, etc.

If the pointer's paint is delaminating, remove the meter from the radio and carefully pry off the plastic face cover. Then, again using great care, remove loose flakes from the pointer by brushing along its length with a soft artist's type brush. Give the pointer a couple sprays of red paint, or with a fine, small brush recoat using well-thinned paint, and reinstall. Work very carefully as the delicate meter movement can easily be damaged. Be sure to place a piece of thin plastic or tin foil sheet between the pointer and backdrop to completely protect the meter innards from paint flecks and the plastic meter scale from paint.

9.8.7.3. Meter Cannot Be Mechanical Zeroed

Problem. The meter pointer cannot be adjusted to the zero position when no power is applied and the transceiver is in its normal operating orientation. The meter used in Swan and other transceivers should be mechanically zeroed to insure best accuracy when adjusting the bias level for the specified PA tube cathode current (usually 40 to 60 mA).

Cause. Ageing, episodes of excessive current, mechanical shocks/jars, etc.

Solution. The following applies to the meter used in the mid-term dual-tube transceiver models. In cases where the meter cannot be mechanically zeroed using the adjustment screw on the meter face, there is an internal adjustment to reposition the pointer's static position for the 0 to 1-ma meter used on dual-tube PA models. Note also that on most Swans (e.g. 350, 400, 500, 700 series), the mechanical adjustment screw is beneath the Swan model label. You must either remove the label to gain access to the front panel adjustment hole, or remove the meter.

Remove meter from the transceiver and carefully remove the plastic front cover by releasing the tabs on the upper and lower edges. Inspection of the meter will show that the pointer is suspended by two delicate spiral hairsprings located on the front and rear of the pointer subassembly. One end of each hairspring is attached to a short slotted metal adjustment arm (the slot of the front arm fits into the front panel's mechanical adjustment screw).

To reposition the pointer, the rear arm (which is difficult to reach) must be adjusted slightly in the proper direction. To do so, first position the front adjustment arm such that the mechanical adjustment screw on the meter front is in its middle position (i.e. rotating the screw left/right will cause the pointer to move left/right off its centered position), then using a simple thin rigid tool with a small curve on the end (thin wood strip, section of flattened coat hanger, a dental pick, etc.), carefully insert the tool between the very bottom of the meter assembly and plastic case and gently change the position of the rear adjustment arm. USE EXTREME CARE as the meter assembly is very delicate and can be easily damaged! An alternative is to disassemble the meter movement from the rear plastic case. This will give very easy access to the adjustment arm, but entails additional risk of damage to the movement, as it will be fully exposed.

9.8.7.4. No Signal Strength Meter on the 240

Problem. The early 240 has a direct reading amp meter (0 to 400 mA) while the later model (with the square meter frame) is a 0-1 mA reading meter which needs a series resistance to calibrate the meter and sense the cathode current. Neither has a signal strength function.

Cause. This is not a problem; it is inherent to the transceiver design and meter used.

Solution. The later transceiver model version using the indirect reading 0 to 1-mA meter can be made to read signal strength, but it requires the addition of a relay. The auxiliary relay contacts (if not already in use) on the back of the radio can also be used. It is a matter of switching the meter back and forth between S-meter operation and cathode current on transmit. The meter used in the early version 240s (either the off-the-shelf commercial unit directly mounted on the panel or the one having a meter frames with broad V shape on the lower section) need too much current to operate as a S meter.

9.8.7.5. Rapid Power On Meter Deflection

Why do Swans have meters that read S unit signal levels from right to left in early designs and left to right in later designs? In response to user feedback that questioned why the meter movement on early designs had to be viewed in two different directions (cathode current left to right, S-unit signal levels from right to left), the meter circuitry was changed so that on Swan 350Cs, 500Cs and later models, the meter reads both cathode current and S unit signal level from let to right. A consequence of this change is that when first turned on, it is normal for the meter pointer to rapidly deflect and slam against the right hand stop. This is hard on the meter, but virtually never causes any damage to the movement or pointer.

The simplest way for Swan to implement the change in S-unit signal reading direction resulted in two separate actions taking place. The first occurs instantly as the meter initially deflects to the right because the meter zeroing circuit takes its reference from the screen voltage of the 2nd IF, which appears as soon as the radio is turned on. The second occurs after the cathode of the 2nd IF warms and starts conducting current. The voltage drop at the cathode resistor offsets the biasing screen voltage and the meter slowly settles down to where the S-meter zero potentiometer tells it to be. Note that if tube-type rectifier power supplies were still used, this problem would have never come up, as both the screen voltage and cathode warming would occur in unison and the screen voltage could not be instantly applied.

9.8.7.6. Meter Pointer Damage – Bent Pointers

When the meter slaps the right hand stop, it is more of a scare to the operator because of its swiftness and the operators valid notion that these meters are quite fragile. Is this movement enough to actually bend the pointer? Not for a normally operating transceiver, where abrupt pointer movement on start-up is standard and damage due to start-up deflection is almost unknown.

However there are a number of ways that actual meter damage can occur, where the coil can burn out or the pointer movement is so violent that bending will occur. A momentary probe slip while measuring voltages that shorts a higher voltage to the meter circuit can burn out the coil instantly or, at a minimum, bend the pointer into a pretzel shape. A short in the PA tube can also result in uncontrolled current from cathode to plate or screen that will slap the pointer against the stop with great force.

Failure of one of the 4.7-Ω cathode resistors in the original Swan 350 and 400 design will do likewise. That design used a pair of 4.7-Ω cathode resistors in parallel solely to cause a small voltage drop at the cathodes that could be measured and translated into the cathode current displayed on the meter. These were 1-W resistors and during long tune-ups or a PA tube short, one could burn open. This changes the combined parallel resistance of 2.3 Ω to the value of the single remaining 4.7-Ω resistor and doubles the voltage sensed by the meter. Bang! Against the stopper. Swan changed these resistors to 1-Ω, 1-W resistors in the late 350 and 400 models. This cut the pointer bending and coil winding burnouts considerably. However, when the power was upped in the 500C, a few of the 1-Ω, 1-W resistors would smoke from time to time. The cure came in with the 500CX when 1- Ω, 2-W resistors were used in the cathode circuit.

9.8.7.7. Rapid Meter Deflection Correction

If one desired to correct the rapid meter deflection on power-up behavior, there are a number of viable ways (there are other, even more tedious approaches to solve this problem, but, since only about one in a thousand meters actually suffer actual damage, their utility is problematic). One possibility is to install back-to-back diodes to at least protect the meter movement somewhat, but only if the actual applied voltage during start-up is enough to make the diodes conduct, so it might not make a difference in this case, but it’s a method often used to protect against meter failure. However, protective diodes in this type circuit could hinder the operation and accuracy of the meter readings. The voltage at the wiper of the meter’s electrical zeroing pot is actually quite low, only on the order of around 1.0-V or less to 2.5-V maximum. The wiper would never be set for 2.5 V because the largest voltage drop across the lower cathode resistor, where the signal voltage is sensed, is about 1 volt. Therefore, the potentiometer would be set to balance the 1-V drop across the lower cathode resistor in order to zero the S meter. Possible solutions include:

- Replace the plastic backdrop in your meter with one of an early 350, 400 or 500 meter and rewire the S-meter circuit in accordance with those earlier schematics.
- Those users that do not use the PTT/VOX switch can disconnect and direct wire the PTT function. Then, connect the meter line through the switch so that the meter can be turned off and on manually just like on the Swan Cygnet models.
- For cases such as the 500C, or other transceivers that have been upgraded to the solid-state carrier oscillator board, thereby eliminating a need for the 0A2 voltage regulator tube, the 0A2 socket can be rewired to handle a 6X4 rectifier tube and used to supply the screen voltage to the 2nd IF 12BA6 tube. With the warm-up time requirement of the 6X4, the S meter won't move until both the 6X4 and 12BA6 come to full life. In the case of the late 350 models, the crystal calibrator punch out on the chassis can be used to mount the socket for the 6X4 rectifier tube.

9.8.8. Relay Cover Removal

Problem. It can be very difficult to in remove the plastic protective cover on the K1 relay.

Cause. This plastic cover of the four-pole relay has a small tab along the bottom edge midway along both long sides, which fits in a corresponding recess in the socket. For relays that are hard-wired directly to the chassis (as opposed to those that are inserted in a plug and removable), it can be exceedingly difficult to remove this cover because of space limitations.

Solution. First, it's a good idea to inspect a relay that is off the unit (at a HamFest or Radio Shack). This is one of those cases where one picture is worth a thousand words. To remove the cover, you must slightly pull out the long sides at the bottom to release the tabs. While there is a special tool to get under the cover and spread it out, any very thin flat tool with a small curved hook on the end will work (with enough care and diligence). Alternately, without a tool, it can also be released by squeezing the plastic cover from the front and back at the bottom to get the sides to flex enough to clear the latching tabs (I've never had success doing this!).

9.8.9. Main Tuning Dial Slipping (Jackson Drive)

Problem. When the transceiver is tuned through the band, slippage occurs, that is, the knob turns, but the dial moves inconsistently or even remains fixed in place.

Cause. The cause may be as simple as loose setscrews on the main tuning dial shaft or most likely, slippage within the Jackson Drive. Early model transceivers use a different mechanical apparatus for tuning.

Solution. If the cause is because of loose setscrews, merely remove the Fine Tuning VFO knob and the aluminum Fast Tuning VFO knob (affixed with two small brass screws) and tighten the setscrews through the access hole in the top of the plastic spacer ring assembly. There are two setscrews on the shaft, just rotate it to gain access to both screws. If the set screws are tight, remove the dial/Jackson Drive assembly as shown in Issue 6 of the Swan Newsletter in Section A.6.3, and tighten the tabs on the rear of the drive that control the amount of friction by carefully compressing very lightly – caution, do not over-tighten. It is very easy to seriously misadjust it so that it is too stiff or has erratic drag during rotation.

9.8.10. Main Tuning Dial Stiff (Jackson Drive)

Problem. When the transceiver is tuned, the frequency tuning dial movement is stiff or tight.

Cause. The cause of this problem most likely is due to congealed grease in the Jackson Drive or possibly due to improper adjustment of its tension tabs. Early model transceivers use a different mechanical apparatus for tuning.

Stiffness can also occur if the plastic spacer ring, on which the Jackson drive is mounted, is cocked, or skewed slightly relative to the drive/tuning capacitor axis of rotation, as might happen if the small hex nuts affixing it by the long bolts to the panel are over-tightened.

Solution. Remove the dial/Jackson clutch/drive assembly as shown in Issue 6 of the Swan Newsletter Section A.6.3. Clean the drive assembly in a grease solvent, thoroughly dry, and repack with grease. The grease can only enter the triple ball bearing inner assembly either through the very thin circular gap on the front assembly or though the shaft hole on the rear of the drive (at the bottom of this shaft hole are three ball bearings). Oiling of these components will not provide a long-term solution.

While the entire clutch assembly can be totally disassembled by bending the rear tabs sufficient to release the tension ring/washer/grease cup, it is probably unwise because after reassembly, the adjustment of the tabs for the correct tension throughout the entire tuning rotation can be exceedingly difficult. If the clutch assembly has been misadjusted, the tabs on the rear of the drive that control the friction can be slightly compressed or decompressed as required, however it's best to be sure that it is really necessary.

If the plastic spacer ring on which the Jackson drive is mounted appears to be the problem, try loosening the two hex nuts slightly and repositioning so that there seems to be no vertical or horizontal pressure on the shaft axis after the nuts are lightly re-tightened.

9.8.11. Voltage Regulation – 0A2

Problem. No 150-V output from the 0A2 tube.

Cause. The 0A2 is the voltage regulator tube so, if it doesn't have any voltage, first confirm that the power supply voltages are present. The MV is supplied to the 0A2 to produce +150 V required for the carrier oscillator. The full +275 V output from pin 6 is also used throughout the rig for most tube plate voltages. Check to make sure that the power supply is operating properly and that there are no broken wires in the cable, Cinch-Jones plug, socket, etc.

Solution. Solution not reported.

9.8.12. Wattmeter 2000A/3000 PEP Inoperative

Problem. The PEP function is inoperative or intermittent; meter pointer deflects negatively when PEP function turned on.

Cause. Bad operational amplifier chip.

Solution. Install a chip socket and replace the operational amplifier chip with a LM741CN or LF356N (Radio Shack). See Section 4.17.7.

9.9. Part Sources

See also the Swan Newsletter, Issue 5, Section A.5.3.

9.9.1. Components

- ***AF/RFPOT & ON/OFF Controls***. These ganged AF and RF gain potentiometers and on-off switches are difficult to locate. Note that the RF and AF potentiometers are different values and tapers. What to do if you have a failure on one section of this type of assembly? A parts rig is certainly the best and the easiest solution. Another option is to check with vendors that specialize in tube-gear refurbishment parts, like Antique Electronic Supply, in hopes of finding an exact replacement with similar potentiometer ranges.

  However, if one cannot be found, repair is possible with a lot of effort. For a bad switch (or potentiometer), one reported successful approach was to find a new pot/switch assembly with the same switch and shaft configuration, take out the wafer from the new pot assembly and replaced it with original pot's wafer (e.g. 20 kΩ) – a bit of a hack job, but it worked. It's best to practice on an old assembly, as this procedure is much easier said than done. Conversely, if the wafer is bad, a new pot's wafer can be inserted into the old assembly.

- ***HAMFESTS***. Pick up useful parts as spares, such as tuned coils (e.g. tuned coil slugs, in case you break an old brittle one while trying to align a unit), spare tubes, etc. for your junk box.

- ***Cinch-Jones Connectors***. Action Electronics, email at: Action-Electronics.com and view website at: *http://www.action-electronics.com/cinch.htm*. Try also Electronics Surplus, Inc. at the following website: *http://www.electronicsurplus.com/dictionary/cat1946.htm* and Electronic Parts Outlet in Webster Texas.

- ***Driver Coils***. The 80 M driver coils from the 350C, 500C, 500CX and 700CX models are interchangeable, so replacements may be obtained from an organ donor parts rig that is any of those models.

- ***K1 Relay***. A reported replacement source for the 4PDT relay K1 used in many transceivers (e.g. 700CX) Newark's (*www.newark.com*) stock P&B KHAU-17D16-12 (Newark # 87F1123) for about $10.00. It's a good quality, gold-plated, bifurcated contact relay that should work well with the lower currents being switched. MarVac Electronics at *http://www.marvac.com/* also should have this relay.
- ***Knobs***. The smaller control knobs used by Swan on most models were originally made by Kurz Kasch Knobs. Cosmos (440 498-7500) still manufactures these knobs (i.e. main tuning knob with 7 flutes and aluminum insert (but without set screws) along with the small load/plate knobs with insert, etc. however purchases must be in bulk quantities (i.e. 25). The spun machined aluminum inserts used on the main tuning dials of the transceiver and external VFO were being sold by Charlie Talbott (email: *pincon@erols.com*) and may still be available.

  The smaller silver knobs used by Swan for the DIAL SET control may be available from MFJ, which reportedly using the same type on their current equipment.

  The standard size and style communications type knobs similar to those used by Swan are carried by Radio Shack.
- ***MV Filter Chokes (117B/ X Power Supply)***. The Peter W Dahl Co. is reported to make a custom wound replacement choke for the MV supply in the 117B and 117C - it may also work for the 117X. Antique Electronics Supply is reported to also have an exact replacement for the choke (part # P-T156R - $10.50) used in the in the 117X's MV supply – it's made by Hammond, is 1.5 Henry, and has the same mounting hole spacing.
- ***Miscellaneous Tubes and Parts Sources***. The web has many venders offering parts for the repair and refurbishment of tube style radios and well as Ham equipment. Try visiting some of the sites listed at the following web page: *antiqueradio.org/parts.htm*
- ***Solid-state Components and Parts***. Solid-state components for Swan transceivers and accessories may be available from: Richard Jacinth (N6OK), 2883 Cottingham St, Oceanside, CA 92054.

  Also, try searching on the Internet using Google or one of the other search engines for semiconductors. There are at least one or two agencies that act as clearinghouses for discontinued semiconductors. Their websites have search engines that will list the stocks of discontinued items at suppliers all over the country.
- ***Speakers***. The loud speakers used by Swan are typically ~4 Ω impedance (remember that impedance is measured with a sinusoidal signal and dc ohmmeter type measurements typically give somewhat lower resistance values) have much smaller magnets and in some cases are of different size than those commonly available today. Finding a replacement speaker with the correct form/fit factor can be difficult because of these physical size constraints.

  In the case of the 117XC power supply, the 4" square speakers units available from parts suppliers typically do not have the small magnet size that will fit within the tight confines of the 117XC cabinet. For transceivers like the 400, space for a larger magnet is limited by tube placement and the 3" by 5" oval size is not readily available. One possible source for replacement speakers is to search out the smaller one-man type TV/Radio/Stereo repair shops (hard to believe these still exist, but they are still around!). They most likely will have a junk box containing odd size speakers salvaged from older TVs and radios that have smaller magnets.
- ***Transformer (Power Supply).*** If you have a bad transformer and really, really want to restore your 117X power supply, the Peter W. Dahl Co. in El Paso, Texas has the transformer available for $165.00. Rather pricey, but some who do serious restoration of vintage equipment deem it worth the cost. The transformer is listed on their WebPages at:
  - *www.pwdahl.com/*
  - *www.pwdahl.com/*dahlcatalog*/hamtrans011404.html#S*

- ***Wrinkle finish paint***. This spray can product can be found at: Plasti-Kote wrinkle finish textured spray paint #217 Black (available from PEP Boys Auto Store), Zynolyte brand wrinkle paint (source unknown), Antique Electronic Supply Black Wrinkle Paint (*www.tubesandmore.com/*), NC Total Electronics Black Wrinkle Paint (*www.nctotalelectronics.com/paints.html#wrinkle*), and wrinkle paint stocked by many auto parts stores (including: Harley Davidson Cycle Shops and Auto Refinisher Suppliers (used for old car heaters)

9.9.2. Vendors

The following list represents only a very small number of the vendors available. Be sure to do an Internet web search for specific items, as there are many other smaller dealers.

- ***A. G. Tannenbaum*** has a fairly good selection of multi-section electrolytic can capacitors, 2-W carbon composite resistors, and other boat-anchor type parts at reasonable prices. They can be reached at A. G. Tannenbaum, P.O. Box 386 Ambler, PA 19002 (USA) Phone: (215) 540-8055 Fax: (215) 540-8327 or visit their website at: *www.agtannenbaum.com/alcan.html/*
- ***Allied Electronics*** has a very wide range of parts, including the 9-pin octal plugs, but no hoods
- ***Antique Electronic Supply***. This vendor offers a wide variety of vintage radio parts ranging from NOS tubes, tube sockets, to reproduction dials and decals. While the focus is mostly on refurbishment of antique AM radios, they offer many products useful for Swan repair. Prices may be a bit higher than other sources, but products appear to be of highest quality. A catalog is available. Their website is located at: *www.tubesandmore.com*.
- ***Cal Crystal Lab***. This vendor is located in California and reportedly was an original supplier of crystals for Swan Electronics. A typical crystal cost is $15.00 apiece. Their phone number is 714-991-1580.
- ***Digitkey*** is a major parts supplier carrying a very wide range of general-purpose electronic parts. Their website is located at: *www.digi-key.com*.
- ***Frontier Capacitor***. This vendor can be reached by phone at: (877) 372-2341 or by e-mail at: *frntcap@bektel.com*. This is a smaller operation that offers all new inventory of radial, axial, metal, poly, tubular, and ceramic capacitors. They also offer a rebuild service for electrolytic cans, but it's expensive. A small catalog is available that can be faxed to you.
- ***Hosfelt Electronics***. Hosfelt Electronics is located in Steubenville, OH (1-888-264-6464). They have reasonably priced new manufacture high-quality electrolytics available in small quantities. Speedy delivery of ordered parts. Phone for catalog or request it on their website, at *www.hosfelt.com*.
- ***International Crystal Manufacturing***. From International Crystal Manufacturing in Oklahoma City (website is *www.icmfg.com/*) you can order pretty much anything you need in the way of crystals in any quantity. Typical per crystal price is $15 range. Their turnaround is about 2 weeks. If you need to call, the phone number is 800-725-1426. Some Swan users feel they use higher quality quartz and are the best crystal source.
- ***JAN Crystals*** JAN Crystals 2341 Crystal Drive Ft. Myers, FL 33906-6017 Phone (800) JAN-XTAL (526-9825). Note that when ordering special purpose crystals, you need to know the crystal frequency, the size parameters (holder type and pin diameter) and circuit conditions. Typical per crystal price is in the $15 range.
- ***Mock Electronics*** in Huntsville deals primarily in NOS electronics parts.
- ***Mouser*** has a website at: *www.mouser.com/*. This is a major, large-scale vendor carrying a very wide range of general-purpose electronic parts. It is a favorite source for many because of the wide variety, no minimum order requirement, friendly service, and prompt shipment.
- ***RF Parts*** are familiar with Swan transceivers and they carry a nice selection of tubes and parts. You can get a free catalog at: *www.rfparts.com*

- ***Newark Electronics*** is a major supplier of general-purpose electronic parts and components. They have a very wide selection and even stock Cinch-Jones connectors.
- ***Total Electronics Co***. In addition to electronic parts, this vendor also sells paint in spray cans, including black wrinkle paint and shades of gray that match Swan front panels (i.e. Swan 175, and Swan 240 upper and lower gray shades). Their Webpage can be found at: *www.nctotalelectronics.com/*. They offer a repair service for older radios and are reported to do front panel silk screening.
- ***W&W Electronics*** in Huntsville, Alabama (phone 256-534-0376 or 256-534-5313), has connectors that are no longer easily obtainable. They are open Monday thru Friday until 5:30 CDST and will ship.

9.10. Repair Help

Perhaps the best places to seek out advice and repair assistance are the on-air Swan Net, the Swan Net email Reflector, and Internet Newsgroups

9.10.1. Tube Transceiver Repair

There are a number of individuals and organizations that do boat-anchor repairs, but, because there has been little feedback reported by Swan owners on most of these, they have not been listed below. Many Swan owners have expressed satisfaction with work done by those listed below.

John is a previous Swan and Cubic employee with years of in-depth expertise in the repair and alignment of Swans. Stu is a Net Controller for the Swan Technical Net and is a prime participant in all phases of the Swan-Net, including Newsletter, Website, and Reflector activities. He has many years of in-depth expertise with the repair and maintenance of Swans and other tube gear. Jeff has been servicing tube equipment for over 30 years, primarily Drakes, but also Swans. Fred is also mentioned as working on Swan and Cubic rigs with some parts available, although his primary emphasis is on Icom and Kenwood radios.

John Bruchey	Jeff Covelli, WA8SAJ	Fred Krause, N2LXD	Stu Morrison, K4BOV
4005 Jupiter Street	5368 Melody Ln.	9915 W. Sidehill Rd	10401 Spencer Hill Road
Sulphur, Louisiana 70665	Willoughby OH 44094.	Ripley, NY	Corning, NY 14830
(337) 558-5681	*wa8saj@ncweb.com*	*emily2@cecomet.net*	*k4bov@juno.com*

9.10.2. Solid-state Repair

As with the tube gear, there are also a number of individuals and organizations that advertise solid-state repair services. Because there is little or no Swan owner feedback, they have all not been listed below. However, Swan owners have expressed great satisfaction with work done by Richard Jacinth, a Cubic employee (and ex-Swan employee). He services Swan and Cubic solid-state radios. Phone (760) 721 6841 after 6 to 9 PM West Coast time or send inquiry via SASE to:

Richard T Jacinth (N6OK)	Rian A Raleigh (AG4ME)
2883 Cottingham St	535 Seaward Road
Oceanside, CA 92054	Corona del Mar, CA 92625
rnjacinth@juno.com	*esotericradio@engineer.com*

9.10.3. Meter Repair

A source for possible meter repair is: Standard Meter Laboratory, 236 Rickenbacker Circle, Livermore, CA 94550, Phone: 925-449-0220, Fax 925-449-1704.

9.10.4. Restoration Information on the Internet

There are many sites that contain useful restoration information including:

- *www.io.com/~nielw/Hint.htm*
- *www.ezlink.com/~crash/parks/caps.html*
- *www.3rdtech.com/nick/rrab.faq.htm*
- *www.nostalgiaair.org/NostalgiaAir/Articles/Index.htm*

10. CLEANING and REFURBISHING

10.1. Preventative Maintenance.

Past repair histories from Swan transceivers indicate a number of marginal design areas or components that are subject to higher failure rates. When doing a refurbishment or just cleaning, some areas of preventive maintenance that might be performed include:

Yearly Maintenance. If you do nothing else in terms of maintenance on your Swan radio, consider at least a once yearly performance of the following simple tasks.

Blow/Vacuum Dust. Pop the top cover off the transceiver and with a soft brush and vacuum crevice tool to loosen up and remove the surface dust and grime. Follow up by blowing any dust out of cracks and crevices, including the PA cage and variable capacitor vanes.

Clean Cinch-Jones Connectors. These connectors are an extremely common cause of problems. Thoroughly clean or burnish all male and female Cinch-Jones connectors on both the ac power cord and power output cable. Carefully bend male connector's pins slightly if poor mechanical connection is being made.

Clean Relays. Dirty relays are another source of common transceiver failures. Clean both K1 and K2 relay contacts to insure problem free operation.

Balanced Modulator Plate Resistors. The 6JH8 (and 7360) balanced modulator tube uses a 100-Ω, ½-W resistor on each plate that operates close to its ½-W rating. If one or both change value significantly as they age, the CAR BAL control will malfunction (cannot null the carrier or only nulls near or at the 9 O'clock or 3 O'clock control positions). Always use replacement resistors with a one-watt rating.

MV Power Dropping Resistor. Later model transceivers use fewer tubes and thus have a reduced current draw and a proportionally lower voltage drop across the 10-W voltage dropping resistor in the 275-V circuit, which nominally provides 215 V to the mixer, VFO, driver, and balanced modulator circuits. On some models, this resistor (e.g. R1605 on the 250) is only 400 Ω and it could be changed to a 600-Ω, 10-W resistor (later units like the 500CX use a 750-Ω, 10-W resistor). Making this change to R1605 will reduce that voltage by 10 to 15 V.

Mixer MV Power Supply Dropping Resistor. On most transceivers, the 215-V (nominal) medium voltage is provided to the mixer stage through a 1-W (R203, a 4.7-kΩ resistor in the 500CX) resistor. This is a frequent failure point as the power rating is somewhat marginal. If changing that resistor, replace with a 2-Watt unit.

Power Supply Electrolytic Capacitor and Diode Replacement. By far the most common failure points with Swan power supplies are a bad diode in the rectifier circuit or a bad electrolytic capacitor in the HV and MV filters. The electrolytic capacitors are especially prone to failure after long periods of storage and subsequent powering-up of the unit. Capacitors need not show physical signs of leakage to be bad. Consider replacement of all power supply electrolytics and perhaps the few electrolytics in the transceiver as well (with perhaps the exception of the can capacitor, which is difficult of impossible to find). While your at it, since diodes are so cheap, consider changing all stock diodes with ones rated at 1,000 V and at least 1 A.

10.2. Smoke Test – The Initial Power-Up

Before applying full ac power to a transceiver that's been in storage an extended time, consider the following steps to minimize component failure (filter capacitors, chokes, transformers, etc.) during resurrection. Even if you have been guaranteed by the previous owner that it "*worked the last time I used it*," or that "*the guy I bought it from said it works perfectly*," or "*it was powered-up a couple of months ago*," it's wise to still do the following steps. Unfortunately, such "*good*" rigs are frequently found to have hard component failures with physical damage (burned or blown resistors, capacitors, etc.) and even missing tubes!

- At the very least, use a vacuum cleaner crevice tool and a soft, long bristle brush to thoroughly remove the worse of any accumulated dust and grime. Follow with a compressed air by a blow out cracks and crevices. Pay especially close attention to the variable capacitors plates, especially those in the in the PA cage. Usually there will not be much debris beneath the chassis, but it's still a good idea to at least pop off the bottom and carefully inspect the innards to make sure there are no obvious signs of failure (bulging or leaking capacitors, burned components, scorch marks, or areas where repair work had previously been performed).

- Make certain the transceiver and power supply are thoroughly dried-out, especially if it had been in storage in a humid or damp environment. If in doubt, enclose it with desiccant in an airtight container for a week or so or place it over a gentle heat source (light bulb) for a day or two.
- Pop open the power supply and inspect the filter capacitors for obvious signs of failure (bulging, leakage, discoloration, etc.) and if possible, perform at least an in-circuit ESR test (Section 10.3.2). If the original capacitors are still in the power supply, it would be wise to replace them, since high leakage can occur even though the units still physically appear good and test good on a capacitor tester.
- Finally, before applying power, make sure all transceiver front panel switches and controls are adjusted to the receive mode, as per the manual.
- While some users simply apply 120-V ac and hope for the best, many use a Variac as described below to slowly power-up the radio over a number of hours (and hope for the best).

Variac Power-Up. The primary reason for powering a power supply and transceiver with a Variac is in the hopes of re-forming the electrolytic capacitors. However the proper method for re-forming capacitors involves a detailed procedure performed with the capacitors physically removed from the equipment, as described in the following paragraphs, a task that only the most dedicated purist might want to pursue.

Most users simply power-up a radio for the first time using, if available, a Variac (a transformer whose secondary voltage is variable from zero volts up to the full ~120-V ac). Since most Variacs are rated at only 2 or 3 amps, they can only power the rig in the receive mode or under idle (low power) conditions in the transmit mode. Bring the ac power level slowly-up in steps up to a full ~120-V ac line voltage over perhaps a 6 to 8-hour period (recommended times vary widely or are simply unspecified in may discussions) – one recommendation suggested starting at no more than 40 to 50-V ac for about an hour and increasing by 10 or 15 V every hour or so. The reduced HV, MV, BIAS, and REL power supply outputs during this time will hopefully limit excessive electrolytic capacitor leakage current that would occur under the full working voltage until the dielectric in the electrolytic filter capacitors has had a chance to re-form (if its going to) at each voltage level. At about 75-V ac or so, with the RF and AUDIO gain fully cw, the receiver should begin to come alive with some audible speaker static. After the unit has been powered up successfully, it's a good idea to again physically inspect the filter capacitors, especially if the original power supply electrolytic capacitors had not been replaced; they may now show damaged and be in the process of failing after the shock of full power application.

Variac Alternative. If you don't have a Variac, a simple method that uses a sequence of different wattage light bulbs wired in series with the ac power cord has been suggested as an alternate. Start with a low wattage light bulb and increase the wattage in steps over time to increase the ac voltage to the rig. A dual-tube PA rig (e.g. 500CX) draws approximately 1.25 A in the receive mode. Reported measured ac voltages at the transformer's primary winding as a function of various bulb sizes are listed in the affixed chart.

BULB SIZE (W)	AC VOLTAGE
40	31.5
60	46.5
100	65.6
200	91.5

* AC Line Voltage = 121.4 V

10.3. Capacitor Testing and Replacement

When replacing electrolytic capacitors with newly manufactured units, do not be surprised if the physical size is much smaller and the value tolerance much tighter than on the original units. This is one case where technology and improved materials have provided a better product.

10.3.1. Capacitor Fundamentals.

In general, five types of capacitors (a.k.a. a condenser, if you're a real old-timer) are use in tube-era radios: (1) variable (air gap with vanes or ceramic compression trimmer type), (2) mica, (3) ceramic disc, (4) paper/wax, and (5) electrolytic (usually used in filtering). The variable, mica, and ceramic disc types rarely fail and usually do not need replacement, even after many years or decades of service. Both paper and electrolytic capacitors deteriorate with age, frequently having excessive leakage (the capacitor begins to start acting like a resistor) that results in degraded electronic performance, the most noteworthy being the ac hum due to leaking electrolytic filter capacitors in the power supply circuits.

Capacitor materials and construction techniques drive the capacitance value that can be fabricated for each type. What dictated with type of capacitor that was used in the various circuits of a radio were of course capacitance value, cost, size, and in some cases specific required performance characteristics, such as stability with heat, a known capacitance variation with heat (e.g. linear temperature coefficient), the need to adjust the capacitance value (trimmers, air-gap variable), etc. Generally capacitors of less than 0.001 μF in value are mica or ceramic; capacitors between 0.001 μF and 1.0 μF are paper, and if it's 1.0 μF or larger, it's usually electrolytic.

Because the range of capacitance values used in radios is immense, covering may orders of magnitude, they are usually expressed in terms of either microfarad, (μF or mF) or picrofard (pF, a.k.a. micromicrofarad, μμF, or mmF). A pf is one-millionth of a μF and a μF is one-millionth of a Farad. Therefore, conversion between μF and pF just involves multiplication or division by a factor of 1,000,000 (10^6 or 10^{-6}). This is easy to do if the magnitudes are converted to scientific notation, where $170 = 1.7 \times 10^2$, $1 = 1 \times 10^0$, $0.0012 = 1.2 \times 10^{-3}$, etc., because multiplication just becomes an addition of the exponents. Notice that decimal numbers have a negative exponent and those greater than one have a positive exponent. For example:

500 pF = 0.005 μF since X μF = (Y pf) x (1×10^{-6} μF/pF), then Y = 500 pF = $5 \times 10^{+3}$ pF,

and ($5 \times 10^{+3}$ pF) x (1×10^{-6} μF/pF) = 5×10^{-3} μF = 0.005 μF.

And conversely,

0.005 μF = 500 pF since Y pf = (X μF) x ($1 \times 10^{+6}$ pF/μF), then X = 0.005 μF = 5×10^{-3} μF,

and (5×10^{-3} μF) x ($1 \times 10^{+6}$ pF) = $5 \times 10^{+3}$ pF = 500 pF

Electrolytic capacitors are generally the only ones that are polarized (market with negative and positive leads or terminals) and it is absolutely essential that polarity is observed, with the positive side goes to positive and the negative side goes to negative, otherwise the capacitor will fail and in the worse case, might even do so very dramatically (explode). Some paper capacitors do have a band or other marking on one end (but never a plus or negative symbol, as that indicates polarity), but that does not signify that it is bipolar, like an electrolytic. The band just signifies that the outermost surrounding conductive film layer in that unit is affixed to that lead. By convention, that lead is usually attached to the ground or negative side of the circuit (usually on the assumption that it would help to suppress any interference), although it is not required. Since paper, mica, ceramic, and variable capacitors are all non-polar, it doesn't matter which side goes to positive or negative.

Most radio circuits are very forgiving as to exact capacitance value (other than frequency determining networks), but not in rated working voltage. That is, when replacing a capacitor, it is usually no big deal if a 0.05 μF is used in place of a 0.047 μF, a 0.002 in place of a 0.0022, a 20 μF is used in place of a 22 μF, or a 30 μF in place of a 33 μF, etc. Even with the larger power supply filter electrolytic capacitor values, sizes need not be exact (remember, most tolerance rating are as usually ±20% to as much as +50%!). However regardless of the value used, never use a substitute with a working voltage rating of less than the original. There is no harm is using higher working voltages than specified.

Mica capacitors are usually rectangular or in shape, rated in terms of picofarads, and usually must be replaced with mica units because of stability or value accuracy issues. Ceramic capacitors are usually shaped like a thin disc and should be replaced with a similar ceramic type. Paper capacitors are small cylindrical shapes, usually with axial leads, and may have a wax-like or white/black hard plastic cover – those types of materials are no longer used. They are most commonly replaced with any of the family of modern plastic/polyester film capacitors, which have both a smaller size and superior performance. There are a confusing array of types of these capacitors, including metalized polyester, metalized polypropylene, metal-foil polypropylene, and Mylar. Any should work fine, although at higher frequencies, polypropylene is more stable than polyester, so for film capacitors under 0.01 μF in value, they are desirable.

10.3.2. Electrolytic Capacitors

Reforming. One of the issues frequently discussed with old, unused electrolytic capacitors is the need for reforming. Review of the various sources and discussions on this topic shows that it is somewhat of a "Black Art," with wide-ranging opinions on both its validity and reforming methodology. Discussed below are two of the more commonly discussed procedures. Remember, if you do any of these types of procedures that the capacitors will retain their charges for an extremely long time and must be manually discharged for safety.

After long periods of un-use, the wet paste electrolyte in electrolytic capacitors can begin to dry out and/or the dielectric properties can change. There is a tendency for its leakage current to increase, ripple to increase, and the rated voltage capability to decrease. It will begin acting more like a resistor than a capacitor. In some cases, this change in dielectric properties may be remedied by reforming the capacitor. That is, a dc voltage is applied and the leakage current is limited until the dielectric has had a chance to reform. Two basic methods are frequently recommended, (1) one in which the full rated voltage is applied through a high value resistor and (2) a second in which the voltage is gradually increased in steps, starting with a low voltage and progressively increasing to the voltage rating while the leakage current is limited by a single lower-valued fixed resistor. In both cases, the capacitor must be physically disconnected from the circuit and in both cases the leakage current should be carefully monitored. If all goes well, the initial higher initial leakage current will steadily decrease to a low value as the electrolyte reforms. Reportedly, capacitor manufacturers during the tube-era recommended that NOS units be re-formed if they were unused for as little as a year or two.

> ***Full Voltage Reforming***. The full voltage re-forming method recommends that the capacitor in question be wired in series with the 30-KΩ, 5-watt resistor and the full dc working voltage applied. The voltage drop across the resistor is then measured. As the capacitor reforms, the voltage drop should decrease rapidly as the leakage current decreases while the dielectric reforms. Use Ohm's law to compute current. It is suggested that only 5 minutes plus one minute for each month of un-use or storage should be all that is required for the capacitor to reform, if it is going to. If the voltage measured across the resistor does not drop to below 10% of the applied voltage at the end of this reforming period, the capacitor is probably not salvageable.

> ***Variable Voltage Reforming***. Another more commonly suggested reforming technique is to start at ~10% of its rated value while simultaneously measuring leakage current (i.e. measuring the voltage across a 1,000 Ω, higher wattage resistor that is in series with the capacitor under test to give a direct reading of current in mA on the meter reading in volts (i.e. I = E/R, therefore 1 V = 0.001 A, 10 V = 0.01 A, etc.), otherwise just use Ohm's Law to convert to current). As the dielectric reforms, the leakage current decreases. The leakage current at maximum working voltage should not exceed 5 mA and the measured dc resistance should be greater than 1 MΩ. Capacitors with higher leakage currents or lower resistance values have too much leakage and must not be used.

Of course, the capacitors have to be physically detached from the power supply or transceiver circuit, and considering the hassle involved in doing this procedure, it would be a lot easier to just bite the bullet and replace them with new capacitors (except perhaps the cans, which can be prohibitively expensive). Most users do not have the equipment or inclination to go through such a time-consuming and elaborate procedure as described above, but rather they opt to just use a Variac to slowly increase the ac voltage applied to the entire power supply and transceiver during its initial power-up.

Effective Series Resistance. Another very useful measure of a capacitor's health is its effective (or equivalent) series resistance (ESR). All capacitors have some value of ESR, which is a function of frequency and whose value determines the ripple current rating. This ESR value is the sum of the in-phase ac resistance. An ideal capacitor has no resistance, and therefore no dc leakage and a phase angle of 90 degrees. A real capacitor has both a leakage resistance and series inductance resistance. The former is equivalent to a resistance in parallel with the capacitor, while the later is equivalent to a resistor in series with the capacitor (ESR). These resistance phenomena are due to leakage from the dielectric, plate material, electrolytic solution, terminal leads and, in the case of the series resistance, is a function of frequency. This means the phase angle will not be 90 degrees (which will degrade the power factor) and the current will not be zero. A higher ESR is primarily caused by the wet electrolytic drying out. An high ESR in a capacitor will cause excessive internal heat build-up, which in-turn further dries out the electrolytic, causing further increases in the ESR. Capacitors with high ESR that look just fine in all other respects have excessive ripple and can cause circuits to fail. It's the most common failure mode of capacitors, especially switching power supplies.

With a high ESR condition, a typical capacitor checker often shows normal capacitance and an ohmmeter indicates a normal dc leakage. Ordinary ohmmeters and most capacitance meters do not measure ESR. An easy ESR testing methodology (requires an oscilloscope and audio oscillator) is described in "*Understanding and Testing Capacitor ESR*," published in the September 2003 issue of *QST*. This procedure places a high frequency (e.g. ~50 kHz), low voltage sine wave across a resistive voltage divider consisting of a higher-resistance current-limiting resistor (e.g. R_1 = 1 kΩ) in series with a low value reference resistor (e.g. R_2 = 5 or 10 Ω or more – the selected value used depends on capacitance value range to be examined). The oscilloscope monitors the waveform amplitude across R_2 after its display gain is first adjusted to obtain full-scale CRT deflection with no test capacitor attached. The test capacitor is then connected in parallel with R_2 and its effect on the scope signal is observed. Since the value of power supply capacitors are relatively high (i.e. <10 μF), its theoretical impedance at higher frequencies, R_C, is very low (<1 Ω), and the parallel impedances (R_C, R_2) will be a low value. Therefore, the signal amplitude across the R_2 reference resistor in the voltage divider displayed on the oscilloscope should drop significantly, to ~10% or less of it's pre-test, full-scale value. If the ESR is high, the parallel resistance will be much higher and the displayed voltage decrease much lower.

For example, with a 1,000-kΩ resistor in parallel with a 5-Ω reference resistor, a good capacitor with a 0.5-Ω impedance results in a ~91% drop in the display's signal level. If a bad capacitor has an impedance of 50-Ω, the display's signal level will drop by only ~9.1%, an easily detected differential. This is a relative or comparative test – good capacitors of significantly different values will yield different signal display level decreases (for a fixed test frequency and resistive voltage divider values) because impedance is a function of both frequency and capacitance value ($X_c = 1/(2\pi FC)$), so a calibration should be done using a known good reference capacitor of similar value to the one being tested. A real benefit of this testing is that it may be performed with the capacitor is still in the circuit. No unsoldering! Review the *QST* article for a detailed discussion.

A quick test of this procedure showed 100% accuracy on a limited test sample. Good capacitors of similar values showed the expected, drastic level changes. A very high leakage (e.g. 300-kΩ measured on a VOM) capacitor, three capacitors with obvious electrolyte extrusion or case bulging, and an open capacitor (no dc resistance) all showed an easily detected abnormal ESR level changes with this test.

10.3.3. Replacing Can Capacitors

When a can capacitor goes bad and a replacement cannot be found, there are two options: (1) just replace the old multi-section can capacitor (leaving old can in place for aesthetics, if room permits) with individual units, disconnecting the old unit and observing polarity (some have suggested just bridging at the old connections, but this can cause problems depending on failure mode), or (2) remove the innards of the old capacitor and insert the smaller, modern individual electrolytic replacement capacitors within the old shell. Certainly a lot more work, but also much more aesthetically pleasing.

10.3.4. Mylar, Paper, Paper Ceramic

If you wish to check the operation of one of these smaller value, non-polarized capacitors, try the following procedure. Switch an ohmmeter to its highest resistance range and hold the probes to the capacitor leads. If the capacitor is good, there should be a sudden deflection towards zero ohms when initially connected and then the pointer should move rapidly to a very high resistance reading as the capacitor charges. A shorted capacitor will be indicated by a constant low resistance reading. An open capacitor will have no (or a very weak) initial deflection. A good rule-of-thumb for checking leakage is to note the resistance reading after about 5 seconds – it should be greater than 10 MΩ. Note that it is difficult to check capacitors with less than 0.001 μF because the meter dip will be negligible due to the low capacitance. If doing multiple readings on the same (or different) capacitor, its leads must be shorted to discharge it between measurements. In addition, if the capacitor is mounted in the circuit with other components in parallel, you will have to unsolder one of the capacitor's leads, unless you are fortunate enough to have a capacitor that can be isolated in the circuit by a switch or relay.

Likewise, for larger valued electrolytic capacitors that are new or have been reformed and have been isolated or disconnected from the circuit, testing with a simple VOM should indicate resistance values in the many MΩ range, but with higher capacitance values (e.g. 100 µF), it will take a long time to fully charge. Certainly, any resistance reading in the 100s of kΩ range has high leakage or one that has a high ESR value must be replaced.

10.4. Jackson Drive Gear Lubrication

See the Swan Newsletter, Issue 6, Section A.6.3, for detailed information on removal of the Jackson drive from the Swan transceivers. The lubrication in the Jackson drive can break down and cause stiff or rough tuning action, requiring cleaning and re-lubrication. To take off the Jackson drive, remove the main fine-tuning knob (set screw) and the aluminum fine-rapid tuning knob cup (two small brass screws). Then with the mechanism exposed remove both nuts and lock washers, and loosen the two setscrews that affix the mechanism to the VFO tuning shaft.

Remove the Jackson drive assembly and soak it in a petroleum solvent. Use a small brush to remove any residual lubricant and let dry. Use a non-fibrous wheel bearing grease or synthetic chassis grease to re-lube the assembly for a long lasting lubrication that results in that nice, silky, hot-knife-thru-butter feel. Suggested alternative lubricants by boat-anchor users also include: TriFlon, Genie garage door openers worm drive grease, and STP (a high-pressure oil additive). Lesser viscosity lubricants (e.g. oil) seem to let the drive ball bearing displace lubricant and they soon start to feel rough. Access to the three bearing and the grease cup area is through the base of the shaft hole in the rear of the unit. The ball bearings are directly at the bottom of this hole. The only other access, other than complete disassembly, is through the very thin circular joint at the front and rear of the drive.

Note that if the Jackson drive is too loose, it may be tightened by gently squeezing the tabs to increase the friction. When re-installing onto the front panel, use the collar, which mounts behind the tuning mechanism to hold the long screw in place by lightly twisting the collar and pinching the long screws. Use a fine pair of needle nose pliers to re-install the lock washer and nuts. Take care to ensure that the collar is properly aligned when tightening the nuts and don't over tighten; any misalignment of the shaft can cause a stiffness in the tuning. Retighten the setscrews and reinstall the rapid tuning cup and fine-tuning knob and you're in business.

10.5. Front Panel, Cleaning, Painting

General Cleaning. For front panel cleaning, a good starting point is a gentler product such as Dawn dish detergent, which has been reported to work well in many cleaning applications. Other more aggressive household cleaners, such as Windex, Glass Plus, Fantastic, Formula 409, Simple Green or just a generic 50% ammonia and 50% water solution mixture, quickly dissolve the tar and grime but be sure to test a small area first, since many cleaners containing ammonia/acidic/citric ingredients can discolor or stain/etch plastic and painted surfaces, particularly if it is allowed to remain concentrated in one spot for any length of time (e.g. a drip or run). Use particular caution with any petroleum based solvent or lighter-fluid type product which can rapidly destroy plastic and eat through paint.

For those unfortunate rigs that have had the ugly masking tape or Dynamo labels attached in days past, the removal of the adhesive residue can be exceedingly difficult. De-Solv-It is a product made specifically for this purpose, however, while this will loosen adhesive residue, it will also dissolve paint, so use with great care. Of course, once removed the some type of replacement labeling is needed – two possibilities are discussed directly below.

Dial and Front Panel Labels. If the control labeling has been damaged by normal user wear or has been totally removed during cleaning, with a good picture from the owners manual or other source, some decal companies are able to scan the image and with the correct size measurements, print reverse decals. Unfortunately, it is rather expensive and they may not print you just one decal – a half dozen or more may be required.

Another option is to carefully duplicate the various labeling using a word processing or presentation software and then print them on a self-adhesive clear Mylar sheet (available at copy stores) or onto specialized printer decal paper (available at *http://www.decal-paper.com/*). With a great deal of care and perseverance, the individual graphics can be cut out affixed to the panel. However, it's probably best to remove existing labeling (or at least the labeling in the entire upper panel or lower portion) to obtain a consistent appearance.

Panel Paint. Total Electronics Co. offers two shades of Swan gray paint. One is an Upper Swan 240 Light Blue/Gray; the other color is a Lower Swan 240 Darker Gray.

Power Supply Grill. Don't mess around with anything other than a metal polish specifically designed for aluminum. Other products will clean the grill, but have a tendency to leave blotchy areas of varying luster when viewed from different angles.

10.6. Placard Removal, Dial/Knob/Meter Cleaning

Model Number Placard Removal. Try using the XYL's (or OM's, nowadays) hair drier. Start with the heat on medium, and carefully watch the placard to be sure it is not discoloring or deforming. With most Swan emblems, this should be no problem. When the adhesive holding it to the faceplate starts to loosen, be very gentle in prying it off. Use a very thin, rigid plastic tool (e.g. some file folder plastic labels may be rigid enough to slip under). It can easily bend during the process, so use care.

Knob Cleaning. Many of the household cleaning products recommended above will actually damage or remove the Bakelite material, washing out the surface color and/or etching its smooth finish. In addition, with prolonged exposure, some cleaners may discolor the aluminum knob disks or leave a residue on the plastic.

A recommended cleaning approach is to use a toothbrush with Windex (non ammonia) or Clorox (for mold/mildew), followed by a toothpaste brushing or polishing with a fine rubbing compound and/or plastic polishing compound (e.g. Novus). Also recommended is a coating of Armorall, automotive wax, and polishing compounds. If an ultrasonic cleaner is available, that should also be work well to remove grime from the crevices. Do not use alcohol – it does not work well and has a tendency to permit a surface oxidation or residue to form.

Thinned typewriter whiteout correction fluid has been suggested to re-color the white knob etched indicators. Just apply the whiteout fluid to the indented knob marker and immediately wipe the surface with a rigid, absorbent sheet of paper (such as the heavy stock used as backing for note pads) to remove any fluid that is on the knob surface.

Polishing. Never Dull is used in the marine industries for use on brass, aluminum, stainless, and other metals. It has been reported to do a good job on faceplates, knobs, and meter faces. While it requires a little elbow grease to rub-in the polish and then rub the darkened polish off with a clean soft cloth, it is gentle and produces a good finish. Test an area in an inconspicuous place first. An extra-fine German chrome polish also is reported to leave no marks and does an excellent job with light pressure and patience.

Knob Aluminum Inserts. If the spun aluminum knob inserts are hopelessly nicked, scratched and discolored, the appearance can be improved with the following procedure. Mount the knob on a wood or metal shaft of exactly the same size as the knob shaft hole in a slow speed drill. Mount so that the knob rotates about its axis without any wobble or wiggle. Once properly aligned, gently press a very fine abrasive coated sponge or fine emery sand paper across the diameter of the insert face as the drill rotates the knob assembly at slow speed. This should improved the appearance of a heavily scratched insert, but don't expect to duplicate the original finish. Use care, as heat build up will cause the glue to soften and release. Any rubbing on the plastic surface will scratch or dull the finish, requiring polishing with a Novus type compound to restore the sheen. See parts section for availability of new replacement knob inserts.

10.7. Chassis Cleaning

Caution: Some boat-anchor transceiver chassis were plated with toxic materials such as cadmium, which are now known to be a health hazard. Before you power up any motorized buffer to remove old crud, consider that you may be inhaling carcinogens or spraying toxic dust around your workspace (assuming you're stripping it down to the bare chassis).

General First Steps. Go to *halicrafters.org/restorationTips* for quite a discussion on cleaning boat anchors. First vacuum lose debris while gently dislodging it with a small, soft, long bristle paintbrush used in conjunction with a vacuum cleaner crevice tool. Follow with compressed air (computer keyboard cleaner, etc.) to blow out remaining surface dust and debris from cracks, crevices, capacitor plates, etc., prior to refurbishing or during routine maintenance to prevent dust buildup. Clean with anything from mild soapy water to more aggressive household products such as Windex or Formula 409. For difficult spots, isopropyl alcohol may be used. Use paper towels, small brushes, Q-tips, toothpicks, light abrasive plastic kitchen scouring pads, etc., to loosen the dirt and reach into small crannies.

Chassis Shower. For a really dirty chassis, one approach suggested is to basically give it a shower. Literally wet the whole thing down (sealing coil can holes, etc.) and use soap and water with a soft brush (after first vacuuming or blowing off dust). Rinse off with a fine, gentle spray. Be patient and don't wet down any moving parts unless you're prepared to disassemble, clean, and lubricate them later. Obviously, with such an aggressive approach, the meter must be removed or protected.

An even more aggressive approach has been recommended for a receiver that is hopelessly embedded with dirt and grime. The following full-bath treatment has supposedly been used in days of yore, however with a sealed VFO enclosure, such a radical approach with a Swan transceiver seems risky at best. Mix 8 oz of household ammonia, 5 oz of Mr. Clean, 4 oz of acetone and 7 pints of water in large container. Immerse the entire radio into this solution and brush the dirt out of the nooks and crannies with a small, long bristled paintbrush. Then, thoroughly wash out the rig with a garden hose. Finally, bake in an oven at 145 degrees for 4 hours (or until done) to dry out. This treatment will remove all traces of oil or grease, so it is necessary to lubricate all capacitor bearings, band-switch junction surfaces, tuning gears, etc. Postscript reports on this procedure cautioned that an oven temperature that is too high (due to thermostat error) will cause plastic dials and parts to warp or melt! In addition, corrosion problems due to not lubricating immediately afterwards were reported.

Solvent Cleaning. Solvents that are more aggressive include carburetor cleaner, CRC Electromotive Cleaner or, mineral spirits, or WD-40, are especially good for cleaning variable capacitors, but the bearings will need lubrication when done. Generally these solvents will not harm resistors, controls, etc., but certainly may damage plastics, dials and some wax covered capacitors or coils – keep solvents off wafer-switch ceramic material and switch contacts since solvent residue can cause problems. They may also take off paint and/or damage paint finishes. Use sparingly and with great care. With any flammable solvent, make sure there is no electrical power in use or open flame nearby and don't apply ac power until thoroughly dry! Electronic circuit board cleaners generally evaporate too quickly to work effectively. Beyond these, there are even more hazardous materials that require extreme caution have been mentioned, including lacquer thinner, acetone, etc. However, these are extreme measures. For obvious health reasons, keep the junk off your skin, work with excellent ventilation, etc.

Steel Wool. Avoid using steel wool at all costs. This may leave miniscule shreds of metal fluff inside crucial components, rendering them useless and making the transceiver difficult and expensive to repair.

Metal Polish. If the chassis is corroded, products such as Brasso metal polish, labeled for chrome and stainless (but not aluminum) has been suggested. Because Brasso is a polish, it dries to a powdery haze that needs to be buffed off. This and other products will also remove the original anodized type chassis finish, so care should be taken in such areas that are still corrosion free.

10.8. Cabinets, Cleaning and Painting

10.8.1. Cleaning

Cleaning methods suggested in older *QST*s for crackle finishes (April 1968) range from benign to very aggressive, including: (1) an art-gum eraser, (2) a household cleaning product such as Mr. Clean, and (3) a strong solvent, such as xylene or gasoline. There are now a multitude of additional products available, many containing ammonia and other more aggressive chemicals, so when cleaning cabinets and front panels, always use caution with any cleaning product, as they can cause discolorations if full-strength puddles or drips remain on the cabinet surface for even a few seconds. Always use sparingly and rinse thoroughly.

10.8.2. Painting/Restoring

If a general cleaning does not satisfactorily restore the cabinet appearance, application of non-paint products, spot paint touch-ups, light paint over-spraying, and complete stripping and repainting have been suggested. Unfortunately, with the heavy crackle coat of paint used by Swan to finish the cabinets, surface nicks, scratches and abrasions are difficult to repair on a piecemeal basis. The original damage is usually still visible without total re-finishing and repainting.

Non-Paint Options. Recommended products for use on cabinet surfaces in good condition for both cleaning and restoring the look of the finish by boat-anchor equipment owners include:

- Liquid Gold/Lemmon Pledge sprayed on a clean soft cloth and rubbed into the surface of the black wrinkle surfaced cabinets of the Swans does a great job – use sparingly, a little goes along way.
- Also reported to have worked well to restore the shine and color without damaging the surface of the black wrinkled cabinet is plain old liquid shoe polish, the kind in the applicator bottle with the sponge on top.
- Both Armor-All and Murphy's Oil Soap have also been reported as being used on cabinet/panel surfaces with good success.

Touch-Up. This option is certainly best if cabinet damage is limited to minor paint chips, especially along the cabinet edges. When a small chip of original finish is missing, apply the paint heavily and work it with a small brush with stiff bristles or fine mesh plastic sponge as it dries to add a crackle-like texture to the repaired spot. Blend the touch-up paint area with the surrounding finish by lightly feathering/patting into the original paint.

- Black fabric paint can be to touch-up of minor chips/flaws.
- Color-matched touch-up paint can be bought at an auto body paint supplier (check Yellow Pages). Bring a sample of the paint (the top of any rig or panel) – their computer system will sense and mix the color.

Over-spraying. If the cabinet texture is in good condition, other than discoloration or staining, a very light over-spray with one of the standard spray can paints or by a very light application with a brush/pad/sponge can do a nice job of restoring the look of the finish. First, try a very small area for dried color/finish appearance. If required, lightly sand cabinet minor rust spots with fine paper. It is usually always best to only apply light, uniform coats and be sure to keep the spray nozzle at least at the recommended application distance (usually 12 to 18 inches). Products recommended, include:

- A coat of clear Krylon satin clear acrylic spray lacquer over the entire cabinet has been noted as bringing the cabinet to an almost new appearance without making it artificially shiny or otherwise non-authentic.
- Rustoleum Textured Finish (Black-Flat Paint). This paint is not really a crinkle finish, but more like a fine sand-like texture. If most of the original finish is still there, it does a rather nice job with a uniform light overcoat. Even when the cabinet is sanded down and most of the original finish texture removed, with two or three light, even coats, this paint still will give a nice presentable look, but not really reminiscent of the original crackle finish.
- Flat Black 21004 Colorplace or Rust Control Spray Enamel. Both will do nice job, but only if most of the original paint (and texture) remains on the cabinet and applied very lightly.
- Computer mixed/matched paint available at an auto body paint supplier (bring a sample of the paint – the top of any rig or panel) can be packaged in a pressured can. Cost could be $30 or more to get a spray can of the right color plus a pint of the remaining paint that can be used with an airbrush. This process is not cheap but will produce the right color.

Strip Cabinet and Re-Coat with Wrinkle Paint. If the cabinet is in hopeless condition, a number of users have recommended stripping off all the old finish before re-painting. It doesn't necessarily have to be taken down to the bare metal, but sanding all surfaces with an orbital type sander with fine/extra-fine sandpaper is essential to remove any rust spots and blend in any scratches, chipped or missing paint, etc. so that these imperfections aren't still visible after painting.

While any standard spray enamel can be used, it will just give a smooth finish totally unlike the original wrinkle paint. Rustoleum Textured Finish Black-Flat Paint provides a fine granulated finish (somewhat akin to a fine powder coat) that is somewhat like the original paint texture (be sure to follow application instructions – light coats applied from no closer than a one foot or more spraying distance is necessary for a smooth application without texture/tone changes).

For a true wrinkle-coat finish, users have repeatedly emphasized the need to apply a heavy, liberal coat. Judging by the relative frequency of paint sag and drip imperfections in Swan cabinets, they also obviously used a very heavy coat of paint during production. Also, in order to obtain the proper curing and a uniform crackle finish, users repeatedly recommend baking the cabinet after painting – pre-heat the cabinet before painting and bake after spraying at 160 degrees until done (if you can get your XYL or OM to agree!). Recommended products include: Plasti-Kote wrinkle finish textured spray paint #217 Black (available from PEP Boys Stores), Zynolyte brand wrinkle paint, Antique Electronic Supply Black Wrinkle Paint (*www.tubesandmore.com/*), NC Total Electronics Black Wrinkle Paint (*www.nctotalelectronics.com/paints.html#wrinkle*), and the wrinkle paint stocked by some auto parts stores, specifically Harley Davidson Cycle shops and auto refinisher suppliers (used for old car heaters).

Powder Coating. Another option is to have your cabinet refinished with a process called powder coating at a commercial/industrial type specialty paint shop and should cost $10 to $15 per cabinet, if a few are done at once. They usually have sand blasting equipment, so the cabinet can be taken down to the bare metal. Powder coating is very sturdy and is baked-on with no solvent. This is the same type of finish coating used on the base of that Vibroplex's anniversary edition of their "bug."

10.8.3. Textured Paint - Detailed Information

Background. There were many different finishes with trade names from wrinkle to crackle to crystal to hoarfrost etc. There is considerable documentation on the formulations and the techniques used with these formulations. This section offers a summary on textured finishes from a three-volume set of books titled "*History of Paint and Varnish Technology*."

It is interesting that what many Swan aficionados today consider beautiful wrinkle finishes were really introduced as a cost saving measure. Most of the wrinkle finishes were developed so that minor defects in paint application would not be noticed and to avoid alternate multi-coat painting processes. These cheap commodity paints of days gone by are now valued highly.

While some of the paint formulations have been kept as trade secrets, others were patented and a very large number of the formulations are well documented. However, the processing steps and conditions needed to produce a particular finish take quite a bit of experimentation to get a reproducible effect in commercial production. While some of the ingredients are difficult to find these days, virtually all can still be obtained. The problem is that a paint manufacturer cannot make a profit producing these old formulations. The old wrinkle painting processes were labor intensive. Today, a reliable paint formulation that gives uniform results from an automated painting operation while being environmentally friendly is what is in vogue.

There are still a few wrinkle finish paints available on the market today. They use different paint chemistry than the old finishes, but they tend to be more reproducible. Most only come in black or perhaps brown or green, however a different color can be obtained by over-spraying a thin colored lacquer over the wrinkle. Remember to let the new wrinkle paint cure for several weeks, so that the solvent in the topcoat lacquer does not attack the paint underneath. This assumes, of course, that the wrinkle paint is true enamel. Lacquer is merely a plastic polymer dissolved in a solvent with pigment added. It does not cure. Instead, the solvent evaporates leaving behind the plastic finish. Lacquers have little solvent resistance, while true enamel takes a very aggressive paint remover to attack it.

Wrinkle Finish. What is usually called wrinkle is a finish that has fine raised lines running across the surface. Various patterns can be obtained from a completely random one, to large sections of parallel ridges, to swirled sections, etc. The original technology was based on incorporating tung oils in the paints. Under proper conditions, tung oil is one of the few drying oils that swell upon drying. Actually, like all oil-based paints, they really do not dry. The paint reacts with oxygen in the air to polymerize and cross-link on a molecular level. This reaction occurs from the outside to the inside as oxygen diffuses in. This is why big blobs of oil-based paint may never cure completely. In the case of these wrinkle paints, the outside surface swells while underneath the skin; the uncured paint is still attached to the substrate. Essentially all the paint can do is wrinkle to provide the additional surface area needed.

Crackle or Alligator Finish. Crackle or alligator paint used an opposite technology. In this process, the paint shrinks upon curing. The paint underneath the skin remains attached to the substrate. To accommodate the shrinking the skin rips apart in little sections leaving slight depressions between the sections. Curing conditions determine the size and texture of the finish obtained.

Gas Checking. Some paints were partially cured in a slightly oxygen deficient atmosphere. This was known as gas checking and was dried in an oven with a slightly rich gas mixture. The carbon monoxide would chemically bond with some of the carbon-carbon double bonds in the drying oils to modify their properties. Final curing still involved polymerization/cross-linking in air.

Hammered Finish. Another popular boat-anchor finish that came after the wrinkle finishes is the hammered finish. This is obtained by incorporating aluminum flakes in a lightly pigmented paint stock. Several of these finishes are still commercially available. It is fairly easy to reproduce a hammer-tone finish at home with care in application.

10.9. Cleaning Pots, Switches, and Connectors.

The following methods and products to clean corrosion and/or restore electrical functionality of potentiometers, switches, and connectors have been recommended by boat-anchor enthusiasts.

Commercial Tuner/Switch Cleaners. Use a small amount of ProGold, DeoxIT, CRC contact cleaner, or any tuner type of control-cleaner sprays, to refurbish switch contacts. For cleaning and lubricating volume controls and other potentiometers, ensure that the product used is specifically recommended for that function, as some of the products are intended only for switch contacts. DeoxIT is packaged in a small spray can (with small straw-type nozzle insert) and also in a small bottle with a needle for precision application of the deoxidizing/lubrication solution. It has a special nozzle that only lets you spray a small bit and shuts itself off, sort of like a pressurized pump spray. These types of contact cleaners are also available in felt-tip type application pens.

Do not soak the ceramic components of the wafer switches, particularly those involved with the VFO signal generation or switching, as some cleaner compounds have ingredients that will soak into the ceramic parts and could alter the insulation properties and hence the electronic performance. As with the petroleum solvent approach suggested below, just a single drop on the actual contact is more than enough.

Petroleum Solvent. Clean wafer switch contacts with a petroleum solvent, such as carburetor cleaner – use only a small amount applied with an eyedropper or thin straw. Wait at least a couple of hours for the switch to thoroughly dry before the equipment is used since the solvents frequently cause up to a couple of hundred kilohertz in frequency shift in the VFO frequency until it is totally dry. This treatment will also work well with tube pin contacts that have any corrosion, grime, or oxidation.

Silver Tarnish Remover. Also suggested for wafer switches that are easily accessible is application of a common silver contact cleaner like Tarn-X for use on the silver/plated band switch contact surfaces with a Q-Tip to remove heavy oxidation. Extreme care is necessary to avoid damaging the switch's pressure/friction contacts. After cleaning, displace the Tarn-X with a non-residue spray cleaner (available from most all electronic supply stores) followed by the Craig Labs Contact Treatment or whatever control preservative is available.

DeoxIT D5 Comments. A number of remarkable claims report a significant improvement in both SWR and RF output power (SWR reduced from 1:4 to 1:2 and about a 7 W power increase) after an application of DeoxIT contact cleaner to all UHF connectors and switch contacts. A caution has also been expressed that DeoxIT should not be used on potentiometers, however others have reported good results with that application.

10.10. Odors

Bad-smell is a subjective term, but in most cases the source in old transceivers its ordinary mildew. Often it is combined with layers of dust and household grime, such as cooking grease, tobacco residue, etc. Mildew is easy to identify. It smells like a stinky old wet basement. Even after a through cleaning and deodorizing, when old tube transceivers are subsequently powered-up and come up to temperature, residual grease and grime, etc. will also heat up, probably releasing more odors.

Besides thorough cleaning, a number of methods have been recommended to remove residual odor, including:

- Using the procedure commonly used on old books and magazines. Place the transceiver in a plastic bag along with about a quart of activated charcoal (available in pet stores for use in aquariums) or a couple of fabric softener sheets normally used in clothes dryers. Leave it in the bag for a couple of weeks and it should come out smelling better.
- Over-spraying the innards lightly with a commercial deodorizer, such as Febreze.
- Appling vanilla essence sparing over all the surfaces using a rag that is just slightly damp has been reported to mask offensive odors effectively. This has been reported to work very well – at the very least, it will make your radio and shack smell rather nice!

10.11. Storage

The biggest enemies are dust, humidity, high temperature, and radiation. Humidity generally combines moisture and oxygen, which can seriously degrade polymers, including natural or synthetic rubber insulation. Humidity will also propagate corrosion, mildew, and mold. Many copper-plated chassis such as used in Drake rigs and others show a susceptibility to this problem. While high temperature during storage will dry out vented components, it usually is a slower acting mode of degradation. Warmth helps drive out humidity while cool or cold surfaces can condense moisture onto the surface.

Thermal radiation can cause discolorations and ultraviolet light (such as from the sun) can do serious damage to paint and polymeric materials (causing cross-linking to occur in polymers such as vinyl and polyethylene). A good quality coax made for UV resistance is much less prone to cross linking, which causes brittleness of the rubber or plastic. To see the effect of UV from fluorescent lighting, look at old Apple Macintosh or IBM computer cases in your local Goodwill or Salvation Army store.

Try keeping long term stored equipment in a sealed, zippered plastic bag that pillows are sold in, along with a couple of small desiccant packets. Store the rigs in an upstairs, temperature-controlled environment. If military procedure for electronic equipment and component storage is a valid guide, the liberal use of desiccant and sealing the components in a foil coated, air and watertight bag or container is the way to go. Coating with anti-fungal treatment also seems to be standard military procedure.

10.12. Antenna Refurbishment

While a bit off the tube-transceiver subject, Swan did offer a line aluminum beams and portable antennas, which occasionally turn up at Hamfests, auctions, etc. Of course, a common problem with such older units is the cumulative effects of exposure to the elements, with corrosion at the assembly points that degrades beam performance (SWR, pattern, etc.) a universal problem.

When refurbishing such older aluminum antennas, a thorough cleaning to remove the corrosion is essential – Scotch-bright pads have been recommended to rapidly and effectively do that job. During reassembling, use of stainless steel hardware (screws, bolts, etc.) is a good idea as is the use of a anti-oxidant/conductivity joint compound on all screws, slip joints, etc. To add a bit of extra protection, some amateurs have even recommended a bead/layer of clear silicone sealant around any joints – it will peel off with relative ease when subsequent maintenance has to be performed.

The joint compound/conductive paste is usually gold or copper colored and is routinely included with new antenna assembly kits. Recommended product lines are No-Ox and Copper-Coat (which is similar to No-Ox but impregnated with copper powder that both conducts heat and is electrically conductive). There is also a Silver-Coat and a Gold-Coat, but these are very expensive. Other brand names suggested include Noalax, IPenatrox, and Ox-Gard; many of these may be purchased at a good electrical supply house.

A. APPENDIX A. SWAN NEWSLETTERS

The following newsletters have been edited to primarily include only technical information.

A.1. ISSUE 1, Summer 1990 (Edited)

A.1.1. VFO Drift

See also Issue 7 of the Newsletter. The 350 series had some inherent drift problems. The problem at least partially relates to thermal and voltage regulation in the rig. Dramatic temperature changes cause drift until the rig thoroughly warms up. Since it is not worth the effort to stabilize the voltage regulation, it is much easier to stabilize the temperature. Swan always packed a lot of power (heat) into a small package and relied on air convection for cooling. Regulating the temperature should result in a much more stable, longer lasting, better performing rig. Therefore, it is beneficial to use a three-inch 12-V muffin fans to provide forced cooling. If you pop rivet them to the side of the case adjacent to the final deck in your Swan rig (the existing holes line up pretty well) you will see good results. Power it from within the rig or obtain an inexpensive power cube.

Much of the instability may go away because the extreme temperature fluctuations have been leveled out. In addition, you will extend the life of the rather expensive final amplifier tubes. If you have a lot of other equipment nestled around your Swan, give the old rig a bit more breathing room. Short of major work on it, this may be the best answer. Expect the old girl to drift for about 20-30 minutes, though not nearly so much.

A.1.2. Herb Johnson Discussion

Swan built over 82,000 rigs, at one time producing as many as 400 per month. Quite a success story from a company that started out on a shoestring! Swan Electronics was the classic American success story. Herb has said that he hand-built most of the first rigs (the single band transceivers) and even hand-lettered the dials, etc. They were always designed and intended to become multi-band rigs and were made physically larger than they had to be because the mentality was one of bigness in those days.

After Herb sold Swan Electronics to Cubic in 1968, he stayed on for about five years until he formed the Atlas Company, which produced some outstanding solid-state rigs. Herb felt the time was right because of Japanese equipment complexity, poor service, and high prices. He also felt he could produce a better performing, more reliable radio. However, with the continuing popularity of the Japanese radios, most American companies took a beating and Herb decided to suspend the production of Atlas equipment. As of the date of this newsletter, the Atlas is still in existence and due to start producing a new HF transceiver model.

A.1.3. Driver Tip, 6GK6

See the Swan Newsletter, Issue 9 for original text and additional information on pin layout.

Contributors. This section included information from Herb Johnson, Frank (W7QDC), Dave (N9HCW), Dean (WA9AZK), and others.

A.2. ISSUE 2, Sep 1990 (Edited)

A.2.1. S Meter Readings

If your S meter is too generous, try using a RCA, Sylvania, or GE 12BA6 in the 2nd IF.

A.2.2. Switch Cleaning

Do not use WD-40 or a cleaner containing oil or any greasy substance on the rotary switches. The switch insulating material tends to get soaked with oil, which can be conductive, causing shorts through the insulation. A good commercial contact cleaner/lubricant is best. Rotary switches are about the most difficult things to repair, if it can even be done at all.

A.2.3. Fuse Rating (Power Supply)

Do not use higher than suggested fuse ratings on power supplies. The transformers are hard to find and expensive to replace and with its failure the power supply usually ends up in the scrap heap. A 10-amp fuse is suggested for the 117X – you should use a 6 or even a 5 amp slow blow.

A.2.4. HUM (AC) – Headphone Jack Location

A good way to get rid of the 60 Hz hum often heard when connecting headphones to the power supply jack is to move the headphone jack to the radio. Be sure to use a jack that switches the audio to the speaker when the headphones are not plugged in. Open secondary audio transformers don't last very long.

Contributors. This section included information from John Bruchey, Dean (WA9AZK), and others.

A.3. ISSUE 3, Nov 1990 (Edited)

A.3.1. Hum (AC) – Ground Wiring

Ground Braid. In the Swan 350 and the 500, the audio line ground is also used for the ac heater current producing 0.1 V of ac at the headphones, causing a hum. One easy answer is to connect a low resistance braid between the transceiver and its power supply.

Ground Wire. A more sophisticated cure is to add a wire between the unused pin 11 of the Cinch-Jones plug from the power supply to the transceiver. A good place to pick up ground is at the headphone jack. Connect the new wire to the rig using the unused pin 11. Either of the two method listed below avoids having a conductor carrying both the ac filament and the audio line grounds.

- In the Swan 350, the ground can be lifted from the output transformer and connected to pin 11 of the Cinch-Jones plug.
- In the Swan 500 the ground can be lifted from terminal 3 of relay K2 and connected with a piece of wire to pin 11 of the Cinch-Jones plug.

Tune-Up Tips. Perhaps one of the most important things that we can do to make our rigs last longer and give the best performance is to keep them properly tuned and aligned. In general, the Swan manuals do a good job of explaining the alignment procedure, but there are two areas they could improve upon. After discussing these with John Bruchey, he agrees. Note that Swan produced a myriad of transceivers – these rules apply to the more popular 350, 500, and 700 series (and maybe others). They make alignment easier and more exact and are similar to those outlined in the 270B and SW-240 manuals that work fine.

A.3.1.1. VFO Alignment

Probably the area that misses the mark the most in the alignment procedure in the manuals is the section dealing with peaking the VFO circuit. The manual suggests the placement of a VTVM (reverse polarity) between pin 1 of the 12BE6 (receiver mixer) and ground. The procedure goes on to explain that on a negative scale, the voltage is peaked at certain frequencies, etc. If you have ever done this, you will notice that some of the circuits will not clearly peak or that the maximum reading (minimum in this case) requires you to totally remove the slugs (probably the 40 meter slug) from its form. Here is the answer, based on discussion with John Bruchey.

A.3.1.2. Alternate VFO Procedure

Instead of connecting a VTVM as described, simply clamp a lead from a field strength meter to the 30 pf capacitor which comes off pin 1 of the 12BE6 mixer, (usually C-702) and adjust the slugs for maximum reading on the same frequencies as shown in the manual. This will greatly simplify the procedure and appears to be the most accurate way to align the circuit. It is not necessary to put the rig into the transmit mode for this procedure. You should see a clear peak when the slug is well within its coil-form.

A.3.1.3. Driver and Mixer Alignment

The other area of improvement is in the alignment of the driver and mixer circuits. Instead of removing the screen voltage by disconnecting a wire and measuring voltage across a 1 kΩ resistor, etc., use the following method:

- Do not disconnect the screen voltage.
- Do not use a voltmeter.
- Instead, with the PA TUNE knob placed in the appropriate position and the rig tuned to the proper frequency and band shown in the chart, (a) turn the microphone gain down, (b) use the PTT to activate the transmitter circuit, (c) inject a little carrier with the carrier balance control, and (d) peak the driver as in normal tune-up. Immediately resonate the finals by dipping the current with the TUNE control. Then peak each related coil in the mixer and driver circuits, being careful not to exceed 100-mA cath-

ode current and only transmitting for about 15 seconds. If you exceed 100 mA, adjust the carrier balance to reduce the current.

This method is suggested in other Swan manuals. Presumably, the reason Swan suggested you disconnect the screen voltage to the finals and tune these circuits as indicated was to help eliminate damage to the finals. If you take a little care and avoid driving the finals too hard or too long, I believe you will find this to be a superior and faster method. Dean, WA9AZK.

A.3.2. Addendum for Alignment on 10 Meters

There have been times when a rig's 10 meter circuit is so twisted out of alignment on that it seems "*I'll never bring the old gal back to proper working order*." This has usually occurred when the well-intentioned owner turns the slugs within the coil-forms several revolutions. Generally, most circuits only need to be touched just a little. Usually a ¼ to ½ turn is more than is needed. This is especially true on 10 meters.

Since there are several places where the 10-meter slugs in both the mixer and RF driver circuits will allow them to resonate like a Stratavarious violin, the trick is to find the proper spot of resonance. To do this, use another receiver tuned to the transmitter's frequency and monitor the S-meter, peaking each of the coils for maximum S-meter reading. So, if you ever have a problem getting your Swan to perform on 10 meters as it should (or for that matter any frequency), try this method. Dean, WA9AZK.

A.3.3. SW-240 Review

I have often repeated that I always felt the SW-240 was one of the best Swan rigs from the standpoint of pure component quality. It uses all ceramic rotary switches and the cabinet is made from a heavier gauge material. It has all the tube designations silk-screened on the chassis, which is an excellent idea. How many times have you taken a marking pen or pencil to label the tube locations on your rig? I particularly like the type of slug coils used on the rig. It uses slugs that are mounted on metal threaded shafts rather than the 100% ferrite slugs using hex IDs found on later rigs. I have broken more than one of the newer type slugs. They seem to get brittle with age and heat. In addition, how often does the barrel of the slug come apart, etc?

Audio. The audio, oh, the audio! My 240 has to have the sweetest audio. I don't have the usual hum problems associated with Swan rigs (even with headphones), and the smoothness of the audio is quite uncanny. I don't know whether it is because of the speaker used or the tube compliment and under-lying circuitry, but it is a pleasure to hear. Another impression I immediately have is the smoothness of the various controls. It just has a feel of quality, even comparing it to many of today's newer equipment. It has a smooth, heavy feel to it, even after all these years, no noisy, scratchy pots, etc.

Weaknesses. Receiver sensitivity seems to be a bit less than the newer Swan rigs, but only marginally. The greatest weakness however is the 6DQ5, PA tube. This tube has a tendency to go soft quite easily, but if you ventilate it properly, it will do just fine. The 240 has a very tight case and needs much better ventilation. If you ensure it has adequate air flow (perhaps even a fan), it will make a world of difference. You know I stand on this soapbox a lot, but reality is the two most destructive elements (excluding the owner) to electronic equipment are heat and pollution. Another rather annoying aspect of the SW-240 I own is that the black accent stripes and knob reference marks have started to come off. This is too bad, because the rest of the radio looks so cherry. However, this is just a little annoyance, though. One other thing that I miss when I use the 240 is a S-meter, but, so what? It almost adds to the charm of the ol' rig. It also provides an opportunity to explain to other hams that they are being heard on a 30+-year-old radio when I tell them I can't give them the obligatory S-meter signal report.

Summary. If you ever get a chance to get a hold of one of these little gems, I encourage you to do so. They are great fun, easy to tune, stable, tough and hold their own on both transmit and receive. If you are very lucky, you will find the optional TCU (transmitter control unit), which makes them a real funky set-up. The TCU includes an external VFO, WWV, VOX and more. It is housed in the same size case and looks real neat next to the old beast. In any event, make sure you obtain the original power supply for the SW-240. It is different from the ubiquitous 117X(C) type supplies. The price with the power supply should be under $200 and who knows what the TCU should bring. Dean, WA9AZK

Contributors. This section included information from K6KA, Jack (KJ6KI), Clarence (W7LII), John Bruchey, Dean (WA9AZK), and others.

A.4. ISSUE 4, ~1992 (Edited)

A.4.1. Tools and Repair Hints

Other than the obvious screw drivers, needle nose pliers, etc., there are a number of useful items to have on hand, including:

- ¼" nut driver (cheap ones will round the hex head). Swans have many of this size sheet metal screw. The power driven variety may not be a good choice since over tightening can occur.
- Non-conductive type screwdriver. One with a small metallic insert works well on trimmer caps.
- A bulb or other suction type de-soldering device. The wick type material is fine, but the suction device is best for the larger solder joints associated with Swans.
- Coil adjusting tools. Make sure it is exactly the right one. The wrong size may damage the small ferrite slugs, which are difficult to extract and replace. With two or three of the proper size, during alignment of sections with 2 or 3 slugs requiring sequential adjustment, they can be left in place.
- Shrink Tubing (See the Swan Newsletter, Issue 5 for applications).
- Butane pipe lighter. The lighter is shaped like a fountain pen and has an adjustable flame. While pricey, it's ideal for warming-up heating shrink tubing.
- Dial-a-value resistor, capacitor, and inductor charts.
- Parts cabinets.
- Section of short nap carpet or towel. Use on your work surface to protect equipment while servicing.
- Multi-outlet power strip.
- Soldering irons (a couple of wattages).
- 409 cleaner. Works well on sprucing up the front cover plates, as does automotive wax. Go easy on the wax, though. Many brands have a fairly aggressive abrasive. It has been reported to discolor aluminum.
- Brake/parts cleaner. With an old radio stripped down to the bare chassis, a spray brake/parts cleaner may be used on it. Be sure if you do this that, all plastic and painted parts are removed. Don't forget to lube everything after this aggressive treatment.

A.4.2. Alignment Tips

When peaking the mixer and driver circuits, re-peak them two or three times. That is to say, after peaking the mixer coil, then peak the driver coil, then again peak the mixer coil, then again peak the driver, etc. Sometimes there is some reactance that changes the optimum points of tune. See also the Swan Newsletter, Issue 3.

A.4.3. Audio Warbling – Bad Can Capacitor

Ever turn your radio on and get a warbling sound? Sometimes this problem is so pronounced that it completely masks all other audio. Most likely it is because the electrolytic twist-lock can capacitor has failed. An easy fix is to simply bridge the defective capacitor. Don't forget that electrolytics have polarity. On the twist lock type, the isolated terminal is positive and the can is negative. The can type twist locks are very durable and should last a long, long time. However, electrolytic capacitors require a periodic applied voltage to maintain the dielectric properties. If a transceiver is unused for a couple years, they can dry out or chemically change such that the dielectric property cannot be re-established. Turn transceivers on from time to time or suffer the consequences.

A.4.4. Max Carrier Mod - Going Off Balance?

Therefore, you want to go off balance. Something that comes up from time to time has to do with the way Swan designed various circuits with regard to offsetting the carrier balance when the radio is placed into the TUNE position. The 350s and the 500s (not Cs or CXs) required the operator to inject some carrier by offsetting the carrier balance if any power is to be generated in the TUNE position. This is inconsistent with the majority of the other Swan radios and sometimes is confusing. It is also easy to forget to null out the carrier after this is done.

Modification. So, what can you do to make this more consistent with the other rigs? Simple. Install a wire from the REC/TUNE wafer switch (usually the only unused terminal) to pin 9 if you have a 7360 or pin 1 if you have a 6JH8 balanced modulator tube. This will take one of the deflection plates to ground and fully offset the carrier balance when you throw the old baby into TUNE. This might help eliminate those reports of "*I hear carrier on your signal*" when you forget to re-null the carrier after tune-up.

CW Operation. If you operate CW, your rig will put out ONLY full power, which may be a bit hard on the finals and create other problems, but if you operate only phone, this will probably be a good solution. The best approach to this was what was done on the 700CX with different switch positions for CW and TUNE. There are many schematics available to refer to for this design should you have questions.

A.4.5. Cygnet Power Output

If it seems like your Cygnet 270B isn't putting out the RF power on CW that it ought, you might initially think that a new final or driver was is in order, along with an alignment. If an old 240 puts out about 120 W and it has just one 6DQ5 in the final, and a 350C with two 6LQ6s puts out about 250-W dc, one would think that a Cygnet with one 6LQ6 and an adequate power supply should do better than 80 W, right? Not so, for if you examine the manual (page 8, Section 6) it states: "*Note that the 270B operates at reduced power in TUNE-CW mode. The PA cathode bias resistor, R406 is in the circuit during TUNE and CW operation. In voice mode the bias resistor is shorted out, and the 270B operates at full PEP input rating*." The same is true of later designs, such as the 350D.

A.4.6. Bias and S-meter Adjustment Confusion

If you have ever adjusted your S-meter instead of your bias there is an easy fix. Place any ¼" shaft knob on the bias control pot. When you reach back to make an adjustment, the knob permits easy identification by feel.

Contributors. This section included information from Monte (N7OQV), Grover (AA2GP), Dean (WA9AZK), and others.

A.5. ISSUE 5, 1993 (Edited)

A.5.1. Swan Articles

The Swan-Net has a list of articles that have been done on Swan equipment over the years. Copies of many of these are already in the library. If you have copies of those that we do not have, please send me a copy. If you would like a copy of one or two, send a SASE. If you want several, contact the Swan-Net to determine costs.

A.5.2. Sub. 8950 or M2057 for the 6LQ6 (500)

There are several changes that must be made to use either the 8950 or M2057 finals in place of the 6LQ6's. The largest change is replacing the 9-pin compactron sockets with 12-pin compactron sockets. There are several styles of 12-pin compactron sockets available. To directly fit in place of the old sockets, the new ones must have a metallic mounting ring with mounting tabs and four ground lugs. The mounting tab holes must be 1-5/16" apart and allow mounting the socket on the underside of the chassis. The socket must fit into a 1" hole. The mounting tabs must be opposite pins 5 and 12. If the exact socket is not available, it should be possible to modify one to work. If the mounting tabs are too far apart, remove the mounting rings from an old 9-pin sockets and machine down the circumference of the new socket to fit the old mounting rings. If you find sockets the right size but have mounting tabs opposite the wrong holes, or if you find sockets that mount from above rather than from underneath, you should be able to re-orient the mounting rings, (Dave, WA0PND)

The M2057 tubes may vary somewhat in height. If it will not fit into the RF cage, add an extra bend in the deck that the sockets mount into. That deck rises from front to back so that the front tube sits lower than the rear tube. Add a bend at the rear so that the rear tube sits at the same level as the front tube. Finally, to gain just a little more clearance at the top, file off some protrusions from the top of the plate cap connectors.

Mount the sockets so that pin 1 is toward the right side of the transceiver. Once you have all the mechanical details taken care of, the rest is simple. It is time to wire the new sockets.

- You'll need the following parts that were removed when you removed the old sockets:
  5 ea. 0.01 µF capacitor
  2 ea. 100 Ω ½ W resistor (you may want to use new ones to take advantage of longer leads)
- You'll need the following new parts:
  3 ea. 0.01 µF capacitor
  2 ea. 0.002 µF capacitor
  2 ea. 1 Ω 5 W or 10 W resistor (wire-wounds seem to work without any problem).
- Depending on how the driver circuits align in your transceiver, you may also need the following:

1 ea. 91 pf mica capacitor
1 ea. 33 pf mica capacitor

- Don't solder connections until all you're done with the following list (unless you need to temporarily tack something to hold it):
    1. Using one of the bus wires removed from the old sockets, run a bus wire through V5 pin 5, V5 pin 9, V4 pin 5, and V4 pin 9.
    2. Connect V5 pin 3 to V5 pin 11.
    3. Connect V4 pin 3 to V4 pin 11.
    4. Connect V5 pin 2 to V5 pin 6.
    5. Connect V4 pin 2 to V4 pin 6.
    6. Connect V5 pin 6 to V4 pin 6.
    7. Connect V5 pin 12 to ground.
    8. Connect V4 pin 12 to ground.
    9. Connect V5 pin 10 to ground.
    10. Connect V5 pin 4 to ground.
    11. Connect V4 pin 10 to ground.
    12. Connect V4 pin 4 to ground.

    12a Connect a 0.002 µF capacitor from V5 pin 3 to ground.

    13. Connect a 0.002 µF capacitor from V4 pin 11 to ground.
    14. Connect a 0.01 µF capacitor from V5 pin 11 to ground.
    15. Connect a 0.01 µF capacitor from V4 pin 3 to ground.
    16. Connect a 0.01 µF capacitor from V5 pin 6 to ground
    17. Connect a 0.01 µF capacitor from V4 pin 6 to ground.
    18. Connect the hot filament wire (brown on white) to V5 pin 1.
    19. Connect V5 pin 1 to V4 pin 1 with short insulated (brown on white) wire.
    20. Connect 0.01-µF capacitor from V5 pin 1 to ground.
    21. Connect 0.01-µF capacitor from V4 pin 1 to ground.
    22. Connect 0.01-µF capacitor from V5 pin 2 to ground.
    23. Connect 0.01-µF capacitor from V4 pin 2 to ground.
    24. Connect 1 Ω resistor from V5 pin 2 to ground.
    25. Connect 1 Ω resistor from V4 pin 2 to ground.
    26. Connect 100 Ω resistor from V5 pin 11 to terminal strip lug, orienting it so that it fits under and clears the bus wire running between the sockets.
    27. Connect 100 Ω resistor from V4 pin 3 to terminal strip lug, orienting it so that it fits under and clears the bus wire running between the sockets.
    28. Connect the 0.002 driver capacitor from terminal lug to V4 pin 9.
    29. Connect the grid RF choke from terminal lug to V5 pin 5.
    30. Connect the meter resistors (there were 3 in parallel in my transceiver) from terminal lug to wire that joins V5 pin 6 and V4 pin 6.
    31. Solder all connections.
- Now do a complete alignment of the driver circuits per the manual. The grid capacitance may be a bit higher in the new finals since you may be unable to peak the 10 meter coil until changing C314 from 220 pf to 91 pf (note that the schematic shows this as being 91 pf but it was actually 220 pf). Likewise, to peak the 15-meter circuit you may have to change C319 from 68 pf to 33 pf. Also, be sure to adjust the neutralization correctly. If the neutralization isn't correct on 10 meter, the 1 Ω cathode resistors may blow when it starts oscillating.
- Still run the final idle current around 50 mA. However, since the M2057's will load up to about 700 mA, low voice peaks will run the meter up to an occasional 300 mA.

A.5.3. Parts Sources (Tube Sockets, etc.)

- Madison Electronics (800)-231-3057
- Antique Electronic Supply, 6221 S. Maple Ave Tempe, AZ 85283 (602)-820-5411
- Handmade Electronics, 1825 Roth Ave. Allentown, PA 18104
- Standard Radio, 360 Rabro Dr, Hauppauge, NY 11788 (516)-234-3330
- Kurluff Enterprises, 4331 Maxson Rd, El Monte, CA 91732 (818)-444-7079

- Richardson Electronics, Ltd. (800)-348-5580

A.5.4. Increased Audio Gain on a HF-700S

If you own a HF-700S, you can dramatically improve your audio gain by clipping out the connection from the side-tone circuit to the grid of the audio amplifier tube. It will cut down the side tone, but it should dramatically improve audio amplification.

A.5.5. Tools and Hints

Shrink Tubing. In addition to using it for insulating wire connections, it is excellent for shoring-up coil-forms that may be coming apart – the wax coated cardboard coil-forms that sometimes start to unravel. Take the larger shrink tube, expand it a bit with needle nose pliers, slide it over the form that is coming apart, and heat.

Coil-Forms. While we are on the subject of coil-forms, a useful product is plumber's Teflon tape. Wrap it around the ferrite slugs that may be too loose (or too tight) and it will smooth things out for the next alignment job.

Cooling, Cleaning, Lubrication, Grounding. A few simple preventive maintenance type items will greatly improve operating efficiency, including: proper cooling of your radio, keeping your radio clean and lubricated, and properly grounding the radio. Poor grounding is the source of many operational problems. Just remember that ½ of your antenna system (electrically) is your ground.

Check Ground Effectiveness. So how can you check the effectiveness of your ac ground? A suggested check, based on a skilled computer controlled machine tools technician's recommendations, is to measure the resistance between your equipment and ground. For a ground system consisting of a 1" ribbon cable hooked to a 1" copper cold water pipe that goes directly to the city hook-up, about 0.1 Ω resistance was measured. The technician indicated that anything less than one was a good ground for his equipment.

A.5.6. Centering the Balance Control

Do you want the carrier balance knob to be positioned straight up when the carrier is nulled? One approach might be to change resistors on each side of the deflection plate circuit to bring the balance control back to the noon position, however this has proved unsuccessful. A simple answer suggested by John Bruchey was simply; "*change balanced modulator tube*." It seems they are all a bit unique and deflect differently. With one or two tube changes, you should find one that is just right. Therefore, with a little tube swapping, all your rigs can have carrier balance knobs that point straight up when carrier is nulled.

A.5.7. Neutralizing Finals

Never, has any subject brought more requests than that of neutralizing finals. Even with decades experience performing the task of neutralizing final(s) on Swan radios, one will not know-it-all by any means. However based on such lengthy experience the following observations are relevant.

Matched Tubes. First, lets talk about matched pairs of finals and that wonderful little gizmo known as a resonator. The question "*must I use only matched finals?*" is certainly a frequent and important one. Some have never used a so-called matched pair of finals, but always use tubes from the same manufacturing lot and have had good results.

Resonator. What is a resonator, what does it do, and how do you know if a tube has one on it? *[Editor Note: See comments below.]* Answer: After asking a number of people, their purpose is still not known. Vendors who sell tubes don't even know what they are and whether their tubes have them or not. However, stay away from finals that have them! They can be found on 6LQ6 and 8950 types. The tubes that have them can be identified as follows: Looking from the top of the tube you will see a wire that connects between the plate cap connector and the actual plate. If there is a piece of metal about the size of a dime welded to that wire, you have a tube with a resonator. If you have problems with the radio not wanting to neutralize, this is most likely your problem. A HF700S that was difficult to align had this little resonator on one of his finals – replacement of the tube resolved the problem. *[Editor Note: Note that the rig-like structure referred to is most likely the getter. Supposedly the placement of the getter is such that it will not effect tube performance, however these are sweep tubes, operated far beyond their typical TV application voltages – such behavior as described above can be true in a specific case as described above, but it will not necessarily be universally true.]*

Resonator and Grid-Lead Radiator (GLR) Issue. *[Author Note: These comments are made in addition to information originally posted on this issue of the Newsletter, based on Reflector discussion.] Back in the 70s and 80s, the term resonator may have been used by some when referring to the getter and/or grid-lead* *radiator. The getter may have been mistaken for the GLR or visa versa. There was also some misleading information as to what the GLR did (radiate control grid heat). One of the additional benefits of the GLR is that it changes the inter-electrode capacitance such that neutralization of the tubes when used in the Swan PA design becomes easier. However even when tubes contain the GLR they can be impossible to neutralize, as was the case with the 8950 tubes used in the 700CX – small individual construction differences adversely affected neutralization.*

In such cases when all attempts to neutralize a radio on the higher bands fail, differences in the getter ring location (top or side of the tube) were noticed, and it was assumed that the ring was affecting the neutralization capability – most likely, these tubes did not contain the GLR. All PA tubes have a getter somewhere in the tube while only half of PA tubes built during the late 70s and early 80s contained the GLR (See Compendium discussion). To complicate matters further, it's quite possible, because of the complex interaction of components (especially at higher frequencies) to substitute a tube that contains the circular getter in the top for one that has it placed elsewhere and have the transceiver neutralize successfully, even though neither tube contained the GLR!

A.5.7.1. Maximum Power Versus Tuning Dip

Noting the matched pair finals and the resonator issues, there is one simple thing you should always remember about final neutralization whether yours is a one-tube radio or has multiple tubes in its PA. A transmitter is properly neutralized when maximum output power (wattmeter reading) occurs at precisely the minimum dip when tuning the PA PLATE and the radio is fully loaded. This condition will occur on a properly neutralized radio when it is tuned for maximum output power, and does not necessarily occur at lower power levels. This means that if your radio puts out the most power somewhere either side of the dip mentioned, it is not properly neutralized. If you remember this, you can monitor how well your radio is neutralized and this will certainly contribute to longer tube life and less potential for RF interference. If you don't understand anything else about neutralization but this, you have all the knowledge required to neutralize your radio. *[Editor Note*: *See discussion of this in the Compendium.]*

A.5.7.2. Neutralization Issues

Brief Neutralization Theory. Basically, the inner electrodes of tubes have differing capacitances and may sometimes feed back. Neutralization involves coupling some capacitance of the output energy of the tube to its input. By doing this, a cancellation of out of phase (undesirable) energy can be accomplished. (See the A.R.R.L. handbook for more details).

Swan Neutralization Procedure. Swan has developed a somewhat elaborate method of PA neutralization as detailed in their manuals. This method is usually good enough to get any given rig into the ballpark, but often (especially on 10 M) the method alluded to previously works better. Use the Swan manual method and then load the rig up for maximum power output and fine-tune the neutralization capacitors for maximum output at PA PLATE dip. Note – since the radio's cabinet and our bodies can adversely affect any given amount of capacitance, it is important (especially on 10 M) that the bottom cover of the radio is on and that a well insulated screw driver is used to minimize additional capacitance from our bodies or surrounding objects.

Tune-Up Problems and Neutralization. Often tune-up problems occur when a rig is not properly neutralized. If your rig seems to be acting strangely, be suspicious that your radio is improperly neutralized. Things like funny screechy noises, pops, or sparks along with erratic meter indications are often symptoms of improper neutralization. Poor tube life and/or one tube glowing red hot when the other doesn't are also symptoms of this problem. Sometimes these problems will occur on one band and not another.

Evidently, problems with this procedure were often encountered by Swan customers, because they issued a detailed supplemental sheet produced by Swan to help their users with this procedure. It is included with mailed copy of this Newsletter. (Not included in this summary).

Contributors. This section included information from Dave (WA0PND), John Bruchey, Dean (WA9AZK), and others.

A.6. ISSUE 6, ~1995 (Edited)

A.6.1. PA Tube Cooling

Here are two relatively simple and inexpensive things that will significantly improve your radio's operating environment and save you money and time.

- First, put a fan on your final amplifier enclosure area. Just pop rivet a 4" muffin fan to the outer cabinet right on the side of the radio.
- Second, remove the sheet metal skirt and the cover plate around the final deck enclosure and spray paint them with a flat black paint. Not only does the black color help to transfer heat away from the tubes into the sheet metal, more importantly, it reduces the possibility of focusing light energy back to a sensitive element within the final tubes. Always disconnect your power supply and ground out the plate connectors before working in this area of your radio.

A.6.2. Band Splatter, RFI

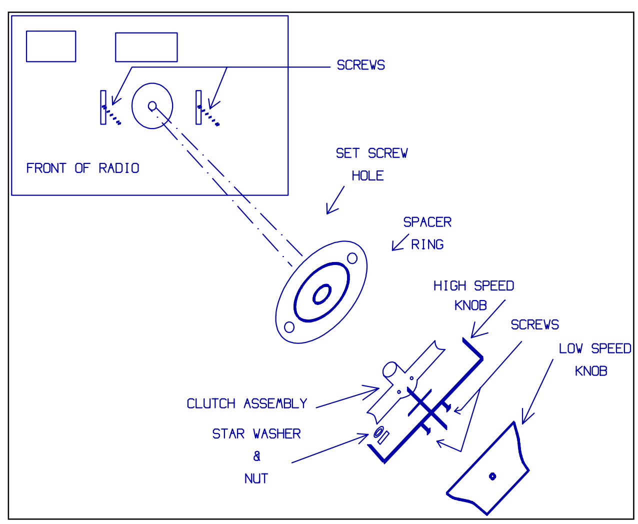
There are a number of ways to keep band splatter, RFI, and other annoying problems to a minimum. The roots of a good, clean signal come from practicing the following basic principles:

- Use proper tune-up procedures, which means for a Swan, tuning for maximum power output.
- Use an appropriate microphone gain, which means audio peaks should not exceed 50% of maximum PA current (dip at tube resonance) at maximum power output. *[Editor Note: Even down to 1/3rd or less has been recommended.]* This is usually about 175-200 M.A. on rigs with 2 tubes in the final, and 100-125 M.A. on single-tube PA units. See your operating manual, and remember radios with weak final tubes might require a reduction in audio peaks (applying the 50% guide line above).
- Use a matched pair of properly neutralized final(s). See also the Swan Newsletter, Issue 5.
- Use a good, low resistance direct ground. That means eliminate all sorts of octopus ground wires, which can often create more problems than no ground at all. The best ground arrangement is to have only one ground lead (as short as possible) going to one rig at a time. An added benefit to good grounding is elimination of RF into and on your microphone, cleaning up your audio and minimizing microphone bite!
- Use a good, clean, tight, properly tuned antenna installation. No loose connections, please.

This doesn't mean that the vast number of consumer products most of us and our neighbors have in our homes will not experience R.F. detection or overload, but using the above is a good first line defense against problems being generated at your station. In over 30 years of Hamming, there are no better practices to keep it clean!

A.6.3. Jackson Drive Service

A detailed service tip on maintaining those fancy smooth, backlash free tuning assemblies found on most tube Swan radios is given below. The sketch and information may help with a tuning knob that is hard to turn. After many years, the old grease will dry out, making it hard to turn. The procedure described will make it work very smoothly, just like new again. (John, WA7JPV)



- To lubricate the dial clutch assembly:
- Remove high and low speed knobs.
- Loosen (2) setscrews through access hole. Remove nuts and star washers. Outer clutch assembly will now slide off the inner shaft.
- A bath of the clutch assembly in a solvent like rubbing alcohol with a good scrubbing with a toothbrush is advisable.
- Put grease into inner end of outer clutch assembly and push onto shaft. This will force grease into the clutch assembly.

- (NOTE): To reassemble, care must be taken to align all parts or the assembly will bind, making it difficult to turn.
- Reinstall the clutch leaving the bolts loose enough so the spacer ring can be moved. Install the low speed knob only. Snug up the clutch set screws, then back them off just enough so the clutch will rotate on the inner shaft without turning the dial.
- If the dial moves, readjust the spacer ring slightly. With proper alignment, the tuning knob will rotate freely without moving the dial.
- At this point carefully tighten the (2) bolts that hold the spacer ring and clutch. Then tighten the (2) set-screws on the clutch assembly.
- Remove the low speed knob and install the high-speed knob. Reinstall the low speed knob.

A.6.4. Tools and Hints

A number of small little helpful tools or test switches are helpful when you service radios.

Foot Switch. Try making a transmit switch so you can engage it with your foot, leaving your hands and eyes free to work where they should. Since we always have to push the push-to-talk switch to set idle current or off-set carrier for neutralization, such an aid will be a real convenience. It can be any type of momentary switch with the appropriate wire and jack mounted to a small project box, or even a piece of wood. Remember, the center ring of the plug is the PTT connection!

Relay Cover Removal. Ever try to lift the plastic cover off the K2 relay for cleaning? Take one of those small (give away) screwdrivers, heated up the tip with a blow torch and quickly put it in my vise and bent it just shy of 90 degrees leaving about a 3/16" leg. It is ideal for inserting under the relay lip to release the tabs that secure the cover to the base.

A.6.5. Why Matched Power Amplifier Tubes?

All amateur radio manufacturers of the vacuum-tube era suggested, strongly recommended, or flat-out dictated that only matched final power amplifier tubes be employed in their equipment. There are good and sound reasons for this, all geared to ensuring optimum performance and maximum tube life.

A.6.5.1. What is a Matched Tube Set?

Same Generic Type. Obviously, all tubes in a set must be the same type (all 6LQ6’s, all 6HF5’s, etc.) Second, but not always an absolute necessity, tubes should be of the same brand - all RCA, all GE, etc. Third, and again not always a concrete requirement, the physical appearance of each tube in a set should be alike. The reason for this is that many tube manufacturers did not build every tube they sold. They routinely supplemented their own production with tubes from other makers. Since the country of origin is required on each tube sold in the USA, it is not uncommon to find, for example, two Westinghouse 12DQ6’s, one made in the USA by General Electric and one made in Hungary by Slobovik Valve Co. or the like. The two tubes don’t look the same dimensionally, yet both have the Westinghouse label.

Similar Electronic Behavior. Next, each tube in a set must behave very similar to each other tube in that set. Sets may contain more than two tubes. Drake transceivers need three 12JB6s or 6JB6’s, the SBE SB1-LA, and SB2-LA linear amplifiers employ six 6JE6/6LQ6s, and the Galaxy 2000 sports ten 6HF5s. In each case, the tubes are wired in parallel and must share the load equally. Meaning, all plates are connected together with a common high B+ supply voltage, all screen grids are connected together to a common medium B+ voltage, all control grids are connected together with a common adjustable -C bias voltage and driver input circuit; and lastly, all cathodes are connected together to ground or a metering circuit.

With all appropriate voltages applied to any of the equipment mentioned above, current will conduct from the cathode to plate in each tube at a rate determined by the bias voltage setting. Using one of the most successful amateur transceivers as an example, the Swan-350 bias control can be set to a position, which will limit current to 50 mA. The cathode current meter is reading combined current, which means the 6HF5’s are conducting 25 mA each. Two 6HF5’s are employed in order to double the power of a single 6HF5 – no other reason. The combined cathode current with no signal or drive is referred to as ‘resting,’ ‘platform’ or ‘idle’ current. Sort of a positioning of the launch point where the tubes can start their distortion-free amplifier duties.

A.6.5.2. Unmatched Tubes

What if the 6HF5’s are not matched? In addition, this will usually be the case if two tubes are pulled from stock at random. Plug in these two fellows and set the idle current to 50 mA for a real surprise. With any of several methods, measuring individual tube currents will show one tube conducting as much as the whole 50 mA while the other is conducting near zero. To make this a little clearer, we'll put numbers with both tubes - one conducting 40 mA and the other 10 mA. The cathode meter reads 50 mA, and the operator has no idea of the mismatch. Since the gain (amplification ratio) of each tube is roughly the same, by modulating in SSB enough to kick the cathode meter to about 200 mA (remember about damped meters – this 200 mA is only about 1/3rd of what's happening in the tubes during SSB) one tube is peaking 115 mA and the other 85 mA or less since they don't always track evenly up the power curve with the same 30 mA lag that existed at idle.

Get the picture? With unmatched tubes, one could be flat topping while the other loafs. Things could be even worse. In reality, when analyzing (100) 6HF5's in the lab to identify matched pairs, the range of cathode currents observed under full voltage test conditions may start as low as 5 mA to perhaps 120 mA per tube. Can you imagine these two extremes in your rig? After biasing this combo to 50 mA, one tube would be so far into cutoff that any signal reaching the linear portion of that tube's power curve would sound like rattling castanets. The other tube, carrying that 50-mA idle current soon becomes overheated and with the operator using the cathode current meter as a guide, is probably driving the pants off this tube trying to get peaks up to 200 mA.

A.6.5.3. Example of Matched Tube Set

During the matching procedure, all voltages are fixed, even the bias supply. Then, the resulting cathode currents are recorded and graphed for each of the (100) 6HF5's. By examining the graph, we can spot the tubes that behave similar to each other. For instance, looking at the middle of a typical test graph we might observe that (1) 6HF5 conducted 71 mA, (4) 6HF5's conducted 70 mA, (1) 69 mA, (2) 68 mA, (1) 67 mA, (3) 66 mA, (6) 65 mA, (1) 64ma, and so on. The six 65 mA tubes represent three matched pairs or two matched triplets or one matched set of six. Therefore, the two 17 mA or two 45 mA or two 68 mA reading tubes would be perfectly satisfactory for use in the Swan 350. These three different cathode currents, even though the same test voltages were applied, results from very small differences in the placement of components inside each tube. So, as long as two or more tubes conduct similar currents, they are considered to be matched. In the case of our Swan 350, the adjustable bias voltage control permits us to accommodate the small assembly inconsistencies by actually dialing in the proper idle current, but that's not a substitution for proper tube selection.

Contributors. This section included information from John (WA7JPV), Stu (K4BOV), Dean (WA9AZK), and others.

A.7. ISSUE 7, May 1996 (Edited)

A.7.1. VFO Drift

When properly maintained and aligned to factory specifications, Swan audio quality is very difficult to transcend by any manufacturers amateur equipment past or present. Moreover, it would be a shame to see these handsome rigs spend any more time in those dark hideaways just because that annoying drift appeared too tough to tame.

A.7.2. VFO Problem Overview

By mid 1965, anyone comparing ham gear based on price and performance easily saw the Swan 350 as an exceptional buy. And not surprisingly, the Swan 350 soon became the hottest selling transceiver of that period. Even to this day, the model name Swan 350 is still the most recognizable of all Swan products. However, within a year or two of regular use, a lack of frequency stability began to appear and gradually worsened to a point of frustration and embarrassment to the user.

Although increased attention was directed toward VFO integrity in later Swan equipment, the same problem tended to develop. Most attempts at the user level to thwart this nuisance instability involved changing anything and everything in the VFO frequency-determining network. Unfortunately, this effort rarely achieved complete success.

So, why was it that Swan amateur equipment built a reputation of having poor frequency control while others of the same era did not? Plain and simple – the Swan VFO needed to produce four (early Swans) or five (late Swans) selectable, widely spaced frequency ranges in order to cover the five different ham bands with a single conversion system. Other leading equipment of the day employed a separate crystal converter for each band, which allowed for use of a single range VFO, typically covering a 500 kHz spread of 5.0 to 5.5 MHz.

A single range VFO requires no switching while the multi-range Swan VFO must be switched from band to band and is therefore ganged to the main band switch via a flexible mechanical link. Under perfect conditions, one section of the VFO rotary wafer switch (located inside the VFO compartment) selects the correct VFO range corresponding to the desired ham band. The other remaining section of the wafer switch grounds out the not-in-use VFO ranges to prevent any unwanted signals. Because the switch is actually connected to components of the tuned L/C circuits, it becomes a part of the overall frequency-determining network. Remember, these types of oscillators are very sensitive to outside forces. Just moving your hand close to an open VFO compartment will shift the frequency.

Through use and time, various actions result in weakening the positive contact areas of the VFO switch. Dirt, wear, and corrosion on these surfaces introduce resistance and capacitance changes. And, it doesn't take much to cause the observable frequency (what you hear coming in and what the other members of your QSO hear coming out) to jump, warble, or drift. Just slightly moving the VFO switch by applying pressure either left or right on the front panel main band switch knob will cause frequency movement. Stu, K4BOV.

A.7.3. Drift Solutions. What can be done?

Clean and/or Replace VFO Switch. Well, it's not always easy. If cleaning the VFO switch does not reduce the problem, a new, unused, or otherwise unworn switch of exact contact layout should be substituted. After disconnecting the old switch, you can prove to yourself that the switch was at fault by hardwiring one band at the points previously made by the switch contacts. This simulates a single range VFO. Under this set-up, any drift should be minimal and, if evident, merely warm-up related. By selecting 80 meters for the hardwiring test on the earlier 5.1745-MHz IF transceivers, the 20-meter band is automatically operational as both bands utilize the same VFO range. Additionally, when connecting 40 meters in this manner, the later 5.5-MHz IF equipment can be easily aligned to operate on 17 meters as both bands use the same VFO range. (The green scale on late Swan VFOs is already calibrated for 17 meters)

Warm-Up Drift. Should correction of warm-up drift be considered essential, positive and negative compensating capacitors are available to tighten things up.

External VFO. In the event changing a worn VFO switch is not an easy task for the user, an external VFO is the next best move. Most Swan external VFOs did not develop any serious drift problem. And, any external VFO manufactured between the time of the Swan 240 and the Swan 700CX can be made to operate any Swan of that period, even the 600T and 600R twins. Some are directly interchangeable and others require one or more minor wiring changes. Some pruning of the tuned circuit coils and calibration is also required when using the late 5.5-MHz IF designed VFO with early 5.1745-MHz IF transceivers and visa versa. When using an external VFO with any drifting Swan, the control circuitry of the model 22(B) VFO adapter and similar circuitry built into later VFOs should be reverse wired for optimum results. That is, you want the external VFO to be A and the internal B. This means the highly stable external VFO is transceiving in position one and is transmit only VFO in position two. So when operating split frequency, the internal VFO is receiving and therefore any drifting on that VFO is only noticeable to the user who can re-adjust the VFO to his own liking as needed without affecting the transmit frequency.

Crystal Control. Crystal control is another option. All Swan crystal controlled external oscillators can be made to operate any of the equipment discussed. These units hold up to 10 crystals and employ a vernier control to flex the crystal frequency over several kHz for tuning refinements. Since production of Swan crystal oscillators was much, much lower than the variable oscillators, they are somewhat hard to come by. However all Swan VFO boards are convertible to crystal control and can be outfitted with the same type vernier as a means of tuning the crystal over a 4 or 5-kHz range. In addition, remember that in early Swans, the 80 and 20-meter bands employ the same VFO range. So one crystal would get you on both bands. For example, the crystal required for operating around 3,920 kHz. Moreover, we say around because the exact frequency is factored in only when we know the precise setting of the carrier oscillator and whether normal or opposite sideband is desired. However, we can get close enough for the vernier to put us right on.

Calculate as follows: 3.920 MHz + 5.173 MHz carrier oscillator frequency = 9.093 MHz crystal frequency. Looking at that same crystal we also see the 20 meter frequency: 9.093 MHz + 5.173 MHz = 14.266 MHz operating frequency.

Crystal Manufacturer. The original manufacturer of Swan crystal filters is:

K & L Quartztek, 20 South 48th Avenue, Phoenix, AZ 85043, (602) 272 7944

A.7.4. Final PA Tube Matching Procedure

Be Very Careful in working with tube-radio voltages, especially with the 900+ High Voltage use in the power amplifier section. Disconnect power supply from the radio when making the changes specified below. Unplugging the ac plug is insufficient, as at least 30 seconds or more will be required for the power supply HV bleeder resistor to drain the 900 V stored in the power supply filter capacitors and connected to the PA tube! *[Editor Note: Also see discussion in the Compendium and the Swan Newsletter, Issue 6.]*

- Disconnect the power supply from the radio, remove the main top cover of the radio, and remove flat cover HV cage, connect radio up to a 50-Ω dummy load.
- Put (or leave) final tubes to be matched in radio.
- Connect radio up to power supply. BE VERY CAREFUL.
- Tune radio up as usual into dummy load. (any frequency is OK)
- Push PTT and set resting current to say, 100 to150 mA (not to critical*). Don't touch setting again until all testing is done.*
- Disconnect power supply. THIS IS IMPORTANT.
- Disconnect one of the two plate connectors hooked to the top of the final tubes. (note which one it is)
- Connect Radio to power supply again. BE CAREFUL
- Turn radio on and let warm-up. (2 or 3 minutes)
- Push PTT and note new resting current. It should be less than previous setting. Write it down.
- Disconnect power supply again. BE CAREFUL
- Hook up plate cap to final tube where it was previously removed, and remove the (other) plate cap that was connected.
- Connect radio to power supply (BE CAREFUL), turn on the radio, and let it warm-up again.
- Push PTT and note resting current. Write it down.
- Do this for all final tubes. Matched tubes should have resting currents within about 10 mA or less of each other for best results. If they don't, keep trying other tubes until a match is obtained, or get a matched pair elsewhere.

A.7.5. Tool Hint

One tool frequently used is the promotion type screwdriver, often given away as advertisements. Place shrink-wrap tubing over the metal shaft so when you neutralize finals you don't short out the screwdriver against the bottom cover on the rig. Another tool used frequently is a good quality, small flashlight. While this is not technically a tool, it is sure necessary for the serious Swan repairer!

A.7.6. Power Output and Linear Amp Ops

Power to S Unit Relationship. Recall the relationship between power and signal strength – doubling of power represents about ½ S unit (3 dB to be exact).

***Need for Linear Amp*?** Understanding this and if you still insist upon using a linear amplifier on the backside of your already powerful Swan, it is a good idea to have ALC (has many names, but Automatic Level Control will do) hooked up. The powerful Swan would otherwise overdrive most linear amplifiers.

ALC Mod. To add an ALC circuit, simply install a 100 kΩ ½ W resistor in series with pin #1 of the 6EW6 (12BA6 later units) 1st IF Amplifier. Then install a 0.01-µF capacitor between the output side of the resistor and ground. A RCA jack is then mounted on the rear with the center conductor connected by wire to the junction of the resistor and capacitor. Hope it helps keep the splatter down! (Drawing is displayed on original page - If needed, send SASE to WA9AZK.)

A.7.7. Periodical Articles For Swan Radios

Title, Source and Date on publication of 94 separate Swan related articles on modifications, reviews, and service bulletins are available. Many of these articles are held in our archives by Norm/W7RXG. If you desire this list, (all on one page) send SASE to K4BOV.)

Contributors. This section included information from Monte (N7OQV), Stu (K4BOV), Dean (WA9AZK), and others.

A.8. ISSUE 8, Oct 1997 (Edited)

A.8.1. KNOW THY SWAN Part I

Many Swan single sideband transceivers became 36 years old this year. Remarkably, this 1st generation of Swan radios and the 3 and 5-band units that followed continue to maintain a significant presence in both American and foreign amateur communities. Few electronic devices for any purpose have achieved such tenure. With the pool of capable tube-era service technicians dwindling to near nonexistence, it becomes apparent that Swan owners must themselves be prepared for the task of troubleshooting and isolating ailing radio circuitry. In order to carry out these future tasks, our motto "*Know Thy Swan*" is absolutely the order of the day. (Stu, K4BOV)

Troubleshooting. First off, the pioneers of Swan radio prepared operation and maintenance manuals that included only a voltage chart for circuit values reference. During that period which saw the single band models and then the 240, 400, 350, 500 and 500C models, the engineering and technical writer staffs reasoned that isolating defective components would be best accomplished through observation of circuit voltages. TIMES HAVE CHANGED! Today, amateur radio enthusiasts do not routinely work with or experiment with the lethal high voltages associated with vacuum tube-radio equipment. Therefore, for the sake of safety the most basic non-hazardous approach to troubleshooting is resistance measuring.

Resistance Chart. This line of thinking requires that a resistance chart be produced showing the measured values found while the radio was in good working condition. Therefore, when something does go wrong beyond tube failure, there will be a means of comparing working radio and non-working radio circuit resistance figures. A resistance chart layout can look similar to the voltage chart shown in any Swan manual. In addition to listing all tubes for the given model to be examined, include lines for K1 and K2 relays, VOX socket, Cinch-Jones plug, and accessory socket. The resistance readings at these non-tube locations can be important in many situations. For example, each model of radio had two or more series and the owner may not possess the schematic, which relates to the series on hand. The model 350 (64-67) evolved through four series where the K1 relay in each series controlled different functions and/or switched different valued components. In addition, K2 was a 2-pole relay in early and 3 pole in late 350 series transceivers. Remember, it is essential to keeping on hand a complete record of circuit parameters that exist when your radio is operating properly. In addition, after tube checking and visual inspections for breaks, burns, etc, the most basic non-hazardous approach to troubleshooting is resistance measuring. Further, a resistance chart must be prepared by the owner because such aids where not included in most Swan manuals

Redundant Measurements. Since there are 100 or more measurement points, it's not hard to make a mistake somewhere in the process. So, if one has the time (this is good training, too!) make the measurements again and record them, comparing one to the other. Do whatever it takes through testing or calibration to make sure your ohmmeter is accurate as possible.

Safety. Remember, all measurements are made with the power supply disconnected from the radio (and maybe stored in a separate room – you never know!).

A.8.2. Addendum for Alignment on 10 Meters

See the Swan Newsletter, Issue 2 for this information.

A.8.3. Power Supply 117X

Introduced in 1965, the Swan 117X universal power supply remained in production for more than a dozen years. Without any change in design, it was produced longer and in greater numbers than any other Swan product. The universal meant it was capable of both ac and dc operation. In order to accomplish each mode using a single power supply, a rather interesting power transformer was required. In this case, the 117-V ac primary and high, medium and bias voltage secondary are of standard construction. However, the low voltage winding is actually an 18-V ac secondary with 9-V ac and 12-V ac taps. With ac operation, the 12-V ac tap is selected through connections at the 15 pin Cinch-Jones connector and feeds filament, lamp and relay current to the appropriate output terminals.

A.8.3.1. Battery Operation

For the dc mode, an inverter (the Model 14X or later 14C) is attached to the rear of the power supply in place of the 15 pin Cinch-Jones connector. With 12 V applied, the inverter flip-flops (like an ac generator) the battery voltage across the entire 18-V ac winding which is now operating as the primary. All output voltages exist just as with ac operation except the 117-V ac winding has become an un-terminated secondary. If desired, light ac loads, such as a lamp, solder iron, electric razor, etc., can be powered here when a proper receptacle is mounted.

A.8.3.2. 117X Transformer

The purpose of the foregoing was to point out the uniqueness of the 117X power transformer. The probability of not locating an exact replacement should the original fail. Well, with so few Swans going mobile these days, the universal transformer is no longer an essential item. Standard power supply transformers can now be salvaged from other manufacturers equipment to accommodate modern day needs. In some cases, it may be desirable to employ the complete power supply and/or speaker cabinet of another manufacturer. The power supplies listed below are capable of running most Swan transceivers to at least the power levels indicated. All need a 12 pin Cinch-Jones plug installed or existing plug rewired to conform to the Swan configuration. Some require one or more minor changes to ensure correct output voltages.

A.8.3.3. Boat-Anchor Era Rig Power Ratings.

Make/Model	SSB PEP Capability	
Drake AC-3	325	W
Drake AC-4	325	"
EICO 751	250	"
Galaxy PSA-300	700	"
Galaxy AC-35	400	"
Galaxy AC-48	250	"
Galaxy AC-384	600	"
Galaxy AC-400	700	"
Hallicrafters PS-150-120	350	"
Hallicrafters PS-500	650	"
Heath HP-23	250	"
National AC-200	250	"
National NCXA	300	"
National AC-500	700	" (HV:1100 V)
Tempo AC ONE	375	"

A.8.4. Model TCU Transmitter Control Unit

The Swan Electronics Corporation Model TCU Transmitter Control Unit is designed to operate in conjunction with the Swan SW-240 Single Sideband Transceiver to provide:

- Separate VFO for non- transceiver operation
- Extended coverage of the 80 meter CW band
- Reception of WWV or WWVH on 15 MHz
- Voice Operated Transmission (VOX)
- 100 kHz Crystal Calibrator

A.8.4.1. SW-240 Installation

Minor modifications to the SW-240 are necessary. All hardware, modification parts, and mounting instructions are furnished with the TCU. The complete unit is housed in a cabinet, which matches the SW- 240 Transceiver. Provisions have been included to mount the SW-117B ac power supply within the TCU cabinet to provide a complete, compact installation with all of the desired operating features.

Frequency Coverage:

1. WWV 15 MHz
2. 80 M 3,500 to 3,650 kHz
3. 75 M 3,650 to 4,000 kHz
4. 40 M 7,000 to 7,300 kHz
5. 20 M 14,000 to 14,350 kHz

Front Panel Controls: VOX Gain, Anti-Trip, Main Tuning, VFO Selector, VFO Range, Calibrate ON-OFF.
Audio Output: Audio output through built-in 3" by 5"speaker, or by phone jack on front panel.
Power Requirements: All power requirements are supplied through 12-conductor cable from the Transceiver.
Dimensions: Width 13¼" Depth 11" Height 5 5/8"
Weight: 8½ pounds without SW-117B power supply.
Note: Rare complimentary 1963 Swan 240 External VFO specification sheet.

Contributors. This section included information from Stu (K4BOV), Dean (WA9AZK), and others.

A.9. Issue 9, Dec 1998 (Edited)

A.9.1. 6GK6 Driver Tube Pin Wiring

Way back in Issue #1 of the Swan News a brief article stressed the importance of disconnecting any wires from pin #6 of the 6GK6 Driver tube socket. In the early days, Swan used this tube socket connection as a sort of terminal strip that made its way to ground. Well, it turns out that later versions of the 6GK6 tube tied that pin (internally) to the screen grid. Not so good! If your pin 6 is tied to ground and you replace a driver tube with one of these newer style tubes (only about 25 years old), you will take out a 100 Ω resistor, a RF choke, and the new tube! Therefore, each time you acquire a new rig, or work on an old one or a friend's rig, take the 30 seconds it takes to snip any connection to pin 6 and isolate it totally.

A.9.2. KNOW THY SWAN, Part II

Voltage Chart. Now we will focus on the next step, which involves voltage measurements. All Swan manuals did include a voltage chart, however the accuracy of the values could not be fully relied upon due to many factors such as the variation in power supplies and capacities, and the many production changes to equipment that resulted in completely different circuit paths. (Stu, K4BOV)

Voltage Chart, Measurement Points. It is known that voltage charts were not always updated to accommodate later runs of the same model radio. Additionally, the effect of accessory and modification loading was seldom addressed. With many of these radios being over 30 years old, there are few that have escaped the wrath of repairs, modifications, etc., and thus, a new voltage chart must be prepared. It can be patterned after the manual version, but additional checkpoints should be added. For the purists, this would mean a space on the chart for the VOX and VFO socket and 12 pin Cinch-Jones plug. It's a good idea to make up several copies of the blank voltage chart for any possible down the road tests. Always affix the model and serial number of the transceiver and power supply somewhere on the associated chart – even the date of test is good for record keeping.

Safety/Accuracy. With all clerical preparations complete, the next consideration is with safety and accuracy. Studying voltage levels in vacuum tube-radio circuits can be dangerous. Therefore, extreme caution is mandatory during the voltage measuring process. For some, it will be necessary to review safety precautions connected with the handling of open electronic equipment and use of multi-meters. If one is the least bit apprehensive about a face-to-face encounter with the voltages awaiting, it would be wise to seek the assistance of someone experienced in electronics troubleshooting, as the information here would not be sufficient to provide adequate guidance on important safety measures.

Purpose. The intent here is to bring to light the need for having the circuit voltages or vital-signs so to speak, of your properly working radio down on paper in the event you need to compare a good radio with a broke radio. Finally, a few pointers. The plate voltage to the Power Amplifier (finals) stage is applied at all times in Swan transceivers when the power is turned on regardless of whether in receive or transmit mode. Never remove the PA cage cover with power on. Think of it as a rattlesnake in a cage. Of course, there are exceptions to any rule – most skilled and long time technicians are careful enough to work without the protective cover. But for now, we are measuring, not working on it, so keep the lid on it!

Accuracy. Next, is accuracy. That's the whole idea, to refine the values provided in original Swan voltage charts to match those unique to the current radio readings. This means meter accuracy of less than 5% error. *[Ed. Note: A proportional meter error of 5% at each voltage reading is not the same as 5% FS; on a 1,000 V scale, a 5% error = ±50 V, regardless of measurement value, a 5% proportional error is also ±50 V at a 1,000 V scale reading, but with a 300 V reading it is only ±15 V.]*

Calibration Standards. Without precision calibration equipment, some Swan transceiver circuits can be employed as standards. For instance, the early Swans employed voltage regulator tubes to keep carrier oscillator tubes stable. The output from the 0A2 tube in Swan-350, 400, 500, and early 500Cs and 350Cs for example, can be used to set your meters at 150 V. The VFO Zener diode that provides the regulated –10 V for early Swan VFOs and –12 V for later units can be relied upon for calibrating the lower range of voltmeters. Make sure which diode you are dealing with though, as many of these have been interchanged or replaced by other values. The Swan VFO does not care whether –10 V or –12 V is in place regardless of radio vintage. In fact, anything from –9 V to –15 V will work fine. It's the voltage regulation that counts.

Redundant Measurements. It's good practice to make all measurements a second time on another blank sheet, then comparing the two. Since there nearly 100 possible check points, it's not hard for even the best of us to make an error.

Technical Questions. Note: Stu will be happy to help you with your technical questions. You can FAX him at (607) 936 2463, e-mail: radyojo@aol.com (or our collective e-mail: swanradio@angelfire.com) or to K4BOV with SASE. Include serial numbers of equipment to be discussed.

A.9.3. Carrier Insertion Modification

See Swan Newsletter, Issue 4 for this information.

A.9.4. Grounding

The topic of grounding comes up from time to time, and it is certainly one of the most important aspects of equipment installation. Think of ground as a place, a large receptacle, for electrons to flow and disburse. Also, in the case of RF energy, grounding performs the same role.

Ground Problems. When we transmit, we subject ourselves, our surroundings, and our equipment to relatively strong electrical fields. Improperly protected from these fields, all sorts of strange things can occur. The most consistent one of these is audio distortion. This usually occurs because the strong RF field enters in any number of places in our communications system. It could be introduced into one of the stages of our transmitter, through our microphones, back through our coax, or even through the electrical system that provides power to our radios (115-V ac lines). So, how does grounding prevent these problems from occurring, and what is the role of grounding?

Lightning. Grounding plays more than one role. First, by having a good low resistance ground for all your equipment (including your antenna), you provide a better, less resistant path for excess electrical energy to be dispelled to ground (e.g. a direct or nearby lightning strike). It has been said, "*A well grounded antenna system is more likely to be struck by lightning, so why improve the chances of a strike by grounding?*" Probably true, but look at the alternative! Think of it this way: If you drive without insurance, you will be more careful and, therefore, you will be less likely to have an accident. Not a good choice.

RF Ground. The other thing grounding does is bleed-off RF. If your rig and associated equipment is properly grounded, you will send the powerful RF, which so much likes to get into everything, on a trip to hell. So, if you have distortion in your audio, or get bit by that old D-104, then look to a better ground for your solution.

Ground Configuration. What is a better ground?

Ground Rod. Here there are many opinions, but one thing can't be debated, the bigger (such as in wire gauge, pipe size, etc.) the better. When I say big, I mean less resistance. So, don't be afraid to use a great big piece of major gauge wire for your ground, and the further away from the ground, the more important this becomes.

Multiple Ground Rods. It is probably true that multiple grounds are a good idea, too. Think of it this way. If your rig is throwing off a lot of RF and your ground is sending that RF to a cold-water plumbing system within your house, chances are everything that is electronic is hooked to that same ground. What if the piping system is a wonderful conductor? And, copper pipe is a wonderful conductor. What if the ground portion of that system isn't perfect, but the circuit is? Get the picture? Not only that, most telephone systems are also connected to the plumbing system. So, theoretically at least, a separate ground for your radio, your antenna, the phone and the electrical system in your house would be less likely to cross-feed. Real life experiences have shown situations such as relocating a ground connection to eliminate an annoying hum in a phone system. Presumably, the regular electrical system was feeding back into the phone system through the plumbing system. Once relocated, the problem disappeared. Also, how many of us have experienced microphone bite because we weren't properly grounded?

A.9.5. Websites For Swan Eyes

Visit Gary's (VE4YH) Virtual Swan Museum at*: www.pcs.mb.ca/~standard/*
Visit AADE's Swan Radio Room at: *www.aade.com/hampedia/swan/swan.htm*

A.9.6. Swan 350 Front Panel

Front panels from late 1967 Swan 350s are not interchangeable with earlier panels and vice versa. The PA PLATE and Course Load controls are mounted higher on the early units. If a non-matching panel MUST be installed, new shaft holes will need to be drilled in the panel.

A.9.7. Swan 400 - Where'd they go?

The Swan 400 was Swan's first 5-band amateur transceiver. At the time it went into production, the Swan 350 was already on the drawing board. The 400 sold well until 6 months later when the 350 was released. The rage at the time was for transceivers that employed built-in VFOs, so the 350 quickly out paced the 400, as an external VFO was required for the latter. Even though the 400 had a slightly longer production period, only about 1,200 units were built compared to 9,000 of the popular 350. At the end of 1967, both models were discontinued to make room for the new 350C and 500C transceivers. But, the 400 was too good of a radio to retire completely. With a few minor changes in order to accommodate non-technical operators and operation outside the ham bands, the 400 found service with military, industrial, and commercial customers. Sales to those groups continued for over 6 years as the 400, initially dubbed the 400F, then the 400G, and, finally the 400H. The commercial 400s went completely unnoticed by the amateur ranks, and it is still equally unknown today that the original 400 design continued production right through to the Swan HF700S – the last tube-radio Swan produced. So, where'd the commercial 400s go?

Well, they are starting to turn up in flea markets, government auctions, military surplus, etc. These transceivers need only a Swan 117X or similar power supply – no speaker needed, as the 400 has a built-in speaker. Specifications include continuous frequency coverage 2 through 24 MHz and limited tune-up requirements. In reality, this unit will cover 160 through 12 meters without any modification. Any Swan external VFO can be retuned to provide the necessary injection frequencies. Unfortunately, commercial use means commercial treatment. Therefore, it is difficult to come across any of these transceivers that have retained their original pleasing appearance.

A.9.8. Swan, Vintage Net Schedules

Swan User	Sunday	14.250	5PM eastern	WA9AZK	UT	Dean
				W7RXG	UT	Norm
				WA5BDR	NM	Jim
Swan Tech	Wednesday	14.251	2300GMT	K4BOV	NY	Stu
Swan Tech	Sat	7.235	2-4PM eastern	K4BOV	NY	Stu
				K1QQ	NJ	Kent
Collins Tech	Tuesday	3.955	8-9PM eastern	W3ST	PA	Dave
Hallicrafters	Saturday	7.280	1700GMT	WB8DML	OH	Jim
Hallicrafters	Sunday	14.293	1800GMT			
Vintage SSB	Sunday	14.293	1900GMT	WB0SNF	NE	Andy
Heathkit	Sunday	14.293	2030GMT	WB6LRG	CA	Don

Periodic updates and further information can be found at: *www.angelfire.com/ny2/hamradio and www.geocities.com/LateMod97*

Contributors. This section included information from Stu (K4BOV), Dean (WA9AZK), and others.

A.10. ISSUE 10, Dec 2000 (Edited)

A.10.1. Tube Substitutions

Electron tubes are still out there and available – for a price, that is. Look at what distributors want for 8950s! Not worth it – many 12-pin power pentodes will do just as good a job and maybe better. For example, the GE 6LB6 is the same tube as the GE 8950 except for filament voltage.

A.10.2. GE Tube Design

In order to cut costs during the final days of GE tube building, several TV horizontal output tubes were built with the same internal hardware. This means these tubes share the same rated plate dissipation. Take a look at the late 8950, 6LB6, 6KD6, 6JS6C, 6MC6, etc from GE - same plate! The 33-W plate was selected as a common component for these tubes rather than continue the added cost of producing several different plates. Only minor socket wiring changes are necessary to make any of these tubes operate in Swan equipment.

6LF6. When going to more hefty tubes like the 6LF6, increased inter-electrode capacitance must be addressed in order to have satisfactory operation on higher frequencies such as 15 and 10 meters. This requires a small change in the RF driver circuits to better match the output of the driver to the input of the 6LF6. Most 6LF6s are rated at 40-W plate dissipation, which will normally correlate to longer life and, with adequate power supply capacity, more output power.

Height. Occasionally, you will find some of the 6LF6s too tall for your PA compartment. In this case, the socket platform can be lowered a ¼" or so to permit 6LF6 (and similar tall tubes) installation. RCA marketed a short 6LF6 with a unique styled 40 W rated plate. This tube would appear to most people as a dual-plate tube as it actually contained two 20-W plates connected together side-by-side. Therefore, the tube was no taller than a 6HF5 – it was a neat package.

A.10.3. Linear Amplifiers

For those wanting to use Swan radios to drive linear amplifiers, there are other options. First, consider that the Swan 2 tube PA radios (Swan 400 through HF700S) are capable of 250 to 400-W PEP of SSB output. Most two-tube 3-500Z linear amplifiers will do 1,200 to 1,300-W PEP output on SSB. This range of power increase is about 4 to 7 dB. However, the driving power needed to see these linear amplifier levels is not 250 to 400 W - it is about 125 W.

Therefore, the RF output of the powerful Swan transceivers must be kept down; otherwise, the grids of those 3-500Zs might start melting. A small change to the Swan 117X power supply will limit transceiver output to about 125-W PEP for those wishing to regularly employ a linear amplifier. This change involves removing the high voltage rectifier circuit from the medium voltage rectifier and grounding the removed connection. That is, the wire from the negative side of the HV bridge rectifier, capacitor and 150 kΩ bleeder/divider resistor joint is disconnected from the positive output of the MV winding and reconnected to a convenient ground point. *[Ed note: This does not apply to earlier power supplies models that use a different transformer design (i.e. 117AC/B/C).]*

This results in an output of roughly 600 V unloaded at the HV terminal and frees up the 275 V winding from having to supply current to the HV on transmit. There is no change to the transceiver at all, just reset the bias control to 50 mA and go!

A.10.4. Tube Substitution

Tube substitution is not just limited to plate capped tubes. If one has a handful of 6GE5s (used in Heathkit single band HW series), 6GF5s, 6HB5s, etc, they will easily retrofit in Swan 12 pin PA tube radios.

With the handful, it should be easy to find at least two tubes that are fairly well matched to each other. After rewiring the PA tube socket for the proper circuit configuration, the plate HV is merely fed down under the chassis (from the plate choke trough well insulated wire) to the plate pin lug. Cover the HV lug and that's it. The RF Driver stages should be realigned after any PA tube substitution.

These smaller tubes will run about 125 PEP output with unmodified Swan power supplies and about 90 W after reducing the plate voltage per the above instructions. Stu/K4BOV

A.10.5. Swan Operations On-Line

Network Website. Via this website, Swan enthusiasts can view a wide range of amateur radio and Swan related information. Additionally, we have made the site somewhat interactive by the inclusion of a Swan Radio QSO Room or chat room on two of the associated pages – both rooms are linked together, so, it doesn't matter which page you enter from.

Reflector. The Swan-Net E-Mail list or reflector was implemented at the first of the year. It is an extension of the Swan Nets and provides another method of keeping Swan owners in touch.

Silent Key. Other pages that are linked to and from the main Swan Radio Network page includes a Silent Key listing where we remember those that donated their friendship to us and have since been lost to the ages.

Trader. Our Swan and Vintage Radio Trader is one of our more popular pages where hams can list wanted, trade or for sale items.

Virtual Museum. The Swan Virtual Museum is nearing completion and will soon showcase the entire Swan Radio line of equipment. The museum can be reached through several links we have placed on the various Swan Radio information pages.

A.10.6. Swan Net Operations

Swan owners enjoy looking at their equipment and operating it. They truly appreciate what Herb Johnson brought to life. In the late 50s, Herb envisioned the eventual wholesale transition from AM to the new and more efficient SSB mode of transmission. He also knew this rush to SSB would not happen overnight or to the degree possible without a low cost affordable radio being offered the hams of that period. During 1960, he completed the design of his original mono-band transceiver models and soon began assembling his first 10 units in a 2-car garage at his Benson, Arizona QTH.

Forty years later, we still marvel at what Herb accomplished with such meager resources. Many of these early radios are still in operation and routinely make their way into our Swan Net sessions each week. Swan Net operations are tailored to meet the looking-at, operating and repair-it needs of Swan owners around the world.

The Swan User Net meets Sundays on 14,250 kHz at 5PM Eastern and continues to be the parent-operating schedule. Swan operators Norm/W7RXG in Salt Lake City, UT, Jim/WA5BDR in Roswell, NM and Jay/WB6MWL in Montclair, CA rotate net control duties on a weekly basis. This net reaches national and international coverage due to the time and day of operation – an excellent place to showcase one's Swan radio.

For assistance and guidance in equipment repair and alignment procedures, the Swan Technical Nets meet Wednesdays on 14,251 kHz at 2300GMT and Saturdays on 7,235 kHz at 2PM Eastern. Stu/K4BOV in Corning, NY and Kent/K1QQ in Sparrow Bush, NY handle net control for both technical nets while Jeff/WA8SAJ in Willoughby, OH takes a turn from time to time with the 40-meter session.

A.10.7. Notch Filter, Early Swan 350 and 400

Notch filters added cost to early radios. Since use of this item and other accessory functions such as VOX, RIT, etc., were not considered essential for communications, they were not incorporated. The plug-in VOX, for example, could be purchased separately. A real IF type notch filter was never offered. However, one can be incorporated in the early Swan 350 and 400 (and even the single band transceivers and Swan 240 with some additional components) quite easily. Only a small change is required in the four-pole crystal filter.

First, let us discuss the early four-pole crystal filter. Prior to mid-1965, all Swan SSB transceivers employed four pole crystal filters. The filter is readily identified by the open 5-crystal complex (four crystals in the case of a Swan 240) mounted on top of the chassis in the middle of the left side. Four crystals are connected in such a way as to produce a bandpass for a small range of AF signals at a frequency just slightly above the IF. The IF in this case is about 5.173 MHz. The IF carrier signal is generated in the carrier oscillator stage, then passed through the balanced modulator and on to the crystal filter.

The carrier signal is more finely tuned by the carrier oscillator trimmer capacitor so that the carrier frequency is right around the lower edge of the crystal filter's bandpass. That is, around 5.173 MHz. The range of the filter's bandpass or open-portal runs from 5.173 to 5.176 MHz, or about 3 kHz. Speech audio from the microphone is impressed on the 5.173 MHz carrier, and, keeping with the laws of signal mixing, an audio frequency appears slightly below the IF and one slightly above the IF. The lower frequency is attenuated because it is outside that 3 kHz bandpass while the higher AF easily passes through the filter. This is the upper sideband or normal sideband in the case of Swan equipment.

Now, here is where the notch comes in. There is a fifth crystal mounted within the crystal filter complex. It has nothing to do with altering the bandwidth of the filter, but does a lot for reducing and suppressing any residual carrier that can't be handled by the balanced modulator. This is a shunt crystal – it shunts out its own frequency. Typically, this crystal is cut for 5,173.1 kHz. The IF carrier hovers around that frequency, so, any carrier that is not nulled out or filtered out by the lower edge of the crystal filter, is shunted by the 5,173.1 kHz crystal.

The object now is to make the frequency of this crystal adjustable across the full 3 kHz spread of the crystal filter bandpass. Simply disconnect the wire from one side of the shunt crystal, place a 50 to 100-µµF variable capacitor in series with the crystal. Connect wires to each side of the variable capacitor and run to the T and C terminals of the auxiliary relay. So when the transceiver goes into transmit, the variable capacitor is switched or shorted out of the circuit.

There is any number of options for mounting the variable notch capacitor. It can be placed inside a small metal box external to the radio and connected directly by tether wires to the proper auxiliary relay terminals. Alternatively, a carefully drilled hole in the front panel can be employed for a permanent, easy access location with tuning knob and all. Rotating the capacitor in a direction that reduces capacitance moves the notch frequency up and across the bandpass of the filter. The notch is extremely deep and sharp – certainly neither as linear nor consistent as the stationary width retaining features of modern notch filters, but overall, it will still out perform most of them.

A.10.8. AM Operation

Since increasingly new hams seem to be finding a fascination with AM operation, it appears this early transmission mode is not just an old-timers game. We are hearing more discussions on the Swan Tech Nets about employing various manufacturers gear for AM schedules. However many are unsure of how safe and effective Swan radios can be for AM use.

First, Swan has always been known for excellent audio quality. This has usually related to SSB. The Swan single band transceivers of the early 60s sounded just as good back then as the new oriental equipment of today. Very little has changed in SSB transmitting content over the years mainly because SSB is SSB. So, if a near perfect reproduction of a persons voice was produced in the early days and since the human voice and ears have not changed since, certainly there is little or nothing further to be accomplished in making it sound any different.

It can be said though, that some manufactures equipment did produce better quality audio than others did – maybe not a lot better, but discernible differences nonetheless. Swan has an edge on some of the SSB transceivers of the 60s and 70s by using balanced modulator AM generation as apposed to screen grid modulation. Balanced modulator AM is about as close to plate modulation as one can get. The Swan AM mode lacks only the double sideband process. Meaning, the RF carrier does not contain the opposite sideband audio frequency due to the crystal filter suppressing the unwanted sideband it normally suppresses during SSB operation. This has absolutely nothing to do with the audio output quality of the transmitter - it remains excellent.

In fact, efficiency is increased by not wasting the power needed to amplify the unwanted or more specifically, unnecessary sideband. The only drawback that comes to mind about single-sideband-with-carrier type AM, is at the receiving station. That is, if one is copying AM delivered from a Swan transceiver, and, has the BFO turned on, the proper SSB position must be selected in order to hear the AF signal. With the BFO off, as most AM receivers are set, demodulation of the AM transmission is normal and oblivious to which sideband is present. Just as with SSB, if the Swan radio is properly aligned and at peak form, the AM quality will be of the highest order.

Optimum AM Performance. Two comments for ensuring optimum AM performance:

- Always run a fan on the PA tubes. Most two-tube PA Swan models need an idle current of about 50 mA. So, with the carrier null adjusted for about 150 mA of carrier power, this increased duty cycle, coupled with longer transmissions associated with AM operating habits, will shorten tube life unless a fan is employed. It is not absolutely required that 150-mA carrier power be the AM operating level, 125 mA or even 100 mA is satisfactory as long as modulation peaks barely trip the meter 5 to 10 mA above the carrier level. About 100-mA carrier power is equivalent to about 75-W dc input and 150 mA would be roughly 125-W dc input.
- Secondly, consider using a separate receiver. Otherwise, unless you have a means of turning off the carrier oscillator between transmissions, you will be constantly zero beating the AM carriers of the many participants of your round-table QSO. Therefore, A good communications receiver can really enhance AM operation by offering variable selectivity, filtering, split frequency, BFO OFF, etc. An external receiver is easily paired with a Swan transceiver. Only two connections are required – the relay terminals on the rear of the Swan are used to mute the receiver and the V6 Output plug on the rear of 500CX and later model Swans is the antenna connection for the external receiver. On Swan 500C and older units, the V6 output must be installed – just a RCA jack or coax connector, a 5 or 10 µµF capacitor and short piece of hook-up wire or coax.

  The external receiver option has an additional incentive. The antenna connection described above is actually one that takes the signal off the output of V6, the receiver RF amplifier. In other words, the signal coming into the transceiver is first amplified by V6, then fed to the transceiver receive mixer stage and to the V6 output. Therefore, the received signal is pre-amplified before it goes to the external receiver, essentially adding an extra RF stage to the front end of the receiver.

A.10.9. Swan Net Schedules, Chat Room

The Swan-Net web page *www.geocities.com/latemod97* contains all, associated links, collective e-mail addresses for contacting Swan Net coordinators, etc. Feel free to contact us with suggestions, technical questions, or submissions of silent key information and equipment swaps/wants/for sales. All of us are proud Swan enthusiasts and want to do whatever possible to keep you enjoying and showing off your Swans.

Contributors. This section included information from Don (N1APY), Stu (K4BOV), and others.

B. APPENDIX B. SWAN ADVERTISMENTS

B.1. February 1971 Product and Price List

DIRECT PRICE LIST

MODEL & ORDER NUMBER	DESCRIPTION	FACTORY DIRECT PRICE
TRANSCEIVER:		
270B	Deluxe Cygnet, 5 Band Transceiver	$399.00
500CX	Deluxe, 5 Band Transceiver	$449.00
250C	6 Meter Transceiver	$399.00
TV-2B	2 Meter SSB Transverter	$289.00
FM-2X	2 Meter FM Transceiver	$229.00
EXT. OSC'S:		
510X	10 Channel xtal osc. for use with all 5 band transceivers	$ 44.00
508	Full coverage VFO for 270B/350C/500C/500CX	$129.00
210	6 Meter VFO for 250C only	$ 99.00
POWER SUPPLIES:		
117XC	117 VAC 50-60 hz AC Supply for 350/500 series with spkr.	$ 95.00
117X	Basic AC Supply, no cabinet or speaker	$ 59.00
14-117	12 volt DC Supply with 117 volt AC Supply	$118.00
14C	12 volt DC Converter for 117-X AC Supply	$ 59.00
14A	12 volt DC Converter for 270B	$ 29.00
AMPLIFIERS:		
VHF-150	2 Meter FM/CW/SSB 150 Watts Power Amplifier	$249.00
1200W	1200 Watt Linear Amplifier with self-contained Power Supply	$189.00
Mark II	5 Band 2000 watt linear amplifier with Power Supply and Tubes	$499.00
Mark 6B	6 Meter 2000 watt linear amplifier with Power Supply and Tubes	$499.00
MOBILE ANTENNAS:		
55	5 bank remote control switching	$ 99.00
45	5 band, manual switching	$ 69.00
35	Single band high Q model	Various
BEAM ANTENNAS:		
TB-4H	4 element, heavy duty	$119.00
TB-3H	3 element, heavy duty	$ 99.00
TB-3	3 element, standard	$ 84.00
TB-2	2 element, standard	$ 69.00
1040	Trap Vertical for 10, 15, 20 & 40 Meters	$ 49.00

Write for the complete 1971 Swan catalog.

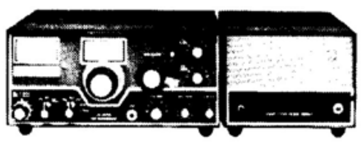
SWAN EASTERN OFFICE
P.O. Box 151
Freehold, New Jersey 07728

SWAN FACTORY
305 Airport Road
Oceanside, Calif. 92054

B.2. October 1972 Product and Price List

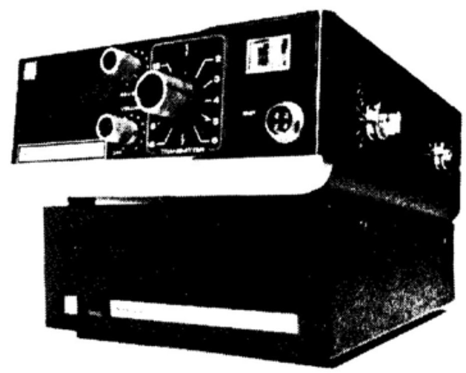
SWAN 500CX—550 watts P.E.P. SSB Transceiver. CW/AM/AGC/VFO and more. 3.5 to 29.7 mHz **$529.95**
With SS-16B (Super-Selective Filter) **$589.95**

SWAN 270B—260 watts P.E.P. SSB Transceiver. Built-in speaker/AC power supply. 3.5 to 29.7 mHz **$469.95**
With SS-16B **$529.95**



SWAN 250C—240 watts P.E.P. Transceiver. CW/AM/SSB/VFO and more. 50 to 54 mHz **$469.95**

SWAN 117-XC—Power supply. 117V ac **$109.95**
SWAN 230-XC—Power supply. 117 to 230V ac **$115.95**



SWAN FM-1210A—10 watts P.E.P. Transceiver. 144 channel combinations. 2 Meter FM **$359.95**

B.3. October 1972 Product and Price List

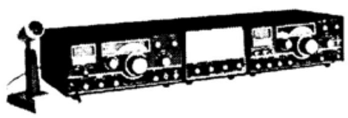
1200X

SWAN 1200X—5 Band Linear Amplifier. 1,200 watts P.E.P. Built-in power supply **$259.95**

SWAN VHF-150—2 Meter Linear Amplifier. 180 watts P.E.P. **$299.95**

SWAN MARK II—Linear Amplifier. 2,000 watts P.E.P. 10 to 80 Meters **$679.95**

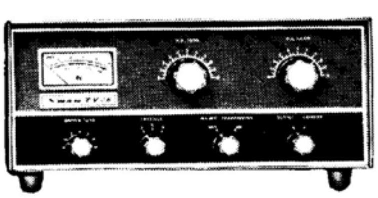
SWAN MARK 6B—Linear Amplifier. 2,000 watts P.E.P. 50 to 54 mHz **$679.95**



SWAN 600T—600 watts P.E.P. 10 to 80 Meter Transmitter **$589.95**

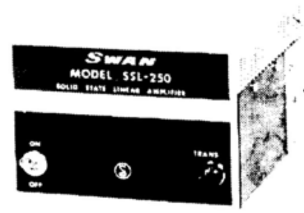
SWAN 600R—Companion Receiver for 600T . **$439.95**
Custom 600R **$545.95**
Custom with SS-16B **$599.95**

SWAN FM-2X—10 watts P.E.P. Transceiver. 12 channels/ built-in speaker. 2 Meter FM **$299.95**



SWAN TV-2C—240 watts P.E.P.
2 Meter Converter **$359.95**

NEW!



SWAN SSL-250—Fully solid-state Linear Amplifier. 250 watts P.E.P. **$299.00**

ACCESSORIES:

NEW!

SWAN WM-1500
Four scale In-Line Watt Meter **$49.95**

SWAN 600S—Speaker	**$21.95**
SWAN 600SP—Deluxe speaker with phone patch	**$64.50**
SWAN 600R CW Filter	**$29.50**
SWAN 600R AM Filter	**$39.95**
SWAN 14-117—Power supply. 12 to 14V dc	**$139.95**
SWAN 14-C—D.C. Converter. 12 to 14V dc	**$69.95**
SWAN 510X—VFO	**$53.95**
SWAN 508—VFO	**$159.95**
SWAN 210—VFO	**$109.95**
SWAN 160—VFO	**$119.00**
SWAN VX-2—AVC	**$35.95**
SWAN FP-1—Phone Patch	**$48.95**
SWAN NS-1—Noise Blanker	**$39.95**

404

444

SWAN 444—Desk Mike	**$28.50**
SWAN 404—Hand Mike	**$21.95**

B.4. August 1973 Product and Price List

SWAN ELECTRONICS MINI-CATALOG

Join the New Age of Amateur Radio Electronics! Equip your ham installation with one of these fine New Fully Solid-State Transceivers . . . each model operates directly from any 12 volt DC supply:

SS-100

SWAN SS-200 (200 Watts P.E.P.) . . $779.00
SWAN SS-100 (100 Watts P.E.P.) . . $699.00
SWAN SS-15 (15 Watts P.E.P.) . . . $579.00
If you must operate from a 115 volt AC source, order one of these power supply units:
SWAN PS-20 (For SS-200/SS-100/SS-15) $139.00
SWAN PS-10 (For SS-100/SS-15). . $ 89.00

AVAILABLE ACCESSORIES INCLUDE:

SWAN 610X (Crystal Controlled Oscillator) . . . . $ 53.95
SWAN SS-16B (Super Selective Filter). . . . . $ 79.95
SWAN SS-208 (External VFO) . . . $159.00
SWAN SS-1200 (1200 Watt P.E.P., tube-type, Linear amplifier $299.00

NEW, ECONOMICAL, FULLY SOLID-STATE MONOBANDERS!!

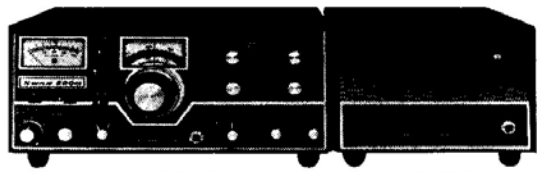
Featuring many of the circuitry designs of the multiband units described above, these 15 Watt P.E.P. input transceivers will give years of reliable service. Operate directly from 12 volts DC with no tune-up time required. SSB and CW modes, transmit ALC, smooth AGC, S-Meter, and no transmitter tuning to mess with. Includes infinite VSWR protection feature.

SWAN MB-40 (7.0 to 7.3 MHz). . . $249.95
SWAN MB-80 (3.5 to 4.0 MHz). . . $249.95

MONOBANDER ACCESSORIES INCLUDE:

Your choice of solid-state amplifiers to boost your range. Usable on any single band from 3 to 30 MHz with the appropriate plug-in filter. Price includes one filter. Please specify band when ordering.

SWAN MB-100 (100 Watt P.E.P.) . . $139.95
SWAN MB-200 (200 Watt P.E.P.) . . $209.95



500CX 117XC

SWAN 500-CX — 500 Watts P.E.P., SSB/CW/AM Transceiver. Covers all amateur bands 80 thru 10 Meters $529.95
With SS-16B Super Selective Filter included $589.95
SWAN 117-XC — 117 volt AC Power Supply $109.95
SWAN 230-XC — 117 to 230 volt AC Power Supply $115.95

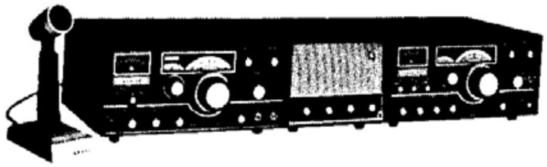
270B

SWAN 270B — 260 watts P.E.P. SSB Transceiver. Built-in speaker/AC power supply. 3.5 to 29.7 mHz. . $469.95
With SS-16B $529.95

ACCESSORIES:

SWAN WM-1500 In-line Wattmeter 5, 50, 500 & 1500 Watt scales. . . $49.95
SWAN 600S — Speaker $21.95
SWAN 600SP — Deluxe speaker with phone patch $64.50
SWAN 600R — CW Filter $29.50
SWAN 600R — AM Filter $39.95
SWAN 14-117 — DC Power Supply $139.95
SWAN 510X — VFO $53.95
SWAN 508 — VFO. $159.95
SWAN 210 — VFO $109.95
SWAN 160 — VFO $119.00
SWAN VX-2 — VOX $35.95
SWAN FP-1 — Phone Patch $48.95
SWAN NS-1 — Noise Blanker $39.95
SWAN 444 — Desk Mike $28.50
SWAN 404 — Hand Mike $21.95

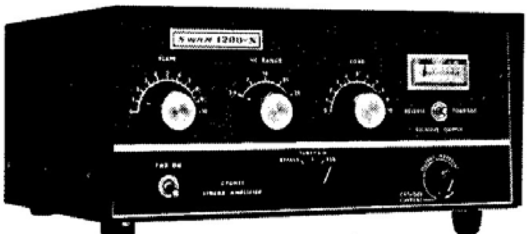
B.5. August 1973 Product and Price List



SWAN 600T – 600 watts P.E.P.
10 to 80 Meter Transmitter **$589.95**
SWAN 600R – Companion
Receiver for 600T. **$439.95**
Custom 600R **$545.95**
Custom with SS-16B **$599.95**

SWAN FM-2X – Operates directly from 12 volts DC. Up to 12 channel operation on 2 meters. Crystals for channels 1, 2 and 3 are included. Provides 10 watts of RF output. Furnished with dynamic microphone **$259.00**
SWAN FM-2X – Snap-on AC Power Supply **$39.95**

LINEAR AMPLIFIERS



1200X

SWAN 1200X – 5 Band Linear Amplifier. 1,200 watts P.E.P. Built-in power supply. **$259.95**
SWAN VHF-150 – 2 Meter Linear Amplifier. 180 watts P.E.P. **$299.95**
SWAN MARK II – Linear Amplifier. 2,000 watts P.E.P. 10 to 80 Meters **$679.95**
SWAN MARK 6B – Linear Amplifier. 2,000 watts P.E.P. 50 to 54 mHz **$679.95**

SWAN FM1210-A – 144 channel combinations are provided through independent switching of 12 transmit and 12 receive frequencies with eight crystals installed. Dynamic microphone included. Covers 144 to 148 MHz **$319.00**
SWAN FM1210-A – Pedestal type AC Power Supply **$49.95**
SWAN VHF-150 – 2 Meter Linear Amplifier. 180 Watt P.E.P. Built-in 117 or 230 volt AC power supply. **$299.95**
SWAN 14C – DC Converter, adapts to SWAN VHF-150 for mobile operation. Also converts 117XC and 230XC to operate with a 12 volt DC source. **$69.95**

– Buy where Hams are always helping Hams, that's SWAN ELECTRONICS!!

Use the nearby coupon for specifications and complete details about the full line of amateur radio products available from **SWAN ELECTRONICS**. No one else manufactures such an extensive array of ham equipment. ***AND,*** only **SWAN** offers you their own Revolving Credit Service Plan. **SWAN** will personally handle the financing of your purchase from beginning to end in full confidence.

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C. APPENDIX C. POWER AMPLIFIER TUBE DATA

The data listed by tube type in the Swan-Net website is shown in the table below. The website also permits sorting of data by plate dissipation or base configuration, with each listing giving a different view of possible substitutes for power amplifier tubes employed in vintage amateur radio transmitters and transceivers. The abbreviations used to identify the data columns are indicated below along with an explanation of the importance placed on each.

C.1. Parameter Definition

TUBE: The tube type shown is a numerical-alphabetical description code. No absolute standard or convention was ever adopted to permit easy recognition of the purpose and application of electron tubes. In the case of ordinary TV and radio tubes, such as with 6BG6 or 12AU6, the 1st digit or digits indicates the significant portion of the required filament voltage. Some very loosely agreed upon guidelines were followed by some manufacturers for selection of the letters section of the code, but not worth mentioning. Generally, the final digit or digits of the code represent the number of active elements or electrodes inside. Numerical coded tubes are usually designated as ruggedized or special purpose types.

BASE: This information relates to the map of element connections to pins at the base of the tube and the location of the plate connection, either top cap or pin. Again, not all manufacturers followed the same rules for matching base diagrams to the supposedly same tube built by someone else. An example of this appears when examining the base configuration of the 6LB6 horizontal deflection tube from RCA, Sylvania, and GE. They are each different; yet, will work in any application that calls for the 6LB6 with one possible exception. The GE does not have the screen grid connected to pin #11, only to pin #3. The other two have connections to both pins #11 and #3. In addition, there is even a minor variation in the base of the RCA and Sylvania that results in those two having different base maps. During the last few years of electron tube building in the USA, nearly all manufacturers bought and sold tubes among themselves, putting the buyers label on the tube. For example, Westinghouse sold receiving tubes for 12 years after they stopped making them. This was not because they had a large enough inventory to last 12 years; but, bought from the dwindling group of US and offshore builders and closed down when the suppliers closed down. Those familiar with each manufacturers characteristic features, which are readily observed through the glass envelope, can identify the production line origin. Only 8, 9 and 12 pin tubes are included in our listings in order to accommodate existing transmitter tube sockets, power supply considerations and, if necessary, the general ease of only requiring minor wiring changes.

PLTD: Means plate dissipation. This is the maximum amount of heat in W that a particular tube plate element can tolerate safely. Plate current under normal operation will heat the plate. Excessive plate current, if not checked by forced air or water-cooling, will destroy or drastically reduce the tenure of PA tubes. In pentodes, the higher the plate dissipation rating, the longer the life expectancy, or in many cases, higher output power can be achieved over a tube with lesser plate dissipation capability.

MPLTV: Maximum plate voltage. Most of the values listed are straight from the manufacturers lips. Keep in mind that horizontal and vertical deflection tubes were designed specifically for TV operation. The use of these tubes for RF power amplifiers in HF transmitting equipment came later. The horizontal output tubes (called sweep tubes in some circles because they sweep the horizontal trace line across the screen.) never see, for example, the rated 990 V in TV service. But, under testing, were found to handle that voltage level easily without coming apart. This fact really caught the eye of amateur transmitter manufacturers.

AVEI: Refers to average cathode current in milliamperes. One must be careful how these ratings are interpreted. Remembering again, horizontal and vertical deflection tubes operate at much reduced plate voltages than our amateur radio transmitting equipment; therefore, the average cathode current is higher than what could possibly be an average for the kind RF power amplifier duty we have planned. Although, not having a perfect correlation, this average current rating just happens to be close to the highest peak currents that can be reached in transmitters before flat topping occurs. This means a pair of 6LV6's, each rated at 400 mA average cathode current can peak around 800 mA under SSB modulation. Swan radio cathode meters cannot follow those peaks due to damping; thus, peaks of roughly 275 mA or so on the meter would equate to about 700-W PEP input.

FVOL: Filament voltage, normally ac or dc acceptable. In nearly all cases we show the numerical-alphabetic coded TV and radio tubes as being 6.3 V types; however tubes with other than 6.3 V filaments were produced. Regardless of the required voltage, all tubes that have identical letter codes and final digits have exactly the same electrical characteristics. For example, a 6JB6 is identical to a 12JB6 electronically, except one is a 6.3 V filament tube and the other is a 12.6 V filament tube. Another example would be the 6LZ6 and 31LZ6 horizontal deflection amplifier tubes. One is a 6.3 V filament tube, while the other is a 31 V filament tube. The wattage consumed by filaments is calculated exactly like that of a light bulb. A 6JB6 filament would be heating at the rate of (6.3 V X 1.2 A) 7.56 W.

FAMP: Filament Amperes. A measure of the thundering electron flow through the filament.

SCRV: Indicates maximum allowable screen voltage. Screen voltage has a major influence on how much current passes through the plate circuit.

SCRD: Screen grid dissipation in W. As screen grid voltage goes up, so does the speed and abundance of electrons shooting towards the plate. That's the job of the screen, to draw current from the cathode by overcoming control grid bias and then accelerate and direct that current toward the plate. However, in doing so, the screen starts looking like a smaller version of the plate and begins drawing its own current from the passing stream of electrons. Therefore, where there is current flow, there is heat and the screen has a limit to the amount of heat it can fend off without melting. Screen grids will glow red similar to the cherry-red glow of the visible plate. However being tucked inside and enclosed by the plate, it can't easily be seen.

PWRO: Typical power output. These figures are somewhat flexible; but, very reasonable capabilities. The old saying "*All tubes are not created equal*." can certainly be applied here. Under test, electron tube performance varies among manufacturers and even over time within a manufacturers own product line. Prior to 1980, most people in the business knew which tube handled a particular task better than another did. The power pentodes we have listed, come from the various ranks of horizontal and vertical deflection tubes, from predominantly audio amplifier backgrounds and early on accepted RF power amplifiers. All will produce RF power. And many, particularly in SSB service, are capable of output power well in excess of the figures shown.

PLTC: Plate circuit connection: Plate Cap or Plate Pin.

C.2. Tube Data

TUBE	BASE	PLTD	MPLTV	AVEI	FVOL	FAMP	SCRV	SCRD	PWRO	PLTC
6AR6	6BQ	21	630	150	6.3	1.2	315	3.5	60	PP
6AV5	6CK	11	550	110	6.3	1.2	175	2.5	25	PP
6BG6 GE	5BT	20	700	110	6.3	0.9	350	3.2	55	PC
6BG6 SYL	5BT	22	700	110	6.3	0.9	350	3.2	55	PC
6BQ6	6AM	11	600	110	6.3	1.2	200	2.5	30	PC
6CA7	8EP	25	800	150	6.3	1.5	425	8.0	50	PP
6CB5	8GD	23	700	200	6.3	2.5	200	3.6	80	PC
6CB5A	8GD	26	880	240	6.3	2.5	220	4.0	100	PC
6CD6G	5BT	15	700	200	6.3	2.5	175	3.0	50	PC
6CD6GA	5BT	20	700	200	6.3	2.5	175	3.0	70	PC
6CL5 GE	8GD	25	700	240	6.3	2.5	200	4.0	75	PC
6CU6	6AM	11	600	110	6.3	1.2	200	2.5	30	PC
6DN6	5BT	16	700	200	6.3	2.5	175	3.0	60	PC
6DQ5	***8JC***	***24***	***900***	***285***	***6.3***	***2.5***	***190***	***3.2***	***95***	***PC***
6DQ6	8AM	15	550	120	6.3	1.2	175	2.5	40	PC
6DQ6A	8AM	18	770	155	6.3	1.2	220	3.6	45	PC
6DQ6B	8AM	18	770	175	6.3	1.2	220	3.6	50	PC
6EX6	5BT	22	770	220	6.3	2.25	195	3.5	70	PC
6FW5	6CK	18	770	175	6.3	1.2	220	3.6	45	PP
6GB5	9NH	17	450	275	6.3	1.38	275	6.0	35	PC
6GC6	8JX	17	770	175	6.3	1.2	220	4.5	65	PC
6GE5	12BJ	17	770	175	6.3	1.2	220	3.5	65	PP
6GJ5	9QK	17	770	175	6.3	1.2	220	3.5	65	PC
6GT5	9NZ	17	770	175	6.3	1.2	220	3.5	65	PP
6GV5	12DR	17	770	175	6.3	1.2	220	3.5	65	PC
6GW6	6AM	17	770	175	6.3	1.2	220	3.5	65	PC
6GY5	12DR	18	770	230	6.3	1.5	220	3.5	75	PC
6HB5	12BJ	18	770	230	6.3	1.5	220	3.5	75	PP
6HD5	12ES	24	770	280	6.3	2.25	220	6.0	80	PP
6HE5	12EY	15	350	75	6.3	0.8	300	2.75	35	PP
6HF5	***12FB***	***28***	***990***	***315***	***6.3***	***2.25***	***190***	***5.5***	***120***	***PC***
6HJ5	12FL	24	770	280	6.3	2.25	220	6.0	80	PP

6JB5	12EY	15	350	75	6.3	0.8	300	2.7	35	PP
6JB6/A	9QL	17	770	175	6.3	1.2	220	3.5	65	PC
6JE6	9QL	24	990	315	6.3	2.5	190	3.2	100	PC
6JE6ABC	***9QL***	***30***	***990***	***350***	***6.3***	***2.5***	***220***	***5.0***	***125***	***PC***
6JF6	9QL	17	770	275	6.3	1.6	220	3.5	70	PC
6JG6	9QU	17	770	275	6.3	1.6	220	3.5	70	PP
6JM6	12FJ	17	770	175	6.3	1.2	220	3.5	65	PC
6JN6	12FK	17	770	175	6.3	1.2	220	3.5	65	PP
6JR6	9QU	17	770	275	6.3	1.6	220	3.5	70	PP
6JS6A/B	12FY	28	990	315	6.3	2.25	190	5.5	120	PC
6JS6C	12FY	30	990	350	6.3	2.25	220	5.5	125	PC
6JT6	9QU	17	770	175	6.3	1.2	220	3.5	65	PP
6JU6	9QL	17	770	275	6.3	1.6	220	3.5	70	PC
6JZ6	12GD	18	770	230	6.3	1.5	220	3.5	75	PC
6KD6	***12GW***	***33***	***990***	***400***	***6.3***	***2.85***	***200***	***5.0***	***135***	***PC***
6KE6	12GM	18	770	230	6.3	1.5	220	3.5	75	PC
6KG6A	9RJ	35	700	500	6.3	2.0	250	7.0	135	PC
6KM6	9QL	20	770	275	6.3	1.6	220	3.5	75	PC
6KN6	12GU	30	770	400	6.3	3.0	220	5.0	115	PC
6KV6	9QU	20	770	275	6.3	1.6	220	2.0	75	PP
6KV6A	9QU	28	900	275	6.3	1.6	220	2.0	105	PP
6LB6 GE	12GJ	33	990	350	6.3	2.25	200	5.0	130	PC
6LB6 RC	12JF	30	990	315	6.3	2.25	200	5.0	120	PC
6LB6 SY	12FY	30	990	315	6.3	2.25	200	5.0	120	PC
6LF6	***12GW***	***40***	***990***	***400***	***6.3***	***2.0***	***275***	***9.0***	***145***	***PC***
6LG6	12HL	28	990	315	6.3	2.0	200	5.0	120	PC
6LQ6	***9QL***	***30***	***990***	***350***	***6.3***	***2.5***	***220***	***5.0***	***125***	***PC***
6LR6	12FY	30	990	375	6.3	2.5	220	5.0	125	PC
6LV6	12GW	40	990	400	6.3	2.0	275	9.0	145	PC
6LW6	8NC	40	990	400	6.3	2.64	280	7.0	140	PC
6LX6 GE	12JA	33	990	400	6.3	2.55	250	5.0	130	PC
6LZ6	9QL	30	990	350	6.3	2.3	220	5.0	125	PC
6MB6	12FY	38	990	400	6.3	2.25	225	7.0	135	PC
6MC6	9QL	33	990	400	6.3	2.85	250	5.0	130	PC
6ME6	9QL	30	990	350	6.3	2.3	220	5.0	120	PC
6MH6	12GW	40	990	400	6.3	2.0	275	9.0	145	PC
6MJ6	***9QL***	***30***	***990***	***350***	***6.3***	***2.5***	***220***	***5.0***	***125***	***PC***
12JF5	12JH	17	770	175	12.6	0.6	220	3.5	65	PC
5881	7AC	23	360	275	6.3	0.9	270	3.0	40	PP
5932	7AC	21	400	210	6.3	0.9	300	2.9	65	PP
6000	6CK	25	600	225	26.5	0.28	300	4.0	65	PP
6146/A	7CK	25	750	250	6.3	1.25	250	3.0	70	PC
6146B	***7CK***	***35***	***750***	***250***	***6.3***	***1.13***	***250***	***3.0***	***75***	***PC***
6159A	7CK	25	750	250	26.5	0.3	250	3.0	70	PC
6159B	7CK	35	750	250	26.5	0.3	250	3.0	75	PC
6384	6BQ	30	750	125	6.3	1.2	325	3.5	60	PP
6550	7AC	42	660	300	6.3	1.8	440	6.0	75	PP
6883	7CK	20	750	225	12.6	0.63	250	3.0	65	PC
6883A	7CK	25	750	250	12.6	0.63	250	3.0	70	PC
6883B	7CK	35	750	250	12.6	0.56	250	3.0	75	PC
7027	7AC	25	450	200	6.3	0.9	400	3.5	55	PP
7027A	7AC	35	600	275	6.3	0.9	500	5.0	75	PP
7212	7CK	25	750	250	6.3	1.25	250	3.0	70	PC
7355	8KN	18	500	145	6.3	0.8	400	3.5	45	PP
7357	7CK	20	750	225	26.5	0.3	250	3.0	65	PC
7408	7AC	14	350	100	6.3	0.45	315	2.2	30	PP
7581	7AC	30	500	200	6.3	0.9	450	5.0	65	PP

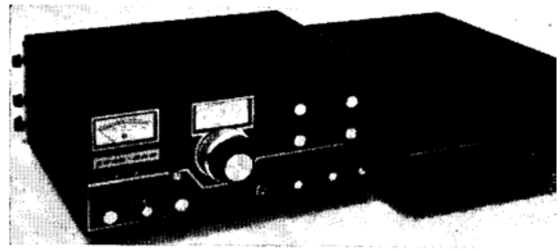
TUBE	BASE	PLTD	MPLTV	AVEI	FVOL	FAMP	SCRV	SCRD	PWRO	PLTC
7581A	7AC	35	500	225	6.3	0.9	450	5.0	70	PP
7591/A	8KQ	19	550	150	6.3	0.8	440	3.3	55	PP
7607	7CK	23	600	225	6.3	1.6	400	4.0	70	PC
7623	6AM	38	1250	290	6.3	1.6	600	6.0	120	PC
7624	6AM	38	1250	290	12.6	0.8	600	6.0	120	PC
7867	5BT	24	700	225	6.3	2.5	175	3.6	80	PC
7868	9RW	19	550	150	6.3	0.8	440	3.3	55	PP
7984	12EU	35	750	275	13.5	0.58	250	3.0	85	PP
8032	7CK	20	750	225	13.5	0.59	250	3.0	65	PC
8032A	7CK	25	750	250	13.5	0.56	250	3.0	75	PC
8042	8LJ	25	650	200	1.6	3.2	200	5.0	70	PC
8149	12DT	35	750	275	*6.5	*1.2	250	3.3	85	PP
8150	12DU	35	750	275	*6.5	*1.2	250	3.3	85	PC
8156	12EU	15	600	125	13.5	0.3	250	2.5	55	PP
8236	8JC	50	1000	500	6.3	2.5	200	3.2	165	PC
8298	7CK	20	750	225	6.7	1.17	250	3.0	65	PC
8298A	7CK	35	750	250	6.3	1.13	250	3.0	75	PC
8417	7AC	35	660	200	6.3	1.6	500	5.0	70	PP
8552	7CK	35	750	250	12.6	0.56	250	3.0	75	PC
8950 GE	***12JW***	***33***	***800***	***350***	***13.0***	***1.1***	***250***	***5.0***	***130***	***PC***
TUBE	**BASE**	**PLTD**	**MPLTV**	**AVEI**	**FVOL**	**FAMP**	**SCRV**	**SCRD**	**PWRO**	**PLTC**

Bold and italicized listings are Swan original configuration tubes.
Parallel filament indicated - also Series filament: 13.0 V @ 0.6 A

D. SWAN 350 PRODUCT REVIEW, SEPT 1965 *QST*

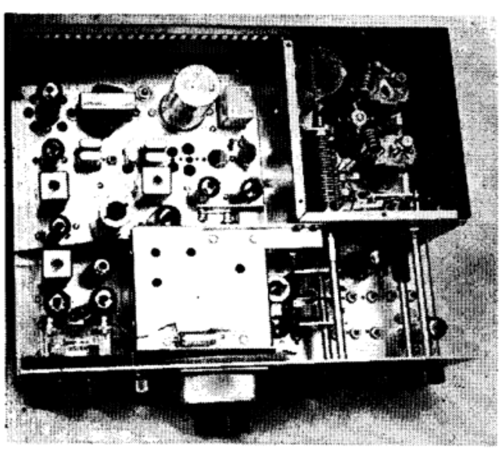
• *Recent Equipment* —

The Swan 350 Transceiver



THE majority of s.s.b. transceivers are all brothers as far as circuitry is concerned, so it is refreshing when a manufacturer uses a different design approach. The Swan 350 is a five-band rig for fixed-station or mobile use. The difference between the 350 and others on the market is that only one frequency conversion is used, transmit or receive, on any band.

In designing an s.s.b. transmitter or transceiver, there are several mixing schemes one can follow. The popular approach is to use a single-range v.f.o. which is mixed with the output of an s.s.b. generator, and then mixed again with a crystal oscillator's output to arrive at the desired output frequency. This system easily provides the stability required for sideband because the v.f.o. is at medium frequency — v.f.o. drift can be considered a function of frequency — and all the high-frequency oscillators are crystal controlled. You never get something for nothing, for with two, or sometimes three, frequency conversions mixer products pop up like an army of ants. Careful choice of frequencies will put most of these products away from the operating frequency, and any troublesome beats left can be attenuated with traps and filters, or so it says in the books.



The sideband generator is located at the bottom center, with the final amplifier at the right. The v.f.o. is braced to the chassis for extra rigidity. The large chrome knob on the front is the fast tuning control, and the plastic knob beyond it the slow-rate tuning. The small chrome knob is the calibration re-set control mentioned in the text.

The engineers at Swan have taken a different approach. The v.f.o.'s frequency range is changed for each band so only one frequency conversion is required. The s.s.b. generator in the 350 is 5 Mc., and its output is mixed with the output of the v.f.o. to produce the operating frequency. Sounds simple, but severe requirements are placed on the v.f.o. It must be stable on rather high frequencies, have a series of frequency ranges (each of which must be temperature compensated) and cover 500-kc. increments on each range so the calibration remains the same regardless of band selected. However, the difficulties in building a v.f.o. for the job are more than offset by the simplicity and reduction in cost that can be obtained with single conversion.

The advantages (and problems) of single conversion are the same in a receiver. The virtues of single conversion receivers have been pointed out recently by W1DX, so we won't repeat them here.[1]

The 350's v.f.o. is shown in Fig. 1. A 2N706, Q_1, functions as a grounded-base Colpitts oscillator. The oscillator is tapped down on the tuned circuit by means of a capacitive divider for high stability. Heating in the v.f.o. is compensated for by C_1 through C_4, the temperature compensating capacitors. Each one has the same capacitance value, but a different temperature coefficient. For maximum stability, the oscillator is run at very low level and a 6EW6 voltage amplifier used to build up sufficient injection levels for the mixers. To insure the stability of this v.f.o. amplifier an 82-ohm grid return resistor is used. An emitter follower, Q_2, is used to match the high impedance of the oscillator output to the low-impedance input of the v.f.o. amplifier.

The basic v.f.o. frequency is 8673–9173 kc., and this range is used for both 80 and 20 meters. Other tank coils are switched in to provide proper injection frequencies for 40, 15, and 10 meters — 12, 16, and 23 Mc. respectively. In the model tested, 500-kc. coverage was provided on each band. Coils L_1 through L_3 are tapped windings with an adjustment slug at either end to provide trimming of the high and low ends of the tuning range.

[1] Goodman, "Some Thoughts on Home Receiver Design," *QST*, May, 1965

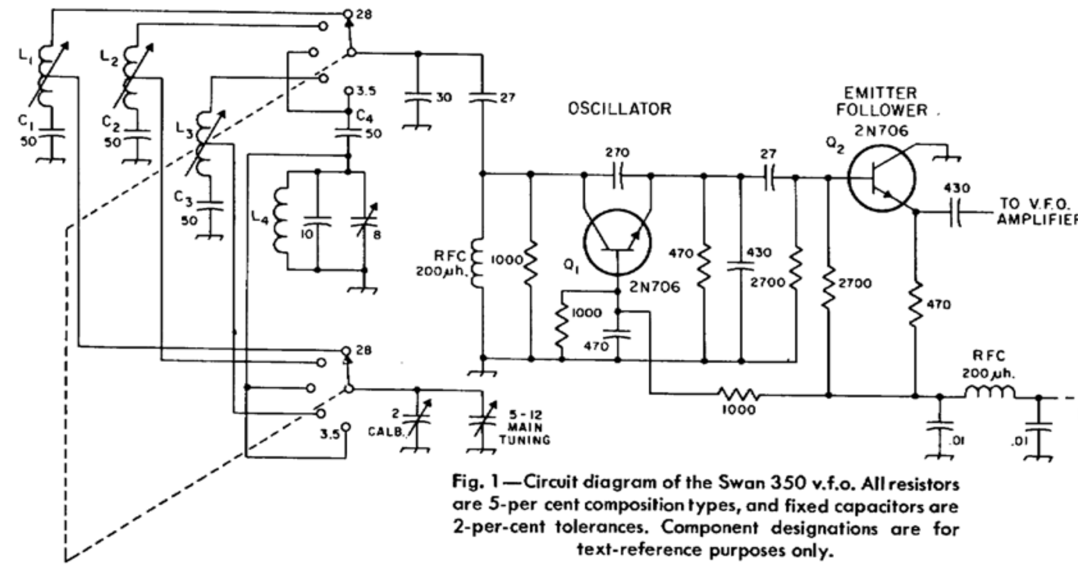


Fig. 1—Circuit diagram of the Swan 350 v.f.o. All resistors are 5-per cent composition types, and fixed capacitors are 2-per-cent tolerances. Component designations are for text-reference purposes only.

The v.f.o. drift during warm-up is about 1 kc. on 80, 40, and 20 meters, and about 2 kc. on 15 and 10. After warm-up, the drift rate is very slow. These drift figures are not as good as some of the multi-conversion rigs, but are certainly acceptable for normal operating. The v.f.o. is quite insensitive to line-voltage changes, no doubt because the transistor's supply voltage is Zener regulated.

Swan has made two changes in the v.f.o. in current production models. A trimmer capacitor has been installed close to the main dial to allow calibration of the v.f.o. with a crystal calibrator which is sold as an accessory. This calibration capacitor was in the unit we tested, but owners of earlier models may wish to obtain a modification kit from Swan, or return the 350 to the factory to have the change made. We would recommend the latter course, as it is quite a job to dismantle the v.f.o., mount the capacitor, and re-align the v.f.o. The other change provides full 10-meter coverage rather than just 500 kc. The v.f.o. coil for 10 and the dial are replaced. Again, a modification kit is available from Swan.

Receiving

For clarity, the block diagram, Fig. 2, shows the receiving and transmitting functions of the 350 separately, except for the v.f.o. The pi-network output circuit of the transmitter section is also used as the input tuned circuit for the receiver r.f. amplifier. This system simplifies switching and construction, but the pi network must be resonated before you hear anything. This may not be a draw-back as the transmitter final will be close to the proper adjustment before drive is applied to the final amplifier. A 12BZ6 is used as the r.f. amplifier. R.f. gain is controlled by changing the cathode resistance in the r.f. and two i.f. amplifier circuits. Oscillator injection for the mixer, a 12BE6, is obtained from the v.f.o. amplifier. The mixer is followed directly by the high-selectivity section, a crystal filter with a center frequency of 5174.5 kc. A trap is included in the input of the receiver to provide extra attenuation of 5-Mc. signals so they will not get in and bother the i.f. Two i.f. amplifiers are used, a 6EW6 and a 12BA6. The i.f. signal and b.f.o. provided by the carrier oscillator are grid-leak detected by one-half of a 12AX7, and the second half is used as an audio amplifier. A 6GK6 audio power amplifier drives a 3 × 5-inch speaker located in the power supply. With the mixing scheme used, lower sideband is received and transmitted on 80 and 40, and upper on 20, 15 and 10. There is no provision for sideband switching.

The triode section of a 6BN8 amplifies some of the audio signal, which is in turn rectified by the diode sections of the same tube, providing an audio-derived a.g.c. voltage. A.g.c. control voltage is applied to the grids of the r.f. stage, mixer, and second i.f. amplifier. The a.g.c. system in the Swan is quite good, as it has none of the thumps and pops on strong signals often heard with simple gain control systems. In fact, the strong-signal handling capability of the 350 is very good — something one needs in this day of big signals.

Transmitting

The filter in the Swan is a two-section crystal type, with an extra shunt crystal to give the filter a steep-sided response on the carrier side, and a sloping response on the other side. With the carrier positioned well down on the filter response extra attenuation of the carrier is obtained, while the audio response is more pleasing to the ear than can be obtained with symmetrical filters. The 350's filter has a nominal response of 3 kc. at −6 db., and 5.7 kc. at −60 db.

The transmitter section begins with a 12AX7

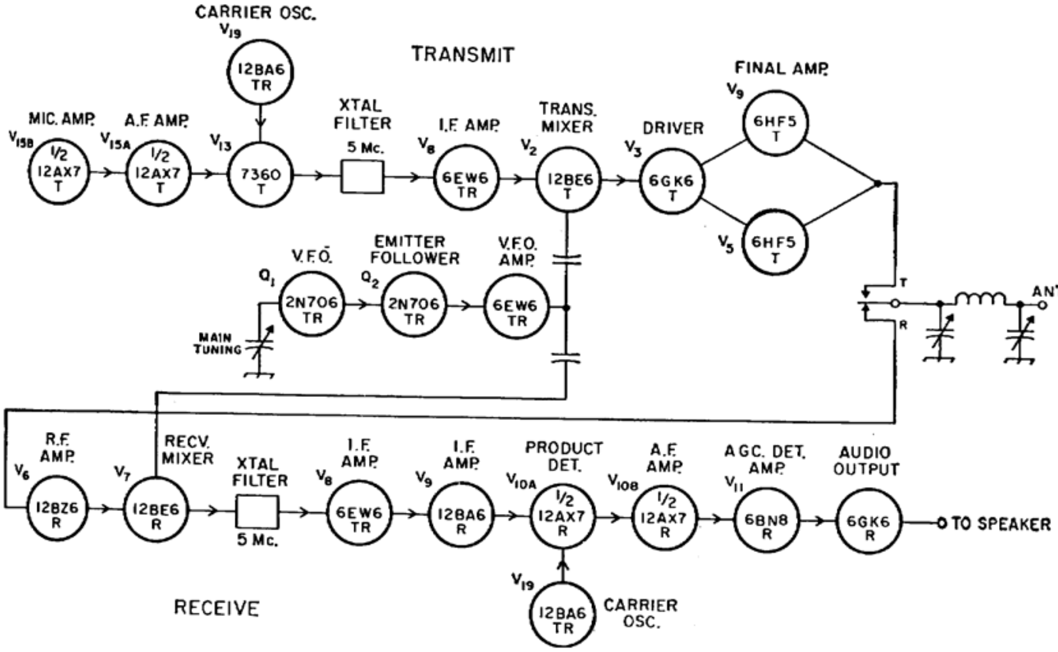


Fig. 2—Block diagram of the transceiver. Transmit and receive functions are shown separately except for the v.f.o. Stages that function on both transmit and receive are marked TR, those functioning only on transmit T, and those only on receive R.

speech amplifier, with the audio capacitively-coupled to one deflection plate of the 7360 balanced modulator. Output of the carrier generator, a 12BA6, is applied to the 7360 grid, and the carrier is balanced out in the push-pull output circuit. On s.s.b. equal voltages are applied to the deflection electrodes; a front-panel control permits balance of these two voltages for best carrier suppression. On c.w. one deflection electrode is grounded to upset the balance, permitting full-carrier transmission. On s.s.b. the carrier oscillator is positioned 300 c.p.s. outside the crystal filter's nominal passband, but on c.w. the oscillator is shifted 500 c.p.s. to place it inside the filter passband so no attenuation of the carrier takes place in the filter.

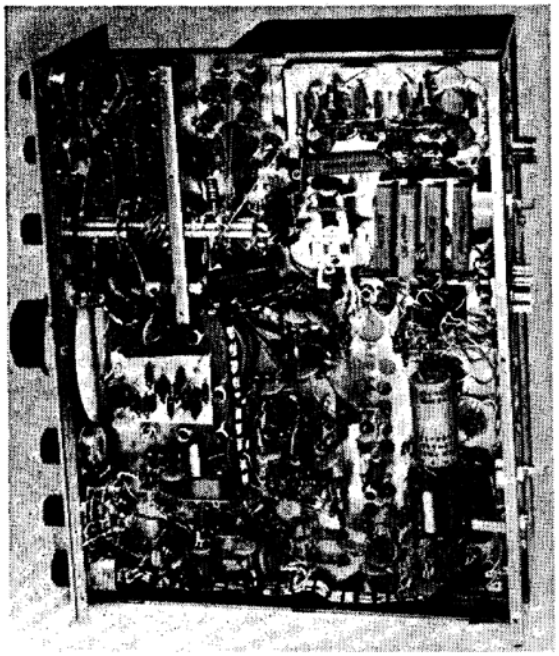
The filter attenuates the unwanted sideband at least 40 db. The wanted sideband is amplified by a 6EW6 after its passage through the filter, and then mixed with the v.f.o. output in a 12BE6, heterodyning it to the band selected. A 6GK6 driver amplifies the signal to sufficient level to drive two 6HF5s to 400 watts p.e.p. on s.s.b., and 320 watts on c.w. An audio-derived a.l.c. system provides a negative voltage to the i.f. amplifier on transmit, reducing the level of drive when the 6HF5s are driven into grid current. As the instruction book points out, this is a *protection* system, and does not remove the responsibility from the operator to set the microphone level correctly — a good point to remember about any s.s.b. transmitter.

Some eyebrows were raised over the 400-watt p.e.p. input figure for the 350. The 6HF5s are color television sweep tubes, so no ratings are published for AB_1-s.s.b. service. The limitation of this type of tube in sideband service is bulb temperature, which in the case of the 6HF5s is 225 degrees C. Obviously, a high-peak, low-average power type of emission like s.s.b. is not going to heat the tubes very much. Thus the real question was whether the tubes could reach the required peak current before saturation. A two-tone test showed that the p.e.p. capability of the 350 was well *beyond* 400 watts.

These sweep tubes will draw current, make no mistake about that. It is the operator's responsibility to see that the tubes are not overheated by long tune-up periods. Having the plate circuit out of resonance results in plate currents of 600–700 ma., so real care is necessary when adjusting the transmitter. If your final tube's life is short, you may not have appreciated the limitations of these sweep tubes, and taken necessary precautions.

The pi-network output circuit will match resistive loads between 50–300 ohms. Fixed capacitors are switched in parallel with a variable to provide a wide range of loading adjustments. Operators will find this adds to the versatility of the rig as compared with the fixed 50-ohm output transceivers.

C.w. has not been forgotten either. Grid-block keying is used with a shaping network to eliminate clicks, resulting in an excellent c.w. note. With a 23-Mc. v.f.o., one might expect some chirp on 10 meters, but there was none when running the transmitter at full c.w. input.



The bottom view reveals no crowding or stacking of parts that make some compact rigs so hard to service. The small printed board at the center is the v.f.o. circuitry. The octal socket at the bottom end of the rear apron is the receptacle for the auxiliary VOX unit.

Other Details

The Swan cabinet assembly is interesting because both the top and bottom covers can be easily removed to work on the unit. The front and rear panels are permanently attached to the chassis. The bottom plate is attached to the chassis with sheet-metal screws. The three-sided top cover is fastened with three screws on either side to Tinnerman fasteners on the sides of the chassis.

An accessory VOX unit is available for plugging into a chassis receptacle on the rear apron. This little transistorized unit has VOX sensitivity, anti-VOX, and delay controls that may be adjusted from the side of the 350. This mounting arrangement of the VOX is fine in fixed-station use, but would be about impossible to reach in an under-the-dash mobile mount. A front-panel switch selects either VOX or push-to-talk operation.

The power supply uses a bridge rectifier for the high voltage, and medium voltage is obtained from a center tap on the high-voltage winding. A half-wave rectifier is used to obtain bias voltage, and another half-wave rectifier on the filament line provides −12 volts for the transistor stages.

The regular readers of this column may have gotten the idea in the past that we throw a lot of rocks at manufacturer's instruction books. The fact is that many of these manuals do not give enough information to enable the owner to familiarize himself with his new piece of equipment. Proper operating instructions are sometimes lacking, and no information on circuitry or maintenance is given. This is definitely not the case with Swan! The instruction book for the 350 gives very complete operating and alignment instructions, in addition to a run-down on the circuits used. The parts list has a description of the part, rather than just a manufacturer's number. With an instruction book like this a ham has a chance to understand his rig, and has the information on hand for servicing it. It is good to know someone still feels the amateur is capable of understanding and repairing his own equipment. — *W1KLK*

Swan 350 Transceiver

Height: 5½ inches.
Width: 13 inches
Depth: 11 inches
Weight: 17 pounds
Power Requirements: 12.6 volts, 5.5 amps., a.c. or d.c.; 12 volts d.c., 250 ma.; −110 volts d.c., 100 ma.; 275 volts d.c., 150 ma.; and 800 volts d.c., 500 ma.
Price Class: 350 transceiver, $400; a.c. power supply $85.

E. SUMMARY OF TRANSCEIVER TUBE COMMONALITY

	120/140	240	250	260	270	300B	350	350C	350D	400	500	500C	500CX	600R	600T	700CX	700/750
0D3	1	1															
0A2			1				1			1		1					
6AL5		1															
6AQ5				1	1	1											
6AU6		1															
6AV6					1	1			1								
6BA6	3	2															
6BE6		1								1							
6BN8			1				1	1		1	1	1	1			1	1
6BZ6	1			1	1								1	2		1	
6CB6		1							1								
6CB6A						1											1
6CW4*			*2/0														
6EW6			2				2	2		2	2	2	2			1	1
6FG6				1											1		
6GK6			2	1	1	1	2	2	1	2	2	2	2		1	2	2
6GW8									1								
6HA5			*1/2														
6JH8			1	1	1	1		1			1		1		1	1	
7360	1	1					1			1		1					
6U8A		1															
6V6GTA	1	1															
12AQ5																	
12AU6	1				1	1											
12AU7/A	1	1															
12AV6	1													2			
12AX7	1	1	2	1	2	2	2	2	2	2	2	2	2	1	1	2	2
12BA6			3	4	3	3	2	2	3	3	2	3	1	2	1	2	2
12BE6	2	1	1	2	2	2	2	2	2	2	2	2	2		1	2	2
12BY7	1	1															
12BZ6							1	1		1	1	1			1		
6DQ5	1	1															
6HF5							2			2							
6KD6															2		
6LQ6				1	1			2			2	2	2				
6MJ6									1								2
6146B			2														
8950						1										2	
Total	*15*	*15*	**18/16*	*12*	*14*	*14*	*16*	*15*	*12*	*17*	*15*	*17*	*14*	*7*	*9*	*14*	*13*

* Tube count dependent on model version (comment also applies to other models not specifically identified).

F. USER NOTES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
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	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
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G. TENETS OF OPERATION AND MAINTENANCE

TEN TENETS OF SWAN OPERATION

1. Allow a warm-up period of at least 15 minutes; drift is normal & part of the "charm" of tube rigs.

2. Use a fan to cool the P.A. Tubes, especially during CW or AM operation.

3. Place a control knob on the bias control to make it easier to locate & adjust.

4. Set bias to the proper cathode current, compensating for any mechanical meter zeroing error.

5. Tune to near the max RF power using a wattmeter, being sure not to load beyond the max power point.

6. Tune-up quickly, using 5 seconds periods. Close PLATE & LOAD adjustments are good enough.

7. Never significantly light-load or detune the GRID to obtain a very low RF power output level.

8. Don't overdrive the audio, adjust the mic gain for SSB peaks no higher than 1/3rd the tune-up current.

9. For AM operation, retune with large inter-band frequency changes & use a lower carrier power level.

10. For CW ops with a VOX installed, switch to CW mode & use the PTT/VOX to go between rcv/xmt.

TEN TENETS OF SWAN MAINTENANCE

1. Always disconnect ac power when working on a rig, waiting a few minutes for filter caps. to discharge.

2. Clean & burnish all relay contacts & Jones connectors as part of routine maintenance.

3. If a rig has been unused for years, power up with a Variac over a multi-hour time period.

4. As a preventive measure, replace all power supply electrolytic caps. and diodes (use 1 amp, 1,000 v).

5. Use a 6 amp slow blow fuse in the 117XC power supply & connect a braid to the transceiver & ground.

6. Make sure 6GK6 driver tube replacements do not have an internal connection to pin 6.

7. When replacing PA tubes, use matched pairs; preferably with grid-lead radiators (if available).

8. Always neutralize new P.A. tubes – don't be surprised if 10 meters is a little difficult!

9. Inspect wiring for loose connections & components for failure indications when working on the unit.

10. When making internal adjustments, always double check to ensure the correct control is being adjusted.

H. INDEX

The following index hopefully will be of assistance in locating specific information within the Compendium. It is a mixture of a classic book-style index and a more informal-style. In the former case, the item of interest is referenced only to a single or small number of pages that deal primarily with that topic. In the latter case, all occurrences to the item of interest, including incidental, are referenced. Thus; if one were interested in the 500C model transceiver, it turns out there are perhaps references on 25 or more pages, including, in additional to the section that specifically addresses that transceiver model, miscellaneous tables, case-studies, examples, etc. Obviously, with such a large number of multi-page references, it usefulness is severely diminished by the need to scan each in hopes of finding the information desired. For that reason, items such as transceiver model numbers, which have numerous references throughout the Compendium, are limited to just a single main page reference, while other terms, such as AB_1 Amplifier, which have a more limited number of occurrences, are all referenced.

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