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PROPRIETARY INFORMATION – WITHHOLD UNDER 10 CFR 2.390

10 CFR 50.90
10 CFR 2.390

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U.S. Nuclear Regulatory Commission
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Peach Bottom Atomic Power Stations, Units 2 and 3
Renewed Facility Operating License Nos. DPR-44 and DPR-56
NRC Docket Nos. 50-277 and 50-278

Subject: License Amendment Request - Expanded Actions for LEFM Conditions

Reference: (1) Exelon letter to the NRC, "Request for License Amendment Regarding Measurement Uncertainty Recapture Power Uprate," dated February 17, 2017 (ADAMS Accession No. ML17048A444)

(2) NRC letter to Exelon, "Peach Bottom Atomic Power Station, Units 2 and 3 – Issuance of Amendments Re: Measurement Uncertainty Recapture Power Uprate," dated November 15, 2017 (ML17286A013)

In accordance with 10 CFR 50.90, "Application for amendment of license or construction permit," Exelon Generation Company, LLC (EGC) requests an amendment to Renewed Facility Operating License (RFOL) Nos. DPR-44 and DPR-56 for Peach Bottom Atomic Power Station (PBAPS), Units 2 and 3, respectively, for off-normal conditions of the Leading Edge Flow Meter (LEFM) ✓+ (CheckPlus) system. The Measurement Uncertainty Recapture (MUR) License Amendment Request (LAR) (Reference 1) submitted by EGC for an increase in licensed thermal power based upon the improved accuracy of the LEFM CheckPlus system was approved by the NRC with the issuance of the Final Safety Evaluation Report and RFOL Amendments 316 and 319 for PBAPS Units 2 and 3, respectively (Reference 2).

The LEFM CheckPlus system has been operational at PBAPS since 2002. The MUR LAR, as approved by the NRC, specified the actions to be taken in the event that one or more LEFMs degraded from the CheckPlus (NORMAL) to the Check (MAINTENANCE) or FAIL mode. Included among those approved actions was authorization to operate at a power level less than the maximum allowable licensed power but greater than pre-MUR level (referred to as an "Intermediate Power Level") when one or more of the LEFMs are in the Check mode.

Attachment 4 transmitted herewith contains Proprietary Information. When separated from Attachment 4, this document is decontrolled.

The proposed change requested herein would expand the number of Intermediate Power Levels from one to four. Specifically, it would establish three separate Intermediate Power Levels for the LEFM CheckPlus system conditions in which one, two or three LEFMs are in Check mode, with none in FAIL mode. A fourth Intermediate Power Level would be for the LEFM condition in which the flow measurement input to the core thermal power calculation for one of the three feedwater lines is from the differential pressure Feedwater (FW) flow nozzle measurement (venturi) as a result of the associated LEFM being in the FAIL mode or otherwise not available for service. The Intermediate Power Levels correspond to the total power uncertainties conservatively calculated for each of the LEFM conditions. The LEFM system installation at PBAPS is unique in that some of the equipment is not accessible during power operation and a degraded LEFM could require a reactor outage to make repairs. This LAR would allow operation at power levels commensurate with the uncertainties in the measurement of core thermal power.

The proposed changes have been reviewed by the PBAPS Plant Operations Review Committee in accordance with the requirements of the EGC Quality Assurance Program.

EGC requests approval of the proposed changes by June 30, 2019.

In accordance with 10 CFR 50.91, "Notice for public comment; State consultation," paragraph (b), EGC is notifying the Commonwealth of Pennsylvania and the State of Maryland of this application for license amendment by transmitting a copy of this letter and its attachments to the designated State Officials.

Attachment 1 contains an evaluation of the proposed changes including an assessment of how implementation will adhere to the principles of simple decision making for the operator and conservative plant operation.

Attachment 2 contains markups of the proposed Technical Requirements Manual Section 3.20 and the associated Bases (for information only), governing the maximum allowed power levels when any of the LEFMs are in other than the CheckPlus mode.

Attachment 3 provides the EGC PBAPS uncertainty calculation for the FW flow nozzle.

Attachment 4 provides the Cameron Total Power Uncertainty calculations for the three Check mode LEFM conditions. It also combines the FW flow nozzle uncertainty calculated in Attachment 3 with the LEFM uncertainties to determine the Total Power Uncertainty when the flow measurement input for one feedwater line is from the FW flow nozzle.

Attachment 4 provides a proprietary version of the Cameron calculations, ER-464P, "Uncertainty Analysis for Thermal Power Determination at Peach Bottom Unit 2 Using the LEFM ✓+ System," Revision 9, and ER-463P," Uncertainty Analysis for Thermal Power Determination at Peach Bottom Unit 3 Using the LEFM ✓+ System," Revision 8. Attachment 5 provides two affidavits executed by Cameron for withholding certain information contained in Attachment 4.

Attachment 6 provides a non-proprietary version of Attachment 4. In accordance with 10 CFR 2.390, "Public inspections, exemptions, requests for withholding," EGC requests withholding of Attachment 4.

Should you have any questions concerning this request, please contact Mr. David Neff at (267) 533-1132.

I declare under penalty of perjury that the foregoing is true and correct. Executed on the 27th day of August 2018.

Respectfully,

D. P. Helker

David P. Helker
Manager – Licensing & Regulatory Affairs
Exelon Generation Company, LLC

Attachments:

1. Evaluation of Proposed Changes
2. Markup of Proposed Technical Requirements Manual and Bases Pages (For Information Only)
3. Exelon Calculation PM-1209 Revision 0, "Peach Bottom Feedwater Flow Uncertainty as Measured in the Plant Computer as Measured by the Flow Nozzles Without Calibration by the LEFM"
4. Cameron ER-464P, " Uncertainty Analysis for Thermal Power Determination at Peach Bottom Unit 2 Using the LEFM ✓+ System," Revision 9 (Proprietary Version), and ER-463P," Uncertainty Analysis for Thermal Power Determination at Peach Bottom Unit 3 Using the LEFM ✓+ System," Revision 8 (Proprietary Version)
5. Cameron Affidavit Supporting Withholding Attachment 4 from Public Disclosure
6. Cameron ER-464NP, " Uncertainty Analysis for Thermal Power Determination at Peach Bottom Unit 2 Using the LEFM ✓+ System," Revision 9 (Non-Proprietary Version), and ER-463NP, " Uncertainty Analysis for Thermal Power Determination at Peach Bottom Unit 3 Using the LEFM ✓+ System," Revision 8 (Non-Proprietary Version)

cc: USNRC Region I, Regional Administrator
USNRC Senior Resident Inspector, PBAPS
USNRC Project Manager, PBAPS
R. R. Janati, Pennsylvania Bureau of Radiation Protection
D. A. Tancabel, State of Maryland

1.0 SUMMARY DESCRIPTION

In February 2017, Exelon Generation Company, LLC (EGC) submitted a Measurement Uncertainty Recapture (MUR) License Amendment Request (LAR) (Reference 1) to revise the Operating License and Technical Specifications (TS) for the Peach Bottom Atomic Power Station (PBAPS) Renewed Facility Operating License (RFOL) Nos. DPR-44 and DPR-56. The 2017 MUR LAR resulted in an increase of 65 megawatts thermal (MWt, approximately 1.66% increase) in rated thermal power (RTP) from 3951 MWt to 4016 MWt. This request was based on the increased accuracy of the Cameron Holding Corporation (hereinafter "Cameron") ✓+ (CheckPlus) Leading Edge Flow Meter (LEFM) ultrasonic feedwater flow measurement instrumentation relative to the feedwater (FW) flow nozzle differential pressure measurement (venturi or venturi meter) when used in the calculation of reactor core thermal power (CTP). The Cameron LEFM system has two operating modes (CheckPlus and Check); and an inoperable mode (Fail). The NRC issued a Safety Evaluation Report (SER) and approved the requested changes on November 15, 2017, with issuance of RFOL Amendments 316 and 319 for PBAPS Units 2 and 3, respectively (Reference 2). These amendments included authorization to operate at a power level of ≤ 4010 MWt after a Technical Requirements Manual (TRM) Required Compensatory Measures Completion Time of 72 hours if one or more LEFMs remain in the Check mode and no LEFMs are in the Fail mode. Following successful power ascension testing, PBAPS Units 2 and 3 achieved the new licensed power level in January 2018.

The LEFM system has been the primary means of FW flow measurement since its installation following implementation of the initial MUR License Amendments 247 and 250 (Reference 3) in 2003. The licensing basis analyses performed for the Extended Power Uprate (EPU) license amendments received in 2014 (Reference 4) did not incorporate a MUR uprate using the improved accuracy of the LEFM system. Therefore, operation at EPU power levels did not include an MUR uprate or restrictions regarding the status of the LEFM system.

The NRC's Safety Evaluation of Cameron Topical Report ER-157P, Revision 8 (Reference 5) requires that, 1) for any single component failure to the LEFM CheckPlus system, continued operation at the pre-failure power level for a pre-determined time and 2) the decrease in core thermal power that must occur following the pre-determined time are plant-specific and must be justified. Accordingly, the 2017 MUR LAR provided the PBAPS plant-specific justification for 1) continued operation at the MUR uprate power level (i.e., ≤ 4016 MWt) for up to 72 hours after one, two or three LEFM(s) degraded to either the Check or the Fail mode and 2) to decrease power level to ≤ 4010 MWt if one or more LEFMs remain in the Check mode for greater than 72 hours and none are in Fail mode.

Since implementation of the MUR in 2018, the required compensatory measure if an LEFM changes from the CheckPlus to the Check or Fail mode or is otherwise taken out of service is to switch the FW flow input for the CTP calculation from the affected LEFM(s) to the associated FW line's nozzle within two hours. If any LEFM is in the Fail mode by the end of the TRM Required Compensatory Measures Completion Time, power must be reduced by 65 MWt to the pre-MUR licensed level of ≤ 3951 MWt.

The LEFM acoustic transducers and cabling are located in the main steam tunnel where the radiation dose rate levels are elevated. This area is a Locked High Radiation Area and inaccessible during normal plant operation. If any of the LEFM components located in the steam tunnel cause the LEFM to be in Fail mode, reactor power is limited to ≤ 3951 MWt until the plant is shut down to identify and correct the problem. This installation configuration is unique to PBAPS. The standard LEFM acoustic transducer installation and associated LEFM system equipment is normally installed in plant areas that are accessible during power operations.

The current Maximum Allowable Power Level (MAPL) TRM limit of ≤ 4010 MWt when one or more LEFMs are in Check mode and none in Fail mode is based on the Cameron calculations in ER-464/463 Revision 5 (Attachment 1 of Reference 12) which assume that all three LEFMs are in Check mode. The compensatory measures and the intermediate power level for this condition were implemented by a revision to the TRM in January 2018.

This LAR provides the plant-specific analyses to support the proposed compensatory measures for operation of the LEFM system at three separate intermediate power levels for an indefinite period when the mass flow input to the CTP calculation is from one, two or three FW lines in Check mode with none in Fail mode; and a fourth intermediate power level when not more than one LEFM is in Fail mode and flow measurement is being provided by the associated FW flow nozzle. The proposed changes would allow operation at power levels commensurate with the uncertainties in the measurement of core thermal power and reduce the magnitude of the required reactivity maneuver and plant power level change for degradation of the LEFM system.

Since the proposed intermediate MAPL limits are based on total power uncertainties (TPUs) calculated at the same 95% confidence levels as the current MAPL limits, the probability of exceeding the thermal power level for which the Emergency Core Cooling Systems have been analyzed in accordance with 10 CFR 50, Appendix K, remains very low.

The LEFM flow measurement uncertainties are based on the same calculation methodology used to support the MUR LAR (Reference 1, Attachment 8 and Reference 12, Attachment 1). In this LAR, EGC is proposing that credit be taken for the lower uncertainties calculated for the condition when only one or two LEFMS are in the Check mode with none in Fail mode rather than considering that all are in Check mode. Similarly, the calculation of the TPU for the condition in which one LEFM is in Fail mode is based on the LEFM Check mode uncertainties calculated for the MUR LAR combined with the FW flow nozzle uncertainty calculated for this LAR (Attachment 3).

The Cameron calculations supporting the LEFM FW flow uncertainties, which the four intermediate power levels are based upon, are provided in Attachment 4. The Cameron calculations use the methodology documented in NRC approved Cameron Topical Report ER-157P-A Revision 8 (Reference 5) and the PBAPS MUR Amendments 316 and 319 (Reference 2).

The calculation for the uncertainty associated with the measurement of FW flow by the FW flow nozzle is provided in Attachment 3 and is based on the instrument setpoint uncertainty calculation methodology described in American Society of Mechanical Engineers (ASME) PTC 6 Report (Reference 11).

The TPU for each of the LEFM operating conditions is determined using the square-root-sum-of-squares (SRSS) approach which is the industry accepted method for combining instrument accuracies. The MAPL for each of the four proposed intermediate LEFM operating conditions is then determined by the following equation:

$$MAPL \leq 4030 \text{ MWt} / (1+\varepsilon), \text{ where}$$

4030 MWt is 102% of pre-MUR licensed power level of 3951 MWt and

ε = TPU for a particular condition

The proposed compensatory measures and intermediate power levels differ from those approved by the NRC's SER for the MUR LAR, although the LEFM uncertainty and TPUs supporting this LAR are consistent with Cameron Topical Report ER-157P-A Revision 8 (Reference 5). The topical report, however, did not consider using the uncertainty associated with FW flow nozzle as an input to a TPU calculation. EGC therefore concluded that NRC pre-approval in the form of a license amendment is required.

2.0 DETAILED DESCRIPTION

The changes to the MAPLs associated with each of the LEFM conditions are described in Section 2.2. If approved, they will be incorporated into a revision to TRM Section 3.20 as shown by the marked-up pages provided in Attachment 2. No changes are required to the Operating Licenses or to the TS by this LAR.

2.1 PBAPS LEFM System

The PBAPS LEFM System consists of three LEFMs, one on each of the three FW lines. Each LEFM contains two independent subsystems or planes with each plane containing four acoustic paths. The LEFM system has two operating modes (CheckPlus and Check) and an inoperable mode (Fail). In the CheckPlus mode (also described in this LAR as the Normal mode), both planes of transducers are in service. If an LEFM is subjected to a failure involving a transducer on one plane of operation, that LEFM reverts to the Check mode (also described in this LAR as the Maintenance mode). The flow data from an LEFM with a single functioning plane (Check mode) has greater associated measurement uncertainty than that from an LEFM with both planes functioning, but less associated measurement uncertainty than that from a FW flow nozzle.

Conditions for operation, required actions, and completion times for the LEFM system are currently contained in TRM Section 3.20, "Leading Edge Flow Meter (LEFM) System." In accordance with PBAPS Updated Final Safety Analysis Report (UFSAR), Section 13.6.8, "Requirements Relocated Out of Technical Specifications," the TRM is a licensee-controlled procedure described in the UFSAR and therefore, changes to the TRM are subject to the requirements of 10 CFR 50.59, "Changes, tests, and experiments." As such, changes to the LEFM TRM are controlled under the provisions of 10 CFR 50.59.

2.2 Current LEFM Compensatory Measures

The LEFM status is determined and reported by the LEFM System computer based upon the number of functional planes in the LEFM and the data quality. If one or more LEFMs go into the Check mode with none in Fail mode, operators must switch flow input to the CTP calculation from the LEFM(s) that are not in CheckPlus mode to the associated calibrated FW flow nozzle within two hours. By the end of the 72-hour TRM Required Compensatory Measures Completion Time, either all LEFMs must be restored to the CheckPlus mode with all flow input to the CTP calculation from the LEFMs or MAPL must be reduced to ≤ 4010 MWt.

If one or more LEFM FW flow nozzle(s) reverts to the Fail mode or is not providing flow input to the CTP calculation, flow measurement from that FW line must be transferred to its calibrated FW flow nozzle within two hours. A FW flow nozzle is considered calibrated when a venturi correction factor (VCF) is applied to the FW flow nozzle measurement in accordance with station procedures. The VCF is the ratio of the flow measurement from the LEFM in CheckPlus mode to that of the associated FW flow nozzle. Under the current requirements, power must then be reduced to the pre-MUR level of ≤ 3951 MWt before the end of the 72-hour TRM Required Compensatory Measures Completion Time if all of the LEFMs have not been restored to either the CheckPlus or Check mode.

If an LEFM changes to a status other than CheckPlus after a TRM condition has been entered for that LEFM (i.e., mode status changes from Check to Fail or Fail to Check), then the completion times for the new required compensatory measures of the applicable TRM condition(s) must be completed based on a start time corresponding to initial entry into the TRM condition.

As stated above, repair of an LEFM that degrades to the Maintenance or Fail mode may have to be delayed until the next refueling outage or require an unscheduled plant shutdown due to the high radiation levels during power operation in the vicinity of the spool pieces containing the flow measurement transducers and cabling.

2.3 Proposed Changes to the LEFM Compensatory Measures for LEFMs in Check

The proposed changes would expand the number of intermediate power levels from one to four. The intermediate power levels correspond to the total power uncertainties (TPUs) conservatively calculated for each of the LEFM system meter conditions. The existing LEFM System TRM Section 3.20 would be revised to include the proposed changes to the Conditions, Required Compensatory Measures and Completion Times. Except for the specific LEFM condition and the interim power levels, the TRM actions and completion times are the same as currently contained in the NRC approved TRM. The LEFM status and proposed maximum interim power levels are described below:

1. Three separate intermediate power levels for the LEFM system meter conditions in which one, two, or three LEFMs are in Maintenance mode, with none in Fail mode.

2. A fourth intermediate power level is for one LEFM in the Fail mode with the other two LEFMs in Normal or Maintenance mode. The FW line FW flow nozzle is then used for the LEFM in Fail mode as the input to the core thermal power calculation.

2.4 Proposed Changes to the LEFM Compensatory Measures for One LEFM in Fail

As with the current LEFM TRM Section 3.20 Required Compensatory Measures and Completion Times, the proposed changes in this LAR require that the FW flow signal from an LEFM that changes from CheckPlus to Check or Fail mode be switched to its associated calibrated FW flow nozzle within two hours.

As with the current LEFM TRM Section 3.20 Required Compensatory Measures and Completion Times, the proposed changes in this LAR require that, when one or more LEFMs are in Check mode with none in Fail mode by the end of the TRM Required Compensatory Measures Completion Time, flow input to the CTP calculation must be switched back to the LEFM and power reduced to the prescribed MAPL. For this LAR, two interim power levels are proposed for one and two LEFMs in the Check Mode based on the TPU for that condition as shown in the table below.

If one LEFM goes into Fail mode or is otherwise not providing flow input to the CTP calculation, and has not been restored to CheckPlus or Check mode by the end of the TRM Required Compensatory Measures Completion Time, power must be reduced to the MAPL commensurate with the TPU for the one LEFM in Fail mode condition shown in the table. If the affected LEFM is restored to the Check mode, power must be reduced to the MAPL appropriate to the LEFM operating condition (i.e., one, two, or three in Check mode with none in Fail mode) shown in the table below.

If this LAR is approved, the MAPLs for the various LEFM operating conditions shown in the table below will be incorporated into a revision to TRM Section 3.20 as provided in Attachment 2.

LEFM OPERATING CONDITION	TPU	MAPL (MWt)	Existing or New TRM Condition
All LEFMs in CheckPlus mode	0.34%	4016	Existing
One LEFM in Check mode; none in Fail mode	0.37%	4015	New
Two LEFMs in Check mode; none in Fail mode	0.43%	4012	New
Three LEFMs in Check mode	0.51%	4009	New
One LEFM in Fail mode with the other two LEFMs in CheckPlus or Check mode, flow measurement by associated FW flow nozzle	1.19%	3982	New
Two or three LEFM's in Fail mode	2%[1]	3951	Existing

3.0 TECHNICAL EVALUATION

3.1 Background

PBAPS Units 2 and 3 have received the following license amendments authorizing increases in licensed CTP:

- In 1994 and 1995, Amendments 198 and 211 to the Units 2 and 3 operating licenses, respectively, authorized a stretch power uprate of 5% from OLTP of 3293 MWt to 3458 MWt
- In 2002, Amendments 247 and 250 to the Units 2 and 3 operating licenses, respectively, authorized an MUR uprate from 3458 MWt to 3514 MWt based on the reduced uncertainty in feedwater flow measurement using the installed LEFM systems (Reference 3).
- In 2014, Amendments 293 and 296 to the Units 2 and 3 RFOLs authorized an EPU increasing power from 3514 MWt to 3951 MWt (Reference 4).
- In 2017, Amendments 316 and 319 to the Units 2 and 3 RFOLs, respectively, authorized an MUR uprate from 3951 MWt to 4016 MWt based on the reduced uncertainty in feedwater flow measurement using the installed LEFM systems (Reference 2).

[1] To comply with 10 CFR 50 Appendix K analysis.

3.2 General Approach

The uncertainties associated with the LEFM operating conditions shown above are calculated as follows:

- The uncertainty calculated for the condition in which feedwater flow on one of the three feedwater lines is being measured by the FW flow nozzle conservatively assumes that the LEFMs on the other two feedwater lines are in Check mode.

- Calculation of the feedwater mass flow uncertainty for a line being measured by the FW flow nozzle assumes that the instrument loop has not been calibrated by the LEFM (i.e., VCF = 1.000).

- The methodology used to calculate the loop uncertainty for the FW flow nozzle is based on EGC-accepted PBAPS plant setpoint methodology. In accordance with this methodology, independent error terms are combined via square root sum of the squares (SRSS) and taken to 2σ or a 95% confidence level. Dependent errors are combined according to their dependency relationships and the biases algebraically summed. ASME PTC-6 (Reference 11) is used to determine the error in the FW flow nozzles because it provides a conservative means to quantify the FW flow nozzle uncertainties, and it takes into account the upstream and downstream flow disturbances due to piping configurations.

- The methodology for the calculation of the feedwater mass flow uncertainty as measured by an LEFM in Check mode is the same as that performed for the MUR LAR (Reference 1) and is consistent with the methodology of Cameron Topical Report ER-157P-A Revision 8 (Reference 5).

- Where PBAPS Units 2 and 3 plant specific data is used, the most conservative value from each Unit is used in the Uncertainty Analysis for thermal power determination.

- The total feedwater mass flow uncertainty is calculated by combining the results for the LEFM and the FW flow nozzle uncertainties as appropriate for each LEFM operating condition using SRSS methodology consistent with ER-157P-A Revision 8.

- The TPU for each LEFM operating condition is calculated by combining the feedwater mass flow uncertainty with other plant specific terms (steam enthalpy, moisture carryover, etc.) using SRSS methodology consistent with ER-157P-A Revision 8.

The TPU calculation (Attachment 4) differs from the methodology described in Cameron Topical Report ER-157P-A Revision 8 (Reference 5) only for the LEFM operating condition in which the flow input to the CTP for one of the FW lines is being measured by the FW flow nozzle.

The inputs and assumptions for the TPU calculation for the LEFM System condition of three LEFMs in the Check Mode are the same as those used in the TPU calculation for the MUR LAR submitted in 2017 (Reference 1, Attachment 8, Appendix B-1), except for the Time Measurement, Item 8, Non-Fluid Delay (Refer to this LAR Attachment 4, Appendix B-2). This uncertainty parameter increased slightly (i.e., from 0.50% to 0.51%) due to a change that corrected an error in the previous revision of the uncertainty calculation. The total uncertainty in the time spent by ultrasonic pulses in a non-fluid media for a single meter is made up of a random component and a systematic component that are root sum squared together (Refer to Reference 1 Attachment 8 Appendix A.5 and this LAR Attachment 4, Appendix A.5). When calculating the impact across multiple meters, the random portion of the term is divided by the square root of the number of meters (i.e., for PBAPS = sqrt(3)) because not only is it random within the meter, but also between meters. The effect of the systematic term though cannot be decreased in this manner and should remain constant even when considering multiple loops. The earlier LEFM calculation (Reference 1 Attachment 8, Appendix B-1) combined both the random and systematic terms and then divided that value by the sqrt(3) incorrectly. This has been corrected in the calculations provided in this LAR (Attachment 4, Appendix B-2).

Using the corrected Time Measurement values and the resulting TPU for three LEFMs in Check mode, the MAPL limit for TRM Required Compensatory Measure calculated value slightly decreased and due to rounding for conservatism, the proposed TRM MAPL limit is lowered from 4010 MWt to 4009 MWt. The Time Measurement parameter change is also used in the TPU calculations for the other LEFM system conditions described in this LAR. This correction was evaluated for impact on current LEFM TRM Required Compensatory Measure actions and appropriate corrective actions have been taken.

3.3 Plant Implementation

The revised compensatory measures will be incorporated into the existing TRM Section 3.20. Only minor changes to other existing procedures will be required. A description of the impact of the implementation of the proposed change with respect to operator decision making and conservative plant operation is provided in Section 3.4 Criterion 1 below.

3.4 Disposition of NRC Criteria for Use of LEFM Topical Reports

Attachment 1 to the MUR LAR (Reference 1) described how the nine criteria established by the NRC in References 7, 8 and 9 for licensees incorporating the LEFM methodology into the licensing basis are satisfied. The NRC approved this request in Amendments 316 and 319 (Reference 2) and specifically discussed in SER Section 3.5.4, “Thermal Power Measurement Uncertainty.” The paragraphs below confirm or update the disposition of these criteria at PBAPS as necessary for LEFM system conditions in which either one, two, or three LEFMs are in Check mode; and for the condition in which the FW flow input from one FW line to the CTP calculation is based on the associated FW flow nozzle.

<u>Criterion 1</u>

Discuss maintenance and calibration procedures that will be implemented with the incorporation of the LEFM, including processes and contingencies for inoperable LEFM instrumentation and the effect on thermal power measurements and plant operation.

Response to Criterion 1

Calibration and Maintenance

The proposed changes will not affect the calibration and maintenance procedures as described in the MUR LAR (Reference 1) for the LEFM system.

With respect to flow measurement by the FW flow nozzle, existing procedures require the calibration of the FW flow nozzle instrument loop every refueling outage. If measurement of FW flow is transferred from an LEFM to the FW flow nozzle, VCF is applied to the FW flow nozzle measurement. The VCF is based on inputs obtained within 24 hours from the time that the LEFM went into Check or Fail mode, or was otherwise removed from service. Operators in the main control room can assess the VCF displayed value which is updated continuously on the Plant Monitoring System (PMS) display. PBAPS Engineering performs a periodic comparison of the VCF value to established trends. These measures will ensure the accuracy of the CTP calculation while relying on feedwater flow measurement from the FW flow nozzle.

LEFM Inoperability

The disposition of Criterion 1, *LEFM Inoperability* contained in the MUR LAR is not changed by this LAR with the exception of the discussion of TRM Section 3.20 (5th paragraph of corresponding section in the MUR LAR) which is replaced by the discussion below.

As described in the following sections, the proposed changes to the compensatory measures requested in this LAR are consistent with the principles of simple decision making on the part of the control room operator and conservative plant operation.

Simple Decision Making

The range of decisions and actions facing the operator will not be fundamentally different or made more complex by the proposed changes than those on which PBAPS operators have been trained on and implemented since the LEFM system was commissioned in 2002. On-line, continuous monitoring of system parameters generates PMS alarms in the control room that immediately alert the operator to a change in status of an LEFM. The operators then execute existing procedure steps to calibrate the FW flow nozzle and switch the CTP calculation input to the FW flow nozzle. Then, if the LEFM is not restored to NORMAL status, the operators must reduce power by 1 to 34 MWt, depending on the LEFM malfunction, by lowering reactor recirculation flow within 72 hours of the initial failure. Additionally, for an LEFM retained in the Maintenance mode, operators must re-align the associated FW flow nozzle measurement input to the plant CTP calculation back to the LEFM by the end of the 72-hour TRM Completion Time period using similar PMS computer input actions.

If for some reason it is not possible to calibrate the FW flow nozzle to its associated LEFM (e.g., a valid Venturi Correction Factor cannot be obtained), the proposed Required Compensatory Measures B.1.1, D.1.1, and F.1 require that power be reduced to a level supported by the uncertainty analysis after two hours. These power levels are specified in TRM Table 3.20-1 for LEFM(s) in the Check mode, or directly in the Compensatory Measures for an LEFM in the Fail mode. Operators would reduce reactor power by lowering reactor recirculation flow using existing reactor power control procedure actions. Operator actions per this TRM are consistent with existing TS actions.

There are no new alarms or operator actions and no changes to operator response times introduced due to this TRM change. A minor revision to existing operating procedures will be made to reflect the new intermediate power levels. Swapping CTP inputs between the LEFM and the FW flow nozzle is a task performed several times a year using a procedure that has been in place since the installation of the LEFMs in 2002.

Because the proposed revision to TRM 3.20 has only a minor impact on existing operating procedures by adding intermediate power levels for when LEFM(s) enter non-Normal statuses, the revision will only have a minor impact on human factors in the areas of human performance and operator training. No additional training (apart from normal training for plant procedure changes) is required to operate the plant due to this TRM revision. The actions for communicating the TRM and procedure changes to the operators will be tracked using the existing Exelon configuration change control process.

A Human Factors Engineering (HFE) evaluation was performed using the guidance in NUREG 1764, "Guidance for the Review of Changes to Human Actions," Revision 1. The HFE determined the following key conclusions:

- Operator actions as they relate to monitoring reactor power via the calorimetric heat balance are not risk significant.
- All operator actions including monitoring, adjusting CTP input parameters, and reducing power as required, have a high probability of success and do not result in the likelihood of undiscovered failures.
- None of the operator actions required by the proposed change are included in Appendix A of NUREG-1764 Revision 1 as "Generic Human Actions that are Risk-Important" for BWRs.
- The proposal does not change operator actions on systems that are of high or moderate risk-importance.
- No changes are involved with the proposed LAR that would require additional reviews for Personnel Functions and Tasks, Design Support for Task Performance or Performance Shaping Factors.
- The proposed TRM change only needs a Level III HFE review.

The control room operator therefore faces a simple set of criteria in deciding what actions to take for an inoperable LEFM, has adequate time to take such actions, and will use existing procedures that have been in place for a substantial period of time.

Conservative plant operation

Conservative plant operation under the new proposed compensatory measures starts with the calculations of the LEFM, FW flow nozzle and total power uncertainties on which the proposed changes to the LEFM system compensatory measures are based. Use of NRC-approved and industry-accepted methodologies and conservative assumptions will provide margin to ensure that the plants will not operate above the licensed thermal power. Plant monitoring instrumentation and procedures will verify that the assumptions underlying the uncertainty calculations remain valid.

The calculations of LEFM uncertainty use the same methodology as in the MUR LAR and are consistent with ER-157P-A Revision 8. Since there is some variation in the calculated LEFM uncertainties for each unit, the uncertainty values from the most limiting meter are applied to all of the LEFM meters. Another element of the conservatism in the LEFM uncertainty calculation is in the assumption made for plane balance variability (PBV). Plane balance refers to the ratio of the FW flow velocities as measured by each of the two planes of transducers in an LEFM CheckPlus system. Uncentered vortex and axial motions known as swirl can cause cross velocities which affect the accuracy of the measurement of feedwater mass flow from each plane and thereby change the plane balance. When operating in the CheckPlus mode, the LEFM flow measurement system will, by design, cancel out the cross velocities impacting each plane and they therefore do not contribute uncertainty to flow measurement. However, during operation in the Check mode, with only one plane of transducers, the uncancelled cross velocities must be considered in the determination of the LEFM uncertainty. Although recent plant-specific operating data indicates an uncertainty attributed to PBV of only 0.19% at a 2σ confidence level, the LEFM uncertainty calculations supporting this LAR (Attachment 4) which, as stated above are the same as those approved by the NRC for the MUR LAR, apply a PBV uncertainty of 0.35%.

The calculation of the flow measurement error for the FW flow nozzle (Attachment 3) uses the ASME PTC-6 Report 1985 (Reference 11) methodology to determine the error in the FW flow nozzle, including upstream and downstream disturbances. FW flow nozzle instrument loop uncertainty is based on EGC setpoint methodology in which independent error terms are combined via SRSS and taken to a 2σ or a 95% confidence level, and dependent errors are combined according to their dependency relationships and biases algebraically summed. The calculation for FW mass flow uncertainty as measured by the FW flow nozzle also assumes that it has not been calibrated to its associated LEFM which assumes a conservative uncertainty as further discussed below.

The TPU calculations which combine the LEFM and FW flow nozzle measurement uncertainties for each of the four intermediate MAPL limits also account for other plant-specific terms along with the FW mass flow uncertainty and combine these terms using SRSS methodology of ASME PTC 19.1 (Reference 10) consistent with ER-157P-A Revision 8.

The accuracy of CTP measurement with flow input from one FW flow nozzle can be maintained indefinitely, if necessary. The feedwater flow process is calibrated every refueling outage. Changes in FW flow nozzle differential pressure for a particular flow are usually due to fouling or erosion which occur over long periods. LEFM to FW flow nozzle measurement ratios are constantly updated in the plant process computer and nightly checks are made to ensure predetermined limits are not exceeded. Any slight drift of the FW flow nozzle measurements while operating at the proposed new intermediate point due to FW flow nozzle fouling would result in a higher than actual indication of feedwater flow and an overestimation of the calculated calorimetric power level. A sudden de-fouling event while on the FW flow nozzle is unlikely and any significant sudden de-fouling would be detected by other plant parameters.

Criterion 2

For plants that currently have LEFMs installed, provide an evaluation of the operational and maintenance history of the installed installation and confirmation that the installed instrumentation is representative of the LEFM system and bounds the analysis and assumptions set forth in Topical Report ER-80P.

Response to Criterion 2

As stated in the MUR LAR, the PBAPS LEFM system installed instrumentation is representative of and bounded by the analysis and assumptions set forth in Topical Report ER-80P (Reference 6).

A review of the maintenance history of the LEFM system since January 2011 indicates the LEFM system continues to be highly reliable. During the period, no LEFMs were in the Fail mode. The LEFM system continued to be used for the FW flow measurement input but the improved uncertainty was not used between implementation of the EPU and MUR amendments. TRM actions for degraded LEFMs were re-instituted with implementation of the MUR amendment in January 2018. Since implementation of the MUR amendments, there were no instances on Unit 3 and one instance on Unit 2 when an LEFM was in the Check mode requiring MAPL reduction. In this instance, Unit 2 power was reduced to 4010 MWt in accordance with the TRM requirements. The Unit 2, Meter 1 transducer coupling has become degraded and has resulted in this LEFM entering the Check mode several times for short periods of time. A forced outage is required to troubleshoot and repair this LEFM.

EGC continues to follow an LEFM system preventive maintenance program based on vendor recommendations, industry lessons learned and performance data reviews. Transducers and LEFM electronics are replaced as determined to be necessary by a review of the equipment's operational history by the LEFM system vendor.

Criterion 3

Confirm that the methodology used to calculate the uncertainty of the LEFM in comparison to the current feedwater instrumentation is based on the accepted plant setpoint methodology (with regard to the development of instrument uncertainty). If an alternative approach is used, the application should be justified and applied to both venturi and ultrasonic flow measurement instrumentation installations for comparison.

Response to Criterion 3

The LEFM system uncertainty calculation methodology continues to be based on EGC-accepted PBAPS plant setpoint methodology as described in Attachment 1 to the MUR LAR. The calculation of the FW flow nozzle uncertainty is also based on EGC-accepted PBAPS plant setpoint methodology.

The methodology for combining the FW flow nozzle and LEFM uncertainties to determine the total mass flow uncertainty, and then combining this with other plant–specific parameters (steam enthalpy, moisture carry-over, etc.) to calculate the TPU is based on the methodology described in the ASME PTC 19.1 methodology (Reference 10).

Criterion 4

For plants where the ultrasonic meter (including LEFM) was not installed with flow elements calibrated to a site-specific piping configuration (i.e., flow profiles and meter factors not representative of the plant specific installation), additional justification should be provided for its use. The justification should show that the meter installation is either independent of the plant specific flow profile for the stated accuracy, or that the installation can be shown to be equivalent to known calibrations and plant configurations for the specific installation including the propagation of flow profile effects at higher Reynolds numbers. Additionally, for previously installed calibrated elements, confirm that the piping configuration remains bounding for the original LEFM installation and calibration assumptions.

Response to Criterion 4

Disposition of this Criterion is not changed by this LAR from that provided in Attachment 1 to the MUR LAR as reviewed and approved by the NRC.

Criterion 5

Justification for continued operation at the pre-failure level for a pre-determined time and the decrease in power that must occur following that time are plant-specific and must be acceptably justified.

Response to Criterion 5

Justification for continued operation at ≤ 4016 MWt for up to 72 hours with one or more LEFMs either in Fail or in Check mode is not changed from that provided in Attachment 1 to the MUR LAR as reviewed and approved by the NRC.

Justification for the required decreases in power by the end of the TRM Required Compensatory Measures Completion Time for each of the proposed intermediate LEFM conditions is provided in the response to Criterion 1 above.

Criterion 6

A CheckPlus operating with a single failure is not the same as an LEFM Check. Although the effect on hydraulic behavior is expected to be negligible, this must be acceptably quantified if a licensee wishes to operate using the degraded CheckPlus at a degraded uncertainty.

Response to Criterion 6

Disposition of this Criterion is not changed by this LAR from that provided in Attachment 1 to the MUR LAR as reviewed and approved by the NRC (Reference 2).

Criterion 7

An applicant with a comparable geometry can reference the above Section 3.2.1 finding [of the Final NRC Safety Evaluation for Caldon Topical Report ER-157P Rev 8] *to support a conclusion that downstream geometry does not have a significant influence on CheckPlus calibration. However, CheckPlus results do not apply to a Check and downstream effects with use of a CheckPlus with disabled components that make the*

CheckPlus comparable to a Check must be addressed. An acceptable method is to conduct applicable Alden Laboratory tests.

Response to Criterion 7

Disposition of this Criterion is not changed by this LAR from that provided in Attachment 1 to the MUR LAR as reviewed and approved by the NRC (Reference 2).

Criterion 8

An applicant that requests an MUR with the upstream flow straightener configuration discussed in Section 3.2.2 [of the Final NRC Safety Evaluation for Caldon Topical Report ER-157P Rev 8] *should provide justification for claimed CheckPlus uncertainty that extends the justification provided in Reference 17. Since the Reference 17 evaluation does not apply to the Check, a comparable evaluation must be accomplished if a Check is to be installed downstream of a tubular flow straightener*.

Response to Criterion 8

Disposition of this Criterion is not changed by this LAR from that provided in Attachment 1 to the MUR LAR as reviewed and approved by the NRC (Reference 2).

Criterion 9

An applicant assuming large uncertainties in steam moisture content should have an engineering basis for the distribution of uncertainties or, alternatively, should ensure that their calculations provide margin sufficient to cover the differences shown in Figure 1 of Reference 18.

Response to Criterion 9

Disposition of this Criterion is not changed by this LAR from that provided in Attachment 1 to the MUR LAR as reviewed and approved by the NRC (Reference 2).

3.5 Deficiencies and Corrective Actions

The handling of any problems, performance or reliability issues with the LEFMs as reported in the MUR LAR is not changed by this LAR. Problems with plant instrumentation, including the LEFM system and FW flow nozzles are documented in the PBAPS corrective action program and necessary corrective actions are identified and implemented. Deficiencies associated with the vendor's processes or equipment are reported to the vendor to support corrective action.

3.6 Reactor Power Monitoring

PBAPS Unit 2 and Unit 3 have procedures that provide guidance for monitoring and controlling reactor power and ensuring that reactor power remains within the requirements of the operating license.

4.0 ADDITIONAL CONSIDERATIONS

4.1 Plant Modifications

No plant modifications are required.

4.2 Operator Training, Human Factors, and Procedures

Implementation of this LAR would only have a minor impact on human factors in the areas of operating procedure changes, operator training and operator human performance. Existing procedures will be modified to reflect the revised TRM Section 3.20 (Attachment 2). There are no changes to the control room, indications, alarms, computer displays or the simulator necessary to implement this LAR. Operators will be trained on implementation of the revised TRM Section 3.20 requirements in accordance with the PBAPS Licensed Operator Training program before implementation. The actions for communicating the TRM and procedure changes to the operators will be tracked using the existing EGC configuration change control process.

As discussed in Section 3.4 under Criterion 1, the proposed change will not impose any complex decision making requirements on the operators and only Level III HFE review is warranted.

4.3 Testing

No additional testing is necessary for implementation of this LAR.

5.0 REGULATORY EVALUATION

5.1 Applicable Regulatory Requirements/Criteria

10 CFR 50, Appendix K, “ECCS Evaluation Models,” requires that emergency core cooling system evaluation models assume that the reactor has been operating continuously at a power level at least 1.02 times the licensed power level to allow for instrumentation error. A change to this paragraph, which became effective on July 1, 2000, allows a lower assumed power level, provided the proposed value has been demonstrated to account for uncertainties due to power level instrumentation error.

The NRC issued a safety evaluation report (Reference 2) on the license amendment request (LAR) submitted by Exelon Generating Company, LLC (EGC) for a Measurement Uncertainty Recapture Power Uprate (Reference 1) and amended the PBAPS Units 2 and 3 operating licenses to allow an increase in maximum licensed thermal power based on a lower calculated uncertainty associated with the measurement of the feedwater flow input to the core thermal power (CTP) calculation from the LEFM system.

This application for a LAR approval is for a change to the compensatory measures for degraded LEFM conditions. The proposed changes would allow operation at power levels commensurate with the uncertainties in the measurement of CTP as calculated in Attachments 3 and 4 for conditions in which the flow from either one, two or three feedwater (FW) lines is being measured by LEFMs that have degraded from the CheckPlus to the Check mode with none in Fail mode as well as when one LEFM is in Fail mode or not providing flow input to CTP, with flow measurement provided by the associated FW flow nozzle.

This application is consistent with the requirements and criteria described in 10 CFR 50, Appendix K and 10 CFR 50.90.

5.2 Precedent

The NRC has approved an intermediate power level for a Check (Maintenance) mode for the following plants:

PLANT	LAR Accession No.	NRC SER Accession No.
PBAPS 2&3	ML17048A444	ML17286A013
Columbia	ML16183A365	ML17095A117
Turkey Point 3&4	ML103610319	ML11293A359
St. Lucie 1	ML103560429	ML12191A220
St. Lucie 2	ML110730341	ML12235A463
Shearon Harris	ML11356A096	ML11124A180
Prairie Island	ML093650061	ML102030573

In the Turkey Point and St. Lucie 1 and 2 safety evaluation reports, the NRC discussed simple decision making and conservative plant operation in the evaluation of the MUR requests. The PBAPS demonstration of compliance with these criteria is provided above in Section 3.4 in the response to Criterion 1.

5.3 No Significant Hazards Consideration

The NRC approved a license amendment request (LAR) by Exelon Generation Company, LLC (EGC) for a Measurement Uncertainty Recapture Power Uprate (Reference 1) and authorized an increase of 65 megawatts in maximum licensed thermal power from 3951 megawatts thermal (MWt) to 4016 MWt in Amendments 316 and 319 to the Peach Bottom Atomic Power Station (PBAPS) Unit 2 and Unit 3 Renewed Facility Operating License (RFOL), respectively. The approved license amendments were based on the increased accuracy of the Cameron Holding Corporation (hereinafter "Cameron") ✓+ (CheckPlus) Leading Edge Flow Meter (LEFM) ultrasonic flow measurement instrumentation relative to the feedwater (FW) flow nozzle (venturi meter) differential pressure measurement installed at PBAPS in the calculation of core thermal power (CTP).

In accordance with 10 CFR 50.90, "Application for Amendment of License, Construction Permit, or Early Site Permit," EGC is proposing that RFOL Nos. DPR 44 and DPR-56 for PBAPS Units 2 and 3, respectively, be amended to allow operation at power levels based on the uncertainties calculated for the measurement of CTP when either one, two or three LEFMs are operable but in a degraded condition (Check mode) with none inoperable; and when one LEFM is inoperable (Fail mode) or the flow input to the CTP calculation for one of the FW lines is from the associated FW flow nozzle. EGC has evaluated whether a significant hazards consideration is involved with the proposed changes in accordance with the three standards set forth in 10 CFR 50.92, "Issuance of Amendment," as discussed below.

1. Does the proposed change involve a significant increase in the probability or consequences of an accident previously evaluated?

Response: No, the proposed change does not significantly increase the probability or consequences of an accident previously evaluated.

The proposed change does not affect system design or operation and thus does not create any new accident initiators or increase the probability of an accident previously evaluated. Accident mitigation systems are not affected and will function as designed.

The proposed change does not increase the licensed thermal power level and will not cause the thermal power level at which the Emergency Core Cooling Systems have been analyzed in accordance with Appendix K to 10 CFR 50 to be exceeded. All safety analyses continue to be bounded by the safety analyses for the current licensed thermal power.

Therefore, the proposed change does not involve a significant increase in the probability or consequences of an accident previously evaluated.

2. Does the proposed change create the possibility of a new or different kind of accident from any accident previously evaluated?

Response: No, the proposed change does not create the possibility of a new or different kind of accident from any accident previously evaluated.

No new accident scenarios, failure mechanisms, or limiting single failures are introduced as a result of operation at power levels based on the uncertainties in the calculation of CTP for the stated LEFM system conditions. Calculation of the uncertainty associated with these plant conditions as well as existing plant instrumentation and procedures ensure that the licensed thermal power and the thermal power level at which the Emergency Core Cooling Systems have been analyzed in accordance with Appendix K to 10 CFR 50 will not be exceeded. No new equipment or procedure changes are involved that could add new accident initiators.

Therefore, the proposed change does not create the possibility of a new or different kind of accident from any accident previously evaluated.

3. Does the proposed change involve a significant reduction in a margin of safety?

Response: No, the proposed change does not involve a significant reduction in a margin of safety.

Operation at power levels based on the uncertainties in the calculation of CTP for the stated LEFM system conditions does not involve a significant reduction in a margin of safety. Calculation of the uncertainties associated with the measurement of core thermal power for these plant conditions as well as existing plant instrumentation and procedures ensure that the licensed thermal power and the thermal power level at which the Emergency Core Cooling Systems have been analyzed in accordance with Appendix K to 10 CFR 50 will not be exceeded.

Therefore, the proposed change does not involve a significant reduction in a margin of safety.

5.4 Conclusions

In conclusion, based on the considerations discussed above, (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) such activities will be conducted in compliance with the Commission's regulations, and (3) the issuance of the amendment will not be inimical to the common defense and security or the health and safety of the public.

Based on the above evaluation, EGC concludes that the proposed amendment presents no significant hazards consideration under the standards set forth in 10 CFR 50.92, paragraph (c), and accordingly, a finding of no significant hazards consideration is justified.

6.0 ENVIRONMENTAL CONSIDERATION

10 CFR 51.22, "Criterion for categorical exclusion; identification of licensing and regulatory actions eligible for categorical exclusions or otherwise not requiring environmental review," addresses requirements for submitting environmental assessments as part of licensing actions. 10 CFR 51.22, paragraph (c)(9) states that a categorical exclusion applies for Part 50 license amendments that meet the following criteria:

i. No significant hazards consideration (as defined in 10 CFR 50.92(c));

ii. No significant change in the types or significant increase in the amounts of any effluents that may be released offsite; and

iii. No significant increase in individual or cumulative occupational radiation exposure.

The proposed change does not involve a significant hazards consideration. No new accident scenarios, failure mechanisms, or limiting single failures are introduced as a result of the proposed change. Operation in accordance with the proposed license amendments will not involve a significant reduction in a margin of safety.

No significant changes in types or amounts of effluents released into the environment will occur as a result of the proposed change. The Pennsylvania Department of Environmental Protection (PDEP) National Pollutant Discharge Elimination System (NPDES) permit provides the effluent limitations and monitoring requirements for wastewater at the site.

There is no significant increase in individual or cumulative occupational radiation exposure.

Accordingly, the proposed amendment meets the eligibility criterion for categorical exclusion set forth in 10 CFR 51.22, paragraph (c)(9). Therefore, pursuant to 10 CFR 51.22, paragraph (b), no environmental impact statement or environmental assessment needs to be prepared in connection with the proposed amendment.

7.0 REFERENCES

1. Exelon letter to NRC, “Request for License Amendment Regarding Measurement Uncertainty Recapture Power Uprate,” dated February 17, 2017 (ADAMS Accession No. ML17048A444)

2. NRC letter to Exelon, “Peach Bottom Atomic Power Station, Units and 3 – Issuance of License Amendment Re: Measurement Uncertainty Recapture Power Uprate” dated November 15, 2017 (ML17286A013)

3. Letter from NRC to John L. Skolds, “Peach Bottom Atomic Power Station, Units 2 And 3 – Issuance of Amendment Re: 1.62% Increase In Licensed Power Level (TAC Nos. MB5192 and MB5193),” dated November 22, 2002

4. NRC letter to Exelon, “Peach Bottom Atomic Power Station, Units and 3 – Issuance of License Amendment Re: Extended Power Uprate, (TAC Nos. ME9631 and ME9632),” dated August 14, 2014 (Accession No. ML14133A046)

5. Caldon (now Cameron) Topical Report ER-157P-A, “Supplement to Caldon Topical Report ER-80P: Basis for Power Uprates with an LEFM ✓ TM or an LEFM CheckPlus TM System,” Rev. 8, dated May 2008

6. Caldon (now Cameron) Topical Report ER-80P, “Improving Thermal Power Accuracy and Plant Safety While Increasing Operating Power Level Using the LEFM ✓+ System,” Rev 0 dated March 1997

7. NRC letter to Florida Power and Light Company, “Turkey Point Units 3 and 4 – Issuance of Amendments Regarding Extended Power Uprate,” dated June 15, 2012 (ML11293A365)

8. NRC letter to Florida Power and Light Company, “St. Lucie Plant, Unit 1 – Issuance of Amendments Regarding Extended Power Uprate,” dated July 9, 2012 (ML12191A220)

9. NRC letter to Florida Power and Light Company, “St. Lucie Plant, Unit 2 – Issuance of Amendments Regarding Extended Power Uprate,” dated September 24, 2012 (ML12235A463)

10. ASME PTC 19.1-1998, “Test Uncertainty, Instruments and Apparatus,” American Society of Mechanical Engineers, 1998

11. ANSI/ASME PTC-6 Report 1985, Guidance for the Evaluation of Measurement Uncertainty in Performance Tests of Steam Turbines

12. Exelon letter to NRC, “Request for License Amendment Regarding Measurement Uncertainty Recapture Power Uprate - Supplement 1 - Request for Non-Proprietary Version of Cameron Corporation Proprietary Documents,” dated March 20, 2017 (ADAMS Accession No. ML17080A067)

ATTACHMENT 2

License Amendment Request

Peach Bottom Atomic Power Station, Units 2 and 3
Docket Nos. 50-277 and 50-278

License Amendment Request - Expanded Actions for LEFM Conditions

Markup of Proposed Technical Requirements Manual and Bases Pages

(For Information Only)

Unit 2	Unit 3
3.20-1	3.20-1
3.20-2	3.20-2
3.20-3	3.20-3
3.20-4	3.20-4
B 3.20-1	B 3.20-1
B 3.20-2	B 3.20-2
B 3.20-3	B 3.20-3

3.20 LEADING EDGE FLOW METER (LEFM) SYSTEM

TRMS 3.20 Three Leading Edge Flow Meters (LEFM) shall be NORMAL and providing flow input to **C**ore **T**hermal **P**ower calculation.

APPLICABILITY: MODE 1 with THERMAL POWER > 3951 MWt

COMPENSATORY MEASURES

-- NOTE --

See Bases for Definitions of **a Flow Meter** in NORMAL, MAINTENANCE and FAIL status.

Separate Condition entry is allowed for each **Flow Meter**.

CONDITION	REQUIRED COMPENSATORY MEASURE	COMPLETION TIME
A. One or more **Flow Meters** in MAINTENANCE	A.1 Replace flow input to the Core Thermal Power calculation from the **affected Flow Meter** with input from the associated calibrated feedwater flow nozzle**.**	2 hours
	<u>AND</u>	
	A.2 Restore affected **Flow Meter** to NORMAL and ensure **it is providing** flow input to the Core Thermal Power calculation**.**	72 hours

B. Required Compensatory Measure and associated Completion Time of Condition A not met.	B.1.1 Reduce MAPL to less than or equal to **value listed in Table 3.20-1**. <u>AND</u> B.1.2 Ensure flow input to the Core Thermal Power calculation is from **the affected Flow Meter in MAINTENANCE**. <u>OR</u> B.2 Reduce MAPL to less than or equal to 3951 MWt	Immediately Immediately Immediately
C. One Flow Meter in FAIL or not providing flow input to the Core Thermal Power calculation.	C.1 Replace flow input to the Core Thermal Power calculation from **affected Flow Meter** with input from the associated calibrated feedwater flow nozzle. <u>AND</u> C.2 **Restore affected Flow Meter to NORMAL and ensure it is providing flow input to the Core Thermal Power calculation**.	2 hours 72 hours

D. Required Compensatory Measure and associated Completion Time of Condition C not met.	**D.1.1 Reduce MAPL to less than or equal to 3982 MWt.** **AND** **D.1.2 Ensure flow input to the Core Thermal Power calculation is from the associated feedwater flow nozzle.** **OR** **D.2 Reduce MAPL to less than or equal to 3951 MWt**	**Immediately** **Immediately** **Immediately**
E. Two or more Flow Meters in FAIL or not providing flow input to the Core Thermal Power calculation.	**E.1 Replace flow input to the Core Thermal Power calculation from affected Flow Meters with input from the associated calibrated feedwater flow nozzles.** **AND** **E.2 Restore affected Flow Meters to NORMAL and ensure they are providing flow input to the Core Thermal Power calculation.**	**2 hours** **72 hours**

F. Required Compensatory Measure and associated Completion Time of Condition E not met.	**F.1 Reduce MAPL to less than or equal to 3951 MWt.**	**Immediately**

LEFM TEST REQUIREMENTS

TEST		FREQUENCY
TR 3.20.1	Perform CHANNEL CALIBRATION	24 months

Table 3.20-1
Allowable MAPL for LEFM System Status

LEFM System Status	MAPL (MWt)
1 Flow Meter in MAINTENANCE, 2 in NORMAL	**4015**
2 Flow Meters in MAINTENANCE, 1 in NORMAL	**4012**
3 Flow Meters in MAINTENANCE, 0 in NORMAL	**4009**

B 3.20 LEADING EDGE FLOW METER (LEFM) SYSTEM

BASES

This TRMS is provided to ensure that Core Thermal Power (CTP) is maintained at a level consistent with the feedwater flow measurement uncertainty. The three LEFM **System** Flow Meters shall be NORMAL and providing flow input to the CTP calculation for power operations above 3951 MWt or CTP must be limited in accordance with this TRMS. This TRMS allows Separate Condition Entry for each LEFM **System** Flow Meter.

The LEFM System consists of three **F**low **M**eters, one in each of the three feedwater lines. Each Flow Meter contains flow transducers arranged in two planes. Plane 1 consists of flow transducer paths 1 through 4 and Plane 2 consists of flow transducer paths 5 through 8. The flow data from a Flow Meter with a single functioning plane has greater associated measurement uncertainty than that from a **F**low **M**eter with both planes functioning, but less associated measurement uncertainty than that from a feedwater flow nozzle (Venturi) **, except within the first 72 hours following Venturi calibration. It has been demonstrated that Venturi-supplied flow data exhibits an insignificant deviation during this period following calibration by a Flow Meter with both planes functioning (see Reference 3). For this reason, following the loss of an LEFM plane, swapping flow input to the associated calibrated Venturi is preferable for the first 72 hours, and CTP is not required to be lowered during this time interval.**

The LEFM System computer converts the Flow Meter data into feedwater flow and temperature signals for that loop, and provides a self-check via Plant Monitoring System computer alarms. There are three possible statuses for a Flow Meter: NORMAL, MAINTENANCE, and FAIL.

A Flow Meter status is considered NORMAL IF:

> The LEFM System Computer indicates that Flow Meter status (mode) to be Normal **(also known as CheckPlus Mode)**.

A Flow Meter status is considered MAINTENANCE IF:

> The LEFM System Computer indicates that Flow Meter status (mode) to be Maintenance **(also known as Check Mode)**.

A Flow Meter status is considered FAIL IF:

> The LEFM System Computer indicates that Flow Meter status (mode) to be Fail.

The Flow Meter status is determined and reported by the LEFM System computer based upon the number of functional planes in the Flow Meter and upon its data quality. For additional background information on the criteria used by the LEFM System computer to determine the status of an individual Flow Meter, see References 1 **and** 2.

When this TRMS is applicable (greater than 3951 MWt) and except as explicitly directed otherwise in the TRM, the feedwater flow input to the Core Thermal Power calculation from a Flow Meter that is not NORMAL is to be replaced with that from the associated calibrated feedwater flow nozzle (Venturi). A feedwater flow nozzle is calibrated when a correction factor based on the LEFM/Venturi ratio is applied to the feedwater flow nozzle measurement in accordance with station operating procedures. This will ensure accuracy of the Core Thermal Power calculation while relying on the feedwater flow nozzle input to the Core Thermal Power calculation. See Reference 3.

The feedwater flow signal from a Flow Meter in FAIL status is to remain replaced by its corresponding feedwater flow nozzle as long as the Flow Meter remains in FAIL. **In the case of a single Flow Meter in FAIL, Compensatory Measure D.1.1 allows for operation at an intermediate power level of 3982 MWt beyond 72 hours, since long-term feedwater flow nozzle instrument drift has been accounted for in the uncertainty analysis (Reference 4). Compensatory Measure D.1.2 does not require the flow nozzle to be calibrated by its associated LEFM since the additional uncertainty is encompassed by the lower intermediate power level. The remaining two Flow Meters must remain in either NORMAL or MAINTENANCE status. If a second LEFM enters FAIL mode, Condition E applies and the completion time clocks for Compensatory Measures E.1 and E.2 immediately start.**

The feedwater flowrate signal from a Flow Meter in MAINTENANCE status is to provide input to the Core Thermal Power calculation when operating at an intermediate power **level specified in Table 3.20-1**. **These** intermediate power level**s** **are** predicated upon all three feedwater flow inputs being provided by Flow Meters that are all in either NORMAL or MAINTENANCE status.

If all three Flow Meters are restored to the NORMAL status after entry into Required Compensatory Measure B.1, then all three Flow Meters must provide feedwater flow input to the Core Thermal Power calculation prior to raising power greater than **the value specified in Table 3.20-1**.

If the status of a Flow Meter changes to a status other than NORMAL after a TRM Condition has been entered for that Flow Meter (i.e., status from MAINTENANCE to FAIL or FAIL to MAINTENANCE), then the Completion Time(s) for the new Required Compensatory Measure(s) of the applicable TRM Condition(s) must be completed based upon a start time corresponding to initial entry into the TRM for the specific Flow Meter. The accuracy of the calibrated feedwater flow nozzle (Venturi) can only be credited for 72 hours based on the insignificant instrument drift, see Reference 3. If the **F**low **M**eter cannot be restored to NORMAL in the 72 hour Completion Time, then CTP must be lowered as directed by the appropriate Required Compensatory Measure based on Flow Meter status at the time.

The analysis supporting the allowable power levels provided in the TRM is contained in References 1 **and** 2.

The LEFM System **and feedwater flow nozzle transmitter** calibration **are** checked at regularly scheduled intervals. The frequency has been selected based on the reliability of the system. **Additionally, parameters which input into the Core Thermal Power calculation are routinely validated to be within established bands**.

CTP restrictions imposed by this TRM are controlled via plant procedures by changing the Maximum Allowable Power Level (MAPL). Changing the MAPL setting within the Plant Monitoring System computer ensures operation is within allowable limits.

REFERENCES:

1. Calculation PM-1201, Uncertainty Analysis for Thermal Power Determination at PB2 Using the LEFM CheckPlus System, VNDR DWG NUMBER ER464

2. Calculation PM-1202, Uncertainty Analysis for Thermal Power Determination at PB3 Using the LEFM CheckPlus System, VNDR DWG NUMBER ER463

3. Technical Evaluation **624827**, **LEFM SYSTEM POST-MUR LAR TECHNICAL EVALUATION**

4. Calculation PM-1209, Peach Bottom Feedwater Flow Uncertainty in the Plant Computer as Measured by the Flow Nozzles Without Calibration by the LEFM

3.20 LEADING EDGE FLOW METER (LEFM) SYSTEM

TRMS 3.20 Three Leading Edge Flow Meters (LEFM) shall be NORMAL and providing flow input to **C**ore **T**hermal **P**ower calculation.

APPLICABILITY: MODE 1 with THERMAL POWER > 3951 MWt

COMPENSATORY MEASURES

-- NOTE --

See Bases for Definitions of a **Flow Meter** in NORMAL, MAINTENANCE and FAIL status.

Separate Condition entry is allowed for each **Flow Meter**.

CONDITION	REQUIRED COMPENSATORY MEASURE	COMPLETION TIME
A. One or more **Flow Meters** in MAINTENANCE	A.1 Replace flow input to the Core Thermal Power calculation from the **affected Flow Meter** with input from the associated calibrated feedwater flow nozzle**.**	2 hours
	<u>AND</u>	
	A.2 Restore affected **Flow Meter** to NORMAL and ensure **it is providing** flow input to the Core Thermal Power calculation**.**	72 hours

B. Required Compensatory Measure and associated Completion Time of Condition A not met.	B.1.1 Reduce MAPL to less than or equal to value **listed in Table 3.20-1**. AND B.1.2 Ensure flow input to the Core Thermal Power calculation is from **the affected Flow Meter in MAINTENANCE**. OR B.2 Reduce MAPL to less than or equal to 3951 MWt	Immediately Immediately Immediately
C. One Flow Meter in FAIL or not providing flow input to the Core Thermal Power calculation.	C.1 Replace flow input to the Core Thermal Power calculation from **affected Flow Meter** with input from the associated calibrated feedwater flow nozzle. AND C.2 **Restore affected Flow Meter to NORMAL and ensure it is providing flow input to the Core Thermal Power calculation**.	2 hours 72 hours

D. Required Compensatory Measure and associated Completion Time of Condition C not met.	**D.1.1 Reduce MAPL to less than or equal to 3982 MWt.** **AND** **D.1.2 Ensure flow input to the Core Thermal Power calculation is from the associated feedwater flow nozzle.** **OR** **D.2 Reduce MAPL to less than or equal to 3951 MWt**	**Immediately** **Immediately** **Immediately**
E. Two or more Flow Meters in FAIL or not providing flow input to the Core Thermal Power calculation.	**E.1 Replace flow input to the Core Thermal Power calculation from affected Flow Meters with input from the associated calibrated feedwater flow nozzles.** **AND** **E.2 Restore affected Flow Meters to NORMAL and ensure they are providing flow input to the Core Thermal Power calculation.**	**2 hours** **72 hours**

F. Required Compensatory Measure and associated Completion Time of Condition E not met.	**F.1 Reduce MAPL to less than or equal to 3951 MWt.**	**Immediately**

LEFM TEST REQUIREMENTS

TEST		FREQUENCY
TR 3.20.1	Perform CHANNEL CALIBRATION	24 months

Table 3.20-1
Allowable MAPL for LEFM System Status

LEFM System Status	MAPL (MWt)
1 Flow Meter in MAINTENANCE, 2 in NORMAL	**4015**
2 Flow Meters in MAINTENANCE, 1 in NORMAL	**4012**
3 Flow Meters in MAINTENANCE, 0 in NORMAL	**4009**

B 3.20 LEADING EDGE FLOW METER (LEFM) SYSTEM

BASES

This TRMS is provided to ensure that Core Thermal Power (CTP) is maintained at a level consistent with the feedwater flow measurement uncertainty. The three LEFM **System** Flow Meters shall be NORMAL and providing flow input to the CTP calculation for power operations above 3951 MWt or CTP must be limited in accordance with this TRMS. This TRMS allows Separate Condition Entry for each LEFM **System** Flow Meter.

The LEFM System consists of three **F**low **M**eters, one in each of the three feedwater lines. Each Flow Meter contains flow transducers arranged in two planes. Plane 1 consists of flow transducer paths 1 through 4 and Plane 2 consists of flow transducer paths 5 through 8. The flow data from a Flow Meter with a single functioning plane has greater associated measurement uncertainty than that from a **F**low **M**eter with both planes functioning, but less associated measurement uncertainty than that from a feedwater flow nozzle (Venturi)**, except within the first 72 hours following Venturi calibration. It has been demonstrated that Venturi-supplied flow data exhibits an insignificant deviation during this period following calibration by a Flow Meter with both planes functioning (see Reference 3). For this reason, following the loss of an LEFM plane, swapping flow input to the associated calibrated Venturi is preferable for the first 72 hours, and CTP is not required to be lowered during this time interval.**

The LEFM System computer converts the Flow Meter data into feedwater flow and temperature signals for that loop, and provides a self-check via Plant Monitoring System computer alarms. There are three possible statuses for a Flow Meter: NORMAL, MAINTENANCE, and FAIL.

A Flow Meter status is considered NORMAL IF:

> The LEFM System Computer indicates that Flow Meter status (mode) to be Normal **(also known as CheckPlus Mode)**.

A Flow Meter status is considered MAINTENANCE IF:

> The LEFM System Computer indicates that Flow Meter status (mode) to be Maintenance **(also known as Check Mode)**.

A Flow Meter status is considered FAIL IF:

> The LEFM System Computer indicates that Flow Meter status (mode) to be Fail.

The **F**low **M**eter status is determined and reported by the LEFM System computer based upon the number of functional planes in the **F**low **M**eter and upon its data quality. For additional background information on the criteria used by the LEFM System computer to determine the status of an individual Flow Meter, see References 1 **and** 2.

When this TRMS is applicable (greater than 3951 MWt) and except as explicitly directed otherwise in the TRM, the feedwater flow input to the Core Thermal Power calculation from a **F**low **M**eter that is not NORMAL is to be replaced with that from the associated calibrated feedwater flow nozzle (Venturi). A feedwater flow nozzle is calibrated when a correction factor based on the LEFM/Venturi ratio is applied to the feedwater flow nozzle measurement in accordance with station operating procedures. This will ensure accuracy of the **C**ore **T**hermal **P**ower calculation while relying on the feedwater flow nozzle input to the Core Thermal Power calculation. See Reference 3.

The feedwater flow signal from a **F**low **M**eter in FAIL status is to remain replaced by its corresponding feedwater flow nozzle as long as the Flow Meter remains in FAIL. **In the case of a single Flow Meter in FAIL, Compensatory Measure D.1.1 allows for operation at an intermediate power level of 3982 MWt beyond 72 hours, since long-term feedwater flow nozzle instrument drift has been accounted for in the uncertainty analysis (Reference 4). Compensatory Measure D.1.2 does not require the flow nozzle to be calibrated by its associated LEFM since the additional uncertainty is encompassed by the lower intermediate power level. The remaining two Flow Meters must remain in either NORMAL or MAINTENANCE status. If a second LEFM enters FAIL mode, Condition E applies and the completion time clocks for Compensatory Measures E.1 and E.2 immediately start.**

The feedwater flowrate signal from a **F**low **M**eter in MAINTENANCE status is to provide input to the Core Thermal Power calculation when operating at an intermediate power level **specified in Table 3.20-1**. **These** intermediate power level**s** are predicated upon all three feedwater flow inputs being provided by **F**low **M**eters that are all in either NORMAL or MAINTENANCE status.

If all three **F**low **M**eters are restored to the NORMAL status after entry into Required Compensatory Measure B.1, then all three **F**low **M**eters must provide feedwater flow input to the Core Thermal Power calculation prior to raising power greater than **the value specified in Table 3.20-1**.

If the status of a **F**low **M**eter changes to a status other than NORMAL after a TRM Condition has been entered for that Flow Meter (i.e.**,** status from MAINTENANCE to FAIL or FAIL to MAINTENANCE), then the Completion Time(s) for the new Required Compensatory Measure(s) of the applicable TRM Condition(s) must be completed based upon a start time corresponding to initial entry into the TRM for the specific **F**low **M**eter. The accuracy of the calibrated feedwater flow nozzle (Venturi) can only be credited for 72 hours based on the insignificant instrument drift, see Reference 3. If the **F**low **M**eter cannot be restored to NORMAL in the 72 hour Completion Time, then CTP must be lowered as directed by the appropriate Required Compensatory Measure based on Flow Meter status at the time.

The analysis supporting the allowable power levels provided in the TRM is contained in References 1 **and** 2.

The LEFM System **and feedwater flow nozzle transmitter** calibration **are** checked at regularly scheduled intervals. The frequency has been selected based on the reliability of the system. **Additionally, parameters which input into the Core Thermal Power calculation are routinely validated to be within established bands**.

CTP restrictions imposed by this TRM are controlled via plant procedures by changing the Maximum Allowable Power Level (MAPL). Changing the MAPL setting within the Plant Monitoring System computer ensures operation is within allowable limits.

REFERENCES:

1. Calculation PM-1201, Uncertainty Analysis for Thermal Power Determination at PB2 Using the LEFM CheckPlus System, VNDR DWG NUMBER ER464

2. Calculation PM-1202, Uncertainty Analysis for Thermal Power Determination at PB3 Using the LEFM CheckPlus System, VNDR DWG NUMBER ER463

3. Technical Evaluation **624827**, **LEFM SYSTEM POST-MUR LAR TECHNICAL EVALUATION**

4. Calculation PM-1209, Peach Bottom Feedwater Flow Uncertainty in the Plant Computer as Measured by the Flow Nozzles Without Calibration by the LEFM

ATTACHMENT 3

License Amendment Request

Peach Bottom Atomic Power Station, Units 2 and 3
Docket Nos. 50-277 and 50-278

License Amendment Request - Expanded Actions for LEFM Conditions

Exelon Calculation PM-1209 Revision 0,
“Peach Bottom Feedwater Flow Uncertainty as Measured in the
Plant Computer as Measured by the Flow Nozzles Without Calibration by the LEFM”

ATTACHMENT 1
Design Analysis Cover Sheet
Page 1

Design Analysis	**Last Page No.:** [6] Attachment F page F2
Analysis No.: [1] PM-1209	**Revision:** [2] 000 Major ☒ Minor ☐
Title: [3] Peach Bottom Feedwater Flow Uncertainty in the Plant Computer as Measured by the Flow Nozzles Without Calibration by the LEFM	
EC No.: [4] 621320	**Revision:** [5] 0

Station(s): [7]	Peach Bottom	**Component(s):** [14]	
Unit No.: [8]	2, 3	See list in Section 1.0	
Discipline: [9]	PEDM		
Descrip. Code/Keyword: [10]	N/A		
Safety/QA Class: [11]	SR		
System Code: [12]	06		
Structure: [13]	N/A		

CONTROLLED DOCUMENT REFERENCES [15]

Document No.:	From/To	Document No.:	From/To
EE-0029	From		

Is this Design Analysis Safeguards Information? [16] Yes ☐ No ☒ If yes, see SY-AA-101-106

Does this Design Analysis contain Unverified Assumptions? [17] Yes ☐ No ☒ If yes, ATI/AR#:

This Design Analysis SUPERCEDES: [18] N/A **in its entirety.**

Description of Revision (list changed pages when all pages of original analysis were not changed): [19]
Initial issue.

Print Name	Sign Name	Date
Patricia A. Ugorcak	Patricia A. Ugorcak	8-24-2017

Method of Review: [21] Detailed Review ☒ Alternate Calculations (attached) ☐ Testing ☐

	Print Name	Sign Name	Date
Reviewer: [22]	David A. Baran	David A. Baran	8/25/2017

Review Notes: [23] Independent review ☒ Peer review ☐

(For External Analyses Only)

	Print Name	Sign Name	Date
External Approver: [24]	Larry P. Lawrence	[signature]	8/25/17
Exelon Reviewer: [25]	Chuck Hallett	[signature]	9/8/19

Independent 3rd Party Review Reqd? [26] Yes ☐ No ☒

	Print Name	Sign Name	Date
Exelon Approver: [27]	Mark Hochreiter	[signature]	9/20/17

ATTACHMENT 2
Owner's Acceptance Review Checklist for External Design Analyses

Design Analysis No.: PM-1209 **Rev:** 0
Contract #: 511303 **Release #:** 399

No	Question	Instructions and Guidance	Yes / No / N/A
1	Do assumptions have sufficient documented rationale?	All Assumptions should be stated in clear terms with enough justification to confirm that the assumption is conservative. For example, 1) the exact value of a particular parameter may not be known or that parameter may be known to vary over the range of conditions covered by the Calculation. It is appropriate to represent or bound the parameter with an assumed value. 2) The predicted performance of a specific piece of equipment in lieu of actual test data. It is appropriate to use the documented opinion/position of a recognized expert on that equipment to represent predicted equipment performance. Consideration should also be given as to any qualification testing that may be needed to validate the Assumptions. Ask yourself, would you provide more justification if you were performing this analysis? If yes, the rationale is likely incomplete.	☑ Yes ☐ No ☐ N/A
2	Are assumptions compatible with the way the plant is operated and with the licensing basis?	Ensure the documentation for source and rationale for the assumption supports the way the plant is currently or will be operated post change and they are not in conflict with any design parameters. If the Analysis purpose is to establish a new licensing basis, this question can be answered yes, if the assumption supports that new basis.	☑ Yes ☐ No ☐ N/A
3	Do all unverified assumptions have a tracking and closure mechanism in place?	**If** there are unverified assumptions without a tracking mechanism indicated, **then** create the tracking item either through an ATI or a work order attached to the implementing WO. Due dates for these actions need to support verification prior to the analysis becoming operational or the resultant plant change being op authorized.	☐ Yes ☐ No ☑ N/A
4	Do the design inputs have sufficient rationale?	The origin of the input, or the source should be identified and be readily retrievable within Exelon's documentation system. If not, then the source should be attached to the analysis. Ask yourself, would you provide more justification if you were performing this analysis? **If** yes, the rationale is likely incomplete.	☑ Yes ☐ No ☐ N/A
5	Are design inputs correct and reasonable with critical parameters identified, if appropriate?	The expectation is that an Exelon Engineer should be able to clearly understand which input parameters are critical to the outcome of the analysis. That is, what is the impact of a change in the parameter to the results of the analysis? If the impact is large, then that parameter is critical.	☑ Yes ☐ No ☐ N/A
6	Are design inputs compatible with the way the plant is operated and with the licensing basis?	Ensure the documentation for source and rationale for the inputs supports the way the plant is currently or will be operated post change and they are not in conflict with any design parameters.	☑ Yes ☐ No ☐ N/A

CALCULATION NO. PM-1209	REVISION NO. 0	PAGE NO. 3 of 35

ATTACHMENT 2
Owner's Acceptance Review Checklist for External Design Analyses

Design Analysis No.: PM-1209 **Rev:** 0

No	Question	Instructions and Guidance	Yes / No / N/A
7	Are Engineering Judgments clearly documented and justified?	See Section 2.13 in CC-AA-309 for the attributes that are sufficient to justify Engineering Judgment. Ask yourself, would you provide more justification if you were performing this analysis? **If** yes, the rationale is likely incomplete.	☐ ☐ ☑
8	Are Engineering Judgments compatible with the way the plant is operated and with the licensing basis?	Ensure the justification for the engineering judgment supports the way the plant is currently or will be operated post change and is not in conflict with any design parameters. **If** the Analysis purpose is to establish a new licensing basis, **then** this question can be answered yes, if the judgment supports that new basis.	☐ ☐ ☑
9	Do the results and conclusions satisfy the purpose and objective of the Design Analysis?	Why was the analysis being performed? Does the stated purpose match the expectation from Exelon on the proposed application of the results? **If** yes, **then** the analysis meets the needs of the contract.	☑ ☐ ☐
10	Are the results and conclusions compatible with the way the plant is operated and with the licensing basis?	Make sure that the results support the UFSAR defined system design and operating conditions, or they support a proposed change to those conditions. If the analysis supports a change, are all of the other changing documents included on the cover sheet as impacted documents?	☑ ☐ ☐
11	Have any limitations on the use of the results been identified and transmitted to the appropriate organizations?	Does the analysis support a temporary condition or procedure change? Make sure that any other documents needing to be updated are included and clearly delineated in the design analysis. Make sure that the cover sheet includes the other documents where the results of this analysis provide the input.	☐ ☐ ☑
12	Have margin impacts been identified and documented appropriately for any negative impacts (Reference ER-AA-2007)?	Make sure that the impacts to margin are clearly shown within the body of the analysis. If the analysis results in reduced margins ensure that this has been appropriately dispositioned in the EC being used to issue the analysis.	☐ ☐ ☑
13	Does the Design Analysis include the applicable design basis documentation?	Are there sufficient documents included to support the sources of input, and other reference material that is not readily retrievable in Exelon controlled Documents?	☑ ☐ ☐
14	Have all affected design analyses been documented on the Affected Documents List (ADL) for the associated Configuration Change?	Determine if sufficient searches have been performed to identify any related analyses that need to be revised along with the base analysis. It may be necessary to perform some basic searches to validate this.	☐ ☐ ☑
15	Do the sources of inputs **and** analysis methodology used meet committed technical and regulatory requirements?	Compare any referenced codes and standards to the current design basis and ensure that any differences are reconciled. If the input sources **or** analysis methodology are based on an out-of-date methodology or code, additional reconciliation may be required if the site has since committed to a more recent code	☑ ☐ ☐

CALCULATION NO. PM-1209	REVISION NO. 0	PAGE NO. 4 of 35

ATTACHMENT 2

Owner's Acceptance Review Checklist for External Design Analyses

Design Analysis No.: PM-1209 **Rev:** 0

No	Question	Instructions and Guidance	Yes / No / N/A
16	Have vendor supporting technical documents and references (including GE DRFs) been reviewed when necessary?	Based on the risk assessment performed during the pre-job brief for the analysis (per HU-AA-1212), ensure that sufficient reviews of any supporting documents not provided with the final analysis are performed.	☑ Yes ☐ No ☐ N/A
17	Do operational limits support assumptions and inputs?	Ensure the Tech Specs, Operating Procedures, etc. contain operational limits that support the analysis assumptions and inputs.	☐ Yes ☐ No ☑ N/A
18.	List the critical characteristics of the product, and validate those critical characteristics. SEE BELOW		

Create an SFMS entry as required by CC-AA-4008. SFMS Number: 59909

CRITICAL CHARACTERISTICS

There are no acceptance criteria for this uncertainty. It is simply stated for use in preparation of the Cameron calculation.

The calculation determines the uncertainty in feedwater mass flow rate as calculated in the Plant Process Computer (PPC) by applying feedwater flow nozzle flow coefficients and density correction based upon measured feedwater inlet temperature to measured the differential pressure of feedwater flow across the nozzle.

Critical inputs were validated by examination of References 4.9, 4.10.1, 4.10.2, 4.10.3 and 4.11 of this calculation.

CALCULATION TABLE OF CONTENTS

CALCULATION NO. PM-1209 REV. NO. 0 PAGE NO. 5

1.0 PURPOSE

The purpose of this calculation is to determine the feedwater mass flow uncertainty in the plant process computer (PPC) as measured by a single feedwater flow nozzle differential pressure instrumentation loop, for the case in which this instrument loop has not been calibrated by the LEFM. The feedwater mass flow uncertainty is developed for the proposed MUR normal steady state operating conditions of temperature, pressure and flow.

The feedwater mass flow measurement is calculated within the PPC by applying flow coefficients and a density correction to the measured differential pressure of feedwater flow across the nozzle. The density correction is based on the measured feedwater inlet temperature.

The instrument loop uncertainties determined within this calculation are applicable to the following components:

Feedwater differential pressure:

Unit 2: FE-2-06-011A, FE-2-06-011B, FE-2-06-011C
FT-2-06-050A, FT-2-06-050B, FT-2-06-050C

Unit 3: FE-3-06-011A, FE-3-06-011B, FE-3-06-011C
FT-3-06-050A, FT-3-06-050B, FT-3-06-050C

Feedwater temperature:

Unit 2: TE-2144A, TE-2144B, TE-2144C, TE-2144D, TE-2144E, TE-2144F
TT-2144A, TT-2144B, TT-2144C, TT-2144D, TT-2144E, TT-2144F

Unit 3: TE-3144A, TE-3144B, TE-3144C, TE-3144D, TE-3144E, TE-3144F
TT-3144A, TT-3144B, TT-3144C, TT-3144D, TT-3144E, TT-3144F

The single nozzle mass flow uncertainty determined within this calculation is intended as an input to the overall thermal power uncertainty calculation performed by Cameron as part of the upgrade to measure feedwater flow with the Cameron Leading Edge Flow Meter (LEFM) Checkplus Ultrasonic Flow Measuring System, for use in the cases in which one or more feedwater lines are measured by the nozzle, and it has not been corrected to the LEFM.

There are no acceptance criteria for this uncertainty. It is simply stated for use in preparation of the Cameron calculation.

If future modifications replace components in any of the analyzed loops, the calculated uncertainty results will remain bounding as long as the replacement components are at least as accurate as those analyzed herein. If the calibration equipment is replaced or calibration processes are modified in the future, the calculated uncertainties remain bounding as long as the calibration equipment is at least as accurate as what is analyzed herein, and the calibration process maintains the same or smaller as left tolerances.

2.0 INPUTS

2.1 The nominal values for operation of Peach Bottom Units 2 and 3 at maximum MUR rated power of 4016 MWt are provided by calculation EE-0029 (Reference 4.11). The following inputs are taken from this calculation for each unit:

2.1.1 Total Feedwater Flow: 16.4440 Mlbm/hr; nominal flow per loop 5.4813 Mlbm/hr

2.1.2 Feedwater Temperature: 383.4°F

2.1.3 Full calibrated span per loop: 8.0000 Mlbm/hr

2.1.4 Operating differential pressures (dP, or h) for nominal rated MUR temperature and flow:

Flow Element	inwc
FE-2-06-11A	h_{r2A} = 301.2
FE-2-06-11B	h_{r2B} = 304.2
FE-2-06-11C	h_{r2C} = 301.8
FE-3-06-11A	h_{r3A} = 301.2
FE-3-06-11B	h_{r3B} = 302.4
FE-3-06-11C	h_{r3C} = 302.4

Table 2.1.4 – MUR Nominal Rated Operating dP, h_r

2.1.5 Operating differential pressures for full span flow, at 376.1°F:

Flow Element	inwc
FE-2-06-11A	h_{S2A} = 638.6
FE-2-06-11B	h_{S2B} = 645.0
FE-2-06-11C	h_{S2C} = 639.9
FE-3-06-11A	h_{S3A} = 638.6
FE-3-06-11B	h_{S3B} = 641.2
FE-3-06-11C	h_{S3C} = 641.2

Table 2.1.5 – Full Span Operating dP, h_S

2.2 From References 4.9, 4.10 and 4.11, the 3D Monicore program in the PPC calculates feedwater mass flow based on the differential pressure points B044, B045, B046, B344, B345 and B346 as follows:

<u>Unit 2:</u>
A Loop: B018 = NSCFW001 * S516 * SQRT(B044)
B Loop: B019 = NSCFW002 * S517 * SQRT(B045)
C Loop: B020 = NSCFW003 * S518 * SQRT(B046)

<u>Unit 3:</u>
A Loop: B318 = NSCFW301 * S816 * SQRT(B344)
B Loop: B319 = NSCFW302 * S817 * SQRT(B345)
C Loop: B320 = NSCFW303 * S818 * SQRT(B346)

Flow correction constants S516, S517, S518, S815, S816 and S817 are from Reference 4.11 (EE-0029 Rev. 5).

<u>Unit 2</u>	S516 = 10.27333	<u>Unit 3</u>	S816 = 10.25728
	S517 = 10.34251		S817 = 10.37076
	S518 = 10.23560		S818 = 10.21455

NSCFWX0X = FWC2*(1.0 + DT*(FWC4) + DT * FWC5))

(all six NSCFW00X and NSCFW30X terms use the same equation)

Feedwater Coefficient (CFW):

DT(I) = TFW(I) – FWC(3,I)

CFW - Feedwater Coefficients used for temperature compensation:

CFW(I) = FWC(2,I)*(1.0+DT(I)*(FWC(4,I)+DT(I)*FWC(5,I)))

Where: I identifies the Feedwater branch
FWC2 = 3.09400E-02
FWC3 = 3.76100E+02
FWC4 = -3.35720E-04
FWC5 = -4.14750E-07
TFW is the average feedwater temperature in each of the 3 feedwater branches

CA0(3)83, CA0(3)84, CA0(3)85: FDWTR VENTURI CORRECTION FACTOR, from 0.5 to 1.5. B018 is multiplied by CA083 to correct the venturi flow to the LEFM. The result goes to WFWBX1 (typ). This calculation determines the uncertainty of the feedwater flow in the case that the LEFM has not been used to correct the venturi, so within this calculation, the correction factor is set to 1, and is not used.

2.3 From References 4.11 and 4.4.17 the feedwater operating pressure is 1100 psig.

2.4 Per Reference 4.17 (included as Attachment F), all Rosemount specifications written as ± implies random uncertainty, and the performance specifications of Rosemount Model 1151 transmitters are stated as 3σ values (3 standard deviations), with the exception of stability (drift) which is a 2σ value

2.5 References 4.4.6 through 4.4.16 show the installation of the feedwater flow nozzles. The first upstream obstruction in each case is a 90° bend, with the exception of FE-3-06-011B, which has a combination of a 45° bend with a 90° bend in a different plane. The first downstream obstruction is a tee in each case.

Nozzle	Upstream	Distance (inches)	Downstream	Distance (inches)
FE-2-06-011A	90° bend	268.75	Tee	85.5
FE-2-06-011B	90° bend	310.7	Tee	85.5
FE-2-06-011C	90° bend	268.75	Tee	85.5 + 3 diam
FE-3-06-011A	90° bend	268.75	Tee	85.5
FE-3-06-011B	45° bend with 90° bend in different plane	186.75	Tee	85.5
FE-3-06-011C	90° bend	310.7	Tee	85.5 + 3 diam

Table 2.5 – Feedwater Line Obstructions

3.0 ASSUMPTIONS

3.1 For calculation of the loop uncertainties, if the confidence level of a published uncertainty is not stated, the information shall be assumed to be 2σ (Reference 4.1).

3.2 For calculation of the loop uncertainties, the insulation resistance error is considered negligible because operation of the instrumentation in an abnormal or harsh environment is not considered by this calculation.

3.3 It is expected that regulated instrument power supplies are designed to function within supply voltage limits. Therefore, the power supply error is considered negligible with respect to other error terms.

3.4 For calculation of the loop uncertainties, if temperature, humidity and pressure errors are not stated by the manufacturer an evaluation is made to ensure that the instrument environmental conditions are bounded by the manufacturer's specified operational limits. If the environmental conditions are bounded, these error effects are considered to be included in the manufacturer's reference accuracy.

3.5 All instruments are located in mild or very low dose environments. For the calculation of the instrument loop uncertainties, radiation induced errors associated with the normal environments have been incorporated only when provided by the manufacturer, and only if the manufacturer's specified effect is based on a dose of at the least the same order of magnitude as the 60 year TID for that location. Otherwise, these errors are considered to be small enough to be adjusted out each time the instrument is re-calibrated, and so are considered to be included within the instrument drift related errors. Radiation induced errors associated with the normal environment are considered to be negligible if the 60 year TID for that location is at least an order of magnitude less than the level specified for the manufacturer's radiation effect.

3.6 For the calculation of the instrument loop uncertainties, seismic effects are not applicable, because the core thermal power uncertainty calculation pertains only to normal full power operation and does not include abnormal operating conditions. Any seismic effects are considered negligible or capable of being calibrated out.

3.7 For the calculation of the instrument loop uncertainties, per the methodology in CC-MA-103-2001 (Reference. 4.1), if there is no drift stated by the manufacturer, the drift may be taken as equal to the required accuracy value. In the case of the RTP computer input and output cards analyzed within this calculation, it is further assumed that the drift value is equal to the vendor accuracy of the card.

3.8 For the calculation of the instrument loop uncertainties, per the methodology in CC-MA-103-2001 (Reference. 4.1), the required accuracy is taken as the larger of either the vendor accuracy or the calibration setting tolerance.

3.9 As stated in Foreword to ANSI/ASME PTC 6 Report-1985 (included in Reference 4.12), the possible errors associated with steam turbine testing are expressed as uncertainty intervals which, when incorporated into this model, will yield an overall uncertainty for the test result which provides 95% coverage of the true value. Therefore, it is assumed that the overall uncertainty of the flow section represents a 2σ value.

3.10 As stated in Note 1 of ANSI/ASME PTC 6 Report - 1985 (Reference 4.12), the overall uncertainty value of the flow element is acceptable for flow elements in service for less than six months. Further, Section 4.17 of this report states that the base uncertainty for flow elements in service for more than six months is likely to change much less with time than indicated for the initial six months. It is therefore assumed that any additional error due to damage or deposits on the flow element will have a negligible impact on the overall loop uncertainty. Since the flow element has been in service greater than six months, for conservatism, the largest Group 1 base uncertainty from Table 4.10 from Reference 4.12 (included in Attachment B) will be used to evaluate the overall flow element errors. As documented in EE-0029 (Reference 4.11), tracer testing was used in 1992 to calibrate the Unit 2 feedwater flow measurement, and ultrasonic testing was used in 1999 to calibrate the Unit 3 feedwater flow measurement. Under normal operating conditions, the LEFM is used to adjust the feedwater flow measured by the nozzles, this calibrating the nozzle measurement to the LEFM measurement, thus these flow elements may be considered to have been calibrated. Based on this, the largest Group 1 (calibrated) base uncertainty from Table 4.10 from Reference 4.12 is conservatively used to evaluate the flow element error.

4.0 REFERENCES

4.1 CC-MA-103-2001, Revision 2, Setpoint Methodology for Peach Bottom Atomic Power Station and Limerick Generating Station

4.2 NEDC-31336P-A, September 1996, "General Electric Company Instrument Setpoint Methodology (Proprietary)"

4.3 IISCP Data Sheets for:

FT-2-06-050A, FT-2-06-050B, FT-2-06-050C
FT-3-06-050A, FT-3-06-050B, FT-3-06-050C
TE-2144A, TE-2144B, TE-2144C, TE-2144D, TE-2144E, TE-2144F
TE-3144A, TE-3144B, TE-3144C, TE-3144D, TE-3144E, TE-3144F
TT-2144A, TT-2144B, TT-2144C, TT-2144D, TT-2144E, TT-2144F
TT-3144A, TT-3144B, TT-3144C, TT-3144D, TT-3144E, TT-3144F

4.4 Peach Bottom Station drawings:

4.4.1. E-1021 Sh. 0001, Revision 29, Cable Spreading and Computer Room Arrangement

4.4.2 M-1-S-25 Sh. 8, Revision 59, Electrical Schematic Diagram Feedwater Control System

4.4.3 M-1-S-25 Sh. 18, Revision 59, Electrical Schematic Diagram Feedwater Control System

4.4.4 E-269 Sh. 00A37, Revision 1, Electrical Schematic and Connection Diagram Computer - Analog Points

4.4.5 E-269 Sh. 00A18, Revision 24, Electrical Schematic and Connection Diagram Computer - Analog Points

4.4.6 M-180, Revision 11, Piping and Mechanical Feedwater Piping System and Supports - Plan

4.4.7 M-181, Revision 4, Piping and Mechanical Feedwater Piping System and Supports Unit No. 2

4.4.9 M-194, Revision 10, Piping and Mechanical Feedwater Piping System and Supports

4.4.10 M-195, Revision 2, Piping and Mechanical Feedwater Piping System and Supports Unit No. 3

4.4.11 ISO-2-6-18, Revision 9, Piping Isometric Ref Dwg M-180, M-181, HISO-601, M-1817 Bill of Material

4.4.12 ISO-2-6-19, Revision 5, Piping Isometric Ref Dwg M-180, M-181, HISO-601, Bill of Material M-31

4.4.13 ISO-3-6-2, Revision 8, Piping Isometric Ref Dwg M-194, HISO-651

4.4.14 ISO-3-6-4, Revision 8, Piping Isometric Ref Dwg M-194, HISO-651

4.4.15 ISO-3-6-5, Revision 7, Piping Isometric Ref Dwg M-194, HISO-651

4.4.16 ISO-3-6-6, Revision 6, Piping Isometric Ref Dwg M-194, HISO-651

4.4.17 M-1-MM-1 Sh. 1, Revision 3, Outline, Dimensional Data Type T6 Flow Nozzles Demineralized Water

4.4.18 A-12, Revision 35, Architectural Floor Plan 135FT-00IN Floor Plan 116

4.4.19 M-577, Revision 12, Instrument Location Turbine Building Unit No 2 Plan at El 135FT-00IN (Conv to History Cat F)

4.5 Peach Bottom Station Surveillance Instructions:

4.5.1 SI2F-6-50-ACC2, Revision 5, Calibration Check of Reactor Feedwater Flow Transmitters FT 2-6-50A, B and C

4.5.2 SI3F-6-50-ACC2, Revision 6, Calibration Check of Reactor Feedwater Flow Transmitters FT 3-6-50A, B and C

4.5.3 SI2T-6-2144-AFC2, Revision 9, Calibration Check of Feedwater Inlet Temperature Instruments TE 2144A, B, C, D, E and F and TT 2-6-2144A, B, C, D, E and F

4.5.4 SI3T-6-3144-AFC2, Revision 10, Calibration Check of Feedwater Inlet Temperature Instruments TE 3144A, B, C, D, E and F and TT 3-6-3144A, B, C, D, E and F

4.6 PassPort data (viewed 04-13-2017) for:

FE-2-06-011A, FE-2-06-011B, FE-2-06-011C
FE-3-06-011A, FE-3-06-011B, FE-3-06-011C
FT-2-06-050A, FT-2-06-050B, FT-2-06-050C
FT-3-06-050A, FT-3-06-050B, FT-3-06-050C
TE-2144A, TE-2144B, TE-2144C, TE-2144D, TE-2144E, TE-2144F
TE-3144A, TE-3144B, TE-3144C, TE-3144D, TE-3144E, TE-3144F
TT-2144A, TT-2144B, TT-2144C, TT-2144D, TT-2144E, TT-2144F
TT-3144A, TT-3144B, TT-3144C, TT-3144D, TT-3144E, TT-3144F

4.7 NE-00164, Revision 6, Specification for Environmental Service Conditions Peach Bottom Atomic Power Stations Units 2 & 3

4.8 R-369-VC-26, Revision 1, Models 3144 and 3244MV Smart Temperature Transmitters (Rosemount 0809-0100-4724 Rev. CA)

4.9 E-mail, K. Schoenknecht to K. Cutler, April 6, 2017 (included as Attachment A)

4.10 Peach Bottom Vendor Prints:

4.10.1 S-102-VC-25, Revision 2, Requirements Specification for the PMS 3D Monicore Interface

4.10.2 S-102-VC-31, Revision 4, PMS 3D Monicore Interface Software Design Description

4.10.3 S-102-VC-40, Revision 0, Requirement Spec for Peach Bottom LESM CheckPlus PMS Interface

4.10.4 S-102-VC-41, Revision 1, LESM PMS Interface Detail design Document

4.11 EE-0029, Revision 5, Determine Proper Calibration of F/W Flow Transmitters FT-2(3)-6-050A(B)(C)

4.12 ANSI/ASME PTC 6 Report 1985, Guidance for Evaluation of Measurement Uncertainty in Performance Tests of Steam Turbines (Select pages included in Attachment B)

4.13 Product Data Sheet 00813-0100-4360 Revision JB, March 2010, Rosemount 1151 Pressure Transmitter (included as Attachment C)

4.14 RTP Corporation Product Specification Sheet, Analog to Digital Converter Card Model RTP 8436/2X Series, December 2001 (included as Attachment D)

4.15 Peach Bottom Updated Final Safety Analysis (UFSAR) Revision 26, April 2017, Section 10.15.3.4, Miscellaneous Rooms and Buildings

4.16 Email dated May 10, 2002 from Dave McCully of RTP Corporation to J. Regan of Key Technologies Inc. providing specifications for RTP Bridge Card and A/D Conversion (included as Attachment E)

4.17 Rosemount Letter, June 24, 1991, T. Layer to E. Kaczmorski, Pressure Transmitter Performance Specifications (Attachment F)

5.0 IDENTIFICATION OF COMPUTER PROGRAMS

Microsoft Excel 2013 was used on a Microsoft Windows 7 operating system as a desktop productivity tool to perform numerical calculations in the preparation of this calculation. Microsoft Excel is exempt from the DTSQA requirements of IT-AA-101. All computations are shown in the calculation and are not dependent on the software.

6.0 METHOD OF ANALYSIS

6.1 The methodology used to calculate the loop uncertainties is based on CC-MA-103-2001 "Setpoint Methodology for Peach Bottom Atomic Power Station and Limerick Generating Station" (Reference 4.1), which is based on GE Setpoint Methodology (Reference 4.2). In accordance with this methodology, independent error terms are combined via square root sum of the squares (SRSS) and taken to a 2σ confidence level. Dependent errors are combined according to their dependency relationships and biases are algebraically summed. In accordance with this methodology, if no vendor drift is stated, then a drift value equal to the required accuracy may be used. For computer cards, per Assumption 3.7, the drift value is taken as the vendor accuracy term.

6.2 For calculation of the loop uncertainties, if the confidence level of a published uncertainty cannot be ascertained, the information shall be assumed to be 2σ (Assumption 3.1, Reference 4.1).

6.3 Instrument calibration setting tolerance represents 100% of the population, and so is applied as a 3σ error.

6.4 For calculation of the loop uncertainties, temperature, humidity and pressure errors, when available from the manufacturer, are evaluated with respect to the environmental service conditions in specification NE-00164 (Reference 4.7). If not provided, an evaluation is made to ensure that the environmental conditions are bounded by the manufacturer's specified operational limits. If the environmental conditions are bounded, these error effects are considered to be included in the manufacturer's reference accuracy. (Assumption 3.4).

6.5 ASME PTC-6 (Reference 4.12) is used to determine the error in the flow nozzles. PTC-6 is used because it provides a very conservative means to quantify the flow nozzle uncertainties, and it takes into account the upstream and downstream flow disturbances due to piping configurations.

6.6 Development of Uncertainty Equations

For a function Y of multiple variables (x_i), such as:

$$Y = f(x_1, x_2, x_3, \ldots, x_n)$$ **Equation 6.6-1**

The change in Y due to changes in the Xn variables is:

Equation 6.6-2

$$dY = \frac{(\partial Y)}{\partial x_1} dx_1 + \frac{(\partial Y)}{\partial x_2} dx_2 + \cdots + \frac{(\partial Y)}{\partial x_n} dx_n$$

If the variables are independent of each other, and their uncertainties are independent of each other, then the uncertainty (U_Y) in Y resulting from the combination of the independent uncertainties in the independent x_n variables is calculated as the square root of the sum of the squares:

Equation 6.6-3

$$U_Y = \left[\left(\frac{\partial Y}{\partial x_1} * \sigma x_1\right)^2 + \left(\frac{\partial Y}{\partial x_2} * \sigma x_2\right)^2 + \cdots + \left(\frac{\partial Y}{\partial x_n} * \sigma x_n\right)^2\right]^{1/2}$$

For dependent variables x_n, or dependent uncertainties, the uncertainty is a sum:

Equation 6.6-4

$$U_Y = \left(\frac{\partial Y}{\partial x_1} * \sigma x_1\right) + \left(\frac{\partial Y}{\partial x_2} * \sigma x_2\right) + \cdots + \left(\frac{\partial Y}{\partial x_n} * \sigma x_n\right)$$

Feedwater differential pressure and temperature are measured via independent instruments. There are no dependent uncertainties between the separate instrument loops, so all input variables and their uncertainties are modeled as independent.

7.0 NUMERIC ANALYSIS AND RESULTS

This section determines the uncertainties of the instrument loops that measure feedwater flow differential pressure and feedwater temperature, and the uncertainty of the mass feedwater flow as calculated in 3D Monicore.

7.1 Feedwater Nozzle Uncertainty

Per methodology Section 6.5, this section determines a bounding uncertainty for the feedwater flow nozzles, based on PTC-6 (Reference 4.12, applicable Tables and Figures are included in Attachment B), for the case in which the flow nozzle has not been calibrated to the LEFM. Per References 4.4.6 through 4.4.17, the feedwater flow nozzles do not have upstream flow straighteners, therefore the overall flow nozzle uncertainty (U) determined based on the combination of the following terms:

$$U = +\sqrt{U_B^2 + U_{LNS}^2 + U_\beta^2 + U_{DSL}^2}$$ **Equation 7.1-1**

U_B = base uncertainty of the nozzle, from Table 4.10 of Reference 4.12

U_{LNS} = minimum upstream straight run uncertainty, from Table 4.11 and Figure 4.5 of Reference 4.12

U_β = beta ratio effect, from Figure 4.6 of Reference 4.12

U_{DSL} = minimum downstream straight run uncertainty from Figure 4.9 of Reference 4.12

First the nearest upstream and downstream bends are determined based on review of the applicable isometric drawings. Then the values from the applicable PTC-6 tables and figures are used to determine the applicable individual uncertainties. Lastly, these uncertainties are combined via SRSS as shown in Equation 7.1-1 above.

Upstream and Downstream Bends:

From Input 2.5, this is a list of the first upstream and downstream obstruction for each feedwater nozzle. The distance in inches is divided by the 15.688 inch pipe diameter (Reference 4.11) to get the number of diameters.

Nozzle	Upstream	Distance (inches)	No. of Diameters	Downstream	Distance (inches)	No. of Diameters
FE-2-06-011A	90° bend	268.75	17.1	Tee	85.5	5.4
FE-2-06-011B	90° bend	310.7	19.8	Tee	85.5	5.4
FE-2-06-011C	90° bend	268.75	17.1	Tee	85.5 + 3 diam	8.5
FE-3-06-011A	90° bend	268.75	17.1	Tee	85.5	5.4
FE-3-06-011B	45° bend with 90° bend in different plane	186.75	18.3	Tee	85.5	5.4
FE-3-06-011C	90° bend	310.7	19.8	Tee	85.5 + 3 diam	5.4

Table 2.5 – Feedwater Line Obstructions

Reference 4.12 classifies the error terms calculated here as random errors. Per Assumption 3.9 the flow element error is taken as a 2σ confidence level

Base Uncertainty (U_B)

Per Assumption 3.10, the largest Group 1 base uncertainty from Table 4.10 of Reference 4.12 is conservatively used for both units, for a calibrated flow nozzle. Thus U_B = 2.5%.

Minimum Upstream Straight Run Uncertainty (U_{LNS})

For Unit 2, the most restrictive upstream case is a straight run of 17.1 diameters from a 90° bend. Interpolating the values in Column 1 of Table 4.11 of Reference 4.12, for a beta ratio of 0.6597, the denominator for the upstream length ratio is 12 diameters. The upstream length ratio is then: straight length ratio = 17.1 diameters/12 diameters = 1.43. The minimum straight run uncertainty (ULNs) is taken from Figure 4.5 of Reference 6 and is approximately 1.5% of flow.

For Unit 3, the most restrictive case is a combination of 45° and 90° bends in different planes, 18.3 diameters upstream. Interpolating the values in Column 2 of Table 4.11 of Reference 4.12, for a beta ratio of 0.6597, the denominator for the upstream length ratio is 17 diameters. The upstream length ratio is then: straight length ratio = 18.3 diameters/17 diameters = 1.08. The minimum straight run uncertainty (ULNs) is taken from Figure 4.5 of Reference 4.12 and is approximately 1.90% of flow.

Beta Ratio Uncertainty (U_β)

From above, β = 0.6597. From Figure 4.6 of Reference 4.12, the beta ratio effect U_β for a calibrated flow element is 0.33% of flow.

Minimum Downstream Straight Run Uncertainty (U_{DSL})

For both units, the most limiting downstream straight run is tee 5.45 diameters downstream of the nozzle. From Table 4.11 of Reference 4.12, the denominator for the minimum downstream length ratio from Column 7 is 4 diameters. The downstream length ratio is 5.45 diameters/4 diameters = 1.36. The minimum straight run uncertainty (U_{DSL}) is taken from Figure 4.9 of Reference 4.12 and is approximately 0.35% of flow.

The overall flow element measurement uncertainty is determined below, utilizing Equation 7.1-1. Per Assumption 3.9, this error is taken as a random 2σ term.

Unit 2

$$U_{FE2} = +\sqrt{U_B^2 + U_{LNS2}^2 + U_\beta^2 + U_{DSL}^2}$$

$U_{FE2} = \pm [(2.5\%)^2 + (1.5\%)^2 + (0.33\%)^2 + (0.35\%)^2]^{0.5}$

$U_{FE2} = \pm$ 2.95 % of flow [2σ]

Unit 3

$$U_{FE3} = +\sqrt{U_B^2 + U_{LNS3}^2 + U_\beta^2 + U_{DSL}^2}$$

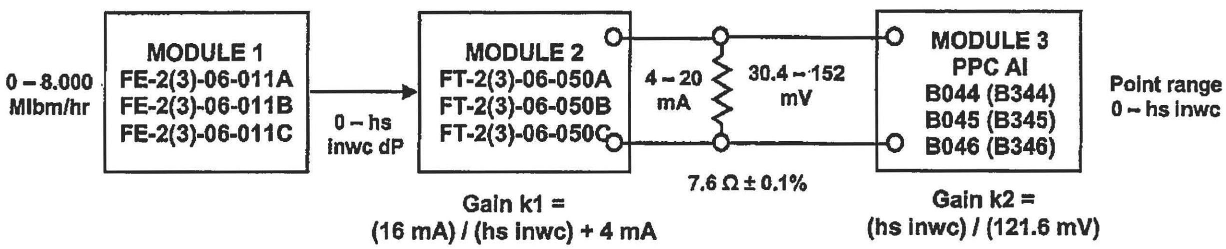
$U_{FE3} = \pm [(2.5\%)^2 + (1.9\%)^2 + (0.33\%)^2 + (0.35\%)^2]^{0.5}$

$U_{FE3} = \pm$ 3.18 % of flow [2σ]

7.2 Feedwater Flow Differential Pressure Measurement Loop Uncertainty

Loop configuration

The analyzed feedwater flow loop consists of the following: flow element, differential pressure transmitter, and PPC analog input (AI) card with a precision resistor across the input. The loop configuration is shown below (Input 2.1, Refs. 4.3, 4.4.2, 4.4.3, 4.5.1, 4.5.2):



Module 1

The flow element develops a differential pressure output based on the square of the flow input. For any flow $F_N = k(h_N)^{1/2}$, for MUR rated flow $F_r = k(h_r)^{1/2}$ and for full span flow $F_S = k(h_S)^{1/2}$,

solving each of these for constant k: $k = F_N/(h_N)^{1/2} = F_S/(h_S)^{1/2} = F_r/(h_r)^{1/2}$

or $h_N = h_r * F_N^2 / F_r^2$ **Equation 7.2-1a**

or $h_S = h_r * F_S^2 / F_r^2$ **Equation 7.2-1b**

This relationship is used to determine h at the points of interest.

Module 2

The transmitter output is linear with respect to the input, thus for any input X (in inwc), the transmitter output T (in mA) is defined as:

Equation 7.2-2

$$T = \frac{(16\ \text{mA})}{(h_S\ \text{inwc})} * X\ \text{inwc} + 4\ \text{mA}$$

For any error σ_X (in inwc) taken through the transmitter to find error in σ_T (in mA):

Equation 7.2-3

$$\sigma_T = \sigma_X * \frac{(16\ \text{mA})}{(h_S\ \text{inwc})}$$

Across Resistor

The mV output across the resistor for any mA input is: **Equation 7.2-4**

$$T = \frac{(121.6\ \text{mV})}{(16\ \text{mA})} * (X - 4)\text{mA} + 30.4\ \text{mV}$$

Module 3

For the differential pressure computer points, the output is linear with respect to the input:

Equation 7.2-5

$$T = \frac{(h_S\ inwc)}{(121.6\ mV)} * (x - 30.4)\ mV$$

For any error σ_X (in mV) taken through the point to find error in σ_T (in inwc):

Equation 7.2-6

$$\sigma_T = \sigma_X * \frac{(h_S\ \text{inwc})}{(121.6\ \text{mV})}$$

The analyzed loop components (and their applicable data) are as follows:

Module 1 – Flow Element FE 2(3)-06-011A, B, C

Make/Model Nozzle/GE Permutit 556-26400 (Reference 4.4.17)

Performance Specifications: (Input 2.1, unless noted otherwise)

Maximum flow 8.0000 Mlbm/hr

Nominal flow at rated power: 5.4813 Mlbm/hr

Differential pressure h_r at nominal flow for MUR operating conditions, Table 2.1.4 from Input 2.1.4:

Flow Element	inwc
FE-2-06-011A	h_{r2A} = 301.2
FE-2-06-011B	h_{r2B} = 304.2
FE-2-06-011C	h_{r2C} = 301.8
FE-3-06-011A	h_{r3A} = 301.2
FE-3-06-011B	h_{r3B} = 302.4
FE-3-06-011C	h_{r3C} = 302.4

Table 2.1.4 – MUR Nominal Rated Operating dP, h_r

Differential pressure h_S at full span flow, Table 2.1.5 from Input 2.1.5:

	From Input 2.1.5
Flow Element	
FE-2-06-011A	h_{S2A} = 638.6
FE-2-06-011B	h_{S2B} = 645.0
FE-2-06-011C	h_{S2C} = 639.9
FE-3-06-011A	h_{S3A} = 638.6
FE-3-06-011B	h_{S3B} = 641.2
FE-3-06-011C	h_{S3C} = 641.2

Table 2.1.5 – Full Span Operating dP, h_S

Accuracy Unit 2: ± 2.95% of flow; Unit 3: ± 3.18% of flow (Section 7.1)

Module 2 – Flow Transmitter FT 2(3)-06-050A, B, C

Make/Model Rosemount Model 1151DP5E22B2 (Reference 4.3)

Performance Specifications: (Reference 4.13, Input 2.4)

Operating Span	hs (inwc) in table above
Upper Range Limit (URL)	750 inwc
Accuracy	± 0.2% of calibrated span [3σ]; includes combined effects of linearity, hysteresis and repeatability
Drift (Stability)	± 0.2% of URL for 6 months [2σ] (range 5, code E)
Temperature Effect	± (0.5% URL + 0.18% cal span) per ambient temperature change of 100°F (55.6 °C) [3σ]
Static Pressure Zero Effect	± 0.25% of URL for 2000 psi, correctable by re-zeroing at line pressure
Static Pressure Span Effect	Correctable to ± 0.25% of URL for 1000 psi.

Note that although the static pressure zero and span effects are caused by a common static pressure condition, they are stated as two separate error effects by Rosemount and are treated as random independent errors per Attachment F and Input 2.4.

No radiation effect stated by manufacturer

No seismic effect stated by manufacturer

Operating Limits

Temperature	- 40°F to 200°F
Humidity	0 - 100 % relative humidity

Calibration Information (Input 2.1, Reference 4.3, 4.5.1, 4.5.2)

Operating Static Pressure	1100 psig	(per Input 2.3)
Operating Span	0 – h_S inwc	
Corresponding Process Range	0 – 8.000 Mlbm/hr	
Required Accuracy	± 0.5%, or ± 0.08 mA, or ± 0.02 Vdc	
Operating Output Span:	4 - 20 mA	
Calibration As-Left Tolerance	± 0.08 mA (0.5%), or ± 0.02 Vdc	

Location Information (Reference 4.7, unless noted otherwise)

Location (Ref. 4.3 & 4.6)	Unit 2: TB2, Rack 20C167, EL. 135', Corridor 219 (Ref. 4.4.18. 4.4.19) Unit 3: TB3, Rack 30C167, EL. 135', Corridor 264 (Ref. 4.4.18. 4.4.19)
Normal Temperature	65 °F (min.) / 102.5 °F (max) / 85°F (normal)
Normal Pressure	-0.25 inwc
Normal Humidity	10 to 90% RH
Radiation	6.43 E4 Rads (60 year TID)

The temperature and humidity limits for this location are bounded by the manufacturer's specified operating limits so per Assumption 3.4 any temperature induced effects are included in the manufacturer's specified temperature effects and any humidity induced effect is considered to be included in the manufacturer's specified accuracy.

A 7.6 Ω ± 0.1% tolerance resistor is used to convert the transmitter 4-20 mA output to a 30.4 - 152.0 mV input to the PPC input card.

Module 3 – Input Card for PPC Point B044, B045, B046 (B344, B345, B346), also called A1713, A1714, A1715 (A2713, A2714, A2715)

Make/Model	RTP 7436 Analog Input Card

Performance Specifications

Card full scale voltage	160 mV (Ref. 4.16)
Input Signal Range	30.4 – 152 mV (4 - 20 mA across a 7.6 Ω resistor) (Refs. 4.4.4 and 4.4.5)
Accuracy (12 bit)	± 0.025% of full scale (Ref. 4.14)
Temperature Effect	50 ppm per °C = 0.005%/°C (Ref. 4.14)
Drift	Not stated
Operating temperature range	0 – 55°C (32 – 131 °F)
Operating humidity range	20% to 80% RH, non-condensing

dP Point Display	0 – h_s inwc, read to 000.0 places

Location Information (Ref. 4.7, unless noted otherwise)

Location (Ref. 4.3)	Unit 2: Analog Input Cabinet, Room 301 Unit 3: Analog Input Cabinet, Room 301
Normal Temperature	65 °F (min.) / 72 °F (max)
Normal Pressure	14.7 psia
Radiation	mild environment

These temperature limits are bounded by the manufacturer's specified operating limits so per Assumption 3.4 any temperature induced effects are considered to be included in the manufacturer's specified temperature effects. The humidity limits of the Computer Room 301 are not stated in Reference 4.7, however, per Reference 4.15 the computer room HVAC controls maintain a constant temperature and humidity. These cards have functioned successfully in these locations for many years. Thus per Assumption 3.4 any potential humidity induced error effects are considered to be included in the manufacturer's specified accuracy.

Calibration Information (Refs. 4.3, 4.5.1, 4.5.2)

The flow loop is calibrated by using a pressure source to simulate pressure input to the transmitter (measured by a pressure gauge of at least 2.5 inwc accuracy), and then reading the voltage to a tolerance of ± 0.04 V (by a voltmeter of at least ±0.02 V accuracy) across a 0.1% tolerance 250 ohm resistor at the input to the feedwater control system, and reading the differential pressure computer point values to a tolerance of ± 4.9 inwc.

Thus the calibration error is based on the ± 2.5 inwc accuracy of the gauge used to read the input pressure, and the reading error of the computer point display. The reading error is the least significant digit of the display, which is ± 0.1 inwc. The maximum surveillance interval is taken as 30 months, based on 24 months including a 25% late factor.

The ± 4.9 inwc loop output tolerance is applied in place of the combined vendor accuracies of the transmitter and the PPC point analog to digital input card, since it is much larger than their combined vendor accuracies (Assumption 3.8).

Determination of Largest Full Span Operating h_S for use in Error Determinations and Units Conversions:

The determination or flow error terms, and their conversion between different units requires the use of a differential pressure value. It is most conservative to use a bounding value to encompass all possible values. The full span flow differential pressure values (h_S) from Input Table 2.1.5, taken from Reference 4.11, are based on a slightly different temperature than is present for MUR operating conditions. Thus the values from Table 2.1.5 are compared to the values resulting from the application of Equation 7.2-1.b to find the largest h_S, which will conservatively be used to find bounding values.

From above, $h_S = h_r * F_S^2 / F_r^2$ **Equation 7.2-1b**

Applying Equation 7.2-1b to h_{r2A} = 301.2 inwc (Input 2.1.4), where

F_S = 8.000 Mlbm/hr (Input 2.1.3) and F_r = 5.4813 Mlbm/hr (Input 2.1.1)

$h_{S2A} = h_{r2A} * F_S^2 / F_{r2A}^2$ = (301.2 inwc)*(8.000 Mlbm/hr)^2 / (5.4813 Mlbm/hr)^2

h_{S2A} = 641.6 inwc

The following table applies Equation 7.2-1b to all the hr values from Input Table 2.1.4:

Flow Element		inwc		inwc
FE-2-06-011A	h_{r2A} =	301.2	h_{s2A} =	641.6
FE-2-06-011B	h_{r2B} =	304.2	h_{s2B} =	648.0
FE-2-06-011C	h_{r2C} =	301.8	h_{s2C} =	642.9
FE-3-06-011A	h_{r3A} =	301.2	h_{s3A} =	641.6
FE-3-06-011B	h_{r3B} =	302.4	h_{s3B} =	644.2
FE-3-06-011C	h_{r3C} =	302.4	h_{s3C} =	644.2

Table 7.2-1 – Full Span Operating h_S per Eq. 7.2-1b

The following table compares the h_S values from Table 2.1.5 to the hs values from Table 7.2-1. The largest and smallest value for each unit is shown in bold.

	From Input 2.1.5		Using Equation 7.2-1b	
Flow Element		inwc		inwc
FE-2-06-011A	h_{s2A} =	**638.6**	h_{s2A} =	641.6
FE-2-06-011B	h_{s2B} =	645.0	h_{s2B} =	**648.0**
FE-2-06-011C	h_{s2C} =	639.9	h_{s2C} =	642.9
FE-3-06-011A	h_{s3A} =	**638.6**	h_{s3A} =	641.6
FE-3-06-011B	h_{s3B} =	641.2	h_{s3B} =	**644.2**
FE-3-06-011C	h_{s3C} =	641.2	h_{s3C} =	**644.2**

Table 7.2-2 –Full Span Operating h_S Comparison

The largest and smallest values for each unit will be applied in the error determinations and unit conversions in order to produce the most conservative results (larger error).

Feedwater Flow Differential Pressure Loop Note: All error values are ±			
Module 1: FE-2(3)-06-011A,B,C			
Module 2: FT-2(3)-06-050A,B,C			
Module 3: PPC Point B044, B045, B046 (B344, B345, B346), also called A1713, A1714, A1715 (A2713, A2714, A2715)			
	U2 Value	U3 Value	Units
MUR Total Nominal Flow FNT= (total, 3 loops) (Input 2.1.1)	16.4440	16.4440	Mlbm/hr
MUR Nominal Rated Flow per loop = FR = FNT/N, where N = 3 (number of loops)	5.4813	5.4813	Mlbm/hr
Full Span Flow per loop = FS (Input 2.1.1)	8.0000	8.0000	Mlbm/hr
hR = largest dP for rated MUR conditions = hr2B for U2; hr3B for U3	304.2	302.4	inwc
hRL = smallest (lowest) dP for rated MUR conditions = hr2A for U2; hr3A for U3	301.2	301.2	inwc
hSU = highest (upper) h at full span flow = hs2B for U2; hs3B for U3 (Table 7.2-2)	648.0	644.2	inwc
hSL = lowest h at full span flow = hs2A for U2; hs3A for U3 (Table 7.2-2)	638.6	638.6	inwc

Module 1: FE-2(3)-6-011A,B,C flow nozzle	U2 Value	U3 Value	Units	σ
UFE2 and UFE3 (Section 7.1)	2.95	3.18	%	
(Error conversions conservatively based on hR)				
Flow and dP are found at UFE% above and below nominal rated flow FR:				
Upper nominal flow limit = FNU = (100 + UFE)%*FR	5.6430	5.6556	Mlbm/hr	
Lower nominal flow limit = FNL = (100 – UFE)%*FR	5.3196	5.3070	Mlbm/hr	
hR = largest h at nominal rated flow = hr2B for Unit 2, = hr3A for Unit 3	304.2	302.4	inwc	
h at upper nominal flow limit hNU = hR * (FNU)^2 / (FR)^2 (per Eq. 7.2-1a)	322.41	321.94	inwc	
h at lower nominal flow limit hNL = hR * (FNL)^2 / (FR)^2 (per Eq. 7.2-1a)	286.52	283.47	inwc	
Upper limit error = hNU - hR	18.2	19.5	inwc	
Lower limit error = hNL - hR	-17.7	-18.9	inwc	
Apply larger of two in both directions:				
Accuracy = A1 = PEA	18.2	19.5	inwc	2
PMA = 0				
Determining maximum hNU and minimum hNL to bound all cases:				
hNU max is as determined above	322.41	321.94	inwc	
hNL min is hR2A – PEA (hRL and PEA from above)	283.00	281.70	inwc	

Module 2: FT-2(3)-06-050A,B,C (errors taken at hNU, hNL using hSU or hSL for max effect)	U2 Value	U3 Value	Units	σ
Rosemount 1151DP5E22B2 (Ref. 4.3)				
Operating Static Pressure (Input 2.3)	1100	1100	psig	
Upper Range Limit (URL) (Ref. 4.13)	750	750	inwc	
Output span: 4-20 mA, linear with dP	16	16	mA	
mANU = mA at hNU = (hNU)*(16 mA)/(hSL inwc) + 4 mA (Per Eq. 7.2-2)	12.08	12.07	mA	
mANL = mA at hNL = (hNL)*(16 mA)/(hSL inwc) + 4 mA (Per Eq. 7.2-2)	11.09	11.06	mA	
Vendor Accuracy = VA2' = 0.2% of span = 0.25%* hSL inwc	1.6200	1.6105	inwc	3
Taken as a 2σ value: VA2 = VA2' *2/3	1.0800	1.0737	inwc	2
TE2' = Temp Effect = (0.5% URL + 0.18% span) /100°F taken from 65 – 102.5 °F as: (0.5%*(hSL inwc) + 0.18%(hSL inwc))*(102.5 - 65)/100	3.0375	3.0197	inwc	3
Taken as a 2σ value: TE2 = TE2' *2/3	2.025	2.0131	inwc	2
SPE2Z = Static pressure zero effect =(1100 psig)* 0.25% URL/2000 psig	1.0313	1.0313	inwc	3
SPE2S = Static Pressure span effect = (1100 psig) * 0.25% URL / 2000 psig	1.0313	1.0313	inwc	3
SPE2' = SQRT(SPE2Z^2 + SPE2S^2)	1.4585	1.4585	inwc	3
Taken as a 2σ value: SPE2 = SPE2' *2/3	0.9723	0.9723	inwc	2
D2' = 0.2% of URL for 6 months = 0.2%*(750 inwc)	3.3541	3.3541	inwc	2
Taken as a 2σ value: D2 = D2' *2/3	2.2361	2.2361	inwc	
Radiation Effect - not applicable per Assumption 3.5				
Seismic Effect - not applicable per Assumption 3.6				

Module 3: PPC Point AI Card for B044, B045, B046 (B344, B345, B346), also called A1713, A1714, A1715 (A2713, A2714, A2715)	U2 Value	U3 Value	Units	σ
RTP 7436 Analog Input Card				
Card full scale voltage	160	160	mV	
Max input Voltage	152	152	mV	
Min input voltage	30.4	30.4	mV	
Voltage span	121.6	121.6	mV	
Vendor Accuracy = VA3' = 0.025% full scale output = 0.025%*(160 mV) (Ref. 4.14)	0.4	0.4	mV	2
Convert to inwc per Eq. 7.2-6 as: VA3 = VA3' * hSU/(121.6 mV)	2.1316	2.1191	inwc	2
TE3' = Temp Effect = 50 ppm full output/°C, taken over 65 to 72°F as: TE3 = 0.005%(160 mV)*(72-65)°F*(5°C/9°F) (Ref. 4.14)	0.0311	0.0311	mV	2
Convert to inwc per Eq. 7.2-6 as: TE3 = TE3' * hSU/(121.6 mV)	0.1657	0.1648	inwc	2
Drift = D3 = A3 (Assumption 3.7)	2.1316	2.1191	inwc	2
Calibration setting tolerance = CST3' = 4.9 inwc	4.9	4.9	inwc	3
CST3 as 2σ value: CST3 = CST3'*2/3	3.2667	3.2667	inwc	3
Accuracy = A23 = MAX(SQRT(VA2^2 + VA3^2),CST3) (Assumption 3.8)	3.2667	3.2667	inwc	2
Resistor Tolerance (taken at hNU and hSL for max effect))				
Convert hNU to mA per Eq. 7.2-2: hNUmA = (16 mA)/(hs inwc)*(hNU inwc) + 4 mA	12.0779	12.0661	mA	
Convert hNUmA to mV per Eq. 7.2-4: hNUmV = (121.6 mV)/(16 mA) *(hNUmA - 4)mA + 30.4 mV	122.19	122.10	mV	
Resistor tolerance = R1v= 0.1%*hNUmV	0.1222	0.1221	mV	2
Convert to inwc per Eq. 7.2-6 as: R1 = R1v * hSL/(121.6 mV)	0.6511	0.6468	inwc	2

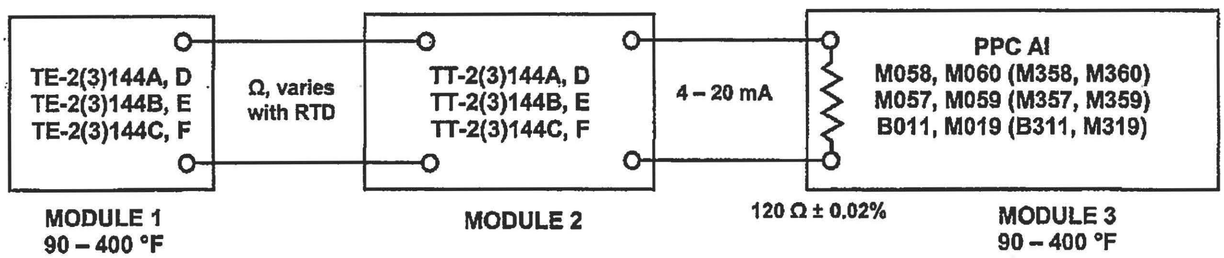
Differential Pressure Loop Calibration Error	U2 Value	U3 Value	Units	σ
Module 2 Input calibration error, based on accuracy of MTE = CLI2 = 2.5 inwc	2.5	2.5	inwc	2
Module 2 Output calibration error = CLO2 = 0 (loop calibration)				
Module 3 Input Calibration Error = CLI3 = 0 (loop calibration)				
Module 3 Output Calibration Error, based on reading error of dP display = CLO3 = 0.1 inwc	0.1	0.1	inwc	2
Module 2 Calibration Error = CC2 = SQRT(CLI2^2 + CLO2^2) = CLI2	2.5	2.5	inwc	2
Module 3 Calibration Error = CC3 = SQRT(CLI3^2 + CLO3^2) = CLO3	0.1	0.1	inwc	2

Differential Pressure Loop Error Calculation	U2 Value	U3 Value	Units	σ
Loop Accuracy: LA = SQRT(A1^2 + VA2^2 + TE2^2 + SPE2^2 + A3^2 + TE3^2 + R1^2)	18.6389	19.9089	inwc	2
Loop Drift: LD = SQRT(D2^2 + D3^2)	3.9587	3.9587	inwc	2
Loop Calibration Error: LC = SQRT(CC2^2 + CC3^2)	2.502	2.502	inwc	2
Loop error: σL = SQRT(LA^2 + LC^2 + LD^2)	19.2182	20.4523	inwc	2

7.3 Feedwater Temperature Measurement Uncertainty

Loop configuration

The analyzed feedwater Reactor Feed Pump temperature loop consists of an RTD wired to a temperature transmitter that sends a signal to the PPC through an analog to digital (A/D) converter. The loop configuration is shown below (Refs. 4.4.4, 4.4.5, 4.4.9, 4.16):



The analyzed loop components (and their applicable data) are as follows:

Module 1 – Temperature Element

Module 1: TE-2(3)144A, B, C, D, E, F

Make/Model: Pyco 22-4079-4.1-12.75, 100 Ω platinum RTD (Reference 4.3)

Performance Specifications:

Required Accuracy	± 0.25% of span (Reference 4.3)
Drift	not specified

Calibration Information (Reference 4.3, 4.5.3, 4.5.4)

Output Span:	ohm output varies with element, but corresponds to 90 to 400 °F
Corresponding Process Range	90 to 400 °F

Location Information (Reference 4.7, unless noted otherwise)

Location (Ref. 4.3)	Unit 2: T2-89, T2-91, T2-93, EL. 165', Area 07, RFP Room Unit 3: T3-90, T3-91, T3-93, EL. 165', Area 07, RFP Room
Normal Temperature	65 °F (min.) / 112.1 °F (max) / 85°F (normal)
Normal Pressure	-0.25 inwc
Normal Humidity	10 to 90% RH
Radiation	6.43 E4 Rads (60 year TID)

Module 2 – Temperature Transmitter TT-2(3)144A, B, C, D, E, F

Make/Model	Rosemount 3144 (Ref. 4.3)

Performance Specifications (Ref. 4.8, unless noted otherwise)

Input Signal Range	ohms matched to input element (112.586 to 177.628 ohms, typical)
Output Signal Range	4 – 20 mA
Required Accuracy	± 0.125%, or ± 0.02 mA (Ref. 4.3)
Digital Accuracy	± 0.18 °F
D/A Accuracy	± 0.02% of span

Total vendor accuracy is sum of digital and D/A accuracies

Stability (Drift) ±0.1% of reading or 0.1°C, whichever is greater, for 24 months

Power Supply Effect ±0.005% of span per volt

Decade box tolerance ± 0.082 ohms

Gain Adjustment (covered by calibration tolerance)

Temperature Effect 0.0015 °C + 0.001% of span per 28°C change in ambient

Temperature Limits - 40 to 185 °F (ambient, operational)

Humidity Limits 0-100%RH

Location Information (Reference 4.7, unless noted otherwise)

Location (Ref. 4.3) Unit 2: T2-82, EL. 150', Area 03, Comp. Room 301, Cabinet C431
Unit 3: EL. 150', Area 03, Comp. Room 301, Cabinet C430

Normal Temperature 65 °F (min.) / 72 °F (max)

Normal Pressure 14.7 psia

Radiation mild environment

Module 3 – Input Card for PPC Point M057, M058, M059, M060, B011, M019 (M357, M358, M359, M360, B311, M319)

Make/Model RTP Analog Input Card

Performance Specifications

Input Signal Range 0.48 – 2.4 V (4-20 mA across a 120 Ω 0.02% tolerance resistor) (Refs. 4.4.2, 4.4.3)

Accuracy (12 bit) ± 0.025% of full scale (Ref. 4.14)

Temperature Effect 50 ppm per °C = 0.005%/°C (Ref. 4.14)

Drift Not stated

Operating temperature range 0 – 55°C (32 – 131 °F)

Operating humidity range 20% to 80% RH, non-condensing

Point Display 90 – 400 °F (Ref. 4.5.3, 4.5.4)

Calibration Information (Reference 4.5.3, 4.5.4)

Calibration As-Left Tolerance ± 1.5 °F PPC point display

Module 3 Location Information (Ref. 4.7, unless noted otherwise)

Location (Ref. 4.3) Unit 2: Analog Input Cabinet, Computer Room 301
Unit 3: Analog Input Cabinet, Computer Room 301

Normal Temperature 65 °F (min.) / 72 °F (max)

Normal Pressure 14.7 psia

Radiation mild environment

These temperature limits are bounded by the manufacturer's specified operating limits so per Assumption 3.4 any temperature induced effects are considered to be included in the manufacturer's specified temperature effects. The humidity limits of the Computer Room 301 are not stated in Reference 4.7, however, per Reference 4.15 the computer room HVAC controls maintain a constant temperature and humidity. These cards have functioned successfully in this location for many years. Thus per Assumption 3.4 any potential humidity induced error effects are considered to be included in the manufacturer's specified accuracy.

Calibration Information (Reference 4.5.3, 4.5.4)

The temperature loop is calibrated by using a decade box of 0 – 200 ohms range with a minimum accuracy ± 0.082 ohms to simulate the RTD input to the temperature transmitter, and then reading the value in volts on the computer point display. The as-found and as-left voltages are converted to temperature and verified to a tolerance of ± 0.4 °F.

Thus the calibration error is based on the ± 0.082 ohm accuracy of the decade box used to read the input to the transmitter and the reading error of the computer point display. The reading error is the least significant digit of the display, which is ± 0.001 volts. The computer cards are not adjusted. The maximum surveillance interval is taken as 30 months, based on 24 months including a 25% late factor.

The ± 0.4°F loop tolerance is applied in place of the vendor accuracy of the PPC point analog to digital input card, since it is larger than the card vendor accuracy (Assumption 3.8).

FW Inlet Temperature Note: All error values are ±
Module 1: TE-2144A, B, C, D, E, F (TE-3144A, B, C, D, E, F)
Module 2: TT-2144A, B, C, D, E, F (TE-3144A, B, C, D, E, F)
Module 3: PPC Point M057, M058, M059, M060, B011, M019 (M357, M358, M359, M360, B311, M319)
Module 2b: Gate card model RTP 7435/50 (021-5234)
with A/D converter model RTP 7436/21 14-bit A/D

Module 1: TE-2144A, B, C, D, E, F (TE-3144A, B, C, D, E, F)	**Value**	**Units**	**σ**
Pyco 22-4079-4.1-12.75 RTD 100 Ω Platinum, dual, 3-wire (Ref. 4.3)			
Upper calibrated range	400	°F	
Lower calibrated range	90	°F	
Input span (400-90) °F (Ref. 4.3)	310	°F	
Output span: approx. 65 ohms, varies by TE to match 90 to 400 °F	65.005	ohms	
Accuracy = A1= 0.25%SPAN = 0.25%*310°F	0.7750	°F	2
Drift = D1 = A1 (Assumption 3.7)	0.7750	°F	2
PMA = 0; PEA = 0			

Module 2 - TT-2144A, B, C, D, E, F (TE-3144A, B, C, D, E, F)	**Value**	**Units**	**σ**
Rosemount Model 3144			
Digital Accuracy = DA = 0.18°F	0.18	°F	2
D/A Accuracy = DAA = 0.2% span = 0.2%* 310°F	0.62	°F	2
Accuracy = A2 = DA + DAA	0.8	°F	2
Stability (drift) = greater of 0.1% rdg or 0.1°C, for 24 months D2' = larger of 0.1%*400 °F = 0.4 °F or 0.1°C*9/5 = 0.18 °F	0.4	°F	2
take as 2 intervals to cover 30 months: D2 = SQRT(2*D2'^2)	0.5657	°F	2
Temperature Effect TE2 = 0.0015°C + 0.001% span per 28°C change in ambient, taken over 65 to 72°F as: TE2 = (0.0015°C)*(9°F/5°C) + 0.001%*(310°F)*(72-65°F)/(28°C*(9°F/5°C))	0.0031	°F	2
Power Supply Effect negligible per Assumption 3.3			

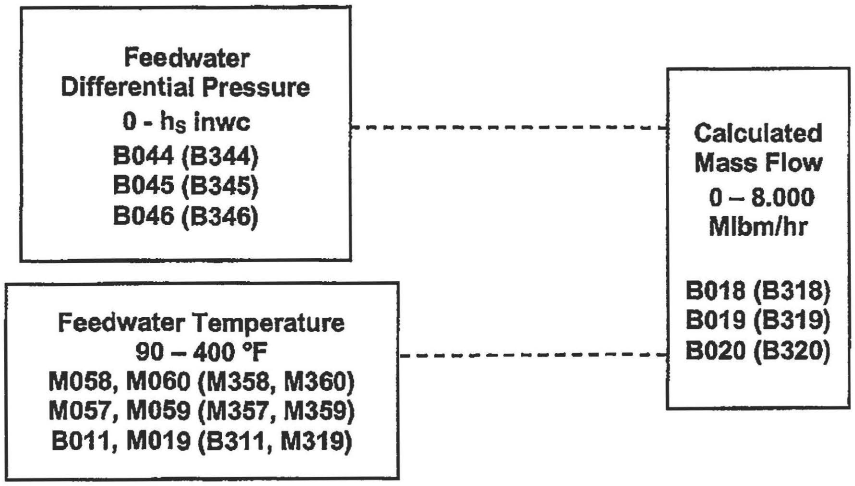
Module 3 - PPC Point AI Card for M057, M058, M059, M060, B011, M019 (M357, M358, M359, M360, B311, M319)	**Value**	**Units**	**σ**
RTP Analog Input Card			
VA3 = Accuracy = 0.025% full scale (Ref. 4.14)	0.1	°F	2
TE3 = Temp Effect = 50 ppm full scale/°C taken over 65 to 72°F as: 0.005%*(400 °F)*(72 - 65)°F*(5°C/9°F) (Ref. 4.14)	0.0778	°F	2
Drift = D3 = A3 (Assumption 3.7)	0.1	°F	2
Calibration Setting Tolerance = CST3' = 0.04 °F	0.4	°F	3
CST3 as 2σ value: CST3 = CST3'*2/3	0.2667	°F	2
Accuracy = A3 = MAX(VA3,CST3) (Assumption 3.8)	0.2667	°F	2
Resistor Tolerances			
R1 = resistor 1 tolerance = 0.02% = 0.02%*400 °F (Ref. 4.4.2, 4.4.3) (Conservatively taken at upper range value of 400°F)	0.08	°F	2

Calibration Error (Refs. 4.5.3, 4.5.4)	**Value**	**Units**	**σ**
Module 1 Input Calibration Error: CLI1 = 0			
Module 1 Output Calibration Error: CLO1 = 0			
Module 1 Calibration Error: CC1 = SQRT(CLI1^2 + CLO1^2) = 0	0	°F	2
Module 2 Input Calibration Error: CLI2 = 0.082 ohms*(310 °F)/(65 ohms)	0.391	°F	2
Module 2 Output Calibration Error: CLO2 = 0			
Module 2 Calibration Error: CC2 = SQRT(CLI2^2 + CLO2^2) = CLI2	0.391	°F	2
Module 3 Input Calibration Error: CLI3 = Input Error = 0			
Module 3 Output Calibration Error: CLO3 = Output Error = 0	0	°F	2
Module 3 Calibration Error: CC3 = SQRT(CLI3^2 + CLO3^2) = 0	0	°F	2
Loop Error Calculation	**Value**	**Units**	**σ**
Loop Accuracy: LA = SQRT(A1^2 + A2^2 + TE2^2 + A3^2 + TE3^2 + R1^2)	1.1507	°F	2
Loop Drift: LD = SQRT(D1^2 + D2^2 + D3^2)	0.9647	°F	2
Loop Calibration Error: LC = SQRT(CC1^2 + CC2^2 + CC3^2)	0.3910	°F	2
Temperature Channel Error Calculation	**Value**	**Units**	**σ**
Loop error σL = SQRT(LA^2 + LC^2 + LD^2)	1.5517	°F	2

7.4 Feedwater Mass Flow Uncertainty in the PPC

Loop configuration

The measured values of the differential pressure across each feedwater nozzle and the reactor feed pump discharge temperature of each loop are inputs used in the PPC to calculate the mass flow of each nozzle. The loop configuration is shown below (Refs. 4.10 and 4.11, Input 2.1.1):



RFP Mass Discharge Flow - PPC Point B018, B019, B020 (B318, B319, B320)

This is a calculated point based on two variables: the feedwater flow differential pressure input and the feedwater inlet temperature (Design Input 2.2, based on References 4.10 and 4.11).

Within the PPC, the 3D Monicore converts the differential pressure input to mass flow as follows:

Unit 2:
A Loop: B018 = NSCFW001 * S516 * SQRT(B044)
B Loop: B019 = NSCFW002 * S517 * SQRT(B045)
C Loop: B020 = NSCFW003 * S518 * SQRT(B046)

Unit 3:
A Loop: B318 = NSCFW301 * S816 * SQRT(B344)
B Loop: B319 = NSCFW302 * S817 * SQRT(B345)
C Loop: B320 = NSCFW303 * S818 * SQRT(B346)

Generically, Bxxx = NSCFWxxx * Sx1x * SQRT (Bx4x) **Eq. 7.4.1**

Where:

Bxxx is feedwater mass flow point, in units of Mlbm/hr

Bx4x is the differential pressure point, in units of inwc

Sx1x are unitless scaling factors determined in Ref. 4.11 as:

Unit 2	S516 = 10.27333	Unit 3	S816 = 10.25728
	S517 = 10.34251		S817 = 10.37076
	S518 = 10.23560		S818 = 10.21455

NSCFWx0x is a density correction in the 3D Monicore, based on difference between the nominal feedwater temperature and the measured reactor feed pump discharge temperature, as:

NSCFWx0x = FWC2*(1.0 + DT * (FWC4 + DT * FWC5)) **Eq. 7.4.2**

Where: DT = TFW – FWC **Eq. 7.4.3**

DT = difference between measured and nominal feedwater temperatures

TFW = measured feedwater temperature for the loop. TFW is the average of the two loop temperature points if both points are good; or TFW is equal the single good point if only one is good. The temperature points are:

Unit 2	Loop A: M058, M060	Unit 3	Loop A: M358, M360
	Loop B: M057, M059		Loop B: M357, M359
	Loop C B011, M019		Loop C: B311, M319

FWC2 = 3.09400E-02
FWC3 = 376.1°F
FWC4 = -3.35720E-04
FWC5 = -4.14750E-07

All of these numbers are constants, except for the measured differential pressure (B044, B045, B046, B344, B345, B346) and measured feedwater temperature (TFW). Thus the feedwater mass flow is calculated as a function of two variables, feedwater differential pressure and feedwater temperature.

First, based on Eq. 7.4.1, in order to simplify the written nomenclature before taking partial differentials, let mass flow be represented as:

$$M = N * S * h^{1/2}$$ **Eq. 7.4.1-1**

Where:

M = mass flow B018, B019, B020, B318, B319, B320 (variable)

N = density correction NSFW001, NSCFW002, NSCFW003, NSCFW301, NSCFW302, NSCFW303 (variable)

S = scaling factor S516, S517, S518, S816, S817, S818 (constant)

h = differential pressure B044, B045, B046, B344, B345, B346 (variable)

Let Eq. 7.4.2 be represented as: $N = C2*(1.0 + D * (C4 + D * C5))$ **Eq. 7.4.2-1**

and Eq. 7.4.3 be represented as: $D = T - C3$ **Eq. 7.4.3-1**

Where:

C2 = FWC2 (constant)

C3 = FWC3 (constant)

C4 = FWC4 (constant)

C5 = FWC5 (constant)

D = DT = feedwater temperature difference (variable)

T = TFW = measured feedwater temperature (variable)

Substituting Eq. 7.4.3-1 into Eq. 7.4.2.-1:

$$N = C2 * (1.0 + (T - C3) * (C4 + (T - C3)*C5))$$

$$N = C2 * (1.0 + C4 * (T - C3) + C5 * (T - C3)^2)$$ **Eq. 7.4.4-1**

Substituting Eq. 7.4.4-1 into 7.4.1-1:

$$M = C2 * (1.0 + C4 * (T - C3) + C5 * (T - C3)^2) * S * h^{1/2}$$ **Eq. 7.4.5-1**

Based on Equation 6.6-3, the uncertainty in feedwater mass flow due to the effects of temperature and differential pressure measurement uncertainties is:

$$U_M = \left[\left(\frac{\partial M}{\partial T} * \sigma_T\right)^2 + \left(\frac{\partial M}{\partial h} * \sigma_h\right)^2\right]^{1/2}$$

This may also be expressed as:

$$U_M = \left[U_{MT}^2 + U_{Mh}^2\right]^{1/2} \qquad \textbf{Eq. 7.4.6}$$

Where U_{MT} is the uncertainty in mass flow due to the effect of temperature measurement uncertainty and U_{Mh} is the uncertainty in mass flow due to the effect of differential pressure measurement uncertainty.

First these two uncertainty effects are determined using bounding conditions for each case in order to determine the maximum error at nominal feedwater flow for MUR operating conditions.

<u>Effect of Temperature Measurement Uncertainty:</u>

Taking the partial differential of Eq. 7.4.5-1 with respect to temperature:

$$\partial M/_{\partial T} = C2 * S * (C4 + 2 * C5 * (T - C3)) * h^{1/2}$$

The uncertainty in feedwater mass flow due to the effect of temperature uncertainty is:

$$U_{MT} = \left[\left(\frac{\partial M}{\partial T} * \sigma_T\right)^2\right]^{1/2}$$

Substituting the partial derivatives from above:

$$U_{MT} = \left[\left(C2 * S * (C4 + 2 * C5 * (T - C3)) * h^{1/2} * \sigma_t\right)^2\right]^{1/2}$$

Substituting the original constants and variables:

$$U_{MT} = \left[\left(FWC2 * Sx1x * \left(FWC4 + 2 * FWC5 * (TFW - FWC3)\right) * (Bx4x)^{1/2} * \sigma_{TFW}\right)^2\right]^{1/2} \qquad \textbf{Eq. 7.4.7}$$

Solving Equation 7.4.7 for Unit 2 and Unit 3 using (from above):

FWC2 = 3.09400E-02 = 0.03094

FWC3 = 3.76100E+02 = 376.1

FWC4 = -3.35720E-04

FWC5 = -4.14750E-07

Unit 2: S516 = 10.27333, S517 = 10.34521, S518 = 10.2356;
so Sx1x = S51x = 10.35 to bound Unit 2 values

Unit 3: S816 = 10.25728, S817 = 10.37076, S818 = 10.21455;
so Sx1x = S81x = 10.38 to bound Unit 3 values

TFW = nominal feedwater temperature at MUR conditions = 383.4 °F

Bx4x = hR = nominal (rated) differential pressure, from Section 7.2
= 304.20 inwc (Unit 2); 302.40 inwc (Unit 3)

σ_{TFW} = feedwater temperature measurement error = ± 1.5517 °F (Section 7.3)

The uncertainty in mass flow due to the temperature measurement uncertainty, based on Eq. 7.4.7:

$$U_{MT} = \left[\left(FWC2 * Sx1x * \left(FWC4 + 2 * FWC5 * (TFW - FWC3)\right) * (Bx4x)^{1/2} * \sigma_{TFW}\right)^2\right]^{1/2}$$

For Unit 2:

$$U_{MT2} = \left[\left(0.03094 * 10.35 * \left((-3.35720E^{-04}) + 2 * (-4.14750E^{-07}) * (383.4 - 376.1)\right) * (304.20)^{1/2} * 1.5517\right)^2\right]^{1/2}$$

$$U_{MT2} = \pm 0.002962 \text{ Mlbm/hr}$$

For Unit 3:

$$U_{MT3} = \left[\left(0.03094 * 10.38 * \left((-3.35720E^{-04}) + 2 * (-4.14750E^{-07}) * (383.4 - 376.1)\right) * (302.40)^{1/2} * 1.5517\right)^2\right]^{1/2}$$

$$U_{MT3} = \pm 0.002962 \text{ Mlbm/hr}$$

<u>Effect of differential pressure measurement uncertainty:</u>

Taking the partial differential with respect to differential pressure:

$$\partial M/_{\partial h} = \frac{1}{2} * C2 * S * (1.0 + C4 * (T - C3) + C5 * (tT - C3)^2) * h^{-1/2}$$

The uncertainty in feedwater mass flow due to the effect of differential pressure uncertainty is:

$$U_{Mh} = \left[\left(\frac{\partial M}{\partial h} * \sigma_h\right)^2\right]^{1/2}$$

Substituting the partial derivatives from above:

$$U_{Mh} = \left[\left(\frac{1}{2} * C2 * S * (1.0 + C4 * (T - C3) + C5 * (T - C3)^2) * h^{-1/2} * \sigma_h\right)^2\right]^{1/2}$$

Substituting the original constants and variables:

$$U_{Mh} = \left[\left(\frac{1}{2} * FWC2 * Sx1x * (1.0 + FWC4 * (TFW - FWC3) + FWC5 * (TFW - FWC3)^2) * (Bx4x)^{-1/2} * \sigma_{Bx4x}\right)^2\right]^{1/2}$$

Eq. 7.4.8

Solving Equation 7.4.8 for Unit 2 and Unit 3 using values from above and:

σ_{Bx4x} = feedwater differential pressure measurement error, from Section 7.2
= ± 19.2182 inwc (Unit 2); ± 20.4523 inwc (Unit 3)

The uncertainty in mass flow due to the differential pressure measurement uncertainty:

For Unit 2:

$$U_{Mh} = \left[\left(\frac{1}{2} * FWC2 * Sx1x * (1.0 + FWC4 * (TFW - FWC3) + FWC5 * (TFW - FWC3)^2) * (Bx4x)^{-1/2} * \sigma_{Bx4x}\right)^2\right]^{1/2}$$

$$U_{Mh2} = \left[\left(\frac{1}{2} * 0.03094 * 10.35 * (1.0 + 03.35720E^{-04} * (383.4 - 376.1) + (-4.14750E^{-07}) * (383.4 - 376.1)^2) * (304.20)^{-1/2} * 19.2182\right)^2\right]^{1/2}$$

$$U_{Mh2} = \pm 0.1760 \text{ Mlbm/hr}$$

For Unit 3:

$$U_{Mh3} = \left[\left(\frac{1}{2} * 0.03094 * 10.38 * (1.0 + 03.35720E^{-04} * (383.4 - 376.1) + (-4.14750E^{-07}) * (383.4 - 376.1)^2) * (302.40)^{-1/2} * 20.4523\right)^2\right]^{1/2}$$

$$U_{Mh3} = \pm 0.1884 \text{ Mlbm/hr}$$

Total uncertainty in mass flow due to both the temperature and differential pressure measurement uncertainty:

Recalling Eq. 7.4-6 from above

$$U_m = \left[U_{mt}^2 + U_{mh}^2\right]^{1/2} \qquad \textbf{Eq. 7.4.6}$$

Combining the uncertainty in mass flow due to temperature measurement uncertainty and differential pressure measurement uncertainty, based on the values determined above from Equations 7.4.7 and 7.4.8.:

For Unit 2: $U_{m2} = [(0.002962)^2 + 0.1760^2]^{1/2} = \pm 0.1760 \frac{\text{Mlbm}}{\text{hr}}$

For Unit 3: $U_{m3} = [(0.002962)^2 + 0.1884^2]^{1/2} = \pm 0.1884 \frac{\text{Mlbm}}{\text{hr}}$

By inspection is can be seen that the temperature measurement error has an insignificant effect on the overall mass flow measurement error, because the effect of the differential pressure measurement error is over 59 times greater. Thus the error contribution due to temperature measurement may be neglected and the error in mass flow is based entirely on the error in differential pressure measurement.

Dividing by single element mass flow (F_R = 5.4813 Mlbm/hr from Section 7.2) to put in terms of percent of flow:

For Unit 2: U_{m2} = (0.1760 Mlbm/hr) / (5.4813 Mlbm/hr) = ± 3.21 of nominal flow

For Unit 3: U_{m3} = (0.1884 Mlbm/hr) / (5.4813 Mlbm/hr) = ± 3.44% of nominal flow

7.5 Feedwater Mass Flow Total Uncertainty

The individual uncertainties for nominal feedwater flow at MUR conditions as determined in Sections 7.1 through 7.4 are:

Section	Parameter	Unit 2	Unit 3
7.1	Single Feedwater Nozzle Uncertainty	± 2.95% of flow	± 3.18% of flow
7.2	Feedwater Flow Differential Pressure Measurement Uncertainty	± 19.2182 inwc	± 20.4523 inwc
7.3	Feedwater Inlet Temperature Measurement Uncertainty	± 1.5517 °F	± 1.5517 °F
7.4	Feedwater Single Loop Mass Flow Uncertainty in the PPC, based only on the uncertainty of the differential pressure measurement	± 0.1760 Mlbm/hr	± 0.1884 Mlbm/hr
		± 3.21% of flow	± 3.44% of flow

Table 7.5-1 Feedwater Mass Flow Uncertainties

8.0 CONCLUSIONS

For Peach Bottom Units 2 and 3, the error in feedwater mass flow as determined in the PPC for a single feedwater flow loop is based entirely on the error of the differential pressure measurement across the nozzle. For Unit 2, this uncertainty is ± 0.1760 Mlbm/hr, or ± 3.21 % of nominal feedwater flow for MUR operating conditions. For Unit 3, this uncertainty is ± 0.1884 Mlbm/hr, or ± 3.44 % of nominal feedwater flow for MUR operating conditions.

These values are provided for input to the Cameron calculations that will determine the overall uncertainty in the Peach Bottom Unit 2 and Unit 3 CTP Calculation for the MUR Uprate. There are no specific acceptance criteria.

If future modifications replace components in any of the analyzed loops, the calculated uncertainty results will remain bounding as long as the replacement components are at least as accurate as those analyzed herein. If the calibration equipment is replaced or calibration processes or procedures are modified in the future, the calculated uncertainties remain bounding as long as the calibration equipment is at least as accurate as what is analyzed herein, and the calibration process maintains the same or smaller as left tolerances.

Patricia Ugorcak

From:	Schoenknecht, Karl A:(BSC) <karl.schoenknecht@exeloncorp.com>
Sent:	Thursday, April 06, 2017 12:06 PM
To:	Cutler, Kenneth E:(GenCo-Nuc)
Cc:	Hamm, Kelly Eugene:(GenCo-Nuc); Patricia Ugorcak
Subject:	<EXTERNAL> RE: Input for FW flow equation in PPC

Ok,
Here is something I wrote up using the Unit 3 points describing the implementation in the computer. It does not describe how the redundancy works (the A points), but maybe this is the confirmation you are looking for?
Karl

B318: 3A Feedwater Mass Flow (Mlb/hr)
B318 = NSCFW301 * S816 * SQRT(B344)
[If the value of B318 goes below constant S863, B318 is clamped to 0 Mlbs/hr]
NSCFW301 =3A F/W FLO CORRECTION FACTOR, calc'd live by 3DMONICORE
B344 (A2713) 3A Feedwater delta-P
S816 = constant (10.2400)
S863 = constant (0.70 Mlb/hr)

B319: 3B Feedwater Mass Flow (Mlb/hr)
B319 = NSCFW302 * S817 * SQRT(B345)
[If the value of B318 goes below constant S863, B319 is clamped to 0 Mlbs/hr]
NSCFW302 = 3B F/W FLO CORRECTION FACTOR, calc'd live by 3DMONICORE
B345 (A2714) 3B Feedwater delta-P
S817 = constant (10.3237)
S863 = constant (0.70 Mlb/hr)

B320: 3C Feedwater Mass Flow (Mlb/hr)
B320 = NSCFW303 * S818 * SQRT(B346)
[If the value of B320 goes below constant S863, B320 is clamped to 0 Mlbs/hr]
NSCFW303 = 3C F/W FLO CORRECTION FACTOR, calc'd live by 3DMONICORE
B346 (A2715) 3C Feedwater delta-P
S818 = constant (10.3544)
S863 = constant (0.70 Mlb/hr)

From: Cutler, Kenneth E:(GenCo-Nuc)
Sent: Thursday, April 06, 2017 1:00 PM
To: Schoenknecht, Karl A:(BSC) <karl.schoenknecht@exeloncorp.com>
Cc: Hamm, Kelly Eugene:(GenCo-Nuc) <Kelly.Hamm@exeloncorp.com>; Patricia Ugorcak <pugorcak@enercon.com>
Subject: RE: Input for FW flow equation in PPC

Karl, this is for MUR (Appendix K round 2), not DFW. MUR would not be changing the formulas. Here is more clarification on the request:

Kelly,

What I most need is an input that says that points B018, B019, B020, B318, B319 and B320 are determined in the PPC from points B044, B045, B046, B344, B345 and B346 as follows:

For Unit 2: B018 = NSCFW001*S516*SQRT(B044) A Loop
B019 = NSCFW002*S517*SQRT(B045) B Loop
B020 = NSCFW003*S518*SQRT(B046) C Loop

For Unit 3: B318 = NSCFW301*S816*SQRT(B344) A Loop
B319 = NSCFW302*S817*SQRT(B345) B Loop
B320 = NSCFW303*S818*SQRT(B346) C Loop

S-102-VC-25 and -31 define how the NSCFW0(3)0x terms are calculated in 3D Monicore, so that part is covered.

EE-0029 determines the S5(8)1X terms, based on the Unit 2 tracer tests from 1992 and the cross flow ultrasonic testing from 1999. Even if they change when EE-0029 is revised, that shouldn't affect the uncertainty determination. But if there is a better input for those values than the current revision of EE-0029, then I should use it. What matters most is a source that states how the B018 type mass flow points are calculated from the B044 type differential pressure points.

I hope this clarifies the request. I can call you after 2 today to verify.

Patty

Ken Cutler, P.E.
Senior Engineer, Electrical/I&C
Peach Bottom Atomic Power Station
(717)-456-4590
Exelon Generation.

From: Schoenknecht, Karl A:(BSC)
Sent: Thursday, April 06, 2017 12:56 PM
To: Cutler, Kenneth E:(GenCo-Nuc)
Cc: Hamm, Kelly Eugene:(GenCo-Nuc); Patricia Ugorcak
Subject: RE: Input for FW flow equation in PPC

Ken,

Is this for Digital Feedwater control upgrade? I had a strange email exchange with Driscoll on this.

Anyway, I would not call this description 100% accurate. The formulas look okay but the description of the redundancy is off.
Unfortunately I don't have a written description, but would be happy to answer questions.
Will these calcs be changed by the mod?

Karl

From: Cutler, Kenneth E:(GenCo-Nuc)
Sent: Thursday, April 06, 2017 12:37 PM
To: Schoenknecht, Karl A:(BSC) <karl.schoenknecht@exeloncorp.com>

Cc: Hamm, Kelly Eugene:(GenCo-Nuc) <Kelly.Hamm@exeloncorp.com>; Patricia Ugorcak <pugorcak@enercon.com>
Subject: FW: Input for FW flow equation in PPC

Karl, would it be possible for you to validate the information Patty is asking about?

Ken Cutler, P.E.
Senior Engineer, Electrical/I&C
Peach Bottom Atomic Power Station
(717)-456-4590
Exelon Generation.

From: Patricia Ugorcak [mailto:pugorcak@enercon.com]
Sent: Thursday, April 06, 2017 10:01 AM
To: Hamm, Kelly Eugene:(GenCo-Nuc)
Cc: Jim Kyer; Larry Lawrence; Cutler, Kenneth E:(GenCo-Nuc)
Subject: [EXTERNAL] Input for FW flow equation in PPC

Kelly,

Attached is Att. 8.1 from PM-1051 Rev. 0. It includes the equations used by the PPC for conversion of the differential pressure input points (B044, B045, B046 type) to mass flow (B018, B019, B020 type). The info is highlighted in yellow on pages 3 and 4. Is there a way I can get a more modern input for this information? Perhaps from someone in a computer group or the PPC system manager?

Patty

Patricia Ugorcak
Senior I&C Engineer
2056 Westings Avenue Ste. 140 | Naperville, IL 60563
Direct: 630.864.3638 | Fax: 630.864.3602
pugorcak@enercon.com | www.enercon.com

TABLE 4.10
BASE UNCERTAINTIES OF PRIMARY FLOW MEASUREMENT

Item	Base Uncertainty, U_B,%	Liquid			Superheated Steam (at Least 25° Superheat)		
		Flow Nozzle			Flow Nozzle		
		Throat Tap	Pipe Wall Tap	Orifice	Throat Tap	Pipe Wall Tap	Orifice
	Group 1 — Calibrated Flow Sections						
A	Meeting Code requirements	0.15 [Note (3)]	0.25 [Note (4)]	0.25 [Note (4)]	0.25 [Note (4)]	0.35 [Note (4)]	0.45 [Note (4)]
B	Calibrated immediately before test and inspected after test, coefficient curve extrapolated	0.25	0.50	0.60	0.50	0.75	1.10
C	Calibrated before installation and inspected before and after test assuring no visible or measurable changes in the flow element	0.35	0.60	0.80	0.70	1.05	1.65
D	Calibrated before permanent installation and installed after initial flushing [Note (1)]	1.25	1.25	1.55	1.60	1.70	2.30
E	Calibrated before permanent installation [Notes (1) and (2)]	2.50	2.50	3.00	2.75	2.80	3.70
	Group 2 — Uncalibrated Flow Sections						
F	Inspected immediately before and after test	0.80	2.00	1.00	1.20	2.50	2.00
G	Inspected immediately before test	1.15	2.50	2.50	1.50	3.00	3.00
H	Inspected before permanent installation (Notes (1) and (2))	2.60	3.20	3.20	3.00	3.70	4.20
I	No inspection and permanent installation			See Par. 4.16(a) (1), Item I			

GENERAL NOTE: Overall uncertainty of flow sections:

With no flow straightener $= \sqrt{(U_B)^2 + (U_{INS})^2 + (U_\beta)^2 + (U_{DSL})^2}$

With a flow straightener $= \sqrt{(U_B)^2 + (U_\beta)^2 + (U_{LS1})^2 + (U_{LS2})^2 + (U_{DSL})^2}$

Where U_B is from this table, U_{INS} is from Fig. 4.5, U_β is from Fig. 4.6, U_{LS1} is from Fig. 4.7, U_{LS2} is from Fig. 4.8, and U_{DSL} is from Fig. 4.9.

NOTES:

(1) Good water chemistry, no after test inspection, less than six months in service (see Par. 4.17).

(2) Reasonable assurance that minimal damage was caused to flow element during initial flushing.

(3) 0.15% pertains to flow sections located in the lower temperature part of the cycle. The 0.15% may increase to 0.25% when the flow section is located in the higher temperature part of the cycle, such as in the boiler feedwater line downstream of the top heater.

(4) Information relative to the construction, calibration, and installation of other flow-measuring devices is described in ASME PTC 19.5-1972. Although these devices are not recommended for the measurement of primary flow, they may be used if they conform to the general requirements of Par. 4.22 of the Code with the following exceptions:

(a) For the requirement of Par. 4.22(a) of the Code, the β ratio shall be limited to the range 0.25 to 0.50 for wall tap nozzles and venturis and 0.30 to 0.60 for orifices.

(b) For the requirement of Par. 4.22(d) of the Code, the appropriate reference coefficient for the actual device given in PTC 19.5 shall be used. The parties to a test should become familiar with the contents of PTC 19.5 regarding these devices.

TABLE 4.11
MINIMUM STRAIGHT LENGTH OF UPSTREAM PIPE FOR ORIFICE PLATES AND FLOW NOZZLE FLOW SECTIONS WITH NO FLOW STRAIGHTENERS

[Minimum Straight Lengths of Pipe Required Between Various Fittings Located at Inlet and Outlet of the Primary Device, and Device Itself (based on information in ASME MFC-3M-1985 and ASME PTC 19.5-1972).]

	On Inlet Side of Primary Device						
	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7
Diameter Ratio	Single 90 deg. Bend or Tee (Flow From One Branch Only)	Two 90 deg. Ells in Same Plane	Two 90 deg. Ells in Same Plane, Separated by 10 Diameters of Straight Pipe [Note (1)]	Two 90 deg. Ells Not in Same Plane [Note (2)]	Reducers and Expanders	Valve or Regulator [Note (3)]	On Outlet Side (For All Inlets)
0.10	6	8.5	6	14	6	16.5	2.5
0.15	6	8.5	6	14	6	17	2.5
0.20	6	8.5	6	14.5	6	18	2.5
0.25	6	8.5	6	15.5	6	18.5	3
0.30	6	8.5	6	16	6	19.5	3
0.35	6	8.5	6	17	6	20.5	3
0.40	6	8.5	6	18	6	22	3.5
0.45	6.5	9	6.5	19.5	6.5	23.5	3.5
0.50	7	10	7.5	21	7	25	3.5
0.55	8	11.5	8.5	22.5	8	27	3.5
0.60	9.5	14	9.5	25	9.5	30	4
0.65	11.5	16	11	29.5	11.5	34	4
0.70	14	19	12	31	14	39	4
0.75	16.5	21.5	13.5	35	16.5	44	4.5

GENERAL NOTES:

(a) All straight lengths are expressed as multiples of pipe diameter *D* and are measured from the upstream end of the inlet section.

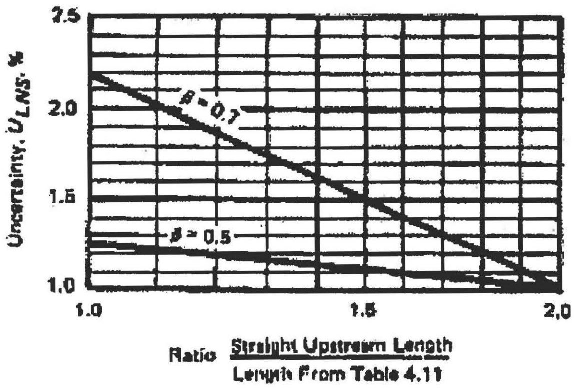
(b) The radius of curvature of a bend or elbow shall not be less than 0.75 times the pipe diameter *D*.

NOTES:

(1) If this length is less than 10 diameters, Column 2 shall apply.

(2) If the two ells in Column 4 are closely preceded by a third ell not in the same plane as the second ell, the piping requirements shown by Column 4 should be doubled.

(3) The valve or regulator in Column 6 restricts the flow; however, a wide open gate valve or plug valve may be considered as not creating any serious disturbance, and it may be located according to the requirements of the fitting preceding it, as permitted in Column 1, 2, 3, or 4.



GENERAL NOTE: Curves are for flow section arrangements where only moderate upstream disturbances are expected (see Par. 4.16).

FIG. 4.5 MINIMUM STRAIGHT RUN OF UPSTREAM PIPE AFTER FLOW DISTURBANCE, NO FLOW STRAIGHTENER

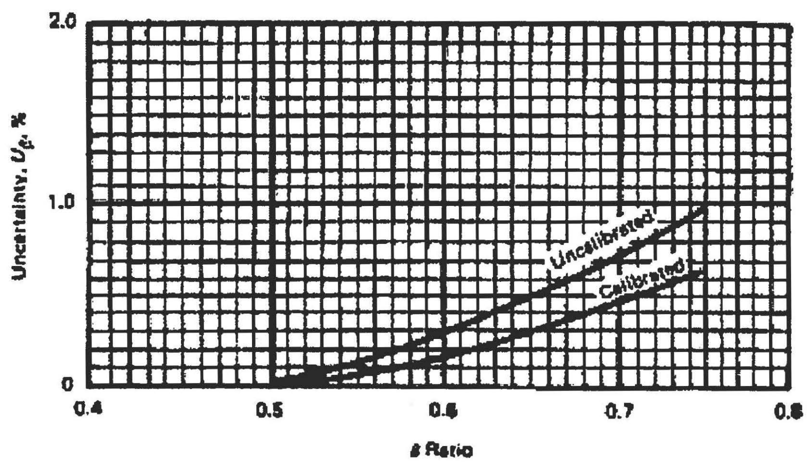


FIG. 4.6 β RATIO EFFECT

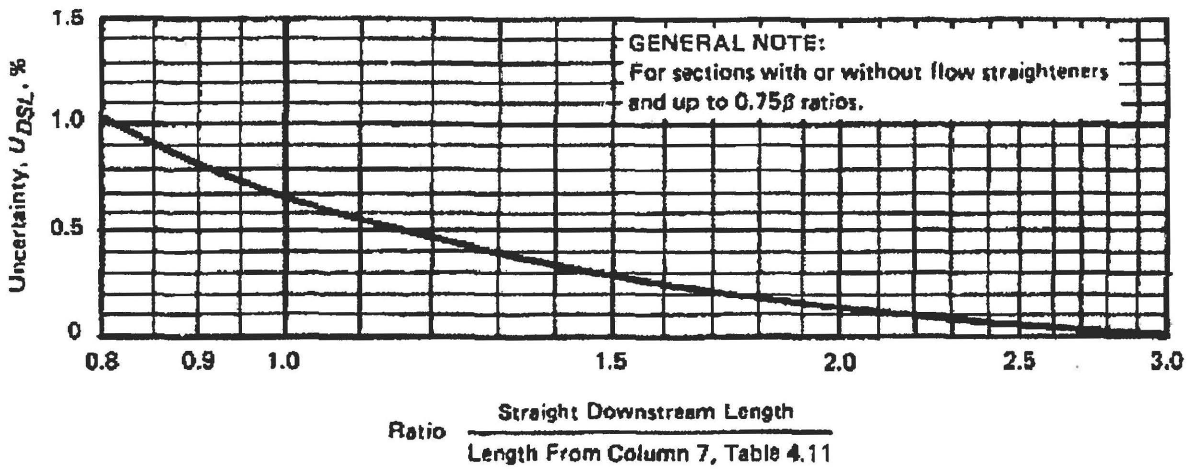
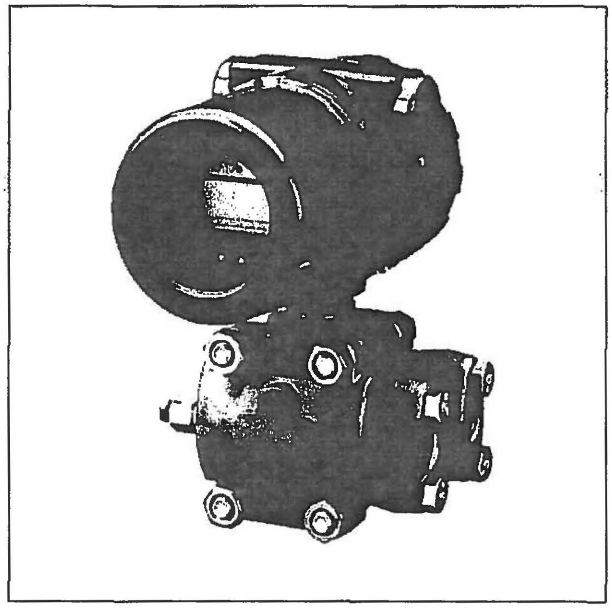


FIG. 4.9 EFFECT OF DOWNSTREAM PIPE LENGTH

Rosemount 1151 Pressure Transmitter

- *Proven field performance and reliability*
- *Commitment to continuous improvement*
- *Reference accuracy of 0.075%*
- *Two-year stability of 0.1%*
- *Rangeability of 50:1*



HART CE

Product Discontinued

Contents

Foundation of Reliable Measurement

With over eight million transmitters installed worldwide, the Rosemount 1151 continues to offer industry leading value. Changing customer needs and new technologies have driven product improvements, while advanced manufacturing and testing processes have guaranteed product quality. The Rosemount 1151 is world-renowned for proven field reliability and longevity.

Proven field performance and reliability

For over 35 years, the 1151 has provided the process control industry with unsurpassed service and reliability in even the harshest of environments. The lasting customer preference results from a combination of advanced technology, and a tradition of field proven performance.

Commitment to continuous improvement

Through ongoing focus on continuous improvement, ±0.075% reference accuracy has been accomplished as a result of manufacturing and engineering enhancements. In addition, Smart electronics offer rangeability to 50:1, reducing the number of transmitters to specify, procure, and carry in inventory. A modular design allows interchangeable mechanical and electrical components, providing backward and forward compatibility.

Application flexibility

The 1151 offers a variety of configurations for differential, gage, absolute and liquid- level measurements including integrated solutions for pressure, level, and flow. High pressure models allow static line pressures up to 4500 psi (310 bar). Multiple wetted materials, as well as alternative fill fluids ensure process compatibility. Smart, analog and low-power electronics are available to meet specific application requirements.

Rosemount Pressure Solutions

Rosemount 3051S Series of Instrumentation
Highest performing scalable pressure, flow and level measurement solutions drive better plant efficiency and more productivity. Innovative features include wireless, advanced diagnostics, and multivariable technologies.

Rosemount 3095 Mass Flow Transmitter
Accurately measures differential pressure, static pressure and process temperature to dynamically calculate fully compensated mass flow.

Rosemount 3051 Pressure Transmitter Family
Proven industry standard performance and reliability to increase plant profitability. Includes the most comprehensive offering to meet all application needs.

Rosemount 2051 Pressure Transmitter
Measure pressure with confidence with a common product family that includes a wide range of output protocols built on the flexible Coplanar™ platform.

Rosemount 305, 306 and 304 Manifolds
Factory-assembled, calibrated and seal-tested transmitter-to-manifold assemblies reduce installation costs.

Rosemount 1199 Diaphragm Seals
Provides reliable, remote measurements of process pressure and protects the transmitter from hot, corrosive, or viscous fluids.

Orifice Plate Primary Element Systems: Rosemount 1495 and 1595 Orifice Plates, 1496 Flange Unions and 1497 Meter Sections
A comprehensive offering of orifice plates, flange unions and meter sections that are easy to specify and order. The 1595 Conditioning Orifice provides superior performance in tight fit applications.

Annubar® Flowmeter Series: Rosemount 3051SFA ProBar®, 3095MFA Mass ProBar, and 485
The state-of-the-art, fifth generation Rosemount 485 Annubar combined with the 3051S or 3095 MultiVariable transmitter creates an accurate, repeatable and dependable insertion-type flowmeter.

Compact Orifice Flowmeter Series: Rosemount 3051SFC, 3095MFC, and 405
Compact Orifice Flowmeters can be installed between existing flanges, up to a Class 600 (PN100) rating. In tight fit applications, a conditioning orifice plate version is available, requiring only two diameters of straight run upstream and two downstream.

ProPlate® Flowmeter Series: Rosemount 3051SFP ProPlate, 3095MFP Mass ProPlate, and 1195
These integral orifice flowmeters eliminate the inaccuracies that become more pronounced in small orifice line installations. The completely assembled, ready to install flowmeters reduce cost and simplify installation.

Specifications

PERFORMANCE SPECIFICATIONS

(Zero-based calibrated ranges, reference conditions, silicone oil fill, 316 SST isolating diaphragms for HART 4-20 mA protocol.)

Accuracy

Output	Model	Accuracy Specification and Span
Output Code S	Ranges 3 through 8 for DP and GP; Ranges 4 through 7 for HP	±0.075% of calibrated span between 1:1 to 10:1 of URL $\pm\left[0.02\left(\frac{URL}{span}\right)-0.1\right]$% of calibrated span between 10:1 and 50:1 of URL
	Square Root Mode	$\pm\left[0.2+0.05\ x\frac{URL}{span}\right]$% of calibrated flow span for all spans
	All other ranges and transmitters	±0.25% of calibrated span for all spans
Output Codes E, G, L, and M	Ranges 3 through 5 for DP and GP	±0.2% of calibrated span for all spans
	P8 Option: Ranges 3 through 8 for DP and GP, all HP and all LT	±0.1% of calibrated span for > 10 inH_2O
	All other ranges and transmitters	±0.25% of calibrated span for all spans

Stability

Output Code	Model	Specification
S	Ranges 3-8	±0.1 of URL for 2 years
E and G	Ranges 3-6	±0.2 of URL for 6 months
	All other ranges	±0.25 of URL for 6 months
L and M	All ranges	±0.25 of URL for 6 months

Temperature Effect

Output Code	Model	Specification
S	DP/GP Ranges 4-8, HP Ranges 4-8	Zero Error = ±0.2% URL per 100 °F (56 °C) Total Error = ±(0.2% URL + 0.18% of calibrated span) per 100 °F; double the effect for other ranges and transmitters
E, G, L, and M	Ranges 4-0	Zero Error = ±0.5% URL per 100 °F. Total Error = ±(0.5% URL + 0.5% of calibrated span) per 100 °F; double the effect for Range 3.

Line Pressure Effect

Model	Zero Error	Span Error
DP Range 4 and 5	±0.25% of URL for 2,000 psi (13790 kPa), correctable through rezeroing at line pressure.	Correctable to ±0.25% of input reading per 1,000 psi (6895 kPa)
DP Range 3	±0.5%, correctable through rezeroing at line pressure.	Correctable to ±0.5% of input reading per 1,000 psi (6895 kPa)
DP Transmitters Ranges 6 - 0	±0.5%, correctable through rezeroing at line pressure.	Correctable to ±0.25% of input reading per 1,000 psi (6895 kPa)
HP Transmitters All Ranges	±2.0% of URL for 4,500 psi (31027 kPa), correctable through rezeroing at line pressure.	Correctable to ±0.25% of input reading per 1,000 psi (6895 kPa).

Vibration Effect

0.05% of URL per g to 200 Hz in any axis

Power Supply Effect

Output Codes S, E, and G

Less than 0.005% of output span per volt

Output Codes L, M

Output shift of less than 0.05% of URL for a 1 V power supply shift

Load Effect

Output Codes S, E, and G

No load effect other than the change in power supplied to the transmitter.

Output Codes L, M

Less than 0.05% of URL effect for a change in load from 100kΩ to infinite ohms.

Short Circuit Condition (Low Power Only)

No damage to the transmitter will result when the output is shorted to common or to power supply positive (limit 12 V).

EMI/RFI Effect

Output shift of less than 0.1% of span when tested to SAMA PMC 33.1 from 20 to 1000 MHz and for field strengths up to 30 V/m.

Mounting Position Effect

Zero shift of up to 1 inH_2O (0.25 kPa).

With liquid level diaphragm in vertical plane, zero shift of up to 1 inH_2O (0.25 kPa). With liquid level diaphragm in horizontal plane, zero shift of up to 5 inH_2O (1.25 kPa) plus extension length on extended units. All zero shifts can be calibrated out. No effect on span.

FUNCTIONAL SPECIFICATIONS

Service

Liquid, gas, and vapor applications

Range and Sensor Limits

TABLE 1. Transmitter Range Availability by Model (URL = Upper Range Limit)

Range Code	1151 Ranges (URL)	DP	HP	GP	DP/GP/Seals	AP	LT
3	30 inH_2O (7.46 kPa)	•	NA	•	NA	NA	NA
4	150 inH_2O(37.3 kPa)	•	•	•	•	•	•
5	750 inH_2O (186.4 kPa)	•	•	•	•	•	•
6	100 psi (689.5 kPa)	•	•	•	•	•	•
7	300 psi (2,068 kPa)	•	•	•	•	•	NA
8	1,000 psi (6,895 kPa)	•	NA	•	NA	•	NA
9	3,000 psi (20,684 kPa)	NA	NA	•	NA	NA	NA
0	6,000 psi (41,369 kPa)	NA	NA	•	NA	NA	NA

TABLE 2. Rangeability

Output Code	Minimum Span(1)	Maximum Span
S (DP and GP, SST, Range 3–8; HP SST, Range 4–7)	URL/50	2 × URL(2)
S (All Others)	URL/50(3)	2 × URL(2)
E, G	URL/6	URL
L	URL/1.1	URL
M	URL/2	URL

(1) Minimum span equals the upper range limit (URL) divided by rangedown.

(2) Transmitter is capable of measuring from –URL to URL.

(3) Accuracy specification for calibrated spans from 1:1 to 6:1 of URL only.

Outputs

Code S, Smart

4–20 mA dc, user selectable for linear or square root output. Digital process variable superimposed on 4–20 mA signal, available to any host that conforms to the HART® protocol.

Code E, Analog

4–20 mA dc, linear with process pressure

Code G, Analog

10–50 mA dc, linear with process pressure

Code L, Low Power

0.8 to 3.2 V dc, linear with process pressure

Code M, Low Power

1 to 5 V dc, linear with process pressure

TABLE 3. Output Code Availability

Code	1151 Output Options/Damping	DP	HP	GP	DP/GP/Seals	AP	LT
S	4–20 mA, Digital, Smart/Variable	•	•	•	•	•	•
E	4–20 mA, Linear, Analog/Variable	•	•	•	•	•	•
G(1)	10–50 mA, Linear, Analog/Variable	•	•	•	•	•	•
L	0.8 to 3.2 V, Linear, Low Power/Fixed	•	•	•	•	•	NA
M	1 to 5 V, Linear, Low Power/Fixed	•	•	•	•	•	NA

(1) Not available with CE mark.

Current Consumption Under Normal Operating Conditions (Low Power Only)

Output Code L

1.5 mA dc

Output Code M

2.0 mA dc

Zero Elevation and Suppression

Output Codes S, E, and G

Zero elevation and suppression must be such that the lower range value is greater than or equal to the (–URL) and the upper range value is less than or equal to the (+URL). The calibrated span must be greater than or equal to the minimum span and less than or equal to the maximum span.

Output Code L

Zero is adjustable ±10% of URL and span is adjustable from 90 to 100% of URL.

Output Code M

Zero is adjustable ±50% of URL and span is adjustable from 50 to 100% of URL.

Span and Zero

Output Code S

Span and zero may be accessed with local adjustments or remotely through a HART-compatible interface.

Output Codes E, G, L, and M

Span and zero are continuously adjustable.

Power Supply

External power supply required. Transmitter operates according to the following requirements:

Output Codes S, E

12 to 45 V dc with no load

Output Code G

30 to 85 V dc with no load

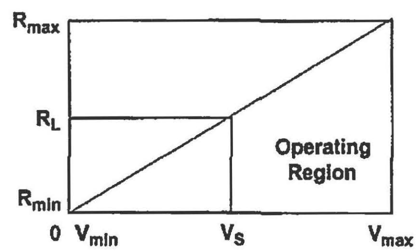
Output Code L

5 to 12 V dc

Output Code M

8 to 14 V dc

Where:



Code	V_{min}	V_{max}	R_{min}	R_{max}	R_L at Supply Voltage (V_S)
S(1)	12	45	0	1650	$R_L = 43.5 (V_S - 12)$
E(2)	12	45	0	1650	$R_L = 50 (V_S - 12)$
G	30	85	0	1100	$R_L = 20 (V_S - 30)$
L	5	12	Low Power Minimum Load Impedance: 100 kΩ		
M	8	14			

(1) A minimum of 250 ohms is required for communication.

(2) For CSA approvals V_{max} = 42.4 V dc.

Static Pressure Limits

Transmitters operate within specifications between the following limits:

Rosemount 1151DP
0.5 psia to 2,000 psig (3.45 kPa to 13790 kPa).

Rosemount 1151HP
0.5 psia to 4,500 psig (3.45 kPa to 31027 kPa).

Rosemount 1151AP
0 psia to the URL.

Rosemount 1151GP
0.5 psia (3.45 kPa) to the URL.

Rosemount 1151LT
Limit is 0.5 psia (3.45 kPa) to the flange rating or sensor rating, whichever is lower.

Overpressure Limits

Transmitters withstand the following limits without damage:

Rosemount 1151DP
0 psia to 2,000 psig (0 to 13790 kPa).

Rosemount 1151HP
0 psia to 4,500 psig (0 to 31027 kPa).

Rosemount 1151AP
0 psia to 2,000 psia (0 to 13790 kPa).

Rosemount 1151GP
Ranges 3–8: 0 psia to 2,000 psig (0 to 13790 kPa).
Range 9: 0 psia to 4,500 psig (31027 kPa).
Range 0: 0 psia to 7,500 psig (51710 kPa).

Rosemount 1151LT
Limit is 0 psia to the flange rating or sensor rating, whichever is lower. See Table 4.

TABLE 4. Flange Pressure Rating

Standard	Class	Carbon Steel Rating	SST Rating
ANSI	150	285 psig(1)	275 psig(1)
ANSI	300	740 psig(1)	720 psig(1)
ANSI	600	1,480 psig(1)	1,440 psig(1)
DIN	PN 10–40	40 bar(2)	40 bar(2)
DIN	PN 10/16	16 bar(2)	16 bar(2)
DIN	PN 25/40	40 bar(2)	40 bar(2)

(1) At 100 °F (38 °C), the rating decreases with increasing temperature.

(2) At 248 °F (120 °C), the rating decreases with increasing temperature.

Burst Pressure All Models

10,000 psig (68.95 MPa) proof pressure on the flanges.

Humidity Limits

0 to 100% relative humidity

Volumetric Displacement

Less than 0.01 in^3 (0.16 cm^3)

Failure Mode Alarm (Output Code S)

If self-diagnosis detects a gross transmitter failure, the analog signal will be driven below 3.9 mA or above 21 mA to alert the user. High or low alarm signal is user selectable.

Overpressure Saturation Value (Output Code S)

If the sensor detects a negative overpressure value, the analog signal will be driven to 3.9 mA. If the sensor detects a positive overpressure value, the analog signal is driven to 20.8 mA.

Level	4–20 mA Saturation Value	4–20 mA Alarm Value
Low	3.9 mA	3.8 mA
High	20.8 mA	21.75 mA

Transmitter Security (Output Code S)

Activating the transmitter security function prevents changes to the transmitter configuration, including local zero and span adjustments. Security is activated by an internal switch.

Damping

Numbers given are for silicone fill fluid at room temperature. The minimum time constant is 0.2 seconds (0.4 seconds for Range 3). Inert-filled sensor values would be slightly higher.

Output Code S

Time constant is adjustable in 0.1 second increments from minimum to 16.0 seconds.

Output Codes E and G

Time constant continuously adjustable between minimum and 1.67 seconds.

Output Codes L, M

Damping is fixed at minimum time constant.

1151LT

Time constant continuously adjustable between 0.4 and 2.2 seconds with silicone oil fill, or 1.1 and 2.7 seconds with inert fill for flush models and electronics codes E or G.

Turn-on Time

Maximum of 2.0 seconds with minimum damping. Low power output is within 0.2% of steady state value within 200 ms after application of power.

Temperature Limits

Operating

Code S: –40 to 185 °F (–40 to 85 °C)

Code E: –40 to 200 °F (–40 to 93 °C)

Code G, L, M: –20 to 200 °F (–29 to 93 °C)

Storage

Code S: –60 to 185 °F (–51 to 85 °C)

Codes E, G, L, M: –60 to 250 °F (–51 to 121 °C)

Process

At atmospheric pressures and above.

TABLE 5. Rosemount 1151 Temperature Limits.

Rosemount 1151DP, HP, AP, GP, LT	
Silicone Fill Sensor	–40 to 220 °F (–40 to 104 °C)
Inert Fill Sensor	0 to 160 °F (–18 to 71 °C)
Rosemount 1151LT High-Side Temperature Limits (Process Fill Fluid)	
Syltherm® XLT	–100 to 300 °F (–73 to 149 °C)
D.C.® Silicone 704	60 to 400 °F (15 to 205 °C)
D.C. Silicone 200	–40 to 400 °F (–40 to 205 °C)
Inert	–50 to 350 °F (–45 to 177 °C)
Glycerin and Water(1)	0 to 200 °F (–18 to 93 °C)
Neobee M-20®(2)	0 to 400 °F (–18 to 205 °C)
Propylene Glycol and Water(2)	0 to 200 °F (–18 to 93 °C)
Syltherm 800	–50 to 400 °F (–45 to 205 °C)

(1) Not suitable for vacuum service.
(2) Not compatible with Buna-N or Ethylene-Propylene O-ring material.

TABLE 6. Fill Fluid Specifications

Fill Fluid	Temperature Limits(1)	Specific Gravity	Coeff. of Therm. Exp. cc/cc/°F (cc/cc/°C)	Viscosity at 25 °C centistokes
D.C.® 200 Silicone	–40 to 400 °F (–40 to 205 °C)	0.934	0.00060 (0.00108)	9.5
D.C. 704 Silicone	60 to 400 °F (15 to 204 °C)	1.07	0.00053 (0.00095)	44
Inert Fill	–50 to 350 °F (–45 to 177 °C)	1.85	0.0004 (0.000864)	6.5
Syltherm®XLT, Silicone	–100 to 300 °F (–73 to 149 °C)	0.85	0.000666 (0.001199)	1.6
Glycerin and Water(2)	0 to 200 °F (–17 to 93 °C)	1.13	0.00019 (0.00034)	12.5
Propylene Glycol and Water(3)	0 to 200 °F (–17 to 93 °C)	1.02	0.00019 (0.00034)	2.85
Neobee M-20®(3)	0 to 400 °F (–17 to 205 °C)	0.900	0.00056 (0.001008)	9.8

(1) Temperature limits are reduced in vacuum service. Contact an Emerson Process Management representative for assistance.

(2) Glycerin and Water and Propylene Glycol and Water are not suitable for vacuum service.

(3) Not compatible with Buna-N or Ethylene-Propylene O-ring material.

Physical Specifications, Standard Configuration

Electrical Connections

1/2–14 NPT conduit with screw terminals and integral test jacks compatible with miniature banana plugs (Pomona 2944, 3690, or equivalent). The HART Hand-Held Interface connections are fixed to the terminal block on smart transmitters.

Wetted Materials

Isolating Diaphragms

316L SST, Alloy C-276, or Tantalum. See ordering table for availability per model type.

Drain/Vent Valves

316 SST or Alloy C-276, see ordering table for availability per model type.

Process Flanges and Adapters

Plated carbon steel, 316 SST or CW-12MW (Cast version Alloy C-276, material per ASTM-A494), see ordering table for availability per model type.

Wetted O-rings

Viton® (other materials also available)

1151LT Process Wetted Parts

Flanged Process Connection

(Transmitter High Side)

Process diaphragms, including process gasket surface

316L SST, Alloy C-276, or Tantalum.

Extension

CF-3M (cast version to 316L SST, material per ASTM-A743) or CW-12MW (Cast version of Alloy C-276, material per ASTM-A494); fits schedule 40 and 80 pipe.

Mounting Flange

Carbon steel or SST.

Reference Process Connection

(Transmitter Low Side)

Isolating Diaphragms

316L SST, Alloy C-276, or tantalum.

Reference Flange and Adapter

CF-8M (Cast version of 316 SST, material per ASTM-A743).

Non-wetted Materials

Fill Fluid

Silicone oil or inert fill

Nuts and Bolts

Plated carbon steel

Blank flange (GP and AP only)

Plated carbon steel

Electronics Housing

Low-copper aluminum or CF-8M (cast version of 316 SST) NEMA 4X

Cover O-rings

Buna-N

Paint

Polyurethane

Process Connections

Rosemount 1151DP, HP, GP, AP

1/4–18 NPT on 2.125-in. (54-mm) centers on flanges for Ranges 3, 4, and 5.

1/4–18 NPT on 2.188-in. (56-mm) centers on flanges for Ranges 6 and 7.

1/4–18 NPT on 2.250-in. (57-mm) centers on flanges for Range 8.

1/2–14 NPT on adapters.

For Ranges 3, 4, and 5, flange adapters can be rotated to give centers of 2.0 in. (51 mm), 2.125 in. (54 mm), or 2.250 in. (57 mm).

Rosemount 1151LT

High pressure side: 2-, 3-, or 4-in., Class 150, 300 or 600 flange; 50, 80, or 100 mm, PN 40 or 10/16 flange.

Low pressure side: 1/4–18 NPT on flange. 1/2–14 NPT on adapter.

Weight

12 lb (5.4 kg) for AP, DP, GP, and HP transmitters, excluding options. Meter option: Add 2 lb (1 kg)

TABLE 7. 1151LT Weight with Flange

Flange(1)	Flush lb. (kg)	2-in (50mm) Ext. lb. (kg)	4-in. (100mm) Ext. lb. (kg)	6-in. (150mm) Ext. lb. (kg)
2-in., Class 150	18 (8.2)	N/A	N/A	N/A
3-in., Class 150	23 (10.4)	25 (11.3)	26 (11.8)	27 (12.3)
4-in., Class 150	29 (13.2)	32 (14.5)	34 (15.4)	36 (16.3)
2-in., Class 300	20 (9.1)	N/A	N/A	N/A
3-in., Class 300	28 (12.7)	30 (13.6)	31 (14.1)	32 (14.5)
4-in., Class 300	38 (17.2)	41 (18.6)	43 (19.5)	45 (20.4)
2-in., Class 600	22 (10.0)	N/A	N/A	N/A
3-in., Class 600	31 (14.1)	33 (15.0)	34 (15.4)	35 (15.9)
DN 50, PN10-40	20 (9.1)	N/A	N/A	N/A
DN 80, PN 25/40	25 (11.3)	27 (12.3)	28 (12.7)	29 (13.2)
DN 100, PN 10/16	25 (11.3)	28 (12.7)	30 (13.6)	32 (14.5)
DN 100, PN 25/40	29 (13.2)	32 (14.5)	34 (15.4)	36 (16.3)

(1) Stainless steel flange weights are listed.

Product Certifications

Approved Manufacturing Locations

Rosemount Inc. — Chanhassen, Minnesota, USA

Emerson Process Management GmbH & Co. — Wessling, Germany

Emerson Process Management Asia Pacific Private Limited — Singapore

Beijing Rosemount Far East Instrument Co., Limited – Beijing, China

European Directive Information

The EC declaration of conformity for all applicable European directives for this product can be found on the Rosemount website at www.rosemount.com. A hard copy may be obtained by contacting our local sales office.

ATEX Directive (94/9/EC)

Emerson Process Management complies with the ATEX Directive.

European Pressure Equipment Directive (PED) (97/23/EC)

1151GP9, 0; 1151HP4, 5, 6, 7, 8 Pressure Transmitters
— QS Certificate of Assessment - EC No. PED-H-100
Module H Conformity Assessment

All other 1151 Pressure Transmitters
— Sound Engineering Practice

Transmitter Attachments: Diaphragm Seal - Process Flange - Manifold
— Sound Engineering Practice

Electro Magnetic Compatibility (EMC) (2004/108/EC)

All models
— EN 61326: 1997 with Amendments A1, A2, and A3

Hazardous Locations Certifications

North American Certifications

Ordinary Location Certification for Factory Mutual

As standard, the transmitter has been examined and tested to determine that the design meets basic electrical, mechanical, and fire protection requirements by FM, a nationally recognized testing laboratory (NRTL) as accredited by the Federal Occupational Safety and Health Administration (OSHA).

Factory Mutual (FM) Approvals

FM Explosion-Proof tag is standard. Appropriate tag will be substituted if optional certification is selected.

Explosion-Proof: Class I, Division 1, Groups B, C, and D. Dust-Ignition Proof: Class II, Division 1, Groups E, F, and G; Class III, Division 1. Indoor and outdoor use. NEMA 4X. Factory Sealed.

I5 Intrinsically safe for Class I, II, and III Division 1, Groups A, B, C, D, E, F, and G hazardous locations in accordance with entity requirements and Control drawing 01151-0214 and 00268-0031. Non- incendive for Class I, Division 2, Groups A, B, C and D hazardous locations.

For entity parameters see control drawing 01151-0214.

Canadian Standards Association (CSA) Approvals

E6 Explosion-Proof for Class I, Division 1, Groups C and D; Class II, Division 1, Groups E, F, and G; Class III, Division 1 Hazardous Locations. Suitable for Class I, Division 2, Groups A, B, C, and D; CSA enclosure type 4X. Factory Sealed.

I6 Intrinsically safe for Class I, Division 1, Groups A, B, C, and D hazardous locations when connected per Drawing 01151-2575. For entity parameters see control drawing 01151-2575. Temperature Code T2D.

Measurement Canada Approvals

C5 Accuracy Approval to the Electricity and Gas Inspection Act for the purchase and sale of natural gas.

European Certifications

I1 ATEX Intrinsically Safe and Combustible Dust
(1151 Smart only)
Certificate No.: BAS99ATEX1294X
ATEX Marking Ex II 1 GD
EEx ia IIC T5 (-60°C ≤ Ta ≤ 40°C)
EEx ia IIC T4 (-60°C ≤ Ta ≤ 80°C)
CE 1180
IP66

TABLE 8. IS Entity Parameters

U_i = 30 V
I_i = 125 mA
P_i = 1.0 W (T4) or 0.67 W (T5)
C_i = 0.034 µF
L_i = 20 µH

Special Conditions for Safe Use (X)

The apparatus, is not capable of withstanding the 500V test as required by EN 50020: 1994. This must be taken into account when installing the apparatus.

N1 ATEX Type n and Combustible Dust
(1151 Smart only)
Certificate No.: BAS 99ATEX3293X
ATEX marking: Ex II 3 GD
EEx nL IIC T5 (-40°C ≤ Ta ≤ 40°C)
EEx nL IIC T4 (-40°C ≤ Ta ≤ 80°C)
Dust Rating: T90 °C (Ta = -20°C to 40°C)
U_i = 45 Vdc Max
CE
IP66

Special Conditions for Safe Use (x)
The apparatus is not capable of withstanding the 500V insulation test required by EN 50021: 1999. This must be taken into account when installing the apparatus.

E8 ATEX Flame-Proof
Certification Number CESI03ATEX037
ATEX Marking Ex II 1/2 G
EEx d IIC T6 (–40 ≤ Ta ≤ 40 °C)
EEx d IIC T4 (–40 ≤ Ta ≤ 80 °C)
CE 1180
V = 60 Vdc maximum

Australian Certifications

Standards Association of Australia (SAA) Certification

E7 SAA Flame-proof
Certificate Number Ex 494X
Ex d IIB + H_2 T6
DIP T6
IP65
Special Conditions for safe use (x):
For transmitters having NPT, PG or G cable entry threads, an appropriate flame-proof thread adaptor shall be used to facilitate application of certified flame-proof cable glands or conduit system.

I7 SAA Intrinsically Safe
(1151 Smart only)
Certificate Number: Ex 122X
Ex ia IIC T5 (T_{amb} = 40 °C)
Ex ia IIC T4 (T_{amb} = 60 °C)
Special Conditions for Safe Use (x):
The equipment has been assessed to the entity concept and accordingly the following electrical parameters must be taken into account during installation.

TABLE 9. Entity Parameters
U_i = 30V
I_i = 125 mA
P_i = 1.0 W (T4) or 0.67W (T5)
C_i = 14.8 nF
L_i = 20 μH

N7 SAA Type n
(1151 Smart only)
Certificate Number: Ex 122X
Ex n IIC T6 (T_{amb} = 40 °C)
Ex n IIC T5 (T_{amb} = 80 °C)
IP66
Special Conditions for safe use (x):
The equipment must be connected to a supply voltage which does not exceed the rated voltage. The enclosure end caps must be correctly fitted whilst the equipment is energized.

Combination Certifications

Stainless steel certification tag is provided when optional approval is specified. Once a device labeled with multiple approval types is installed, it should not be reinstalled using any other approval types. Permanently mark the approval label to distinguish it from unused approval types.

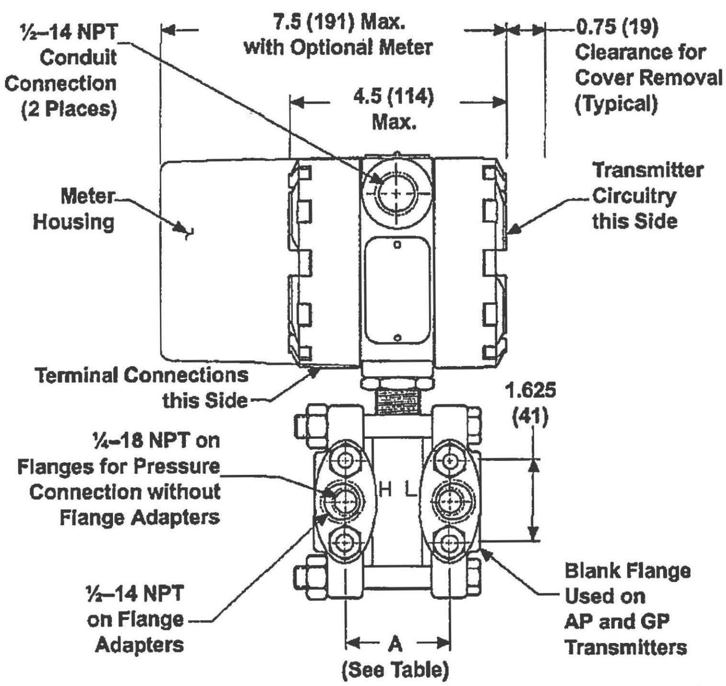
C6 Combination of I6 and E6,

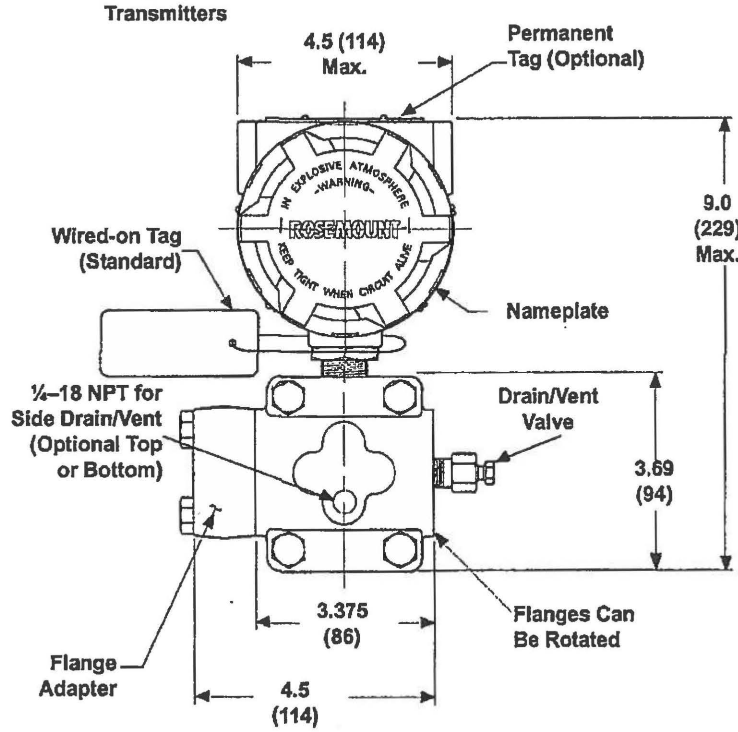
K5 Combination of FM Approvals Explosion-Proof and I5.

K6 Combination of E6, I6, I1, and E8

Dimensional Drawings

1151 Transmitter

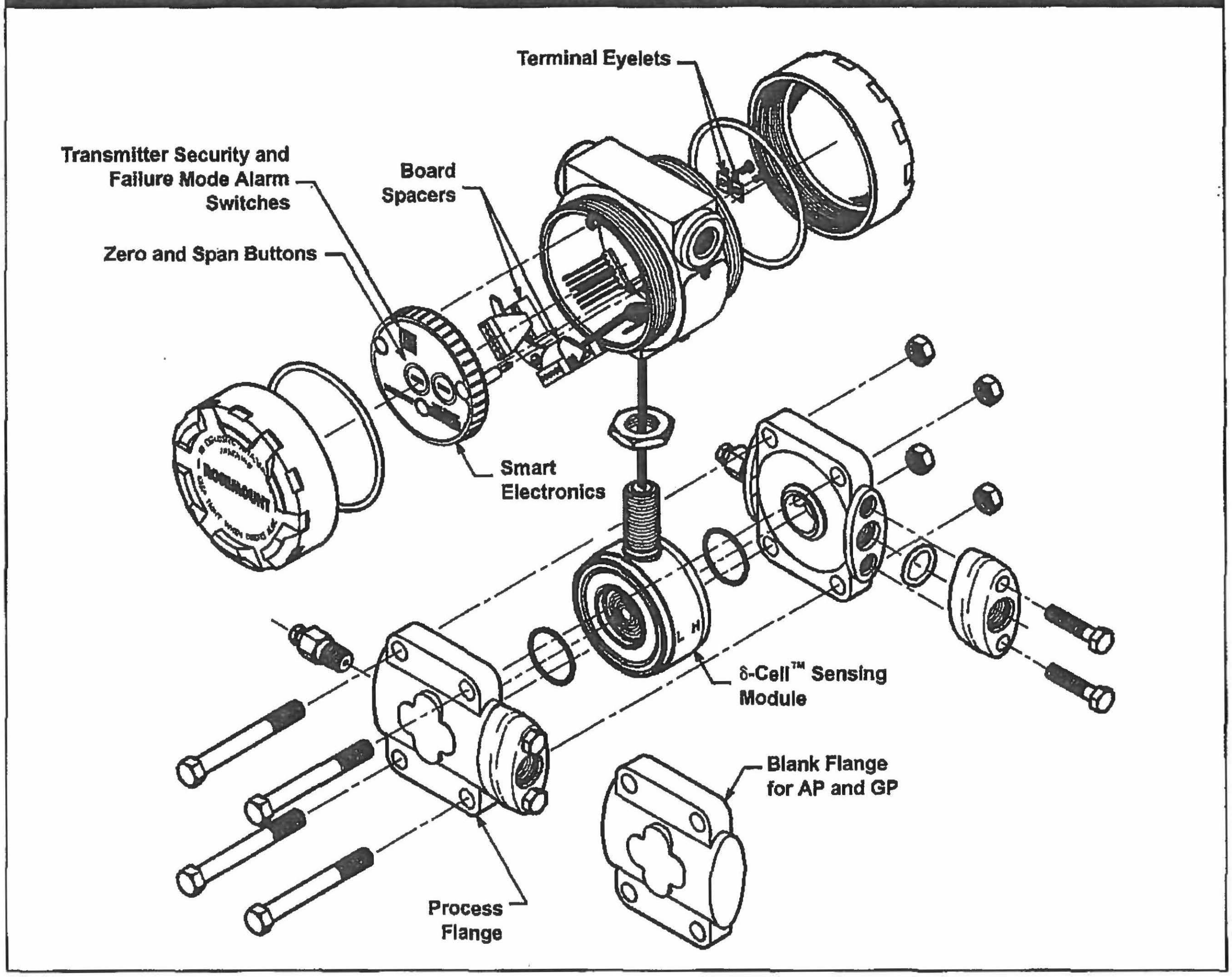




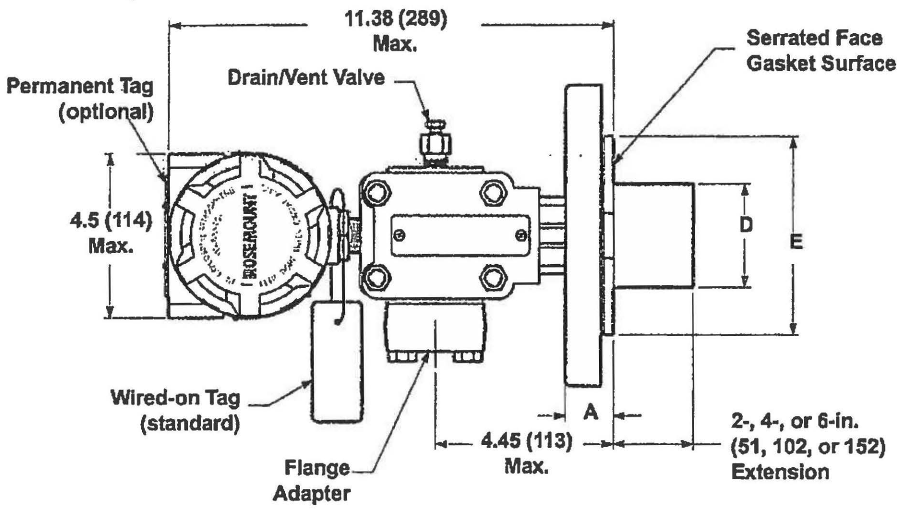
Flange Distance "A" Center to Center		
Range	inches	mm
3, 4, 5	2.125	54
6, 7	2.188	56
8	2.250	57
9	2.281	58
0	2.328	59

NOTE
Dimensions are in inches (millimeters).

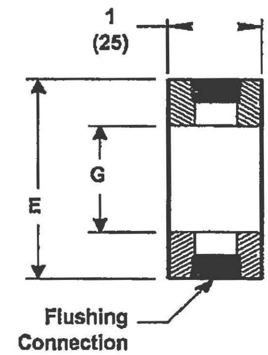
Typical Transmitter Exploded View with Smart Electronics

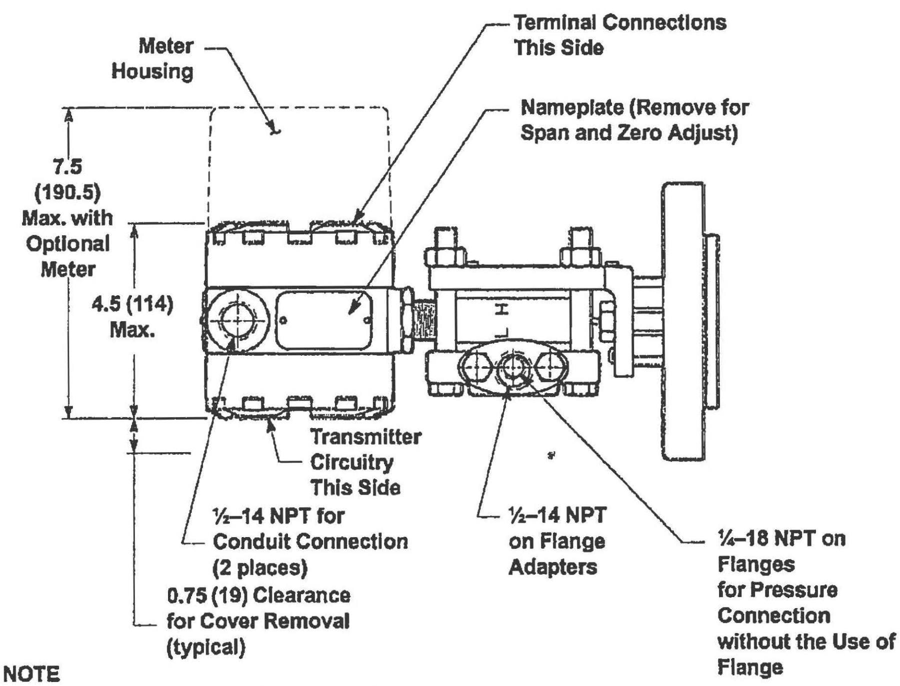


1151LT

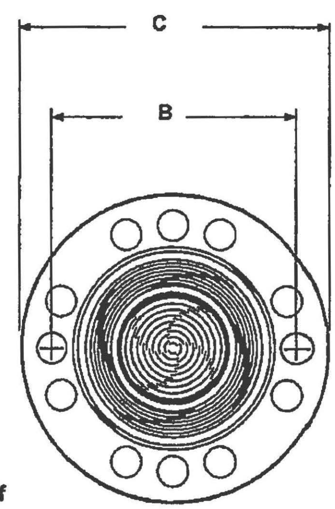


OPTIONAL FLUSHING CONNECTION RING (LOWER HOUSING)





DIAPHRAGM ASSEMBLY AND MOUNTING FLANGE



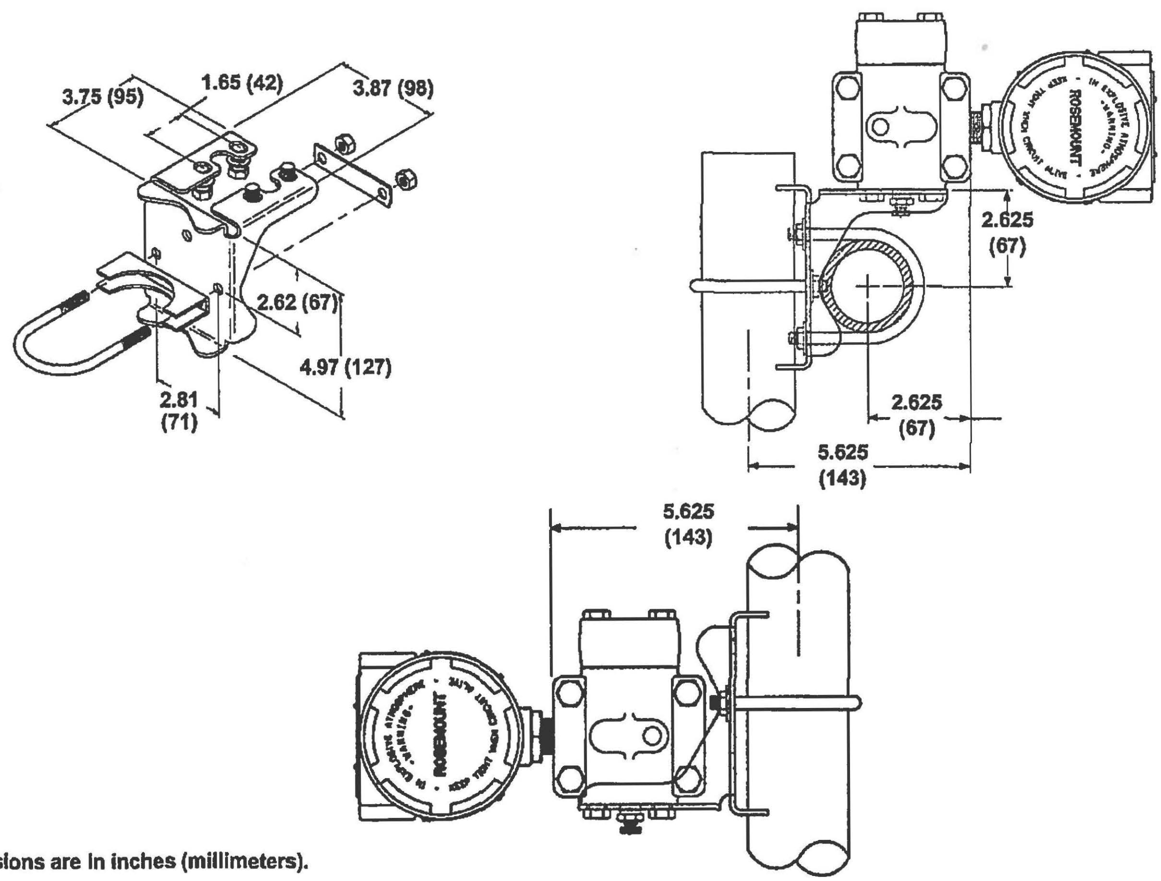
NOTE
Dimensions are in inches (millimeters).

TABLE 10. 1151LT Dimensional Specifications

Class	Pipe Size	Flange Thickness A	Bolt Circle Diameter B	Outside Diameter C	No. of Bolts	Bolt Hole Diameter	Exten. Diam. D (1)	O.D. Gask. Surf. E	Proc. Side G
ANSI 150	2 (51)	1.12 (28)	4.75 (121)	6.0 (152)	4	0.75 (19)	NA	3.6(92)	2.12 (54)
	3 (76)	1.31 (33)	6.0 (152)	7.5 (191)	4	0.75 (19)	2.58 (66)	5.0 (127)	3.5 (89)
	4 (102)	1.31 (33)	7.5 (191)	9.0 (229)	8	0.75 (19)	3.5 (89)	6.2 (158)	4.5 (114)
ANSI 300	2 (51)	1.25 (32)	5.0 (127)	6.5 (165)	8	0.75 (19)	NA	3.6(92)	2.12 (54)
	3 (76)	1.50 (38)	6.62 (168)	8.25 (210)	8	0.88 (22)	2.58 (66)	5.0 (127)	3.5 (89)
	4 (102)	1.62 (41)	7.88 (200)	10.0 (254)	8	0.88 (22)	3.5 (89)	6.2 (158)	4.5 (114)
ANSI 600	2 (51)	1.12 (28)	5.0 (127)	6.5 (165)	8	0.75 (19)	NA	3.6(92)	2.12 (54)
	3 (76)	1.37 (35)	6.62 (168)	6.62 (168)	8	0.88 (22)	2.58 (66)	5.0 (127)	3.5 (89)
DIN PN10-40	DN 50	26 mm	125 mm	165 mm	4	18 mm	NA	4.0 (102)	2.5 (63)
DIN PN 25/40	DN 80	30 mm	160 mm	200 mm	8	18 mm	65 mm	5.4 (138)	3.7 (94)
	DN 100	30 mm	190 mm	235 mm	8	22 mm	89 mm	6.2 (158)	4.5 (114)
DIN PN 10/16	DN 100	26 mm	180 mm	220 mm	8	18 mm	89 mm	6.2 (158)	4.5 (114)

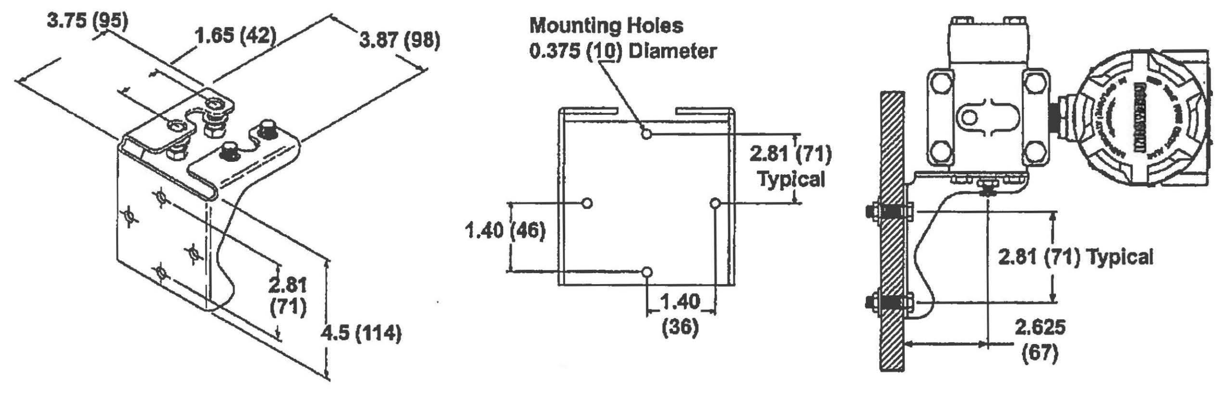
(1) Tolerances are 0.040 (1.02), –0.020 (0.51).

Mounting Bracket Option Codes B1, B4, and B7



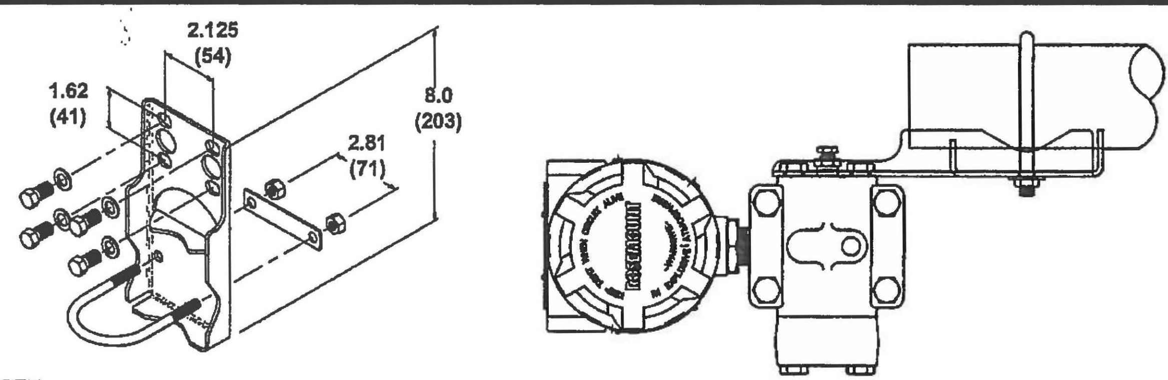
NOTE
Dimensions are in inches (millimeters).

Panel Mounting Bracket Option Codes B2 and B5



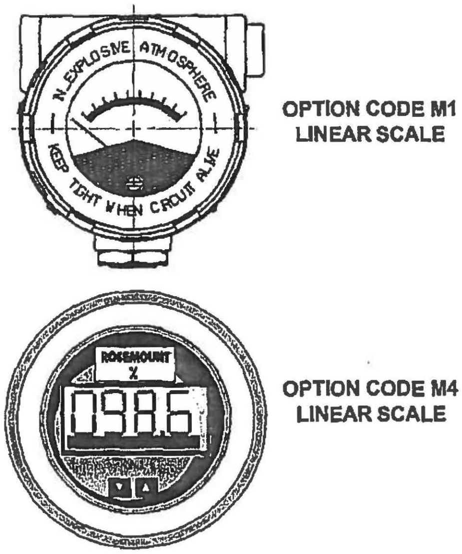
NOTE
Dimensions are in inches

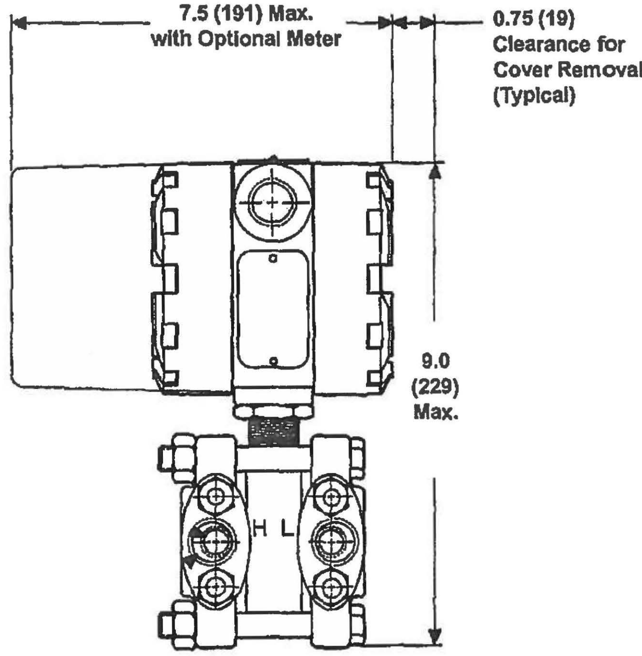
Flat Mounting Bracket Option Codes B3, B6, and B9



NOTE
Dimensions are in inches (millimeters).

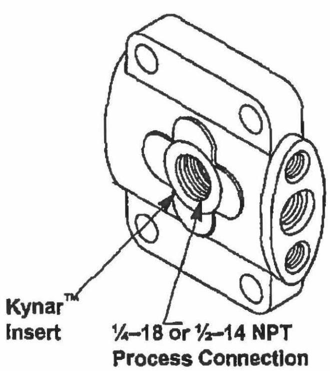
Meter Options



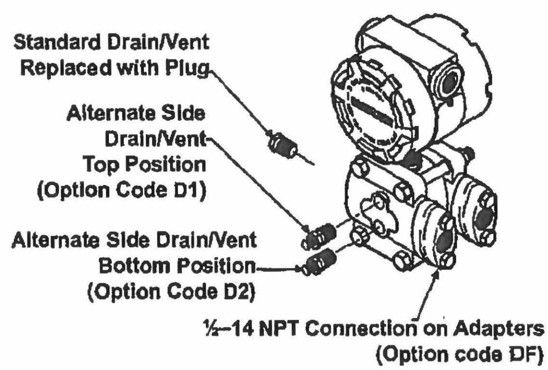


NOTE
Dimensions are in inches

Flange Insert



1151 Process Connections



Ordering Information

• = Applicable — = Not Applicable

Model	Transmitter Type	DP	HP	GP	AP
1151DP	Differential Pressure Transmitter	•	—	—	—
1151HP	Differential Pressure Transmitter for High Line Pressures	—	•	—	—
1151GP	Gage Pressure Transmitter	—	—	•	—
~~1151AP~~	~~Absolute Pressure Transmitter~~ Discontinued	—	—	—	•

Code	Pressure Ranges (URL) (select one)	DP	HP	GP	AP
3	30 inH2O (7.46 kPa)	•	—	•	—
4	150 inH2O (37.3 kPa)	•	•	•	•
5	750 inH2O (186.4 kPa)	•	•	•	•
6	100 psi (689.5 kPa)	•	•	•	•
7	300 psi (2068 kPa)	•	•	•	•
8	1,000 psi (6895 kPa)	•	—	•	•
9	3,000 psi (20684 kPa)	—	—	•	—
~~0~~	~~6,000 psi (41369 kPa)~~ Discontinued	—	—	•	—

Code	Transmitter Output (select one)	DP	HP	GP	AP
S	4–20 mA with Digital Signal based on HART Protocol (Smart)	•	•	•	•
E	4–20 mA, Linear with Input	•	•	•	•
~~G[(1)]~~	~~10–50 mA, Linear with Input~~ Discontinued	•	•	•	•
L[(2)]	Low Power 0.8 to 3.2 Vdc	•	•	•	•
~~M[(2)]~~	~~Low Power 1 to 5 Vdc~~ Discontinued	•	•	•	•

MATERIALS OF CONSTRUCTION[(3)]								
Code	**Flanges/Adapters**	**Drains/Vents**	**Diaphragms**	**Fill Fluid**	**DP**	**HP**	**GP[(4)]**	**AP[(4)]**
52	Nickel-plated Carbon Steel	316 SST	316L SST	Silicone	•	•	•	•
53	Nickel-plated Carbon Steel	316 SST	Alloy C-276	Silicone	•	•	•	•
55	Nickel-plated Carbon Steel	316 SST	Tantalum	Silicone	•	—	•	—
22	316 SST	316 SST	316L SST	Silicone	•	•	•	•
23	316 SST	316 SST	Alloy C-276	Silicone	•	•	•	•
25	316 SST	316 SST	Tantalum	Silicone	•	—	•	—
33[(5)]	Cast C-276	Alloy C-276	Alloy C-276	Silicone	•	•	•	•
35	Cast C-276	Alloy C-276	Tantalum	Silicone	•	—	•	—
73[(5)]	316 SST	Alloy C-276	Alloy C-276	Silicone	•	•	•	•
83[(5)]	Nickel-plated Carbon Steel	Alloy C-276	Alloy C-276	Silicone	•	•	•	•
5A	Nickel-plated Carbon Steel	316 SST	316L SST	Inert	•	—	•	—
5B	Nickel-plated Carbon Steel	316 SST	Alloy C-276	Inert	•	—	•	—
5D	Nickel-plated Carbon Steel	316 SST	Tantalum	Inert	•	—	•	—
2A	316 SST	316 SST	316L SST	Inert	•	—	•	—
2B	316 SST	316 SST	Alloy C-276	Inert	•	—	•	—
2D	316 SST	316 SST	Tantalum	Inert	•	—	•	—
3B	Cast C-276	Alloy C-276	Alloy C-276	Inert	•	—	•	—
3D	Cast C-276	Alloy C-276	Tantalum	Inert	•	—	•	—
7B[(5)]	316 SST	Alloy C-276	Alloy C-276	Inert	•	—	•	—
8B[(5)]	Nickel-plated Carbon Steel	Alloy C-276	Alloy C-276	Inert	•	—	•	—

Code	Mounting Brackets (optional - select one)	DP	HP	GP	AP
B1	Bracket, 2-in. Pipe Mount	•	•	•	•
B2	Bracket, Panel Mount	•	•	•	•
B3	Bracket, Flat, 2-in. Pipe Mount	•	•	•	•
B4	B1 Bracket w/Series 316 SST Bolts	•	•	•	•
B5	B2 Bracket w/Series 316 SST Bolts	•	•	•	•
B6	B3 Bracket w/Series 316 SST Bolts	•	•	•	•
B7	316 SST B1 Bracket with 316 SST Bolts	•	•	•	•
B9	316 SST B3 Bracket with 316 SST Bolts	•	•	•	•

Code	LCD Display[6] (optional - select one)	DP	HP	GP	AP
M1	Analog Scale, Linear Meter, 0–100%	•	•	•	•
M2	Analog Scale, Square Root Meter, 0–100% Flow	•	•	—	—
M4[7]	LCD Display, Linear Meter, 0–100%	•	•	•	•
M6	Analog Scale, Square Root Meter, 1–10√	•	•	—	—
M7[7][8]	LCD Display, Linear Meter, Special Configuration	•	•	•	•
M8[7]	LCD Display Square Root Meter, 0–100% Flow	•	•	—	—
M9[7]	LCD Display, Square Root Meter, 0–10√	•	•	—	—

Code	Product Certifications (optional - select one)	DP	HP	GP	AP
E8	ATEX Flameproof	•	•	•	•
I1[9]	ATEX Intrinsic Safety	•	•	•	•
N1[9]	ATEX Type n	•	•	•	•
I5[9]	FM Intrinsically Safe, Division 2	•	•	•	•
K5[9]	FM Explosion-Proof, Dust Ignition-proof, Intrinsically Safe, Division 2	•	•	•	•
C6[9]	CSA Explosion-Proof, Intrinsically Safe	•	•	•	•
I6[9]	CSA Intrinsically Safe	•	•	•	•
K6[9]	CSA Explosion-Proof, Dust Ignition-proof, Intrinsically Safe, Division 2	•	•	•	•
E6	CSA Explosion-Proof, Dust Ignition-proof, Division 2	•	•	•	•
E7	SAA Flameproof, Dust Ignition-proof	•	•	•	•
I7[9]	SAA Intrinsic Safety	•	•	•	•
N7[9]	SAA Type n	•	•	•	•
C5[10]	Measurement Canada Accuracy Approval	•	•	•	•

NOTE
FM explosion-proof approval is standard.

Code	Housing (optional - select one)	DP	HP	GP	AP
H1[11]	SST Non-wetted Parts on Transmitter without Meter	•	•	•	•
H2[11]	SST Non-wetted Parts on Transmitter with Meter	•	•	•	•
H3	SST Housing, Covers, Conduit Plug, Lock-nut, without Meter	•	•	•	•
H4	SST Housing, Covers, Conduit Plug, Lock-nut, with Meter	•	•	•	•
C2[12]	M20 Conduit Threads	•	•	•	•
J1	G½ Conduit Threads	•	•	•	•

Code	Terminal Blocks (optional - select one)	DP	HP	GP	AP
R1	Integral Transient Protection (Only available with output options S and E)	•	•	•	•

Code	Bolts for Flanges and Adapters (optional - select one)	DP	HP	GP	AP
L3	ASTM A193-B7 Flange and Adapter Bolts	•	•	•	•
L4	316 SST Flange and Adapter Bolts	•	•	•	•
L5	ASTM A193-B7M Flange and Adapter Bolts	•	•	•	•

Code	Process Connections (optional[13])	Materials	DP	HP	GP	AP
D1	Side Drain/ Vent, Top	316 SST	•	•	•	•
		Cast C-276	•	•	•	•
D2	Side Drain/ Vent, Bottom	316 SST	•	•	•	•
		Cast C-276	•	•	•	•
DF	½–14 NPT Flange adapter(s)- Material determined by flange material	Carbon Steel	•	•	•	•
		316 SST	•	•	•	•
		Cast C-276	•	•	•	•
D4[14]	Conformance to DIN EN61518 Ranges 3, 4, 5 with ¼ NPT Process Connections Thread (Available in Germany Only)		•	•	—	—
D5[14]	Conformance to DIN EN61518 Ranges 6, 7, 8, without ¼ NPT Process Connections Thread (Available in Germany Only)		•	•	—	—
D6	316 SST Low Side Blank Flange		—	—	•	•
D9	JIS Process Connection–RC ¼ Flange with RC ½ Flange Adapter	Carbon Steel	•	•	•	•
		316 SST	•	•	•	•
		Cast C-276	•	•	•	•
G1	DIN Spacing (Single Entry Port, No Side V/D Hole Flange)		•	•	•	•
G2	DIN Spacing (Single Entry Port, Two Side V/D Hole Flange)		•	•	•	•
G3	DIN Spacing (Dual Entry Port, No Side V/D Hole Flange)		•	•	•	•
G4	DIN Spacing (Dual Entry Port, One Top Side V/D Hole Flange)		•	•	•	•
G5	DIN Spacing (Dual Entry Port, One Bottom Side V/D Hole Flange)		•	•	•	•
G6	DIN Spacing (Dual Entry Port, Two Side V/D Hole Flange)		•	•	•	•

Code	Description	DP	HP	GP	AP
K1(15)	Kynar Insert, ¼–18 NPT	•	—	•	—
K2(15)	Kynar Insert, ½–14 NPT	•	—	•	—
S1(16)(17)	Assemble to one Rosemount 1199 diaphragm seal	•	—	•	—
S2(16)(17)	Assemble to two Rosemount 1199 diaphragm seals	•	—	—	—
S4(17)(18)	Assemble to Rosemount 1195 Integral Orifice	•	—	—	—
S6(17)	Assemble to Rosemount 304 Manifold or Connection System	•	•	•	•
Code	**Wetted O-ring Material (optional - select one)**	**DP**	**HP**	**GP**	**AP**
W2	Buna-N	•	•	•	•
W3	Ethylene-Propylene	•	•	•	•
W4	Aflas	•	•	•	•
W6(19)(20)	Spring-loaded PTFE	•	—	•	•
W7(20)(21)	PTFE	•	—	•	•
Code	**Special Configuration (Software) (optional - select one)**	**DP**	**HP**	**GP**	**AP**
CN(22)(23)	Analog Output Levels Compliant with NAMUR Recommendation NE43: 27-June-1996 and Low Alarm Level	•	•	•	•
C4(22)(23)	Analog Output Levels Compliant with NAMUR Recommendation NE43: 27-June-1996 and High Alarm Level	•	•	•	•
C9(23)	Software Configuration (Requires completed Configuration Data Sheet)	•	•	•	•
Code	**Special Certifications (optional - select one)**	**DP**	**HP**	**GP**	**AP**
Q4	Calibration Certificate	•	•	•	•
Q8(24)	Material Traceability per EN 10204 3.1.B	•	•	•	•
Q16(25)	Surface Finish Certification for Sanitary Remote Seals	•	•	•	•
Code	**Procedures (optional - select one)**	**DP**	**HP**	**GP**	**AP**
P1(26)	Hydrostatic Testing, 150% Maximum Working Pressure	•	•	•	•
P2(27)	Cleaning for Special Service	•	•	•	•
P3	Cleaning for <1 PPM Chlorine/Fluorine	•	•	•	•
Code	**Performance**	**DP**	**HP**	**GP**	**AP**
P8(28)	Calibrate to 0.1% Accuracy	•	•	•	•
Code	**Outputs (optional - select one)**	**DP**	**HP**	**GP**	**AP**
V1(29)	Reverse Output	—	—	•	—
V2(30)	4–20 mV Test Signal	•	•	•	•
V3(30)	20–100 mV Test Signal	•	•	•	•
Typical Model Number:	**1151DP 4 S 52 B3 M4**				

(1) Output Code G is not available with CE Mark.
(2) Meter or SST housing not valid with this option.
(3) Bolts and conduit plugs are plated carbon steel.
(4) On GP and AP transmitters, the low-side flange is plated carbon steel. For a stainless-steel low-side flange, order process connection Option Code D6.
(5) These selections meet NACE material recommendations per MR 01-75.
(6) Not available with Output Codes L or M, or Option Codes V2 or V3.
(7) Not available with Output Codes G, V2, or V3.
(8) Specify the range, mode, and engineering units. The 20 mA value must be greater than the 4 mA value.
(9) Not available with Output Codes E, G, L, or M.
(10) Limited availability depending on transmitter type and range. Contact an Emerson Process Management representative.
(11) Option includes SST housing, covers, conduit plug, locknut, L4 bolting, and D6 low side blank flange for GP and AP transmitters. Option Codes L4 and D6 parts are included with housing Option Codes H1 and H2.
(12) Not available with Output Codes L or M. Available only with aluminum housing.
(13) Allowable combinations are: D1, D2, D6 or D8, S1.
(14) Material Traceability Certificate Option Q8 available.
(15) The maximum working pressure on this option is 300 psig. Available only with materials of construction Option Code 2x.
(16) This option may only be used on Ranges 4–8.
(17) "Assemble-to" items are specified separately and require a completed model number.
(18) This option has a maximum static pressure rating of 3,000 psi, and is available only for Ranges 3, 4, and 5.
(19) Contains a Alloy C-276 spring that is wetted by the process.
(20) Available for the ranges of DP (3-8), AP (4-8), and GP (3-8).
(21) PTFE O-ring has seal property limitations; Consult an Emerson Process Management representative for more information.
(22) NAMUR-Compliant operation is pre-set at the factory and cannot be changed to standard operation in the field.
(23) Available with Output Code S only.
(24) This option is available for the transmitter flange and adapters only.
(25) Requires one of the Diaphragm Seal Assembly codes (S1 or S2).
(26) Hydrostatic testing for Range 0, 125% maximum working pressure.
(27) Fluorolube® grease on wetted O-rings.
(28) Available with Output Codes E, G, L, M; SST diaphragms; Spans of 10 inH_2O and greater.
(29) Reverse output option is not needed with smart electronics; configured via HART-based communicator.
(30) Not available with Output Codes L or M.

Model	Product Description
1151LT	Flange-Mounted Liquid Level Transmitter

Code	Range
4	150 inH2O (0–635 to 0–3,810 mmH2O)
5	750 inH2O (0–3,175 to 0–19,050 mmH2O)
6	2,770 inH2O (0–11.96 to 0–70.36 mmH2O)

Code	Output	
S	4–20 mA with Digital Signal based on HART Protocol (Smart)	
E	4–20 mA, Linear with Input	
~~G[(1)]~~	~~10–50 mA, Linear with Input~~	Discontinued

Code	Size	Material	Extension Length
G0	2 in./DN 50	316L SST	Flush Mount Only
H0	2 in./DN 50	Alloy C-276	Flush Mount Only
J0	2 in./DN 50	Tantalum	Flush Mount Only
A0	3 in./DN 80	316L SST	Flush Mount
A2	3 in./DN 80	316L SST	2 in./50 mm
A4	3 in./DN 80	316L SST	4 in./100 mm
A6	3 in./DN 80	316L SST	6 in./150 mm
B0	4 in./DN 100	316L SST	Flush Mount
B2	4 in./DN 100	316L SST	2 in./50 mm
B4	4 in./DN 100	316L SST	4 in./100 mm
B6	4 in./DN 100	316L SST	6 in./150 mm
C0	3 in./DN 80	Alloy C-276	Flush Mount
C2	3 in./DN 80	Alloy C-276	2 in./50 mm
C4	3 in./DN 80	Alloy C-276	4 in./100 mm
C6	3 in./DN 80	Alloy C-276	6 in./150 mm
D0	4 in./DN 100	Alloy C-276	Flush Mount
D2	4 in./DN 100	Alloy C-276	2 in./50 mm
D4	4 in./DN 100	Alloy C-276	4 in./100 mm
D6	4 in./DN 100	Alloy C-276	6 in./150 mm
E0	3 in./DN 80	Tantalum	Flush Mount Only
F0	4 in./DN 100	Tantalum	Flush Mount Only

When specifying these option codes, a lower housing must be selected from the flushing connection options.

NOTE
Extension diameters are sized to fit Schedule 80 pipe. Consult factory for Schedule 40 pipe.

MOUNTING FLANGE				
Code	Size	Rating	Material	Applicable with these High Pressure Side Diaphragm Sizes
M	2-in.	Class 150	CS	2 in./DN 50
A	3-in.	Class 150	CS	3 in./DN 80
B	4-in.	Class 150	CS	4 in./DN 100
N	2-in.	Class 300	CS	2 in./DN 50
C	3-in.	Class 300	CS	3 in./DN 80
D	4-in.	Class 300	CS	4 in./DN 100
P	2-in.	Class 600	CS	2 in./DN 50
E	3-in.	Class 600	CS	3 in./DN 80
X	2-in.	Class 150	SST	2 in./DN 50
F	3-in.	Class 150	SST	3 in./DN 80
G	4-in.	Class 150	SST	4 in./DN 100
Y	2-in.	Class 300	SST	2 in./DN 50
H	3-in.	Class 300	SST	3 in./DN 80
J	4-in.	Class 300	SST	4 in./DN 100
Z	2-in.	Class 600	SST	2 in./DN 50
L	3-in.	Class 600	SST	3 in./DN 80
Q	DN 50	PN 10-40	CS	2 in./DN 50
R	DN 80	PN 40	CS	3 in./DN 80
S	DN 100	PN 40	CS	4 in./DN 100
V	DN 100	PN 10/16	CS	4 in./DN 100
K	DN 50	PN 10-40	SST	2 in./DN 50
T	DN 80	PN 40	SST	3 in./DN 80
U	DN 100	PN 40	SST	4 in./DN 100
W	DN 100	PN 10/16	SST	4 in./DN 100

Code	Low-Side Flange and Adapter	Drain/ Vent Valves	Low-Side Isolator Diaphragm	Low-Side Fluid Fill
	SENSOR MODULE AND LOW-SIDE MATERIALS OF CONSTRUCTION			
52	Nickel-plated CS	316 SST	316L SST	Silicone
55	Nickel-plated CS	316 SST	Tantalum	Silicone
22	316 SST	316 SST	316L SST	Silicone
23	316 SST	316 SST	Alloy C-276	Silicone
25	316 SST	316 SST	Tantalum	Silicone
33	Cast C-276	Alloy C-276	Alloy C-276	Silicone
35	Cast C-276	Alloy C-276	Tantalum	Silicone
5D	Nickel-plated CS	316 SST	Tantalum	Inert
2A	316 SST	316 SST	316L SST	Inert
2B	316 SST	316 SST	Alloy C-276	Inert
2D	316 SST	316 SST	Tantalum	Inert
3B	Cast C-276	Alloy C-276	Alloy C-276	Inert
3D	Cast C-276	Alloy C-276	Tantalum	Inert

Code	Process Fill - High Pressure Side	Temperature Limits
A	Syltherm XLT	–100 to 300 °F (–73 to 135 °C)
C	D. C. Silicone 704	60 to 400 °F (15 to 205 °C)
D	D. C. Silicone 200	–40 to 400 °F (–40 to 205 °C)
H	Inert	–50 to 350 °F (–45 to 177 °C)
G	Glycerin and Water	0 to 200 °F (–17 to 93 °C)
N	Neobee M-20	0 to 400 °F (–17 to 205 °C)
P	Propylene Glycol and Water	0 to 200 °F (–17 to 93 °C)

Code	Options
S1[2][3]	Assemble to one Rosemount 1199 diaphragm seal
	LCD Display
M1[4]	Analog Scale, Linear Meter 0-100%
M4[4]	LCD Display, 0–100%
M7[4][5]	LCD Display, Linear, Special Configuration
	HAZARDOUS LOCATIONS CERTIFICATIONS
E8	ATEX Flameproof
I1[6]	ATEX Intrinsic Safety
N1[6]	ATEX Type n
I5[6]	FM Intrinsically Safe, Division 2
K5[6]	FM Explosion-Proof, Dust Ignition-proof, Intrinsically Safe, Division 2
C6[6]	CSA Explosion-Proof, Intrinsically Safe
I6[6]	CSA Intrinsically Safe
K6[6]	CSA Explosion-Proof, Dust Ignition-proof, Intrinsically Safe, Division 2
E6	CSA Explosion-Proof, Dust Ignition-proof, Division 2
E7	SAA Flameproof, Dust Ignition-proof
I7[6]	SAA Intrinsic Safety
N7[6]	SAA Type n
C5[7]	Measurement Canada Accuracy Approval

NOTE
FM explosion-proof approval is standard.

	OTHER OPTIONS
W5	Copper O-ring for Vacuum Service (Nonwetted)
C2(8)	M20 Conduit Threads
Q4	Calibration Data Sheet
Q8(9)	Material Traceability per EN 10204 3.1B
Q16	Surface Finish Certification for Sanitary Remote Seals (all options)
QZ	Remote Seal System Performance Calculation Report
V1(10)	Reverse Output
V2	4–20 mV Test Signal
V3	20–100 mV Test Signal
F_	Select One Code from Flushing Connections Lower Housing Option. See Table 11.
Typical Model Number: 1151LT 4 S A0 A 52 D F1	

(1) Not available with Output Codes E and G.
(2) For welded capillary assemblies, order sensor module and low-side materials of construction Option Code 22 (refer to 00813-0100-4016 for more information).
(3) "Assemble-to" items are specified separately and require a completed model number.
(4) Not available with Option Codes V2, or V3.
(5) Specify the Range, Mode, and Engineering Units. Also, the 20 mA value must be greater than the 4 mA value.
(6) Not available with Output Codes E and G.
(7) Limited availability depending on transmitter type and range. Contact an Emerson Process Management representative.
(8) Not available with Output Codes L or M. Available only with aluminum housing.
(9) Available for the diaphragm, upper housing, flange, adapter, extension, and lower housing.
(10) Reverse output option is not needed with smart electronics; configured via HART-based communicator.

TABLE 11. Flushing Connections Lower Housing Options

• = Applicable — = Not Applicable

Code	Flushing Connection Ring Material (Lower Housing)	Flushing Connections	Size	Diaphragm Size 2-in.	3-in.	4-in.
F1	SST	1	1/4 - 18 NPT	•	•	•
F2	SST	2	1/4 - 18 NPT	•	•	•
F3(1)	Cast C-276	1	1/4 - 18 NPT	•	•	•
F4(1)	Cast C-276	2	1/4 - 18 NPT	•	•	•
F7	SST	1	1/2 - 14 NPT	•	•	•
F8	SST	2	1/2 - 14 NPT	•	•	•
F9	Cast C-276	1	1/2 - 14 NPT	•	•	•
F0	Cast C-276	2	1/2 - 14 NPT	•	•	•

(1) Not available with high pressure side Option Codes A0, B0, and G0.

Standard Accessories

All models are shipped with drain/vent valves, and one instruction manual per shipment.

Tagging

The transmitter will be tagged, at no charge, in accordance with customer requirements. All tags are stainless steel. The standard tag is wired to the transmitter, however a permanently attached tag is available upon request. Tag character height is 0.125 in. (0.318 cm).

Calibration

Transmitters are factory calibrated to the customer's specified range. If calibration is not specified, the transmitters are calibrated at maximum range. Calibration is performed at ambient temperature and pressure.

Options

The following sections describe a variety of available options for the 1151 Transmitter. These options permit greater application flexibility.

Optional Manifolds

Refer to Manifold Product Data Sheet (document number 00813-0100-4839).

Optional Diaphragm and Sanitary Seals

Refer to Product Data Sheet (document numbers 00813-0100-4016 or 00813-0201-4016)

Mounting Brackets

B1 Bracket for 2-in. Pipe Mounting
- Bracket for mounting transmitter on 2-in. pipe
- Constructed of carbon steel with carbon steel U-bolt
- Coated with polyurethane paint

B4 Bracket for 2-in. Pipe with 316 SST Bolts
- Same bracket as Option Code B1 with 316 SST bolts

B7 304 SST Bracket and 316 SST Bolts for 2-in. Pipe Mounting
- Same bracket as Option Code B1 with all SST materials

B2 Bracket for Panel Mounting
- Bracket for mounting transmitter on panel or wall
- Constructed of carbon steel with carbon steel bolts
- Coated with polyurethane paint

B5 Bracket for Panel with 316 SST Bolts
- Same bracket as Option Code B2 with 316 SST bolts

B3 Flat Bracket for 2-in. Pipe Mounting
- Bracket for vertical mounting of transmitter on 2-in. pipe
- Constructed of carbon steel with carbon steel U-bolt
- Coated with polyurethane paint

B6 Flat Bracket for 2-in. Pipe with 316 SST Bolts
- Same bracket as Option Code B3 with 316 SST bolts

B9 304 SST Flat Bracket and 316 SST Bolts for 2-in. Pipe Mounting
- Same bracket as Option Code B3 with all 316 SST materials

Bolts and Nuts for Flanges and Adapters

Options permit bolts and nuts for flanges and adapters in the specified material.
- L3 ANSI/ASTM A - 193-B7
- L4 Austenitic 316 SST
- L5 ANSI/ASTM A193-B7M

Meters

Analog
- Meters have 2-in. (50.8 mm) scale
- Plug-in mounting configuration
- Indication accuracy ±2%
- Operating temperature limit: –40 to 150 °F (–40 to 65 °C)
- Meters are enclosed in a housing certified by Factory Mutual as Explosion-Proof for Class I, Division 1, Groups B, C, and D; Class II, Division 1, Groups E, F, and G and Class III, Division 1
- For optional CSA explosion-proof approval, see certification Option Code E6
- M1 Linear Analog Meter, 0–100% Scale
- M2 Square Root Analog Meter, 0–100% Flow Scale
- M6 Square Root Analog Meter, 0– 10√ Scale

LCD
- 4-digit display
- Indication accuracy ±0.25% of calibrated span ±1 digit
- Display resolution at ±0.5% of calibrated span ±1 digit
- Operating temperature limit: –4 to 158 °F (–20 to 70 °C)
- Plug-in mounting configuration
- Meters are enclosed in a housing certified by FM as Explosion-Proof for Class I, Division 1, Groups B, C, and D; Class II, Division 1, Groups E, F, and G and Class III, Division 1
- For Optional CSA explosion-proof approval, see certification Option Code E6
- Reverse output not available with LCD Display
- M4 Linear LCD Meter, 0 to 100%
- M7 Special Scale LCD Meter
  - Specify:
    - Range (2 0 mA value must be greater than 4 mA value)
    - Mode
    - Eng ineering Units
- M8 Square Root LCD Display, 0 to 100%
- M9 Square Root LCD Display, 0–10√ Scale

NOTES
Meter Options are not available with Output Codes L or M, or Option Codes V2 or V3. Meter Options M4, M7, M8, and M9 are not available with Output Code G.

Process Connections

D1 Side Drain/Vent-Top

- Drain/vent valve mounted in side of flange.
- Top position used to vent gas buildup in liquid process applications with transmitter mounted vertically.
- Plug of same material as requested flange inserted in end of flange opposite adapter.

D2 Side Drain/Vent-Bottom

- Drain/vent valve mounted in side of flange.
- Bottom position used to drain liquid buildup in gas process applications with transmitter mounted vertically.
- Plug of same material as requested flange inserted in end of flange opposite adapter.

D6 316 SST Low Side Flange (1151GP and 1151AP Only)

DF 1/2–14 NPT flange adapters

- Options provide 1/2–14 NPT process connection on flanges rather than 1/4–18 NPT

K1 1/4–18 NPT Kynar™ Process Flange Insert

K2 1/2–14 NPT Kynar Process Flange Insert

- Options provide Kynar plastic process flange insert that prevents process from coming in contact with the metal of the flange. One process insert for the 1151GP and LT; two inserts for the 1151DP.
- Process connections are from the side.
- Available with carbon steel and stainless steel process flanges only.
- Pressure Maximum: 200 psi at 200 °F with Kynar impulse piping; 300 psi at 200 °F with metal impulse piping.

S1 Assembled with One 1199 Remote Diaphragm Seal

S2 Assembled with Two 1199 Remote Diaphragm Seals

- Options provide for the assembly of one or two remote diaphragm seals.

S4 Assembled with 1195 Integral Orifice

- Designed for highly accurate, small-bore flow measurement of any clean gas, liquid, or vapor.
- Reduce the costs associated with traditional orifice plate installations.
- Several configurations are available factory assembled to Rosemount differential pressure transmitters.(1)
- Wide orifice bore/flow range capability.
- Wide choice of process connections, including threaded, socket weld, and ANSI flanges.
- Static pressure maximum limit is 3,000 psig.
- Wetted materials are available that comply with NACE MR 01-75(90).
- Available only with Ranges 2, 3, 4, and 5.

(1) Applicable only to orifice assemblies without piping.

Wetted O-rings

- Standard: Viton®
- W2 Buna N
- W3 Ethylene-Propylene
- W4 Aflas®
- W5 Copper O-ring for Vacuum Service (Nonwetted - 1151LT only)
- W6 Spring-Loaded PTFE
  - Contains a Alloy C-276 spring that is in contact with the process fluid. Consult factory if Alloy C-276 is unacceptable.
- W7 PTFE

Procedures

Standard Configuration

Unless otherwise specified, transmitter will be shipped as follows:

Engineering Units:	inH_2O
4 mA:	0
20 mA:	Upper Range Limit
Output:	Linear
Software Tag:	Blank

Customer may specify the above items at no charge. Software tag (8 characters) is left blank unless specified.

C9 Custom Configuration (Option Code C9)

If Option Code C9 is ordered, the customer may specify the following data in addition to the standard configuration parameters.

Descriptor:	16 characters
Message:	32 characters
Date:	Day, Month, Year
Damping:	Seconds
Burst Mode:	Select Output Choice
Failure Mode:	High or Low
Transmitter Security:	Off or On

TABLE 12. Hydrostatic Test Pressure

Model	Test Pressure
1151DP	3,000 psi
1151HP	6,750 psi
1151AP	2,000 psi
1151GP	
Ranges 3–8	2,000 psi
Range 9	4,500 psi
Range 0	7,500 psi
1151LT	
Class 150 Flange	450 psi
Class 300 Flange	1,100 psi

P1 Hydrostatic Testing

- Each transmitter is hydrostatic tested according to Table 12.
- Test medium is water.
- This option provided for transmitters with remote diaphragm seal on application only.
- Rosemount Procedure 1746 outlines the testing procedure.

P2 Cleaning for Special Service

- This option minimizes contaminants to the process system by cleaning wetted surfaces with a suitable detergent.
- Rosemount Procedure 97412 outlines the cleaning procedure.

P3 Cleaning for <1 PPM Chlorine/Fluorine

Outputs

V1 Reverse Output

- This option permits reversing of pressure input so that electrical output will increase as pressure input decreases.
- This option applies only to 1151GP and 1151LT. When this option is selected, the process flange, adapter, drain/vent valve, appropriate O-rings, and bolting are installed on low side of transmitter. Not available for Ranges 9 and 0.
- Not available with 1151AP. Reverse output on 1151DP and 1151HP can be obtained by connecting high-pressure input to low side of transmitter and vice versa.
- This option should not be ordered with smart transmitters (Output Code S). The 1151 Smart transmitter can be configured for reverse output through a HART-Compatible interface.

V2 1 Ω Test Resistor

- A 1 Ω precision resistor is mounted across the test terminals to provide 4–20 mV output or a 10–50 mV output if 10–50 mA output is used.
- This option cannot be used with any meter options or Option Codes I5 or I6.

V3 5 Ω Test Resistor

- A 5 Ω precision resistor is mounted across test terminals to provide 20–100 mV output or a 50–250 mV output if 10–50 mA output is used.
- This option cannot be used with any meter options or Option Codes I5 or I6.

Rosemount 1151 Configuration Data Sheet

BOLD = Required Value
*= Default

○ Select only one of the items provided
☐ One or more of the listed items can be selected

Customer Information

Customer: ____________________ Contact Name: ____________________

Phone No: ____________________ Fax No./Email: ____________________

P.O./Reference No.: ____________________ P.O. Line Item: ____________________

Quote No. ____________________ Model No.: ____________________

Customer Signoff: ____________________

Tagging

Tag No.: ____________________

Software Tag: ____________________

Output Information

4 mA= ____________________ 0*

20 mA= ____________________ Upper Range Limit*

Units =
- ○ inH_2O*
- ○ inHg
- ○ ftH_2O
- ○ mmH_2O
- ○ mmHg
- ○ psi
- ○ bar
- ○ mbar
- ○ g/cm^2
- ○ kg/cm^2
- ○ Pa
- ○ kPa
- ○ Torr
- ○ Atm
- ○ MPa
- ○ mmH_2O at 4 °C
- ○ inH_2O at 4 °C

* psi for Ranges 6–0 in.
* inH_2O for Ranges 3–5 in.

Output= ○ Linear* ○ Square Root

NOTE
Custom configuration information below this line requires C9 option code.

Output Information

Damping (0-16 sec. at 0.1 increments): ____________ (0.2 sec.*, 0.4 sec.* for Ranges 3-5)

Transmitter Information

Descriptor: ____________________ (16 characters)
Message: ____________________ (32 characters)

Date: ____________ (Date of Calibration*)

Signal Selection	
◯ 4–20 mA with simultaneous digital signal based on HART protocol*	
◯ Burst mode of HART digital process variable	
Burst mode output options:	
◯ Primary variable	◯ Primary variable in percent of range and mA
◯ All dynamic variables in engineering units	◯ All dynamic variables in engineering units and the primary variable mA value
◯ Multidrop Communication	Transmitter Address (1-15): ____ (default = 0)

Security Information	
Write Protect: ◯ On ◯ Off*	Alarm Failure Mode: ◯ Low ◯ High*

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Chanhassen MN 55317 USA
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Fax +65 6777 0947
Service Support Hotline : +65 6770 8711
Email : Enquiries@AP.EmersonProcess.com

EMERSON.
Process Management

Analog to Digital Converter Card

RTP 8436/2X

PRODUCT HIGHLIGHTS

- High-speed analog signal multiplexing
- Wide-range signal capability
- 12 or 14-bit bipolar or unipolar A/D conversion
- 16-bit bipolar A/D conversion
- Differential or single-ended input capability
- Calibration-free operation

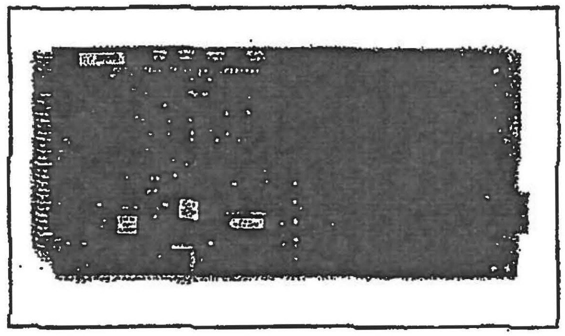
PRODUCT OVERVIEW

The RTP 8436/2X Series Analog to Digital Converter Card was designed to be form, fit, and functionality compatible with the RTP 7436/2X card. This card demonstrates RTP's commitment to it's non-obsolescence policy. Like its predecessor, this card provides low-cost, multiple-channel analog input capability to RTP Universal I/O Subsystems. The card set can be used in conjunction with digital input/output cards, analog output cards, and special function cards to provide substantial versatility in a single chassis. The card set handles input signals, whether they are low-level, high-level, wide-range, or any combination from a wide variety of standard transducers such as thermocouples, RTD's, and pressure transducers.

A single A/D Converter card can perform conversions for up to 15 Universal Gate Cards with any combination of Relay Transformer-Coupled, or Solid-State Cards. The A/D Converter card provides a maximum of 240 single-ended channels or 120 differential channels per RTP Universal I/O Subsystem chassis. Single-ended and differential channels can be intermixed. Similarly, Relay Gate Cards, Transformer-Coupled Gate Cards, and Solid-State Gate Cards can be intermixed in a system configuration.

A/D Converter cards are available in three configurations to fulfill the speed and accuracy requirements of most users. Either 12-bit or 14-bit, successive approximation A/D Converters can be specified with a choice of bipolar or unipolar inputs. The input for the 16-bit converter is bipolar.

The output data format is 2's complement, sign extended. Two 12-bit speed versions of the card are available to provide a standard speed with a maximum rate of 25,000 samples per second (s/sec) or a high speed version of 50,000 s/sec. The 14-bit A/D Converter operates at sample rates of 38,000 s/sec,



RTP 8436/2X, Analog to Digital Converter Card

and the 16-bit A/D Converter operates at 32,400 s/sec.

Each A/D Converter has a programmable amplifier with gain ranges of 1, 2, 4, or 8. The A/D Converter card accepts single-ended or differential inputs under user program control. A/D Converter cards are user configurable to accept pulses to synchronize data conversions to an external clock.

THE RTP COMMITMENT

Superior Reliability

RTP products have been engineered to provide high reliability in the field. The Analog to Digital Converter Card is designed to the same standards as other RTP products which have been qualified under the demanding Class IE Nuclear Safety guidelines established by the Nuclear Regulatory Commission. RTP's exacting product standards result in minimal system downtime, worry free maintenance, and a high return on investment.

Engineering Support

RTP provides off-the-shelf delivery as well as custom-engineered solutions. RTP also backs each of its products with full technical support and complete documentation. Call your RTP representative for additional information, specifications, and prices.

Non-Obsolescence Policy

In addition to an outstanding 3-Year Warranty, it is the policy of RTP Corp. to support its products through the normal life span of the plant or equipment. Only RTP offers this level of support for its products.

RTP Corp. 2705 Gateway Drive Pompano Beach, Florida 33069
PHONE (954) 974-5500 FAX (954) 975-9815 INTERNET: http://www.rtpcorp.com EMAIL rtpinfo@rtpcorp.com

SPECIFICATIONS

Gain Accuracy

12-bit: ±0.025% of full-scale, ±50ppm/°C.
14-bit: ±0.0125% of full-scale, ±50ppm/°C.
16-bit: ±0.00625% of full-scale, ±50ppm/°C.

Power Requirements

+5 VDC @ 475 mA
+15 VDC @ 55 mA
–15 VDC @ 55 mA

Environmental

Operating Temperature Range: 0°C to +55°C
Storage Temperature Range: –20°C to +85°C
Relative Humidity Range: 20% to 80%, non-condensing

Model Variations

The Analog to Digital Converter Card is available in several variations to suit application specific requirements:

12-Bit

- Standard Speed or High Speed
- Unipolar or Bipolar
- Binary to 10.24 VFS
- Decimal to 10.00 VFS

14-Bit

- Unipolar or Bipolar
- Binary to 10.24 VFS
- Decimal to 10.00 VFS

16-Bit

- Bipolar
- Binary to 10.24 VFS
- Decimal to 10.00 VFS

RTP offers a complete line of Data Acquisition and Process Control Systems. Contact RTP with your most challenging requirements and let us explain how we can meet your specific needs.

Jenny Regan

From: dave.mccully@rtpcorp.com
Sent: Friday, May 10, 2002 9:03 AM
To: jenregan@comcast.net
Cc: don.chase@rtpcorp.com; sal.provanzano@rtpcorp.com; jack.sloan@rtpcorp.com
Subject: Re[2]:Need info on RTP components for Exelon

Jennifer,

There are 2 types of errors introduced by the 038-0012-XYZ 4-Channel, 3-Wire RTD Bridge Card.

1. Adjustment: To get the most accurate readings, you need to adjust the gain and offset including the field wire. You will need to do precision resistance substitution where the RTD is located and then adjust the gain and offset of the Bridge Card. This is because the lead resistance becomes part of the bridge circuit. Cards are shipped from the factory adjusted for near zero ohm cables.

2. Temperature: The combined effects of the power supply and resistor temperature drift is +-80 PPM/Degree C.

The accuracy of the 7435/50 (021-5234) Gate Card and 8436/21 14-Bit A/D Converter has 2 components. Note that the A/D is required as the gate card by itself performs no function. The 160 mv range is mentioned because the bridge cards are usually designed to put out 100 mv for the upper temperature of the specified range.

1. Static Accuracy: +-0.0638% of full scale on the 160 mv range.

2. Temperature: +-0.013% of full scale per Degrees C on the 160 mv range.

If you need any additional information, please feel free to contact us.

Regards,

David McCully, Applications Engineer
RTP Corp.
1834 SW 2 Street
Pompano Beach, FL 33069
Phone: Direct (954) 984-7203 or (954)-974-5500, Extension 7203
FAX: (954) 975-9815
E Mail: dave.mccully@rtpcorp.com
Internet: http://www.rtpcorp.com

____________________Reply Separator____________________
Subject: Re:Need info on RTP components for Exelon
Author: Don Chase
Date: 5/9/02 1:31 PM

Mr. Chase:
Please reply to this email or give me a call regarding accuracy specifications on the following RTP parts at Peach Bottom nuclear plant:

RTP 038-00120154, signal conditioning card for 100 ohm RTD input RTP 021-5234-00(last digit illegible), analog input card for signal conditioning unit output, to digital computer input.

I could not find these part numbers on your web site. Thanks in advance for your help.

Rosemount Inc.
12001 Technology Drive
Eden Prairie, MN 55344 U S A
Tel (612) 941-5560
Telex 4310012
Fax (612) 828-3088

June 24, 1991

Mr. Ed Kaczmorski
Commonwealth Edison Co.
Nuclear Engineering
1400 OPUS Place, Suite 400
Downers Grove, IL 60515

Re: Pressure Transmitter Performance Specifications

Dear Mr. Kaczmorski,

Per your request, the following information is forwarded to clarify the performance specifications of Rosemount commercial grade and nuclear qualified instrumentation.

Nuclear Qualified Instrumentation:

Rosemount Nuclear Qualified instrumentation applicable to Commonwealth Edison Plants are the Model 1152, 1153 Series B, 1153 Series D, 1154 and 1154 Series H Pressure Transmitters; Model 353C Conduit Seals; and the Model 710DU Trip/Calibration System. The specifications referenced in Rosemount literature are separated into 'Nuclear Specifications' which include the DBE simulation and 'Performance Specifications' which include transmitter performance under plant reference conditions.

The 'Nuclear Specifications' which include Radiation, Seismic, LOCA/HELB, and Post DBE are derived from the Type Testing completed on each model type. Due to the limited sample size in the Type Tests, these specifications are based on worst case errors plus margin as referenced in IEEE 323-1974 (1983). For most practical purposes, these specifications are considered 2-sigma. (Two standard deviations).

The 'Performance Specifications' are determined from testing completed on large samples of each model type. In addition, all manufactured units are tested to insure meeting published specifications prior to shipment. Therefore, these specifications are considered 3-sigma. (Three standard deviations).

There is one exception to this rule. The Point Drift Specification of ±.20% URL for 24 Months which replaces the Stability Specification of +/-.25% URL for 6 months for all nuclear transmitters is considered to be 2-sigma based on the sample size used during testing.

Rosemount Inc.
12001 Technology Drive
Eden Prairie, MN 55344 U.S.A

Calculation PM-1209-Revision 0
Attachment F
Page F2 of F2

Commercial Grade Instrumentation:

The specifications published for Rosemount commercial grade instrumentations are considered to be 3-sigma. All Model 1151 Transmitters, 444 Temperature Transmitters and related hardware specifications were based on testing of very large sample sizes. In addition, most all specifications are verified during manufacturing of the instruments.

Specifications written as +/- for both Nuclear and Commercial Grade instrumentation implies random uncertainty allowances within the specification band. These specifications are normally distributed for most practical purposes.

We anticipate this information will assist you in the interpretation of Rosemount specifications. If we can be of further assistance, please do not hesitate to contact us.

Sincerely,

Timothy J. Layer
Marketing Engineer
Rosemount Nuclear Products

cc: N. Hyrniw #7

TJL

ATTACHMENT 5

License Amendment Request

Peach Bottom Atomic Power Station, Units 2 and 3
Docket Nos. 50-277 and 50-278

License Amendment Request - Expanded Actions for LEFM Conditions

Cameron Affidavit Supporting Withholding
Attachment 4 from Public Disclosure

Caldon Ultrasonics Technology Center

1000 McClaren Woods Drive
Coraopolis, PA 15108
Tel +1 724-273-9300
Fax +1 724-273-9301

CAMERON
A Schlumberger Company

August 3, 2018
CAW 18-07

Document Control Desk
U. S. Nuclear Regulatory Commission
Washington, DC 20555

APPLICATION FOR WITHHOLDING PROPRIETARY INFORMATION FROM PUBLIC DISCLOSURE

Subject: Cameron Engineering Report ER-464 Rev. 9 "Uncertainty Analysis for Thermal Power Determination at Peach Bottom Unit 2 Using the LEFM ✔ + System"

Gentlemen:

This application for withholding is submitted by Cameron (Holding) Corporation, a Nevada Corporation (herein called "Cameron") on behalf of its operating unit, Caldon Ultrasonics Technology Center, pursuant to the provisions of paragraph (b)(1) of Section 2.390 of the Commission's regulations. It contains trade secrets and/or commercial information proprietary to Cameron and customarily held in confidence.

The proprietary information for which withholding is being requested is identified in the subject submittal. In conformance with 10 CFR Section 2.390, Affidavit CAW 18-07 accompanies this application for withholding setting forth the basis on which the identified proprietary information may be withheld from public disclosure.

Accordingly, it is respectfully requested that the subject information, which is proprietary to Cameron, be withheld from public disclosure in accordance with 10 CFR Section 2.390 of the Commission's regulations.

Correspondence with respect to this application for withholding or the accompanying affidavit should reference CAW 18-07 and should be addressed to the undersigned.

Very truly yours,

Joanna Phillips
Nuclear Sales Manager

Enclosures (Only upon separation of the enclosed confidential material should this letter and affidavit be released.)

August 3, 2018
CAW 18-07

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF ALLEGHENY:

Before me, the undersigned authority, personally appeared Joanna M. Phillips, who, being by me duly sworn according to law, deposes and says that she is authorized to execute this Affidavit on behalf of Cameron Holding Corporation, a Nevada Corporation (herein called "Cameron") on behalf of its operating unit, Caldon Ultrasonics Technology Center, and that the averments of fact set forth in this Affidavit are true and correct to the best of her knowledge, information, and belief:

Joanna M. Phillips
Nuclear Sales Manager

Signed and sworn to before me

this 3rd day of

August, 2018

Frances A. Lewis
Notary Public

COMMONWEALTH OF PENNSYLVANIA
NOTARIAL SEAL
Frances A. Lewis, Notary Public
Coraopolis Boro, Allegheny County
My Commission Expires Nov. 25, 2018
MEMBER, PENNSYLVANIA ASSOCIATION OF NOTARIES

1. I am the Director of Business Development for Nuclear and Defense Markets of Caldon Ultrasonics Technology Center, and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing and rulemaking proceedings, and am authorized to apply for its withholding on behalf of Cameron.

2. I am making this Affidavit in conformance with the provisions of 10 CFR Section 2.390 of the Commission's regulations and in conjunction with the Cameron application for withholding accompanying this Affidavit.

3. I have personal knowledge of the criteria and procedures utilized by Cameron in designating information as a trade secret, privileged or as confidential commercial or financial information.

4. Cameron requests that the information identified in paragraph 5(v) below be withheld from the public on the following bases:

   Trade secrets and commercial information obtained from a person and privileged or confidential

   The material and information provided herewith is so designated by Cameron, in accordance with those criteria and procedures, for the reasons set forth below.

5. Pursuant to the provisions of paragraph (b) (4) of Section 2.390 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

   (i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Cameron.

   (ii) The information is of a type customarily held in confidence by Cameron and not customarily disclosed to the public. Cameron has a rational basis for determining the types of information customarily held in confidence by it and, in that connection utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitutes Cameron policy and provides the rational basis required. Furthermore, the information is submitted voluntarily and need not rely on the evaluation of any rational basis.

Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Cameron's competitors without license from Cameron constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, and assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Cameron, its customer or suppliers.

(e) It reveals aspects of past, present or future Cameron or customer funded development plans and programs of potential customer value to Cameron.

(f) It contains patentable ideas, for which patent protection may be desirable.

The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs (a), (b) and (c), above.

There are sound policy reasons behind the Cameron system, which include the following:

(a) The use of such information by Cameron gives Cameron a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Cameron competitive position.

(b) It is information that is marketable in many ways. The extent to which such information is available to competitors diminishes the Cameron ability to sell products or services involving the use of the information.

(c) Use by our competitor would put Cameron at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Cameron of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Cameron in the world market, and thereby give a market advantage to the competition of those countries.

(f) The Cameron capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

(iii) The information is being transmitted to the Commission in confidence, and, under the provisions of 10 CFR §§ 2. 390, it is to be received in confidence by the Commission.

(iv) The information sought to be protected is not available in public sources or available information has not been previously employed in the same manner or method to the best of our knowledge and belief.

(v) The proprietary information sought to be withheld is the submittal titled:

Cameron Engineering Report ER- 464 Rev. 9 "Uncertainty Analysis for Thermal Power Determination at Peach Bottom Unit 2 Using the LEFM ✔ + System"

- Table of Contents page ii contains partial proprietary information
- Pages 1, 2, 4, 5 contain partial proprietary information
- Appendix A Table of Contents contains partial proprietary information
- Appendix A.4, A.5, B.2, C.1 and C.2 Cover Pages contains partial proprietary information
- Appendices A.1, A.2, A.4, A.5, B.1, B.2, C.1 and C.2 are proprietary in their entirety

It is designated therein in accordance with 10 CFR §§ 2.390(b)(1)(i)(A,B), with the reason(s) for confidential treatment noted in the submittal and further described in this affidavit. This information is voluntarily submitted for use by the NRC Staff in their review of the accuracy assessment of the proposed methodology for the LEFM CheckPlus System used by Peach Bottom Atomic Power Station for flow measurement at the licensed reactor thermal power level of 4016 MWt.

Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Cameron because it would enhance the ability of competitors to provide similar flow and temperature measurement systems and licensing defense services for commercial power reactors without commensurate expenses. Also, public disclosure of the information would enable others to use the information to meet NRC requirements for licensing documentation without the right to use the information.

The development of the technology described in part by the information is the result of applying the results of many years of experience in an intensive Cameron effort and the expenditure of a considerable sum of money.

In order for competitors of Cameron to duplicate this information, similar products would have to be developed, similar technical programs would have to be performed, and a significant manpower effort, having the requisite talent and experience, would have to be expended for developing analytical methods and receiving NRC approval for those methods.

Further the deponent sayeth not.

Caldon Ultrasonics Technology Center

1000 McClaren Woods Drive
Coraopolis, PA 15108
Tel +1 724-273-9300
Fax +1 724-273-9301

CAMERON
A Schlumberger Company

August 3, 2018
CAW 18-08

Document Control Desk
U. S. Nuclear Regulatory Commission
Washington, DC 20555

APPLICATION FOR WITHHOLDING PROPRIETARY INFORMATION FROM PUBLIC DISCLOSURE

Subject: Cameron Engineering Report ER-463 Rev. 8 "Uncertainty Analysis for Thermal Power Determination at Peach Bottom Unit 3 Using the LEFM ✔ + System"

Gentlemen:

This application for withholding is submitted by Cameron (Holding) Corporation, a Nevada Corporation (herein called "Cameron") on behalf of its operating unit, Caldon Ultrasonics Technology Center, pursuant to the provisions of paragraph (b)(1) of Section 2.390 of the Commission's regulations. It contains trade secrets and/or commercial information proprietary to Cameron and customarily held in confidence.

The proprietary information for which withholding is being requested is identified in the subject submittal. In conformance with 10 CFR Section 2.390, Affidavit CAW 18-08 accompanies this application for withholding setting forth the basis on which the identified proprietary information may be withheld from public disclosure.

Accordingly, it is respectfully requested that the subject information, which is proprietary to Cameron, be withheld from public disclosure in accordance with 10 CFR Section 2.390 of the Commission's regulations.

Correspondence with respect to this application for withholding or the accompanying affidavit should reference CAW 18-08 and should be addressed to the undersigned.

Very truly yours,

Joanna Phillips
Nuclear Sales Manager

Enclosures (Only upon separation of the enclosed confidential material should this letter and affidavit be released.)

August 3, 2018
CAW 18-08

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF ALLEGHENY:

Before me, the undersigned authority, personally appeared Joanna Phillips, who, being by me duly sworn according to law, deposes and says that she is authorized to execute this Affidavit on behalf of Cameron Holding Corporation, a Nevada Corporation (herein called "Cameron") on behalf of its operating unit, Caldon Ultrasonics Technology Center, and that the averments of fact set forth in this Affidavit are true and correct to the best of her knowledge, information, and belief:

Joanna M. Phillips
Nuclear Sales Manager

Signed and sworn to before me

this 3rd day of

August, 2018

Frances A. Lewis
Notary Public

COMMONWEALTH OF PENNSYLVANIA
NOTARIAL SEAL
Frances A. Lewis, Notary Public
Coraopolis Boro, Allegheny County
My Commission Expires Nov. 25, 2018
MEMBER, PENNSYLVANIA ASSOCIATION OF NOTARIES

1. I am the Nuclear Sales Manager of Caldon Ultrasonics Technology Center, and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing and rulemaking proceedings, and am authorized to apply for its withholding on behalf of Cameron.

2. I am making this Affidavit in conformance with the provisions of 10 CFR Section 2.390 of the Commission's regulations and in conjunction with the Cameron application for withholding accompanying this Affidavit.

3. I have personal knowledge of the criteria and procedures utilized by Cameron in designating information as a trade secret, privileged or as confidential commercial or financial information.

4. Cameron requests that the information identified in paragraph 5(v) below be withheld from the public on the following bases:

   Trade secrets and commercial information obtained from a person and privileged or confidential

   The material and information provided herewith is so designated by Cameron, in accordance with those criteria and procedures, for the reasons set forth below.

5. Pursuant to the provisions of paragraph (b) (4) of Section 2.390 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

   (i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Cameron.

   (ii) The information is of a type customarily held in confidence by Cameron and not customarily disclosed to the public. Cameron has a rational basis for determining the types of information customarily held in confidence by it and, in that connection utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitutes Cameron policy and provides the rational basis required. Furthermore, the information is submitted voluntarily and need not rely on the evaluation of any rational basis.

Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Cameron's competitors without license from Cameron constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, and assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Cameron, its customer or suppliers.

(e) It reveals aspects of past, present or future Cameron or customer funded development plans and programs of potential customer value to Cameron.

(f) It contains patentable ideas, for which patent protection may be desirable.

The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs (a), (b) and (c), above.

There are sound policy reasons behind the Cameron system, which include the following:

(a) The use of such information by Cameron gives Cameron a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Cameron competitive position.

(b) It is information that is marketable in many ways. The extent to which such information is available to competitors diminishes the Cameron ability to sell products or services involving the use of the information.

(c) Use by our competitor would put Cameron at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Cameron of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Cameron in the world market, and thereby give a market advantage to the competition of those countries.

(f) The Cameron capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

(iii) The information is being transmitted to the Commission in confidence, and, under the provisions of 10 CFR §§ 2. 390, it is to be received in confidence by the Commission.

(iv) The information sought to be protected is not available in public sources or available information has not been previously employed in the same manner or method to the best of our knowledge and belief.

(v) The proprietary information sought to be withheld is the submittal titled:

Cameron Engineering Report ER- 463 Rev. 8 "Uncertainty Analysis for Thermal Power Determination at Peach Bottom Unit 3 Using the LEFM ✔ + System"

- Table of Contents page ii contains partial proprietary information
- Pages 1, 2, 4, 5 contain partial proprietary information
- Appendix A Table of Contents contains partial proprietary information
- Appendix A.4, A.5, B.2, C.1 and C.2 Cover Pages contains partial proprietary information
- Appendices A.1, A.2, A.4, A.5, B.1, B.2, C.1 and C.2 are proprietary in their entirety

It is designated therein in accordance with 10 CFR §§ 2.390(b)(1)(i)(A,B), with the reason(s) for confidential treatment noted in the submittal and further described in this affidavit. This information is voluntarily submitted for use by the NRC Staff in their review of the accuracy assessment of the proposed methodology for the LEFM CheckPlus System used by Peach Bottom Atomic Power Station for flow measurement at the licensed reactor thermal power level of 4016 MWt.

Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Cameron because it would enhance the ability of competitors to provide similar flow and temperature measurement systems and licensing defense services for commercial power reactors without commensurate expenses. Also, public disclosure of the information would enable others to use the information to meet NRC requirements for licensing documentation without the right to use the information.

The development of the technology described in part by the information is the result of applying the results of many years of experience in an intensive Cameron effort and the expenditure of a considerable sum of money.

In order for competitors of Cameron to duplicate this information, similar products would have to be developed, similar technical programs would have to be performed, and a significant manpower effort, having the requisite talent and experience, would have to be expended for developing analytical methods and receiving NRC approval for those methods.

Further the deponent sayeth not.

ATTACHMENT 6

License Amendment Request

Peach Bottom Atomic Power Station, Units 2 and 3
Docket Nos. 50-277 and 50-278

License Amendment Request - Expanded Actions for LEFM Conditions

Cameron ER-464NP, " Uncertainty Analysis for Thermal Power Determination at Peach Bottom Unit 2 Using the LEFM ✓+ System," Revision 9 (Non-Proprietary Version), and ER-463NP," Uncertainty Analysis for Thermal Power Determination at Peach Bottom Unit 3 Using the LEFM ✓+ System," Revision 8 (Non-Proprietary Version)

CAMERON
A Schlumberger Company

Measurement Systems

Caldron® Ultrasonics

Engineering Report: ER-464NP Revision 9

UNCERTAINTY ANALYSIS FOR THERMAL POWER DETERMINATION AT PEACH BOTTOM UNIT 2 USING THE LEFM✓+ SYSTEM

Prepared by: Ryan Hannas
Reviewed for Proprietary Info: Joanna Phillips
Approved by: Bobbie Griffith

August 2018

CAMERON
A Schlumberger Company

Measurement Systems

Engineering Report No. ER-464P, Rev 9
August 2018

CAMERON
A Schlumberger Company

Measurement Systems

Engineering Report: ER-464NP Revision 9

UNCERTAINTY ANALYSIS FOR THERMAL POWER DETERMINATION AT PEACH BOTTOM UNIT 2 USING THE LEFM✓+ SYSTEM

Table of Contents

1.0 INTRODUCTION

The LEFM✓ and LEFM✓+[1] are advanced ultrasonic systems that accurately measure the volume flow and temperature of feedwater in nuclear power plants. Using a feedwater pressure signal input to the LEFM✓ and LEFM✓+ mass flow is determined. The mass flow and temperature outputs are used, along with other plant data, to compute reactor core thermal power. The technology underlying the LEFM✓ ultrasonic instruments and the factors affecting their performance are described in a topical report, Reference 1, and a supplement to this topical report, Reference 2.

The LEFM✓+, which contains two LEFM✓'s, is described in another supplement to the topical report, Reference 3. The exact amount of the uprate allowable under a revision to 10CFR50 Appendix K depends not only on the accuracy of the LEFM✓+ outputs but also on the uncertainties in other inputs to the thermal power calculation.

It is the purpose of this document to provide an analysis of the uncertainty contribution of the LEFM✓+ System to the overall thermal power uncertainty at Peach Bottom Unit 2. [

] This report addresses three specific operating conditions:

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Trade Secret & Confidential Commercial Information

The uncertainties in LEFM mass flow and feedwater temperature are used in the calculation of the thermal power uncertainty due to the LEFM✓+ (Appendix B). This appendix complies to the methodology of the Topical Report (References 1 and 2) and provides the bound for the uncertainty uprate that the plant may recognize. [

] A detailed discussion of the methodology for combining these terms is described in Reference 3.

Trade Secret & Confidential Commercial Information

This analysis is a bounding analysis for Peach Bottom Unit 2. [

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The uncertainties in these values are bounded by this analysis.

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2.0 SUMMARY

The uncertainty approach is documented in Reference 3. The Maintenance Mode uncertainty results below use the conservative plane balance term found in Appendix A.2.

1. Mass Flow Uncertainty

   The uncertainty in the LEFM✓+'s system mass flow is as follows:

   - All meters in Normal Mode, ± 0.30%
   - [ ]
   - [ ]
   - [ ]
   - [ ]

   [ ]

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Trade Secret & Confidential Commercial Information

2. Temperature Uncertainty

   The uncertainty in the LEFM✓+ feedwater temperature is as follows:

   - [ ]
   - [ ]
   - [ ]
   - [ ]
   - [ ]

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3. Thermal Power Uncertainty

   The thermal power uncertainty approach is documented in Reference 3 and Appendix B of this document. The total uncertainty in the determination of thermal power related to the LEFM✓+ system is as follows:

   - All meters in Normal Mode, ± 0.34%
   - [ ]
   - [ ]
   - [ ]
   - [ ]

   [ ]

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Trade Secret & Confidentia Commercia Information

3.0 APPROACH

All errors and biases are calculated and combined according to the procedures defined in Reference 4 and Reference 5 in order to determine the 95% confidence and probability value. The approach to determine the uncertainty, consistent with determining set points, is to combine the random and bias terms by the means of the RSS approach provided that all the terms are independent, zero-centered and normally distributed.

Reference 4 defines the contributions of individual error elements through the use of sensitivity coefficients defined as follows:

A calculated variable P is determined by algorithm f, from measured variables X, Y, and Z.

P = f (X, Y, Z)

The error, or uncertainty in P, dP, is given by:

$$dP = \left.\frac{\partial f}{\partial X}\right|_{YZ} dX + \left.\frac{\partial f}{\partial Y}\right|_{XZ} dY + \left.\frac{\partial f}{\partial Z}\right|_{XY} dZ$$

As noted above, P is the determined variable--in this case, reactor power or mass flow-- which is calculated via measured variables X, Y, and Z using an algorithm f (X, Y, Z). The uncertainty or error in P, dP, is determined on a per unit basis as follows:

$$\frac{dP}{P} = \left\{\frac{X}{P}\left.\frac{\partial f}{\partial X}\right|_{YZ}\right\}\frac{dX}{X} + \left\{\frac{Y}{P}\left.\frac{\partial f}{\partial Y}\right|_{XZ}\right\}\frac{dY}{Y} + \left\{\frac{Z}{P}\left.\frac{\partial f}{\partial Z}\right|_{XY}\right\}\frac{dZ}{Z}$$

where the terms in brackets are referred to as the sensitivity coefficients.

If the errors or biases in individual elements (*dX/X, dY/Y, and dZ/Z* in the above equation) are all caused by a common (systematic) boundary condition (for example a common instrument) the total error dP/P is found by summing the three terms in the above equation. If, as is more often the case, the errors in X, Y, and Z are independent of each other, then Reference 4 recommends and probability theory requires that the total uncertainty be determined by the root sum square as follows (for 95% confidence and probability):

$$\frac{dP}{P} = \sqrt{\left[\left(\left\{\frac{X}{P}\left.\frac{\partial f}{\partial X}\right|_{YZ}\right\}\frac{dX}{X}\right)^2 + \left(\left\{\frac{Y}{P}\left.\frac{\partial f}{\partial Y}\right|_{XZ}\right\}\frac{dY}{Y}\right)^2 + \left(\left\{\frac{Z}{P}\left.\frac{\partial f}{\partial Z}\right|_{XY}\frac{dZ}{Z}\right)^2\right]}$$

Obviously, if some errors in individual elements are caused by a combination of boundary conditions, some independent and some related (i.e., systematic) then a combination of the two procedures is appropriate.

4.0 OVERVIEW

The analyses that support the calculation of LEFM✓+ uncertainties are contained in the appendices to this document. The functions of each appendix are outlined below.

Appendix A.1, LEFM✓+ Inputs

This appendix tabulates dimensional and other inputs to the LEFM✓+ which is used for the computation of mass flow and temperature. [ ] are used in this appendix.

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Appendix A.2, LEFM✓+ Uncertainty Calculations

This appendix calculates the uncertainties in mass flow and temperature as computed by the LEFM✓+ using the methodology described in Appendix E of Reference 1 and Appendix A of Reference 3[3], with uncertainties in the elements of these measurements bounded as described in both references[4]. The spreadsheet calculation draws on the data of Appendix A.1 for dimensional information. [ ]

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This appendix utilizes the results of the calibration testing for the plant spool piece(s) for the uncertainty in the profile factor (calibration coefficient). The engineering reports for the spool piece calibration tests are referenced in Appendix A.3 to this report.

Appendix A.3, Meter Factor and Meter Factor Uncertainty

The calibration test report for the spool piece(s) establishes the overall uncertainty in the meter (profile) factor of the LEFM✓+. The elements of the meter factor uncertainty include [ ] are also elements in establishing the uncertainty in meter factor.

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[ ]

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[3] Reference 3 (ER 157P) develops the uncertainties for the LEFM✓+ system. Because this system uses two measurement planes, the structure of its uncertainties differs somewhat that of an LEFM✓.

[4] Reference 3 (ER 157P) revised some of the time measurement uncertainty bounds. The revised bounds are a conservative projection of actual performance of the LEFM hardware. ER 80P used bounds that were based on a conservative projection of theoretical performance.

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Trade Secret & Confidentia Commercia Information

Appendix A.4, [ ]

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Appendix A.5, [ ]

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Appendix B, Total Thermal Power Uncertainty using the LEFM ✓+

The total thermal power uncertainty for a plant using the LEFM✓+ system is calculated in this appendix. It combines the results provided in Appendix A, along with plant specific terms (ex., steam enthalpy, moisture carryover, etc.).

These terms have been combined in a method consistent with that described in the Topical Report and its supplements (References 1, 2, and 3). Appendix B reconciles the results of this analysis with ER157(P-A) Rev. 8 (Reference 3).

Appendix C, Total Thermal Power Uncertainty [
]

Appendix C has a special calculation for Peach Bottom [
]

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5.0 REFERENCES

1) Cameron Topical Report ER-80P, "Improving Thermal Power Accuracy and Plant Safety While Increasing Operating Power Level Using the LEFM Check System", dated March 1997, Revision 0

2) Cameron Engineering Report ER-160P, "Supplement to Topical Report ER 80P: Basis for a Power Uprate with the LEFM System", dated May 2000, Revision 0

3) Cameron Engineering Report ER-157(P-A), "Supplement to Caldon Topical Report ER-80P: Basis for Power Uprates with an LEFM Check or an LEFM CheckPlus", dated May 2008, Revision 8

4) ASME PTC 19.1, Measurement Uncertainty

5) Caldon Engineering Report ER-590, "The Effects of Random and Coherent Noise on LEFM CheckPlus Systems", Rev. 2

Appendix A

Appendix A.1, LEFM✓+ Inputs

Appendix A.2, LEFM✓+ Uncertainty Calculations

Appendix A.3, LEFM✓+ Spool Piece(s) Meter Factor and Meter Factor Uncertainty

Appendix A.4, [ ]

Appendix A.5, [ ]

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Appendix A.1

LEFM✓+ Inputs

No Attachment to follow, as Appendix is Proprietary in its Entirety

Appendix A.2

LEFM✓+ Uncertainty Calculations

No Attachment to follow, as Appendix is Proprietary in its Entirety

Appendix A.3

LEFM✓+ Spool Piece(s) Profile Factor and Profile Factor Uncertainty

Reference Caldon Engineering Reports

ER-441 Rev 1, "Profile Factor Calculation and Accuracy Assessment for the Peach Bottom Unit 2 Replacement LEFM✓+ Spool Pieces", August 2016

Appendix A.4

[ ]

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No Attachment to follow, as Appendix is Proprietary in its Entirety

Appendix A.5

[ ]

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No Attachment to follow, as Appendix is Proprietary in its Entirety

Appendix B-1

Thermal Power Uncertainty Calculation using the LEFM✓+ System

No Attachment to follow, as Appendix is Proprietary in its Entirety

Appendix B-2

Thermal Power Uncertainty Calculation using the LEFM✓+ System
[ ]

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No Attachment to follow, as Appendix is Proprietary in its Entirety

Appendix C-1

Thermal Power Uncertainty Calculation [

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Confidential
Commercial
Information

No Attachment to follow, as Appendix is Proprietary in its Entirety

Appendix C-2

Thermal Power Uncertainty Calculation [

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No Attachment to follow, as Appendix is Proprietary in its Entirety

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Measurement Systems

Caldon® Ultrasonics

Engineering Report: ER-463NP Revision 8

UNCERTAINTY ANALYSIS FOR THERMAL POWER DETERMINATION AT PEACH BOTTOM UNIT 3 USING THE LEFM✓+ SYSTEM

Prepared by: Ryan Hannas
Reviewed for Proprietary Info: Joanna Phillips
Approved by: Bobbie Griffith

August 2018

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Measurement Systems

Engineering Report No. ER-463NP, Rev 8
August 2018

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A Schlumberger Company

Measurement Systems

Engineering Report: ER-463NP Revision 8

UNCERTAINTY ANALYSIS FOR THERMAL POWER DETERMINATION AT PEACH BOTTOM UNIT 3 USING THE LEFM✓+ SYSTEM

Table of Contents

1.0 INTRODUCTION

The LEFM✓ and LEFM✓+[1] are advanced ultrasonic systems that accurately measure the volume flow and temperature of feedwater in nuclear power plants. Using a feedwater pressure signal input to the LEFM✓ and LEFM✓+ mass flow is determined. The mass flow and temperature outputs are used, along with other plant data, to compute reactor core thermal power. The technology underlying the LEFM✓ ultrasonic instruments and the factors affecting their performance are described in a topical report, Reference 1, and a supplement to this topical report, Reference 2.

The LEFM✓+, which contains two LEFM✓'s, is described in another supplement to the topical report, Reference 3. The exact amount of the uprate allowable under a revision to 10CFR50 Appendix K depends not only on the accuracy of the LEFM✓+ outputs but also on the uncertainties in other inputs to the thermal power calculation.

It is the purpose of this document to provide an analysis of the uncertainty contribution of the LEFM✓+ System to the overall thermal power uncertainty at Peach Bottom Unit 3. [

] This report addresses three specific operating conditions:

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The uncertainties in LEFM mass flow and feedwater temperature are used in the calculation of the thermal power uncertainty due to the LEFM✓+ (Appendix B). This appendix complies to the methodology of the Topical Report (References 1 and 2) and provides the bound for the uncertainty uprate that the plant may recognize. [

] A detailed discussion of the methodology for combining these terms is described in Reference 3.

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This analysis is a bounding analysis for Peach Bottom Unit 3. [

]

The uncertainties in these values are bounded by this analysis.

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2.0 SUMMARY

The uncertainty approach is documented in Reference 3. The Maintenance Mode uncertainty results below use the conservative plane balance term found in Appendix A.2.

1. Mass Flow Uncertainty

   The uncertainty in the LEFM✓+'s system mass flow is as follows:

   - All meters in Normal Mode, ± 0.30%
   - [ ]
   - [ ]
   - [ ]
   - [ ]

   [ ]

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Trade Secret & Confidential Commercial Information

2. Temperature Uncertainty

   The uncertainty in the LEFM✓+ feedwater temperature is as follows:

   - [ ]
   - [ ]
   - [ ]
   - [ ]
   - [ ]

Trade Secret & Confidential Commercial Information

3. Thermal Power Uncertainty

   The thermal power uncertainty approach is documented in Reference 3 and Appendix B of this document. The total uncertainty in the determination of thermal power related to the LEFM✓+ system is as follows:

   - All meters in Normal Mode, ± 0.34%
   - [ ]
   - [ ]
   - [ ]
   - [ ]

   [ ]

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[2] [ ]

Trade Secret & Confidentia Commercia Information

3.0 APPROACH

All errors and biases are calculated and combined according to the procedures defined in Reference 4 and Reference 5 in order to determine the 95% confidence and probability value. The approach to determine the uncertainty, consistent with determining set points, is to combine the random and bias terms by the means of the RSS approach provided that all the terms are independent, zero-centered and normally distributed.

Reference 4 defines the contributions of individual error elements through the use of sensitivity coefficients defined as follows:

A calculated variable P is determined by algorithm f, from measured variables X, Y, and Z.

$$P = f(X, Y, Z)$$

The error, or uncertainty in P, dP, is given by:

$$dP = \left.\frac{\partial f}{\partial X}\right|_{YZ} dX + \left.\frac{\partial f}{\partial Y}\right|_{XZ} dY + \left.\frac{\partial f}{\partial Z}\right|_{XY} dZ$$

As noted above, P is the determined variable--in this case, reactor power or mass flow-- which is calculated via measured variables X, Y, and Z using an algorithm f (X, Y, Z). The uncertainty or error in P, dP, is determined on a per unit basis as follows:

$$\frac{dP}{P} = \left\{\frac{X}{P}\left.\frac{\partial f}{\partial X}\right|_{YZ}\right\}\frac{dX}{X} + \left\{\frac{Y}{P}\left.\frac{\partial f}{\partial Y}\right|_{XZ}\right\}\frac{dY}{Y} + \left\{\frac{Z}{P}\left.\frac{\partial f}{\partial Z}\right|_{XY}\right\}\frac{dZ}{Z}$$

where the terms in brackets are referred to as the sensitivity coefficients.

If the errors or biases in individual elements (*dX/X, dY/Y, and dZ/Z* in the above equation) are all caused by a common (systematic) boundary condition (for example a common instrument) the total error dP/P is found by summing the three terms in the above equation. If, as is more often the case, the errors in X, Y, and Z are independent of each other, then Reference 4 recommends and probability theory requires that the total uncertainty be determined by the root sum square as follows (for 95% confidence and probability):

$$\frac{dP}{P} = \sqrt{\left[\left(\left\{\frac{X}{P}\left.\frac{\partial f}{\partial X}\right|_{YZ}\right\}\frac{dX}{X}\right)^2 + \left(\left\{\frac{Y}{P}\left.\frac{\partial f}{\partial Y}\right|_{XZ}\right\}\frac{dY}{Y}\right)^2 + \left(\left\{\frac{Z}{P}\left.\frac{\partial f}{\partial Z}\right|_{XY}\right\}\frac{dZ}{Z}\right)^2\right]}$$

Obviously, if some errors in individual elements are caused by a combination of boundary conditions, some independent and some related (i.e., systematic) then a combination of the two procedures is appropriate.

4.0 OVERVIEW

The analyses that support the calculation of LEFM✓+ uncertainties are contained in the appendices to this document. The functions of each appendix are outlined below.

Appendix A.1, LEFM✓+ Inputs

This appendix tabulates dimensional and other inputs to the LEFM✓+ which is used for the computation of mass flow and temperature. [

] are used in this appendix.

Trade Secret & Confidential Commercial Information

Appendix A.2, LEFM✓+ Uncertainty Calculations

This appendix calculates the uncertainties in mass flow and temperature as computed by the LEFM✓+ using the methodology described in Appendix E of Reference 1 and Appendix A of Reference 3[3], with uncertainties in the elements of these measurements bounded as described in both references[4]. The spreadsheet calculation draws on the data of Appendix A.1 for dimensional information. [

]

Trade Secret & Confidential Commercial Information

This appendix utilizes the results of the calibration testing for the plant spool piece(s) for the uncertainty in the profile factor (calibration coefficient). The engineering reports for the spool piece calibration tests are referenced in Appendix A.3 to this report.

Appendix A.3, Meter Factor and Meter Factor Uncertainty

The calibration test report for the spool piece(s) establishes the overall uncertainty in the meter (profile) factor of the LEFM✓+. The elements of the meter factor uncertainty include [

] are also elements in establishing the uncertainty in meter factor.

Trade Secret & Confidentia Commercia Information

[

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Trade Secret & Confidential Commercial Information

[3] Reference 3 (ER 157P) develops the uncertainties for the LEFM✓+ system. Because this system uses two measurement planes, the structure of its uncertainties differs somewhat that of an LEFM✓.

[4] Reference 3 (ER 157P) revised some of the time measurement uncertainty bounds. The revised bounds are a conservative projection of actual performance of the LEFM hardware. ER 80P used bounds that were based on a conservative projection of theoretical performance.

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Appendix A.4, [ ]

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Trade Secret & Confidential Commercial Information

Appendix A.5, [ ]

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Trade Secret & Confidential Commercial Information

Appendix B, Total Thermal Power Uncertainty using the LEFM ✓+

The total thermal power uncertainty for a plant using the LEFM✓+ system is calculated in this appendix. It combines the results provided in Appendix A, along with plant specific terms (ex., steam enthalpy, moisture carryover, etc.).

These terms have been combined in a method consistent with that described in the Topical Report and its supplements (References 1, 2, and 3). Appendix B reconciles the results of this analysis with ER157(P-A) Rev. 8 (Reference 3).

Appendix C, Total Thermal Power Uncertainty [
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Appendix C has a special calculation for Peach Bottom [
]

Trade Secret & Confidential Commercial Information

5.0 REFERENCES

1) Cameron Topical Report ER-80P, "Improving Thermal Power Accuracy and Plant Safety While Increasing Operating Power Level Using the LEFM Check System", dated March 1997, Revision 0

2) Cameron Engineering Report ER-160P, "Supplement to Topical Report ER 80P: Basis for a Power Uprate with the LEFM System", dated May 2000, Revision 0

3) Cameron Engineering Report ER-157(P-A), "Supplement to Caldon Topical Report ER-80P: Basis for Power Uprates with an LEFM Check or an LEFM CheckPlus", dated May 2008, Revision 8

4) ASME PTC 19.1, Measurement Uncertainty

5) Caldon Engineering Report ER-590, "The Effects of Random and Coherent Noise on LEFM CheckPlus Systems", Rev. 2

Appendix A

Appendix A.1, LEFM✓+ Inputs

Appendix A.2, LEFM✓+ Uncertainty Calculations

Appendix A.3, LEFM✓+ Spool Piece(s) Meter Factor and Meter Factor Uncertainty

Appendix A.4, [ ]

Appendix A.5, [ ]

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Appendix A.1

LEFM✓+ Inputs

No Attachment to follow, as Appendix is Proprietary in its Entirety

Appendix A.2

LEFM✓+ Uncertainty Calculations

No Attachment to follow, as Appendix is Proprietary in its Entirety

Appendix A.3

LEFM✓+ Spool Piece(s) Profile Factor and Profile Factor Uncertainty

Reference Caldon Engineering Reports

ER-375 Rev 1, "Profile Factor Calculation and Accuracy Assessment for the Peach Bottom Unit 3 Replacement LEFM✓+ Spool Pieces", August 2016

Appendix A.4

[ ]

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No Attachment to follow, as Appendix is Proprietary in its Entirety

Appendix A.5

[ ]

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No Attachment to follow, as Appendix is Proprietary in its Entirety

Appendix B-1

Thermal Power Uncertainty Calculation using the LEFM✓+ System

No Attachment to follow, as Appendix is Proprietary in its Entirety

Appendix B-2

Thermal Power Uncertainty Calculation using the LEFM✓+ System
[ ]

Trade Secret & Confidential Commercial Information

No Attachment to follow, as Appendix is Proprietary in its Entirety

Appendix C-1

Thermal Power Uncertainty Calculation [

]

Trade Secret & Confidential Commercial Information

No Attachment to follow, as Appendix is Proprietary in its Entirety

Appendix C-2

Thermal Power Uncertainty Calculation [
]
[ ]

Trade Secret & Confidential Commercial Information

No Attachment to follow, as Appendix is Proprietary in its Entirety

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