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10 CFR 50.90

RS-04-105

July 19, 2004

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-001

Quad Cities Nuclear Power Station, Units 1 and 2
Facility Operating License Nos. DPR-29 and DPR-30
NRC Docket Nos. 50-254 and 50-265

Subject: Additional Information to Support Review of the Request for Technical Specification Changes Related to Primary Containment Isolation Instrumentation (Main Steam Line Flow-High)

Reference: Letter from P.R. Simpson (Exelon Generation Company, LLC) to U. S. NRC, "Technical Specification Changes Related to Primary Containment Isolation Instrumentation (Main Steam Line Flow-High)," dated June 10, 2004

In the referenced letter, Exelon Generation Company, LLC (EGC) requested changes to the Technical Specifications of Facility Operating License Nos. DPR-29 and DPR-30 for Quad Cities Nuclear Power Station, Units 1 and 2. The proposed changes revise the Main Steam Line Flow-High surveillance requirements and allowable value for Primary Containment and Control Room Emergency Ventilation isolations.

In a communication from Mr. Larry Rossbach to Mr. Thomas Roddey on July 7, 2004, the NRC requested additional information regarding these proposed changes. The attachment to this letter provides the requested information. This additional information provides the set point and allowable value calculation for the proposed change.

Should you have any questions, please contact Mr. Thomas G. Roddey, at (630) 657-2811.

Respectfully,

Patrick R. Simpson

Patrick R. Simpson
Manager – Licensing

Attachment: Main Steam Line High Flow Differential Pressure Setpoint Analysis, QDC-0200-I-1369

A001

cc: Regional Administrator – NRC Region III
NRC Senior Resident Inspector – Quad Cities Nuclear Power Station
Illinois Emergency Management Agency – Division of Nuclear Safety

ATTACHMENT

Main Steam Line High Flow Differential Pressure Setpoint Analysis

QDC-0200-I-1369

Exelon Nuclear

CC-AA-309-1001
Revision 0

ATTACHMENT 1
Design Analysis Cover Sheet

Last Page No. 33

Analysis No. QDC-0200-I-1369 **Revision** 0
EC/ECR No. EC 345323 & EC 345324 **Revision** 0 & 0
Title: Main Steam Line High Flow Differential Pressure Setpoint Analysis

		Component(s)	
Station(s)	Quad Cities		
Unit No.:	Units 1 & 2	DPT 1(2)-0261-2A (-2B, -2C, -2D)	DPT 1(2)-0261-2J (-2K, -2L, -2M)
Discipline	I	DPT 1(2)-0261-2E (-2F, -2G, -2H)	DPT 1(2)-0261-2N (-2P, -2R, -2S)
Description Code/Keyword	I03, I04/ Setpoint	DPIS 1(2)-0261-2A-1 (-2B-1, -2C-1, 2D-1)	
Safety Class	Safety Related	DPIS 1(2)-0261-2E-1 (-2F-1, -2G-1, 2H-1)	
System Code	RX (0200)	DPIS 1(2)-0261-2J-1 (-2K-1, -2L-1, -2M-1)	
Structure		DPIS 1(2)-0261-2N-1 (-2P-1, -2R-1, -2S-1)	

CONTROLLED DOCUMENT REFERENCES

Document No.	**From/To**	**Document No.**	**From/To**
QCIS 0200-16	To	QCIS 0200-64	To
QCIS 0200-17	To	QCIS 0200-65	To
QCIS 0200-62	To	QCIS 0200-66	To
QCIS 0200-63	To	QCIS 0200-67	To

Is this Design Analysis Safeguards? Yes ☐ No ☒
Does this Design Analysis Contain Unverified Assumptions? Yes ☐ No ☒ ATI/AR#
Is a Supplemental Review Required? Yes ☐ No ☒ If yes, complete Attachment 3

	Print Name	Sign Name	Date
Preparer	Patricia A. Ugorcak	Patricia A. Ugorcak	02-24-04
Reviewer	Richard H. Low	Richard H Low	02-24-04

Method of Review ☒ Detailed Review ☐ Alternate Calculations ☐ Testing
Review Notes:

	Print Name	Sign Name	Date
Approver	I. A. Khan	IaKhan	02-24-04
(For External Analyses Only) Exelon Reviewer	Joseph R. Basak	Joseph R Basak	2/27/04
Approver	JOE P. TAFT		2/27/04

Description of Revision (list affected pages for partials):
Initial Issue in support of EC 345323 and 345234

THIS DESIGN ANALYSIS SUPERCEDES: QDC-3000-I-0986 Revision 001, after implementation of ECs 345323 & 345324

ATTACHMENT 1
General Review Questions
Page 1 of 1

DESIGN ANALYSIS NO. QDC-0200-I-1369 **REV:** 0
EC 345323 and EC 345324

		Yes	No	N/A
1.	Does the design analysis conform to design requirements?	☑	☐	☐
2.	Does the design analysis conform to applicable codes, standards, and regulatory requirements?	☑	☐	☐
3.	Have applicable design and safety limits been identified?	☑	☐	☐
4.	Is the analysis method appropriate?	☑	☐	☐
5.	Are the methods used and recommendations given conservative relative to the design and safety limits?	☑	☐	☐
6.	Are assumptions/Engineering Judgments explained and appropriate?	☑	☐	☐
7.	Have appropriately verified Computer Program and versions been identified, when applicable?	☐	☐	☑
8.	Does the Computer Program conform with the NRC SER or similar document when applicable?	☐	☐	☑
9.	Has the input been correctly incorporated into the design analysis?	☑	☐	☐
10.	Has the input been reviewed by all cognizant design authorities?	☐	☐	☑
11.	Are the analysis outputs and conclusions reasonable compared to the inputs and assumptions?	☑	☐	☐
12.	Are the recommendations/results/conclusions reasonable based on previous experience?	☑	☐	☐
13.	Has a verification of the design analysis been performed by alternate methods?	☐	☑	☐
14.	Has all input data been used correctly and is it traceable?	☑	☐	☐
15.	Has the effect on plant drawings, procedures, databases, and/or plant simulator been addressed? in EC	☑	☐	☐
16.	Has the effect on other systems been addressed? in EC	☑	☐	☐
17.	Have any changes in other controlled documents (e.g. UFSAR, Technical Specifications, COLR, etc.) been identified and tracked? in EC	☑	☐	☐
18.	When applicable, are the analysis results consistent with the proposed license amendment?	☑	☐	☐
19.	Have other documents that have used the calculation as input been reviewed and revised as appropriate?	☐	☐	☑

ATTACHMENT 2
Owners Acceptance Review Checklist for External Design Analysis
Page 1 of 1

DESIGN ANALYSIS NO. QDC-0200-I-1369 **REV:** 0
EC 345323 and EC 345324

		Yes	No	N/A
1.	Do assumptions have sufficient rationale?	☑	☐	☐
2.	Are assumptions compatible with the way the plant is operated and with the licensing basis?	☑	☐	☐
3.	Do the design inputs have sufficient rationale?	☑	☐	☐
4.	Are design inputs correct and reasonable?	☑	☐	☐
5.	Are design inputs compatible with the way the plant is operated and with the licensing basis?	☑	☐	☐
6.	Are Engineering Judgments clearly documented and justified?	☑	☐	☐
7.	Are Engineering Judgments compatible with the way the plant is operated and with the licensing basis?	☑	☐	☐
8.	Do the results and conclusions satisfy the purpose and objective of the design analysis?	☑	☐	☐
9.	Are the results and conclusions compatible with the way the plant is operated and with the licensing basis?	☑	☐	☐
10.	Does the design analysis include the applicable design basis documentation?	☑	☐	☐
11.	Have any limitations on the use of the results been identified and transmitted to the appropriate organizations? in EC	☑	☐	☐
12.	Are there any unverified assumptions?	☐	☑	☐
13.	Do all unverified assumptions have a tracking and closure mechanism in place?	☐	☐	☑

EXELON REVIEWER: Joseph R. Basak Joseph R Basak **DATE:** 2/27/04
Print / Sign

DESIGN ANALYSIS TABLE OF CONTENTS

ANALYSIS NO. QDC-0200-I-1369 REV. NO. 0 PAGE NO. 2

1.0 PURPOSE

The purpose of this calculation is to determine Calibration Setpoints, Technical Specification Allowable Values, and Expanded Tolerances for the Unit 1 and 2 instrumentation that initiates closure of main steam isolation valves on high main steam line flow. Only instrument errors associated with normal operating conditions are considered. The trip signal provided by the transmitters is required in response to a Main Steam Line Break (MSLB). The location of the transmitters is projected to be a harsh environment only during the HPCI line break accident or during a LOCA. No significant heat up beyond normal conditions is expected prior to and during the time these instruments are required to function for the MSLB. This calculation addresses the specifications in GE SIL No. 438, Rev 1 (Ref 5.6).

This safety-related calculation is valid under normal operating conditions for the instruments listed below. These instruments sense High Steam Line Flow indicative of a Main Steam Line Break and initiate a Main Steam Line Isolation when flow exceeds the trip Setpoint. These instruments also indicate differential pressure (dP) developed by the associated Main Steam Line flow venturi. However, the indication function of the instruments is not within the scope of this calculation. The instrument configuration is based on implementation of ECs 345323 and 345324 (Ref. 5.13), which install the transmitters and trip units listed below.

Venturi Flow Elements

FE 1-0261-1A	FE 2-0261-1A
FE 1-0261-1B	FE 2-0261-1B
FE 1-0261-1C	FE 2-0261-1C
FE 1-0261-1D	FE 2-0261-1D

Differential Pressure Transmitters

DPT 1-0261-2A through 2H	DPT 2-0261-2A through 2H
DPT 1-0261-2J through 2N	DPT 2-0261-2J through 2N
DPT 1-0261-2P, 2R, and 2S	DPT 2-0261-2P, 2R, and 2S

Master Trip Units

DPIS 1-0261-2A-1 through 2H-1	DPIS 2-0261-2A-1 through 2H-1
DPIS 1-0261-2J-1 through 2N-1	DPIS 2-0261-2J-1 through 2N-1
DPIS 1-0261-2P-1, 2R-1, and 2S-1	DPIS 2-0261-2P-1, 2R-1, and 2S-1

2.0 METHODOLOGY AND ACCEPTANCE CRITERIA

2.1 Methodology

2.1.1 The methodology used for this calculation is that presented in NES-EIC-20.04, "Analysis of Instrument Channel Setpoint Error and Instrument Loop Accuracy" (Reference 5.2).

2.1.2 Because this is a Tech Spec loop, the Total Error (TE) is evaluated in conformance with a Level 1 Setpoint as defined in Reference 5.2, Appendix D, Graded Approach to Determination of Instrument Channel Uncertainty. As a Level 1, this means that the random errors (σ) to a 1σ value are combined via square-root-sum-of-the-squares (SRSS), and the non-random errors (e) are added. The total error is the sum of the random errors times two and non-random errors.

$$TE = 2\sigma + \Sigma e$$

2.1.3 Clarifications to calculation methodology are as noted below.

A. Calculated values will be rounded to five decimal places for intermediate error calculation values and to three or less decimal places for final results, to match the calibration procedure values.

B. Radiation induced errors associated with normal environments are incorporated when provided by the manufacturer. If these error effects are not provided, they are considered to be small and capable of being adjusted out during calibration and are included within drift related errors.

C. For normal errors seismic events less than or equal to an OBE are considered to produce no permanent shift in the input/output relationship of a device. For seismic events greater than an OBE, it is assumed that affected instrumentation will be recalibrated as necessary prior to any subsequent accident, negating any permanent shift that may have occurred.

D. Per Appendix I of NES-EIC-20.04 (Ref. 5.2), the effects of radiation (eR), humidity (eH), power supply (eV), calibration standard equipment (STD), and seismic (eS) under normal operating conditions may typically be considered negligible. For the evaluation of normal operating conditions, these errors are considered negligible unless otherwise noted.

E. For LOCA in the opposite unit, humidity levels outside the drywell are specified as 100% (NC) or lower (Ref. 5.19.1). Appendix I of NES-EIC-20.04 (Ref. 5.2) recommends consideration of humidity effects only in a condensing environment. Therefore, since the environment is non-condensing in this situation, humidity effects are still considered negligible unless specified otherwise by the vendor.

With a LOCA in one unit, radiation levels in the opposite unit are considered to be within the "Normal" levels for that unit. Any airborne radiation concerns, in the LOCA unit, would be controlled by that unit's emergency ventilation system and thus should not impact the opposite unit. In addition, shielding between units is considered adequate to preclude any radiation streaming concerns.

F. An Allowable Value (AV) is determined in accordance with the methodology of Reference 5.2 Appendix C, as follows.

$$AV = SPc + Zav$$

Where SPc = calculated trip setpoint, and Zav is the combination of those applicable uncertainties that have been determined to affect the trip setpoint. Thus, only the reference accuracy or repeatability (RA or RPT), calibration error (CAL), setting tolerance (ST), drift (DR) and if applicable, the input error (σin) are included.

The allowable value (AV) is determined in terms of units of the input signal to the first device in the instrument loop. A setting tolerance (ST) for the loop calibration is selected based on 1.0% of calibrated span. Although not used for the AV determination, the STs for individual loop components are selected based on 0.5% of calibrated span. This ensures that the overall loop ST is greater than any of the individual component STs. Per Reference 5.2, the STs are considered 3σ values.

G. Expanded as-found tolerances (ET) are computed for the trip setpoint in accordance with the methodology of Reference 5.3, based on the applicable uncertainties Zav. The formula used to compute ET (for consistency with the Improved Technical Specification project) is:

$$ET = [0.7 * (AV - SPc - ST)] + ST, \text{ where } AV = SPc + Zav$$

$$ET = [0.7 * (Zav - ST)] + ST$$

If the computed ET is found to be less than the ST, the ET is conservatively set equal to the ST value.

H. Temperature related errors are evaluated across the full range of ambient temperatures at which the device is used. The errors are based on the difference between the calibration temperature and the worst-case temperature at which the device is used. This methodology provides a conservative error evaluation by considering the full range of ambient temperature change specified for the applicable EQ zone. For instruments located in the reactor building, the calibration temperature is taken as the average within the normal temperature range (no LOCA in either unit) as defined in Reference 5.19.1, which is a realistic minimum calibration temperature. The instrument temperature error is evaluated from the calibration temperature to the maximum "elevated" normal temperature, which accounts for one unit's reactor building heating up due to loss of HVAC, due to a LOCA in the opposite unit. The temperature used is the maximum after the opposite unit LOCA. For instruments located in areas with a small ambient range, such as the control room or aux electric room, the temperature error is simply determined for a shift across the entire temperature range from one endpoint to the other, because in this case either extreme is a realistic calibration temperature.

I. The only temperature induced M&TE errors evaluated are those specified by the manufacturer for a specific model number, taken across the full range of non-LOCA normal temperatures. This is done because while one unit is in a LOCA, the other will be in the process of shutting down, so it assumed that no calibrations will be performed.

2.2 Acceptance Criteria

There are no acceptance criteria for the setpoint or allowable value determination. The setpoint and allowable value are calculated in accordance with the methodology and the results are provided for use.

The expanded tolerances are determined as described above in Section 2.1.3.G and are acceptable if the result is greater than or equal to the applicable setting tolerance and does not result in a violation of an applicable limit.

3.0 ASSUMPTIONS / ENGINEERING JUDGMENTS

3.1 Published instrument vendor specifications are considered to be 2 sigma values unless specific information is available to indicate otherwise.

3.2 Evaluation of M&TE errors is based on the assumption that the test equipment listed in Section 4 is used. Use of test equipment less accurate than that listed will require evaluation of the effect on calculation results.

3.3 In accordance with Reference 5.9, it is assumed that the M&TE listed in Section 4 is calibrated to the required manufacturer's recommendations and within the manufacturer's required environmental conditions. As such, it is assumed that the calibration standard accuracy error of M&TE is negligible with respect to the other terms.

3.4 With a LOCA in one unit, the radiation levels in the opposite unit are considered to be within the "Normal" levels for that unit. Any airborne radiation concerns, in the LOCA unit, would be controlled by that unit's emergency ventilation system and thus should not impact the opposite unit. In addition, shielding between units is considered adequate to preclude any radiation streaming concerns.

3.5 As stated in Paragraph 4.17 of Reference 5.15 (ANSI/ASME PTC 6 Report – 1985), the overall uncertainty values of the flow elements in Table 4.10 of Reference 5.15 are acceptable for flow elements in service for less than or up to six months. It further 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 a flow element will be negligible with respect to the initial six-month uncertainty and will therefore not have a measurable impact on the overall loop uncertainty. Since the flow elements have been in service greater than six months, for conservatism, the largest Group 2 base uncertainty from Table 4.10 will be used to evaluate the overall flow element error.

3.6 As shown in Section 4.3.3, Reference 5.7.2 states a normal operating range of 40% to 50% relative humidity (RH) for the Rosemount Model 710DU trip system. As shown in Section 4.4.2, the location at which the trip system is installed is at 40% to 70% RH for normal operating conditions. Therefore, the normal RH of this zone exceeds the vendor's specified normal range. Per engineering judgment, it is reasonable to expect that no additional error will be induced on an electronic device such as the 710DU trip system from raising the RH from 50% to 70%. Temperature changes in this zone (the cable spreading room) are gradual, and at up to 70% RH, the RH remains low enough that condensation will not be produced.

4.0 DESIGN INPUTS

4.1 Steam flow rate = 11.713 X 10^6 lbm/hr. (Reference 5.10.1.)

4.2 Per Reference 5.22 (Attachment D), the stated values for Rosemount transmitter 1153 Series B Reference Accuracy, Ambient Temperature Effect, Static Pressure Effect and Power Supply Effect have a 3σ confidence level.

4.3 Instrument Channel Configuration

The instrument loop configuration is as designed by ECs 345323 and 345324 (Reference 5.13). It consists of a venturi flow element for each Main Steam Line that develops a differential pressure (dP) signal proportional to the square of steam flow. A transmitter senses this dP and sends an output signal to a master trip unit. When steam flow increases the dP to the setpoint, the trip unit de-energizes an auxiliary relay to initiate the PCIS Group 1 Isolation Logic (UFSAR Table 7.3-1, Ref. 5.10.3). There are dP loops connected across each venturi, for each of four logic channels, for a total of 16 output contacts per unit.

4.3.1 Module 1 Data: Venturi Flow Element w/Throat Taps

EPNs: FE 1(2)-0261-1A, (-1B, -1C, -1D)

Manufacturer: BIF	(Ref. 5.8)
Type: 20 inch PN A176730 Machined 304 SS	(Ref. 5.8, 5.14)
Reference Accuracy: 0.5 % Flow	(Ref. 5.8, 5.14)

Note: For FE 2-0261-1A, the reference accuracy was affected by damage found during Q2M20 as discussed in Reference 5.16. As specified in Reference 5.17, the reference accuracy value for FE 2-0261-1A is increased by 0.5% to 1.0 %.

4.3.2 Module 2 Data: Differential Pressure Transmitter (Ref. 5.7.1 and Design Input 4.2, except as noted otherwise)

EPN	DPT 1(2)-0261-2A, through -2S, excluding -2I, -2O, -2Q [Ref. 5.13]
Manufacturer	Rosemount [Ref. 5.13]
Model No.	1153DB7PA [Ref. 5.13]
URL	300 psid [Ref. 5.13]
Output	4-20 mA [Ref. 5.13]
Reference Accuracy [3σ]	±0.25% calibrated span
Drift [2σ]	±0.2% upper range limit (URL) for 30 months
Normal Temperature Range	40°F to 200°F
Humidity Limits	0-100%RH (NEMA 4X)
Temperature Effect [3σ]	±(0.75% URL + 0.5% span) / 100°F
Static Pressure Zero Effect [3σ]	±0.5% URL/1000 psi, correctable through re-zeroing at line pressure
Static Pressure Span Effect [3σ]	±0.5% Input Reading / 1000 psi
High Line Pressure Correction	+1.25% of input/1000psi
Overpressure Limit	2000 psig
Power Supply Effect (3σ)	Less than 0.005% output span per volt
Relative Humidity	0-100% RH
Radiation Effect [2σ]	±8.0% URL during/after exposure to 2.2 x 10^7 rads TID
Seismic Effect [2σ]	±0.5% URL during/after ZPA of 4g

4.3.3 Module 3 Data: Master Trip Unit (Ref. 5.8, 5.7.2)

EPN	DPIS 1(2)-0261-2A-1 through -2S-1, excluding -2I-1, 2O-1 and 2Q-1
Manufacturer	Rosemount
Model No.	710DU0TT23032
Input Signal	4-20 mA
Output Signal	Bi-stable: 24Vdc for Logic Level 1, <1Vdc for Logic Level 0
Repeatability (Normal) [2σ]	±0.13%(Span) (60 °F to 90 °F) ±0.20%(Span)/100 °F (Above 90 °F)
Radiation Limits	None specified within limits below
Seismic Effect	None specified within limits below
Drift	Included in repeatability for up to 6 months
Temperature Effect	Included in repeatability
Temperature Limits	60°F to 90°F (normal) 160°F (24 hours, once/year) 185°F (Accident for 6 hours) 150°F (Accident for 8 hours)
Relative Humidity	40 to 50% RH (normal) 90% for 24 hours once/year; 90% for 14 hours (accident)
Radiation Limits	$\leq 10^5$ RADS (air) 20 year TID (Normal) 2 x 10^5 RADS (air) 24 hour TID (Accident)
Seismic Limits	1.17g OBE and 1.75g SSE
Power Supply	22 to 28 Vdc

Note: Repeatability specifications are applicable for a period of 6 months.

4.4 Environmental Data

4.4.1 Environmental Data for Transmitter Locations (Reference 5.8, 5.19.1, 5.10.2, 5.19.2, 5.13)

Reactor Building	1-2201-10B, -10C	2-2202-9B, -10B
Floor Elevation 554' / RHR Corner Rooms	1A (SE) RHR Corner Room: N-19	2A & 2B (NE & SE) RHR Corner Rooms: M-7, M-13
EQ Zones	5	5, 6
	Normal Operating Conditions	
Ambient Temperature Range	65°F to 104°F	
Ambient Pressure	14.7 psia	
Humidity	20 to 90% RH	
Radiation	<1.0E04 RADs (40-Yrs)	

4.4.2 Environmental Data for Trip Unit Location

Trip Unit Locations: (Reference 5.8, 5.19.1, 5.13)

Service Building	1-2201-73A, B, AA, BB	2-2202-73A, B, AA, BB
Floor Elevation 609' / Cable Spreading Room	G-26	F-26
EQ Zone 18a	Normal Operating Conditions	
Ambient Temperature Range	70°F to 80°F	
Ambient Pressure	14.7 psia	
Humidity	40 to 70% RH	
Radiation	<1.0E04 RADs (40-Yrs)	

4.5 Calibration Data (for analog trip system installed by EC 345323 and 345324)

Per ECs 345323 and 345324, the operating input range (calibrated span) for the transmitters is 0-300 psid for a 4-20 mA output.

ECs 345323 and 345324 will revise the calibration procedure(s) to calibrate the main steam high flow dP instrument loops in the same way as the other existing analog trip instrument loops are calibrated. Specifically, for the loop calibration, first the transmitter calibration is done with pressure input read on certified pressure M&TE, while reading mA output at the transmitter and Vdc input to the MTU on certified DMMs. Then the trip point actuation will be observed in response to increasing pressure input, with a setting tolerance in input pressure units. Per 2.1.3.F, as established by ECs 345323 and 345324, the setting tolerance is ±3.0 psid (1.0% of span) for the string calibration of the trip point. For the transmitter calibration, per 2.1.3.F, the setting tolerance is established as ±0.08 mA (0.5% of span).

For the MTU calibration check, the stable input current is applied and read at the trip unit on the Rosemount readout assembly and calibration unit installed in the instrument nests in panels 2201(2)-73A (B, AA, BB). Current is increased until the trip unit actuates. Per 2.1.3.F, as established by ECs 345323 and 345324, the setting tolerance is ±0.08 mA (0.5% of span) for the calibration of the trip unit alone.

Per Reference 5.11, typical surveillance intervals and late factors for the transmitter/trip unit instrument loops are as follows:

Calibration Frequency:	Transmitter through trip unit loop calibration:	24 months
	Trip Unit Alone:	92 days

Late Factor 25 % Nominal Frequency (Ref. 5.11)

Reference 5.11 will be revised to include these values for the MSL High Flow Isolation Signal.

4.6 Calibration Instrument Data – Calculation NED-I-EIC-0255, Measurement and Test Equipment (M&TE) Accuracy Calculation For Use With ComEd BWR(s), Rev. 0, Reference 5.9 (pages 66 and 86), is used to provide the errors for the calibration instruments noted herein. Since ECs 345323 and 345324 will replace the MSL High Flow switches with transmitters and trip units, the calibration procedures must be revised to include the test equipment listed here. The list provides the errors for these instruments from the above noted calculation. The list also provides the evaluation parameters used in NED-I-EIC-0255.

4.6.1 Pressure Sensing M&TE, for transmitter input

Calibration Instrument MTE	Error (1σ)	Evaluation Parameters
MTE2 - Heise CMM (0 – 400 psig)	± 1.744484 psig	104 °F
MTE3 - Druck DPI 601 (0 – 500 psig)	± 0.730068 psig	104 °F

Note: MTE error values for the Druck DPI-601 could be reduced slightly by using the actual calibration limit for reading value. For convenience, the error values were simply transposed from Reference 5.9, as the impact on the total instrument loop error is insignificant.

4.6.2 Rosemount Calibration Unit and Readout Assembly (Ref. 5.7.2)

Stable Calibration Current Range: 3.5 to 20.5 mA Stability: ± 5 µA (2σ per Section 3.1)

Readout Assembly Resolution: ±0.01 mA over normal temperature range of 40°F to 104°F, (2σ per Section 3.1).

Per Reference 5.23, errors associated with the calibration unit are included in the trip unit repeatability. Therefore, no additional calibration error is required for the MTU.

4.7 From Reference 5.11 the maximum limit for Reactor pressure at the steam dome is 1005 psig (~ 1020 psia). For dry saturated steam at this pressure, the temperature is 546.99 °F (Reference 5.12, page A-15).

4.8 The isentropic exponent for an ideal gas is the ratio of specific heats of fluid. For dry saturated steam at 1050 psia and 550 °F the value is approximately 1.255 (Reference 5.6). According to Reference 5.12, page A-9, the value is approximately 1.257 for dry saturated steam at 1000 psia. Therefore, the isentropic exponent for dry saturated steam at 1020 psia is between these values and is approximately 1.256.

4.9 Coefficient of discharge for a venturi tube with a machined entrance cone, C = 0.995 (Ref. 5.6 p3). Per Reference 5.12 page A-20, this value is approximately constant for fully turbulent flow.

4.10 Venturi throat inside diameter, d = 9.97 in (Reference 5.14).

4.11 Pipe inside diameter (20", sch 80 – Reference 5.8), D = 17.938 in (Reference 5.12 page B-18).

4.12 Area thermal expansion factor, F_a = 1.0092 (Reference 5.6).

4.13 Upstream specific volume (ft^3/lbm) at 1020 psia and 546.99 °F, v = 0.4362 ft^3/lbm (dry, saturated steam – ASME Steam Tables - 1967).

4.14 The flow element is a BIF venturi according to Reference 5.8. The accuracy of BIF venturi tubes is ±0.5% flow according to vendor information. (Reference 5.18, Attachment B)

4.15 The Licensed Power Uprate (LPU) Rated Steam Flow is 11.713 Mlb/hr (Ref. 5.10.1). Dividing this across the four main steam lines, 100% power flow in each steam line is (11.713 Mlb/hr)* (1000 klb/Mlb)/4 = 2928.25 klb/hr.

4.16 The Analytical Limit (AL) for this function is 140% of LPU Rated Steam Flow (Ref. 5.10.3). Based on four main steam lines, the AL per steam line is:

AL (per steam line) = 140% (2928.25 klb/hr) = 4099.55 klb/hr

4.17 From Reference 5.15 (ASME PTC 6), the steam flow element accuracy error presented is valid only if the ratio of the dP to the inlet pressure is ≤0.10. The dP and inlet pressure at 100% flow are utilized to calculate the pressure ratio. Using Reference 5.6, dP at 100% flow (2928.25 klb/hr per venturi) is 111.06 psid (as calculated in Section 6.0 of this calculation). The maximum inlet pressure at 100% flow is 1020 psia and the density (rho) is 2.293 (lb/ft^3). The ratio of dP to inlet pressure is:

Units 1 & 2: Press. Ratio@100% PWR = 111.06 psi / 1020 psia = 0.109

Although the ratio slightly exceeds 0.10, the uncertainties from ASME PTC 6 (Reference 5.15) are considered a reasonable approximation of the flow element uncertainties.

4.18 As stated in Foreword to ANSI/ASME PTC 6 Report – 1985 (Ref. 5.15), 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, the overall uncertainty of the flow section is taken to represent a 2σ value.

4.19 For the purpose of this calculation, ambient environmental conditions (pressure, temperature, or humidity) in the zone of the process pipe will have no effect on the flow element in comparison to the effects of the process flow itself, because the flow element is a steel nozzle inside the 20" process line. The ambient pressure and humidity clearly can have no effect on the nozzle inside the process line, and the nozzle will be at the temperature of the process. No ambient zone effects for the nozzle location will be applied to the nozzle.

5.0 REFERENCES

5.1 ANSI/ISA-S67.04-1994, "Setpoints for Nuclear Safety Related Instrumentation"

5.2 "Analysis of Instrument Channel Setpoint Error and Instrument Loop Accuracy," NES-EIC-20.04, Revision 3, October 23, 2000

5.3 "Instrument Performance Trending," ComEd procedure ER-AA-520 Revision 3, 9-6-2002

5.4 Quad Cities Unit 1 Instrument Surveillance Procedures:

- 5.4.1 QCIS 0200-16, Rev. 7, Unit 1 Division I Main Steam Line High Flow Indicator and Switch Calibration and Functional Test
- 5.4.2 QCIS 0200-17, Rev. 7, Unit 1 Division I Main Steam Line High Flow Switch Calibration and Functional Test
- 5.4.3 QCIS 0200-62, Rev. 1, Unit 1 Division II Main Steam Line High Flow Indicator and Switch Calibration and Functional Test
- 5.4.4 QCIS 0200-65, Rev. 2, Unit 1 Division II Main Steam Line High Flow Switch Calibration and Functional Test

5.5 Quad Cities Unit 2 Instrument Surveillance Procedures:

- 5.5.1 QCIS 0200-63, Rev. 0, Unit 2 Division I Main Steam Line High Flow Indicator and Switch Calibration and Functional Test
- 5.5.2 QCIS 0200-64, Rev. 0, Unit 2 Division II Main Steam Line High Flow Indicator and Switch Calibration and Functional Test
- 5.5.3 QCIS 0200-66, Rev. 1, Unit 2 Division I Main Steam Line High Flow Switch Calibration and Functional Test
- 5.5.4 QCIS 0200-67, Rev. 1, Unit 2 Division II Main Steam Line High Flow Switch Calibration and Functional Test

5.6 General Electric Service Information Letter (SIL) No. 438, Rev.1, dated May 5, 1994, regarding "Main Steam Line High Flow Trip Setting" (Attachment A)

5.7 VTIP Binder C0066 Volumes 1 and 2

- 5.7.1 VTIP Manual R369-0299, Rosemount Product Manual for Alphaline Transmitters 1153 Series B, Manual 4302, dated May 1999 (In VTIP Binder C0066 Volume 1)
- 5.7.2 VTIP Manual R369-0035, Rosemount Model 710DU Operations Manual, 4471-1, dated April 1983 (In VTIP Binder C0066 Volume 2)

5.8 Quad Cities PassPort Component Data Sheets for the following components:

DPT 1(2)-0261-2A through 2S (excluding -2I, -2O, -2Q), as revised per ECs 345323 Rev. 0 and 345324 Rev. 0

DPIS 1(2)-0261-2A-1 through 2S (excluding -2I-1, -2O-1, -2Q-1), as revised per ECs 345323 Rev. 0 and 345324 Rev. 0)

FE 1-0261-1A thru 1D, FE 2-0261-1D (Rev 001)

FE 2-0261-1A thru 1C (Rev 000)

5.9 Calculation NED-I-EIC-0255, Rev. 0, "Measurement and Test Equipment (M&TE) Accuracy Calculation for Use With Commonwealth Edison Company Boiling Water Reactors", dated 4/14/94

5.10 Quad Cities UFSAR, Rev. 7, January 2003
  5.10.1 Table 4.1-3, Thermal and Hydraulic Design Data
  5.10.2 Section 9.4.7, Reactor Building Ventilation System
  5.10.3 Table 7.3-1, Analytical Limits for Group Isolation Signals

5.11 Quad Cities Technical Specifications, Amendments 218 and 212

5.12 Crane Technical Paper No. 410, 25th Printing, 1991

5.13 EC 345323 Rev. 0 and EC 345324 Rev. 0, Main Steam Line High Flow Switch Replacement

5.14 "20IN 17.938 x 9.974 Venturi Insert Nozzle" Vendor Drawing (BIF General Signal Corporation), A-176730 Rev. 1, dated 1/13/69

5.15 ANSI/ASME PTC 6 Report, "Guidance for Evaluation of Measurement Uncertainty in Performance Tests of Steam Turbines", Sections 4.15 – 4.18, 1985

5.16 EC 338015, Revision 0, Evaluation of Main Steam Line 'A' Flow Restrictor Damage

5.17 BIF Engineered Flow Applications Letter from Joseph M. Motta to Jeffrey Drowley (Exelon), dated July 17, 2002 (Attachment C)

5.18 BIF Vendor Information (Attachment B)

5.19 Quad Cities Drawings:
  5.19.1 Environmental Zone Maps, M-4A Series
    Sh. 1, Rev. E, Basement Floor Plan Figure 1
    Sh. 2, Rev. F, Ground Floor Plan, El. 595'-0", Figure 2
    Sh. 6, Rev. A, Notes and References
  5.19.2 Quad Cities Drawing M-6, Rev. C, General Arrangement Basement Floor Plan Units 1 & 2

5.20 Quad Cities Drawings, as revised for EC 345323
  5.20.1 CID-13 Sh. 1, Control and Instrumentation Main Steam System - Quad Cities Station Unit 1
  5.20.2 M-13 Sh. 1, Diagram of Main Steam Piping
  5.20.3 4E-1503A, Schematic Diagram PCIS Panel 901-15 Trip Logic & Condenser
  5.20.4 4E-1503B, Schematic Diagram PCI System Panel 901-17 Trip Logic

5.21 Quad Cities Drawings, as revised for EC 345324
  5.21.1 CID-60 Sh. 1, Control and Instrumentation Main Steam System – Quad Cities Station Unit 2
  5.21.2 M-60 Sh. 1, Diagram of Main Steam Piping
  5.21.3 4E-2503A Sh. 1, Schematic Diagram PCIS Panel 902-15 Trip Logic & Condenser
  5.21.4 4E-2503A Sh. 2, Schematic Diagram PCIS Panel 902-15 Trip Logic & Condenser
  5.21.5 4E-2503B Sh. 1, Schematic Diagram PCIS Panel 902-17 Trip Logic & Condenser
  5.21.6 4E-2503B Sh. 2, Schematic Diagram PCIS Panel 902-17 Trip Logic

5.22 Letter, Rosemount Nuclear Instruments, 4 April 2000, Rosemount Instrument Setpoint Methodology (Attachment D)

5.23 Telecon, N. Archambo of Bechtel to T. Layer of Rosemount, 6-16-93, Rosemount Model 710DU Trip/Calibration Unit Specifications (Attachment E)

6.0 CALCULATIONS

Using Reference 5.6, (GE SIL 438, Rev. 1) the operating differential pressures developed across each of the four main steam venturi are determined. The differential pressures for 100% power (per Design Input 4.15, 2928.25 klb/hr per venturi) and 140% power (per Design Input 4.16, 4099.55 klb/hr per venturi) are calculated as follows.

From Attachment to GE SIL 438, Rev. 1:

$W = 1890.07*(CYd^2F_a)*[(\rho\Delta P)/(1 - \beta^4)]^{½}$ **Eq. 1**

Where: W = mass steam flow in lb/hr
C = discharge coefficient = 0.995
Y = gas expansion factor (ratio)

$Y = \{r^{2/k}(k/(k-1))[(1-r^{[(k-1)/k]})/(1-r)][(1-\beta^4)/(1-\beta^4r^{2/k})]\}^{½}$ **Eq. 2**

And: r = ratio: throat StatPres to inlet StatPres (psia) = $(P_1 - \Delta P)/P_1$
k = ratio of specific heats, or isentropic exponent, dry saturated steam = 1.256 for pressure of 1020 psia
d = throat diameter Units 1 and 2: 9.970"
Fa = area thermal expansion factor = 1.0092
ρ = density of upstream fluid (1/v = 1 / 0.4362 @ 1020 psia = 2.293)
ΔP = differential pressure (psid)
β = ratio of throat to pipe diameters Units 1 and 2: (9.970"/17.938")

Solving for ΔP: $\Delta P = [W/(1890.07*CYd^2F_a)]^2[(1-\beta^4)/\rho]$ **Eq. 3**

Initial value at $Y=1$: $\Delta P = [W/(1890.07*Cd^2F_a)]^2[(1-\beta^4)/\rho]$ **Eq. 4**

Starting with Equation 4 and then using Equations 3 and 2, the following tables successively iterate the differential pressures at 100% and 140% (AL) flow values, until the value stops changing. The values determined are operating differential pressures at the corresponding system static pressure as shown for each flow. In these iterations, all calculated values are rounded to 5 decimal places, and then the final dP is rounded to 2 places.

Operating dPs

C			k	D	F		β	k/(k-1)	2/k
0.995			1.256	9.97	1.0092		0.555803	4.906250	1.592357
W	Static P	ρ	ΔP@Y=1	r1	Y1	ΔP1	r2	Y2	ΔP2
2928250	1020	2.293	95.04243	0.90682	0.93599	108.48635	0.89364	0.92684	110.63893
4099550	1020	2.293	186.28316	0.81737	0.87327	244.27359	0.76052	0.83255	268.75276
			r3	Y3	ΔP3	r4	Y4	ΔP4	
2928250	1020	2.293	0.89153	0.92537	110.99072	0.89119	0.92513	111.04832	
4099550	1020	2.293	0.73652	0.81513	280.36244	0.72513	0.80680	286.18167	
			r5	Y5	ΔP5	r6	Y6	ΔP6	
2928250	1020	2.293	0.89113	0.92509	111.05792	0.89112	0.92509	111.05792	
4099550	1020	2.293	0.71943	0.80262	289.17027	0.71650	0.80047	290.72573	
			r7	Y7	ΔP7	r8	Y8	ΔP8	
2928250	1020	2.293	0.89112	0.92509	111.05792	0.89112	0.92509	111.05792	= 111.06
4099550	1020	2.293	0.71497	0.79935	291.54099	0.71418	0.79876	291.97184	
			r9	Y9	ΔP9	r10	Y10	ΔP10	
4099550	1020	2.293	0.71375	0.79845	292.19861	0.71353	0.79829	292.31575	
			r11	Y11	ΔP11	r12	Y12	ΔP12	
4099550	1020	2.293	0.71342	0.79821	292.37434	0.71336	0.79816	292.41098	
			r13	Y13	ΔP13	r14	Y14	ΔP14	
4099550	1020	2.293	0.71332	0.79813	292.43296	0.71330	0.79812	292.44029	
			r15	Y15	ΔP15	r16	Y16	ΔP16	
4099550	1020	2.293	0.71329	0.79811	292.44762	0.71329	0.79811	292.44762	
			r17	Y17	ΔP17	r18	Y18	ΔP18	
4099550	1020	2.293	0.71329	0.79811	292.44762				= 292.45

From the table above, the differential pressure at 100% flow (2928.25 klb/hr) is 111.06 psid, and at the AL of 140% flow (4099.55 klb/hr) is 292.45 psid.

6.1 FLOW ELEMENT ERRORS - Module 1

Classification of Module

Per Section 4.3.1, Module 1 is a venturi, with steam flowing through it developing differential pressure at the process taps. Therefore, it is classified as an analog module.

6.1.1 Random Error (σ_1)

6.1.1.1 Venturi Uncertainty (UO)

The error associated with the venturi is calculated per the methodology contained in Reference 5.15, using the largest Group 2 base uncertainty value per Assumption 3.5, for a flow nozzle with throat tap without upstream flow straighteners. Per the general note in Table 4.10 of Reference 5.15, the following formula applies:

$$UO = (U_B^2 + U_{LNS}^2 + U_\beta^2 + U_{DSL}^2)^{0.5}$$

Base Uncertainty (U_B)

The base uncertainty U_B is taken from Table 4.10 of Reference 5.15, Item H, for steam flow through a nozzle with throat tap in an uncalibrated section, without upstream flow straighteners:

$U_B = 3.0$ % flow

Note: The base accuracy of 3% flow is conservative and bounds the vendor reference accuracy of ± 1.0% for FE 2-0261-1A and ± 0.5% for the other FEs as defined in Section 4.3 for Module 1.

Minimum Upstream Straight Run Uncertainty (U_{LNS})

Per Sections 4.10 & 4.11, the inner pipe diameter is 17.938" and the nozzle throat diameter is 9.970". This produces a beta ratio $\beta = 9.970/17.938 = 0.556$. Conservatively approximating with an upstream straight pipe run ratio of 1 for a 0.5 β ratio curve in Figure 4.5 of Reference 5.15, means that $U_{LNS} = 1.25\%$ of flow.

Therefore: $U_{LNS} = 1.25\%$ flow

Beta Ratio Uncertainty (U_β)

From Figure 4.6 of Reference 5.15 the beta ratio effect for an uncalibrated flow element with a beta ratio of up to 0.56 is:

$U_\beta = 0.18\%$ of flow

Minimum Downstream Straight Run Uncertainty (U_{DSL})

Per Sections 4.10 & 4.11, the inner pipe diameter is 17.938" and the nozzle throat diameter is 9.970". This produces a beta ratio $\beta = 9.970"/17.938" = 0.556$. Conservatively approximating with a downstream straight pipe run ratio of 0.8 for up to a 0.75 β ratio curve in Figure 4.9 of Reference 5.15, means that $U_{LNS} = 1.05\%$ of flow.

Therefore: $U_{LNS} = 1.05\%$ flow

Nozzle Overall Uncertainty (UO)

As stated in the beginning of this section, the overall flow element uncertainty is then calculated as: (which is taken as a 2σ value per Design Input 4.18)

$\text{UO} = \pm(U_B^2 + U_{LNS}^2 + U_\beta^2 + U_{DSL}^2)^{0.5} = \pm((3.0)^2 + (1.25)^2 + (0.18)^2 + (1.05)^2)^{0.5}$
$= \pm 3.42$ % of flow [2σ]

6.1.1.2 Nozzle Reference Accuracy (RA1)

The overall uncertainty is stated in terms of % of flow. This will be converted into terms of klb/hr and then psid, and used as the reference accuracy. The reference accuracy will be determined for the flow value corresponding to the AL value 140% of flow, because this will always be larger than the actual instrument setpoint value.

From Section 6.1.1.1, UO = ±3.42 % of flow [2σ]

At 4099.55 klb/hr (140% flow), and dividing by 2 to get a 1σ value:

$\text{UO}_{140} = \pm 3.42\,\% * (4099.55 \text{ klb/hr})/2 = \pm 70.102 \text{ klb/hr}$ [1σ]

The differential pressure must be determined for flows of 4099.55 ±70.102 klb/hr, which equals 4029.448 klb/hr and 4169.652 klb/hr.

dP determination

Equations 1, 2, 3 and 4 below are taken from Reference 5.6, GE SIL 438, Revision 1.

From Attachment to GE SIL 438, Rev. 1: $W = 1890.07*(CYd^2F_a)*[(\rho\Delta P)/(1 - \beta^4)]^{1/2}$ Eq. 1

Where: W = mass steam flow in lb/hr
C = discharge coefficient = 0.995
Y = gas expansion factor (ratio)

$Y = \{r^{2/k}(k/(k\text{-}1))[(1\text{-}r^{[(k-1)/k]})/(1\text{-}r)][(1\text{-}\beta^4)/(1\text{-}\beta^4 r^{2/k})]\}^{1/2}$ Eq. 2

And: r = ratio: throat StatPres to inlet StatPres (psia) = $(P_I - \Delta P)/P_I$
k = ratio of specific heats, or isentropic exponent, dry saturated steam = 1.256 for a pressure of 1020 psia
d = throat diameter Units 1 and 2: 9.970"
Fa = area thermal expansion factor = 1.0092
ρ = density of upstream fluid (1/v = 1 / 0.4362 @ 1020 psia = 2.293)
ΔP = differential pressure (psid)
β = ratio of throat to pipe diameters Units 1 and 2: (9.970"/17.938")

Solving for ΔP: $\Delta P = [W/(1890.07*CYd^2F_a)]^2[(1\text{-}\beta^4)/\rho]$ Eq. 3

Initial value at Y=1: $\Delta P = [W/(1890.07*Cd^2F_a)]^2[(1\text{-}\beta^4)/\rho]$ Eq. 4

Starting with Equation 4 and then using Equations 3 and 2, the following table successively iterates the differential pressures for desired flow values, until the value stops changing. The values determined are operating differential pressures at the corresponding system static pressure as shown for each flow. In these iterations, all calculated values are rounded to 5 decimal places, and then the final dP is rounded to 2 places.

Units 1 & 2 Operating dPs

C			K	D	F		β	k/(k-1)	2/k
0.995			1.256	9.970	1.0092		0.555803	4.906250	1.592357
W	Static P	ρ	ΔP@Y=1	R1	Y1	ΔP1	r2	Y2	ΔP2
4029448	1020	2.293	179.96677	0.82356	0.87766	233.63597	0.77095	0.84008	255.00637
4169652	1020	2.293	192.70848	0.81107	0.86879	255.31199	0.74969	0.82471	283.33375
			r3	Y3	ΔP3	r4	Y4	ΔP4	
4029448	1020	2.293	0.74999	0.82492	264.46528	0.74072	0.81819	268.83387	
4169652	1020	2.293	0.72222	0.80467	297.62213	0.70821	0.79437	305.39025	
			r5	Y5	ΔP5	r6	Y6	ΔP6	
4029448	1020	2.293	0.73644	0.81507	270.89595	0.73442	0.81359	271.88242	
4169652	1020	2.293	0.70060	0.78875	309.75769	0.69632	0.78558	312.26262	
			r7	Y7	ΔP7	r8	Y8	ΔP8	
4029448	1020	2.293	0.73345	0.81289	272.35087	0.73299	0.81255	272.57884	
4169652	1020	2.293	0.69386	0.78376	313.71454	0.69244	0.78270	314.56483	
			r9	Y9	ΔP9	r10	Y10	ΔP10	
4029448	1020	2.293	0.73277	0.81239	272.68622	0.73266	0.81231	272.73993	
4169652	1020	2.293	0.69160	0.78208	315.06378	0.69111	0.78172	315.35403	
			r11	Y11	ΔP11	r12	Y12	ΔP12	
4029448	1020	2.293	0.73261	0.81227	272.76679	0.73258	0.81225	272.78023	
4169652	1020	2.293	0.69083	0.78151	315.52353	0.69066	0.78138	315.62853	
			r13	Y13	ΔP13	r14	Y14	ΔP14	
4029448	1020	2.293	0.73257	0.81224	272.78694	0.73256	0.81224	272.78694	
4169652	1020	2.293	0.69056	0.78131	315.68509	0.69050	0.78126	315.72550	
			r15	Y15	ΔP15	r16	Y16	ΔP16	
4029448	1020	2.293	0.73256	0.81224	272.78694				= 272.79
4169652	1020	2.293	0.69047	0.78124	315.74166	0.69045	0.78123	315.74975	
			r17	Y17	ΔP17	r18	Y18	ΔP18	
4169652	1020	2.293	0.69044	0.78122	315.75783	0.69043	0.78121	315.76591	
			r19	Y19	ΔP19	r20	Y20	ΔP20	
4169652	1020	2.293	0.69043	0.78121	315.76591	0.69043	0.78121	315.76591	= 315.77

From Section 6.0, the differential pressure at 140% flow (4099.55 klb/hr) is 292.45 psid. Therefore the flow element error in terms of psid is:

At −3.42% flow: FEL = 272.79 psid − 292.45 psid = -19.66 psid
At +3.42% flow: FEH = 315.77 psid − 292.45 psid = 23.32 psid

The greater in magnitude of these is conservatively applied in both directions as the flow element reference accuracy.

RA1 = ± 23.32 psid $[1\sigma]$

6.1.1.3 Calibration Error and Setting Tolerance (CAL1 & ST1)

The flow element is a passive mechanical device that is not field calibrated. Therefore,

$CAL1 = 0$ and $ST1 = 0$

6.1.1.4 Drift ($\sigma D1$)

The flow element is a passive mechanical device that does not drift. Therefore,

$\sigma D1 = 0$

6.1.1.5 Random Input Errors ($\sigma 1_{IN}n$)

The nozzle is the first element in each loop and therefore has no random input errors. Therefore,

$\sigma 1_{IN}n = 0$ [1σ]

6.1.1.6 Determination of Total Random Errors ($\Sigma\sigma 1$)

$$\Sigma\sigma 1 = [RA1^2 + CAL1^2 + ST1^2 + \sigma D1^2 + \sigma 1_{IN}n^2]^{0.5}$$

Because all these values are zero except for RA1, this simplifies to: $\Sigma\sigma 1 = RA1$

at 140% flow: $\Sigma\sigma 1 = RA1 = \pm 23.32$ psid [1σ]

6.1.2 Non-Random Errors ($\Sigma e1$)

The nozzle is a passive mechanical device, a piece of steel welded inside of a pipe section. The differential pressure monitored at the taps is proportional to the square of the flow through the nozzle. As such it is not affected by the following non-random errors:

Ambient Humidity Errors: $e1H = 0$; Per Design Input 4.19, no ambient effects inside the pipe.

Ambient Temperature Errors: $\varepsilon 1T = 0$; per Design Input 4.19, no ambient effects inside the pipe.

Radiation Errors: $e1R = 0$; radiation will not affect the dP developed by the nozzle.

Seismic Errors: $e1S = 0$; seismic event will not alter the nozzle.

Static Pressure Effects: $e1SP = 0$; changes in static pressure are accounted for in the process error.

Ambient Pressure Errors: $e1P = 0$; per Design Input 4.19, no ambient effects inside the pipe.

Power Supply Effects: $e1V = 0$; no power supply

6.1.2.1 Process Error ($e1p$)

The differential pressure at the taps of the venturi flow element for a given mass flow rate varies with the upstream steam line pressure primarily due to variation in saturated steam density with pressure. The differential pressure varies to a lesser extent with changes in expansion factor. However, the equations of flow in Section 6.0 show the process effect is inversely proportional with steam line pressure so that decreasing pressure (decreasing density) results in a conservatively higher DP for a given mass flow rate. Fluctuation in operating pressure during full power operation is restricted to below the nominal Reactor Steam Dome pressure in accordance with specification 3.4.10 of Reference 5.11. Therefore, the random effect on differential pressure that can contribute a non-conservative error is zero and the random process error is established as,

$$e1p = 0$$

6.1.2.2 Non-Random Input Errors ($e1_{IN}$)

The nozzle is the first element in the loop and so has no non-random input errors, therefore:

$$e1in = 0$$

6.1.2.3 Total Non-Random Error ($\Sigma e1$)

In accordance with Section 2.1.2, the bias errors from Section 6.1.2 through 6.1.2.2 are added. Therefore,

$$\Sigma e1 = \pm[e1H + e1T + e1R + e1S + e1SP + e1P + e1V + e1p + e1_{IN}]$$

Because all of these errors are zero, $\Sigma e1 = 0$

6.2 DIFFERENTIAL PRESSURE TRANSMITTER ERRORS - Module 2

Classification of Module

Module 2 is a differential pressure transmitter that senses the differential pressure across the main steam venturi and produces an analog signal proportional to differential pressure that is sent to the master trip unit. It has an analog input operating range of 0-300 psid (Input 4.5), and an analog output range of 4-20 mA (Input 4.3.2). Therefore, it is classified as an analog module.

6.2.1 Transmitter Random Errors ($\sigma 2$)

6.2.1.1 Transmitter Reference Accuracy (RA2)

By direct application of the vendor's specifications listed in Section 4.3.2:

$$RA2 = \pm 0.25\% * (\text{Span}) \quad [3\sigma]$$
$$= \pm 0.25\% * (16\text{ mA})/3 = \pm 0.01333\text{ mA} \quad [1\sigma]$$

6.2.1.2 Transmitter Calibration Error (CAL2)

Per Section 4.5, the transmitter is calibrated in a string with the trip unit by applying pressures of known accuracy to the input and adjusting the devices for proper output. Therefore the transmitters contribution to the calibration error is based only on the error of the MTE used to measure the transmitter input pressure, and consists of the following random components:

- the inaccuracy of the calibration standards used to calibrate the measurement and test equipment (STD2)
- the inaccuracy of the pressure gauge used to measure the transmitter input pressure during calibration (MTE2)

These quantities will be calculated and combined by the SRSS method.

6.2.1.2.1 Calculation of STD2

Per Section 3.3, the calibration standard accuracy error of the measurement and test equipment is negligible as noted below:

$$STD2 = 0$$

6.2.1.2.2 Calculation of MTE2

MTE2 is defined as the error induced on the transmitter as a result of the inaccuracy of the pressure gauge used to measure the input signal to the device during calibration. For conservatism, the pressure gauge with the worst accuracy is used in this error determination. From the M&TE accuracy data listed in Section 4.6.1:

$$MTE2 = \pm 1.74448\text{ psid} \quad [1\sigma]$$

This is converted to mA by multiplying by the ratio of the transmitter input to output spans (CF_{EO}). Per 4.5, the transmitter will be calibrated to operate at 0-300 psid input for a 4-20 mA output.

$$MTE2' = CF_{EO} * MTE2 = (16\text{ mA}/300\text{ psid}) * (\pm 1.74448\text{ psid}) = \pm 0.09304\text{ mA} \quad [1\sigma]$$

6.2.1.2.3 Total Calibration Error (CAL2)

The total calibration error associated with the transmitter is:

$$CAL2 = \pm[(STD2)^2 + (MTE2')^2]^{1/2} = \pm[(0)^2 + (0.09304\text{ mA})^2]^{1/2} = \pm 0.09304\text{ mA} \quad [1\sigma]$$

6.2.1.3 Transmitter Setting Tolerance (ST2)

From Section 4.5 and 2.1.3.F, the setting tolerance for the string calibration to the MTU is ±3.0 psid, taken as a 3σ value. This is converted to mA by multiplying by the ratio of the spans, as in Step 6.2.1.2.2, and taken to a 1σ value by dividing by 3:

$$ST2 = (\pm 3.0 \text{ psid})*CF_{EO} / 3 = (\pm 3.0 \text{ psid})*(16 \text{ mA} / 300 \text{ psid}) / 3 = \pm 0.05333 \text{ mA} [1\sigma]$$

6.2.1.4 Drift Error (DR2)

From the vendor's specifications listed in Section 4.3.2, the drift error for the transmitter is given below. Per Input 4.5, the surveillance interval (SI) for the device is 24 months with an additional 25% late factor. Therefore, the expected drift error converted to 1σ is:

$$\begin{aligned} DR2 &= \pm(0.2\%(URL)/30 \text{ months})(SI)(1.25) \quad [2\sigma] \\ &= \pm(0.2\%(300 \text{ psid})/30 \text{ months})(24 \text{ months})(1.25) / 2 = \pm 0.30000 \text{ psid} \quad [1\sigma] \end{aligned}$$

This is converted to mA by multiplying by the ratio of the spans, as in Step 6.2.1.2.2:

$$\begin{aligned} DR2' &= DR2*(16 \text{ mA}/300 \text{ psid}) = (\pm 0.30000 \text{ psid})*(16 \text{ mA}/ 300\text{psid}) \\ &= \pm 0.01600 \text{ mA} \quad [1\sigma] \end{aligned}$$

6.2.1.5 Temperature Error (e2T)

From Section 4.4.1, the ambient temperature of the transmitter environment during normal operating conditions, varies from a minimum of 65 °F to a maximum of 104 °F. From the vendor's specifications listed in Section 4.3.2, the error induced on the transmitter as a result of this temperature variation converted to 1σ is:

$$\begin{aligned} e2T &= \pm((0.75\%(URL) + 0.5\%(Span))/100 \text{ °F})(\Delta T) \quad [3\sigma] \\ &= \pm((0.75\%(300 \text{ psid}) + 0.5\%(300 \text{ psid}))/100 \text{ °F})(104 \text{ °F} - 65 \text{ °F}) / 3 \\ &= \pm 0.48750 \text{ psid} \quad [1\sigma] \end{aligned}$$

This is converted to mA by multiplying by the ratio of the spans, as in Step 6.2.1.2.2:

$$\begin{aligned} e2T' &= e2T*(16 \text{ mA}/300 \text{ psid}) = (\pm 0.48750 \text{ psid})*(16 \text{ mA}/300 \text{ psid}) \\ &= \pm 0.02600 \text{ mA} \quad [1\sigma] \end{aligned}$$

6.2.1.6 Static Pressure Error (e1SP)

From Section 4.3.2, the error induced on the transmitter due to the system static pressure is composed of a zero effect and a span effect. These two values will be determined and combined algebraically. From Section 4.7, the static pressure is 1005 psig.

6.2.1.6.1 Zero Effect

The static pressure zero effect is defined as the error induced on the instrument zero when the device is zeroed at atmospheric pressure but operated at line pressure. This error is given by:

$$\begin{aligned} ZE &= (\pm 0.5\%(URL)/1000 \text{ psi})*(\text{Static Pressure}) \\ &= (\pm 0.5\%(300 \text{ psid})/1000 \text{ psi})*(1005 \text{ psi}) \\ &= \pm 1.50750 \text{ psid} \quad [3\sigma] \end{aligned}$$

6.2.1.6.2 Span Effect

The static pressure span effect is defined as the uncertainty associated with the correction factor used to compensate for the shift in output span due to the system static pressure. The upper calibration limit is used in this error determination as this will produce the most conservative error analysis result. From Section 4.3.2, the uncertainty is given by:

SE = (±0.5%(Reading)/1000 psi)*(Static Pressure)
= (±0.5%(300 psid)/1000 psi)*(1005 psi)
= ±1.50750 psid [3σ]

6.2.1.6.3 Total Static Pressure Error (e2SP)

For conservatism, the total error induced on the transmitter as a result of the system static pressure is calculated by algebraically combining the zero and span effects as determined below:

e2SP = ±[ZE + SE] = ±[1.50750 psid + 1.50750 psid]
= ±3.01500 psid [3σ]

This is converted to mA by multiplying by the ratio of the spans, as in Step 6.2.1.2.2, and taken at a 1σ value:

e2SP' = (e2SP)*(16 mA/300 psid)/3 = (±3.015 psid / 3)*(16 mA/300 psid)
= ±0.05360 mA [1σ]

6.2.1.7 Power Supply Error (e2V)

Per Section 4.3.2, the vendor specifies a power supply effect of <0.005% span per volt. This effect is considered negligible with respect to other errors per Section 2.1.3.D.

e2V = 0 mA [1σ]

6.2.1.8 Radiation Error (e2R)

Per Section 4.4.1, the radiation at the transmitter location is <1.0E04 rads, which is considered a mild environment. Therefore, the radiation effect is negligible per Section 2.1.3.B & D, so:

e2R = 0 mA [1σ]

6.2.1.9 Seismic Error (e2S)

Per section 2.1.3.C & D, for normal errors, seismic events less than or equal to an OBE are considered to produce no permanent shift in the input/output relationship of a device. For seismic events greater than an OBE, it is assumed that affected instrumentation will be recalibrated as necessary prior to any subsequent accident, negating any permanent shift that may have occurred. Therefore:

e2S = 0 mA

6.2.1.10 Random Input Errors (σ2in)

The random input error is the total random error from the flow element, which is the first module in the loop. From Section 6.1.1.6, Σσ1 = ± 23.32 psid, [1σ]. Therefore:

σ2in = Σσ1 = ± 23.32 psid [1σ]

This is converted to mA by multiplying by the ratio of the spans, as in Step 6.2.1.2.2:

$\sigma 2in' = (\sigma 2in)*(16\ mA/300\ psid) = (\pm 23.32\ psid)*(16\ mA/300\ psid)$
$= \pm 1.24373\ mA$ $[1\sigma]$

6.2.1.11 Calculation of σ2

The total random error associated with the transmitter is determined below using the values calculated in Sections 6.2.1.1 through 6.2.1.10.

$$\sigma 2 = \pm[(RA2)^2 + (CAL2)^2 + (ST2)^2 + (DR2')^2 + (e2T')^2 + (e2SP')^2 + (e2V)^2 + (e2R)^2 + (e2S)^2 + (\sigma 2in')^2]^{1/2}$$

$$= \pm[(0.01333\ mA)^2 + (0.09304\ mA)^2 + (0.05333\ mA)^2 + (0.01600\ mA)^2 + (0.02600\ mA)^2 + (0.05360\ mA)^2 + (0\ mA)^2 + (0\ mA)^2 + (0\ mA)^2 + (1.24373\ mA)^2]^{1/2}$$

$$= \pm 1.24994\ mA \quad [1\sigma]$$

Per Section 2.1.3.F, the allowable value (AV) is based on the combination of RA, CAL, ST, and DR. The random input error (σ2in) is not included because this is based on the flow element errors, and is not part of the actual instrument channel calibration uncertainty, and so will not affect AV verification during calibration. Thus,

$$\sigma 2AV = \pm[(RA2)^2 + (CAL2)^2 + (ST2)^2 + (DR2')^2]^{1/2}$$

$$= \pm[(0.01333\ mA)^2 + (0.09304\ mA)^2 + (0.05333\ mA)^2 + (0.01600\ mA)^2]^{1/2}$$

$$= \pm 0.10924\ mA \quad [1\sigma]$$

6.2.2 Non-Random Errors (e2)

6.2.2.1 Humidity Error (e2H)

The transmitter humidity limit is 100% RH per the vendor's specifications listed in Section 4.3.2. From Section 4.4.1 the upper humidity limit within the transmitter location during normal operating conditions is 90% RH. Therefore:

e2H = 0

6.2.2.2 Ambient Pressure Error (e2AP)

Per Section 4.4.1, the normal conditions at the transmitter location have a pressure of 14.7 psia. Ambient pressure errors are not stated in the vendor's specification for the transmitter, nor would any effect be expected for this type of differential pressure transmitter, therefore:

e2AP = 0

6.2.2.3 Process Error (e2P)

This is a sealed differential pressure cell transmitter that is connected to pressure taps across the main steam line venturis. The process error is included in the non-random input error from the venturi. Therefore:

e2P = 0

6.2.2.4 Non-Random Input Errors (e2in)

The non-random input error to the transmitter is the non-random error present at the output of the flow element. From Section 6.1.2.3, Σe1 = 0

$e2in = \Sigma e1 = 0$

6.2.2.5 Total Non-Random Error ($\Sigma e2$)

The total non-random error for the transmitter during normal operating conditions is given by the sum of the symmetric and bias errors as demonstrated below:

$\Sigma e2 = e2H + e2AP + e2P + e2in$

$\Sigma e2 = 0 + 0 + 0 + 0$

$\Sigma e2 = 0$

6.2.3 Rosemount differential pressure transmitter static pressure span correction

Per Rosemount Manual 4302 (Reference 5.7.1), if a differential transmitter is calibrated with the low side at ambient pressure but will be used at high line pressure, the span adjustment should be corrected to compensate for the effect of static pressure on the unit. From Design Input 4.7, the process line static pressure is approximately 1005 psig. The desired differential pressure range is 0-300 psid. For Range Code 7, the adjustment is 1.25% of input/1000 psi. Thus,

Corr factor = (1.25% input/1000 psi) * 1005 psi = 1.26% of differential pressure input

No zero correction is needed because there is no zero elevation or suppression, so the effect can be trimmed out after installation with the unit at operating pressure. The span adjustment is:

Convert 1.26% input span to % of output span: 1.26% * (16 mA) = 0.202 mA

Add the mA correction to the ideal full scale output: 20 mA + 0.202 mA = 20.202 mA

Therefore, for an operating range of 0-300 psid at a static pressure at the transmitter of 1005 psig, the adjusted calibration range at ambient pressure (0 psig) is:

Zero point: 0 psid input, 4 mA output

Full span: 300 psid input, 20.202 mA output

6.3 MASTER TRIP UNIT ERRORS - Module 3

Classification of Module

Module 3 is a master trip unit (MTU), which receives an analog input from the transmitter, and generates a change of state in a discrete output when the input approaches the setpoint. Therefore it is classified as a bi-stable module. It has an analog input range of 4-20 mA (Input 4.3.3), corresponding to an operating range of 0-300 psid (Input 4.5) at the transmitter.

6.3.1 MTU Random Errors (σ3)

6.3.1.1 MTU Repeatability (RPT3)

Per Section 4.3.3, the repeatability is ±0.13% of span for temperatures between 60°F and 90°F. Per Section 4.4.2, the ambient temperature varies from 70°F to 80°F. Thus:

RPT3 = ±0.13% * (Span) [2σ]
= ±0.13% * (16 mA)/2
= ±0.01040 mA [1σ]

6.3.1.2 MTU Calibration Errors (CAL3)

For the quarterly surveillance, the MTU is calibrated with the Rosemount Model 710DU calibration unit. The calibration unit provides an adjustable output current to the input of the MTU for use in MTU trip setpoint verification and/or adjustment. The calibration current is displayed on the trip/calibration current indicator located on the front panel of the calibration unit Readout Assembly. Per Section 4.6.2, the inaccuracy associated with the use of the calibration unit is included in the trip unit repeatability, so no other calibration error is required. Therefore:

CAL3 = 0 [1σ]

6.3.1.3 MTU Setting Tolerance (ST3)

From Section 4.5, the MTU setting tolerance is ±0.08 mA, and is considered a 3σ value, thus:

ST3 = ±0.08 mA/3 = ±0.02667 mA [1σ]

6.3.1.4 Drift Error (DR3)

Drift is calculated based on a 92 day interval plus a 25% late factor. This gives a total surveillance interval (SI3) of

SI3 = (92 days * (1.25) = 115 days

From Section 4.3.3 the drift is included in its other specifications for up to 6 months (180 days). Therefore:

DR3 = ± 0 [1σ]

6.3.1.5 MTU Temperature Error (e3T)

From Section 4.3.3 the temperature effect of the MTU is included in the repeatability error determination. Therefore:

e3T = 0

6.3.1.6 Radiation Error (e3R)

From Section 4.4.2, the radiation level within the MTU environment during normal operating conditions is < 1 x 10E4 RADS TID. From Section 4.3.3, the accuracy of the MTU will remain within its stated repeatability within radiation levels 1 x 10E5 RADS TID. Therefore:

$e3R = 0$

6.3.1.7 Seismic Error (e3S)

Per Sections 2.1.3.C & D, the seismic error is not applicable, as noted below:

$e3S = 0$

6.3.1.8 Static Pressure Error (e3SP)

The MTU is not directly in contact with the process and is, therefore, not susceptible to errors induced as a result of process pressure variations. Therefore:

$e3SP = 0$

6.3.1.9 Power Supply Error (e3V)

There are no power supply variation effects stated in the vendor's specifications for this device. Per Section 2.1.3.D error effects associated with power supply fluctuations are considered negligible. Therefore:

$e3V = 0$

6.3.1.10 Random Input Errors (σ3in)

The random error present at the input to the MTU during normal operating conditions, σ3in, is the random error present at the output of the transmitter and was calculated in Section 6.2.1.11

$\sigma3in = \sigma2 = \pm 1.24994\ mA$ [1σ]

The random error present at the input to the MTU due to the transmitter, σ3inAV, used for calculating the allowable value, was calculated in Section 6.2.1.11 as σ2AV.

$\sigma3inAV = \sigma2AV = \pm 0.10924\ mA$ [1σ]

6.3.1.11 Calculation of Total Random Error (σ3)

The total random error is the SRSS of the random errors from Sections 6.3.1.1 through 6.3.1.10. Therefore,

$$\sigma3 = \pm [(RPT3)^2 + (CAL3)^2 + (ST3)^2 + (DR3)^2 + (e3T)^2 + (e3R)^2 + (e3S)^2 + (e3SP)^2 + (e3V)^2 + (\sigma3in)^2]^{1/2}$$

$$= \pm [(0.01040\ mA)^2 + (0\ mA)^2 + (0.02667\ mA)^2 + (0\ mA)^2 + (0\ mA)^2 + (0\ mA)^2 + (0\ mA)^2 + (0\ mA)^2 + (0\ mA)^2 + (1.24994\ mA)^2]^{1/2}$$

$= \pm 1.25027\ mA$ [1σ]

Converting to psid by using the ratio of the spans as in Step 6.2.1.2.2:

$\sigma3p = (\pm 1.25027\ mA)*(300\ psid/16\ mA) = \pm 23.44252\ psid$ [1σ]

Per Section 2.1.3.F, the applicable uncertainties used in the determination of the allowable value (AV) for the MTU alone are a combination of RA, CAL, ST, and DR, since the mA input to the MTU is generated by the trip system calibration unit. Thus,

$$\begin{aligned}\sigma 3AV &= \pm[(RPT3)^2 + (CAL3)^2 + (ST3)^2 + (DR3)^2]^{1/2}\\ &= \pm[(0.01040\ \text{mA})^2 + (0\ \text{mA})^2 + (0.02667\ \text{mA})^2 + (0\ \text{mA})^2]^{1/2}\\ &= \pm 0.02863\ \text{mA} \qquad [1\sigma]\end{aligned}$$

For the string calibration, the applicable uncertainties used in the determination of the allowable value are a combination of RA, DR, and σ3inAV, since CAL and ST are included in σ3inAV. Thus,

$$\begin{aligned}\sigma 3AVSTRING_{mA} &= \pm[(RPT3)^2 + (DR3)^2 + (\sigma 3inAV)^2]^{1/2}\\ &= \pm[(0.01040\ \text{mA})^2 + (0\ \text{mA})^2 + (0.10924\ \text{mA})^{2]1/2}\\ &= \pm 0.10973\ \text{mA} \qquad [1\sigma]\end{aligned}$$

This is converted to psig by multiplying by the ratio of the loop input to output spans, as in step 6.2.1.2.2:

$$\sigma 3AVSTRING_P = (\pm 0.10973\ \text{mA})*(300\ \text{psid}/16\ \text{mA}) = \pm 2.05744\ \text{psid} \qquad [1\sigma]$$

6.3.2 MTU Non-Random Errors

6.3.2.1 Humidity Error (e3H)

There are no humidity related errors described in the vendor's specifications for this device. Per Sections 2.1.3.D and 3.6, humidity effects associated with the MTU are included in the repeatability error determination. Therefore:

$$e3H = 0$$

6.3.2.2. Ambient Pressure Error (e3P)

The MTU is an electrical device and as such is not affected by ambient pressure changes. Therefore:

$$e3P = 0$$

6.3.2.3. Process Error (e3p)

The MTU is not directly in contact with the process and is, therefore, not susceptible to errors induced by process variations. Therefore:

$$e3p = 0$$

6.3.2.4 Non-Random Input Error (e3in)

The non-random error present at the input to the MTU during normal operating conditions, Σe2, is due to the transmitter and was calculated in Section 6.2.2.5:

$$e3in = \Sigma e2 = 0$$

6.3.2.5 MTU Total Non-Random Error (Σe3)

The total bias non-random error associated with the MTU for determining the calculated setpoint is:

$$\begin{aligned}\Sigma e3 &= e3H + e3P + e3p + e3in = 0 + 0 + 0 + 0\\ &= 0\ \text{psid}\end{aligned}$$

6.4 TOTAL ERROR AND SETPOINT ANALYSIS

Per Section 2.1.2, total error is: TE = $2\sigma + \Sigma e$. Because the setpoint may be checked by either application of pressure at the transmitter, or by reading mA at the MTU, values are calculated in psid and converted to mA.

6.4.1 Channel Total Error at MTU Output, TE3

The channel total error for MTU actuation, using values from Sections 6.3.1.11 and 6.3.2.5:

In operating psid: $TE3 = 2^*\sigma 3 + \Sigma e3 = 2^*(\pm 23.44252 \text{ psid}) + (0 \text{ psid}) =$ **±46.89 psid**

6.4.2 Determination of Setpoint

Since a rigorous drift analysis has not been performed for these instrument loops, the setpoint must consider margin. Therefore, the calculated setpoint is determined from the Analytical Limit (AL) and the total error as follows for an increasing setpoint. Per Reference 5.2,

$$SPc = AL - TE - MAR$$

The required margin, per Section 8.0 of Appendix A to Reference 5.2, is 0.5% of instrument measurement span. Per Section 4.5 of this calculation, the calibrated span is 300 psid. Therefore the required margin is computed as follows:

MAR = 0.5% (300 psid) = 1.5 psid

The values of the Analytical Limit and total error terms in psid are:

AL = 292.45 psid [Section 6.0] TE = 46.89 psid [6.4.1]

Therefore, the calculated setpoint, SPc, is:

SPc = 292.45 psid – 46.89 psid – 1.5 psid = 244.06 psid increasing

SPc = 244.0 psid increasing (conservatively rounded)

This is converted to mA based on a 0-300 psid input corresponding to a 4-20 mA output, as:

$$SPc_{mA} = (244.0 \text{ psid}) * [(20 \text{ mA} - 4 \text{ mA})/(300 \text{ psid} - 0 \text{ psid})] + 4 \text{ mA}$$

$$= (244.0 \text{ psid}) * [(16 \text{ mA})/(300 \text{ psid})] + 4 \text{ mA} = \mathbf{17.01\ mA\ increasing}$$

To determine the setpoint in terms of pressure input during calibration (SPc_{CAL}), with no static pressure present on the transmitter, for a 0-300 psid input corresponding to a 4-20.2 mA output:

$$SPc_{CAL} = (17.01 \text{ mA} - 4.00 \text{ mA}) * [(300 \text{ psid} - 0 \text{ psid})/(20.2 \text{ mA} - 4.00 \text{ mA})]$$

$$= \mathbf{240.9\ psid\ calibration\ pressure\ increasing}$$

6.4.3 Determination of Allowable Value

Appendix C of Reference 5.2 provides the instructions for calculating an Allowable Value (AV) for an increasing setpoint as:

AV = SPc + applicable uncertainty

Applicable uncertainty is a value calculated from the errors and uncertainties that have been determined to affect the trip setpoint at the time of the as-found measurement and is expressed as a 2σ value, since these setpoints are considered Level 1.

From Section 6.4.2 of this calculation, the calculated setpoint, SPc, has a value as follows:

SPc = 244.0 psid increasing

For the string calibration check of the setpoint, the applicable uncertainty (au) is determined as the combination of MTU repeatability (RPT3), Drift (DR3), and AV random input error (σ3inAV).

$auSTRING = \sigma 3AVSTRING_P = \pm 2.05744$ psid [1σ] [6.3.1.11]

Thus, the au is calculated as follows, in operating psid, to a 2σ value:

In psid: $au_P\ (2\sigma) = 2 * (\pm 2.05744 \text{ psid}) = \pm 4.11488 \text{ psid} = \pm 4.1 \text{ psid}$

Therefore, the AV is calculated as: $AV \leq SPc + au$

In process pressure: $AV \leq 244.0 \text{ psid} + 4.1 \text{ psid}$

$\mathbf{AV \leq 248.1 \text{ psid}}$

The terms included in the AV determinations above were treated in the same way as they were in the setpoint determination. Therefore, adequate margin exists between the Analytical Limit and the Allowable Value, and no check calculation is required. The string calibration AV is conservatively used for both the string calibration (in psid) and the MTU calibration check (in mA).

Converting the AV from operating dP units to mA, based on a 0-300 psid transmitter input corresponding to a 4-20 mA trip unit input:

$AV \leq (248.1 \text{ psid}) * (16 \text{ mA} / 300 \text{ psid}) + 4 \text{ mA} = \mathbf{17.23 \text{ mA}}$

To determine the AV in transmitter input pressure during calibration, with no static pressure present on the transmitter, this is converted based on a 0-300 psid transmitter input corresponding to a 4-20.2 mA transmitter output during calibration:

$AV \leq (17.23 \text{ mA} - 4 \text{ mA}) * (300 \text{ psid} / 16.2 \text{ mA}) = \mathbf{245.0 \text{ psid}}$

6.4.4 Determination of Expanded Tolerance (Administrative As-Found Limit)

Because the calibration check on this setpoint can be done as a loop, for the 24 month re-fuel cycle, and as the MTU only, as a quarterly check, an ET will be determined for both. First it will be determined in operating process units.

ET in psid for loop calibration

Per Section 2.1.3.G, the Expanded Tolerance for the loop calibration from the transmitter through the MTU actuation is determined as follows (consistent with the method used to calculate ET for the ITS project):

$ET = \pm [0.7 * (au_P(2\sigma) - ST)] + ST$ (where ST is 2σ)

$ST2(3\sigma) = \pm 3.0$ psid [4.5]

$ST2(2\sigma) = 2*(ST2(3\sigma)/3) = 2*(\pm 3.0 \text{ psid})/3 = \pm 2.0$ psid

$au_P(2\sigma) = 4.1$ psid [6.4.3]

$ET = \pm [0.7 * (4.1 \text{ psid} - 2.0 \text{ psid})] + 2.0 \text{ psid} = \pm 3.47 \text{ psid}$

ET = ± 3.4 psid (conservatively rounded)

In order to evaluate the computed ET value, two comparisons are made. First the Expanded Tolerance must exceed the 3σ value of the Setting Tolerance.

In psid: **ET (3.4 psid) > ST (3.0 psid) PASS**

Secondly, the actual setpoint, plus the Expanded Tolerance, must not exceed any applicable limit. The only limit of concern here is the Allowable Value. Per Section 6.4.2, the setpoint in terms of operating dP is 244.0 psid. Per Section 6.4.3, the Allowable Value is in terms of operating dP is 248.1 psid.

SPc + ET = 244.0 psid + 3.4 psid = 247.4 psid < AV (248.1 psid) PASS

Therefore, the ET is acceptable as defined at a value of 3.4 psid.

ET in mA for MTU calibration

Per Section 2.1.3.G, the Expanded Tolerance for the quarterly functional check of the MTUs is determined as follows (consistent with the method used to calculate ET for the ITS project):

$$ET = \pm\,[0.7 * (au_{mA}(2\sigma) - ST)] + ST \quad \text{(where ST is } 2\sigma)$$

For the MTU calibration check, the applicable uncertainty is determined using $\sigma 3AV$ from Section 6.3.1.11, which is based on the combination of MTU Repeatability (RPT3), Drift (DR3), Setting Tolerance (ST3) and Calibration Error (CAL3).

$$\sigma 3AV(1\sigma) = \pm\,0.02863 \text{ mA} \qquad [1\sigma] \qquad [6.3.1.11]$$

Thus, the au to 2σ is calculated as:

$$au_{mA}(2\sigma) = 2 * (\sigma 3AV\,(1\sigma)) = 2 * (\pm\,0.02863 \text{ mA}) = \pm\,0.05726 \text{ mA}$$

From 6.3.1.3, ST3 for the MTU alone is $ST3 = \pm\,0.02667$ mA $[1\sigma]$

$$ST3(2\sigma) = 2*(ST3(1\sigma)) = 2*(\pm\,0.02667 \text{ mA}) = \pm\,0.05334 \text{ mA}$$

$$ET = \pm\,[0.7 * (0.05726 \text{ mA} - 0.05334 \text{ mA})] + 0.05334 \text{ mA} = \pm\,0.05608 \text{ mA}$$

ET = ± 0.05 mA (conservatively rounded)

In order to evaluate the computed ET value, two comparisons are made. First the computed ET must exceed the 3σ value of the Setting Tolerance.

ET (0.05 mA) < ST (0.08 mA) FAIL

Therefore, per Section 2.1.3.G, the ET is set equal to the ST of ±0.08 mA, so **ET = ±0.08 mA.**

Secondly, the actual setpoint, plus the Expanded Tolerance, must not exceed any applicable limit. The only limit of concern here is the Allowable Value. Per Section 6.4.2, the actual setpoint is 17.01 mA. Per Section 6.4.3, the Allowable Value is 17.23 mA.

SPc + ET = 17.01 mA + 0.08 mA = 17.09 mA < AV (17.23 mA) PASS

Therefore, the ET is acceptable as defined at a value of ±0.08 mA.

ET in mA for transmitter calibration

Per Section 2.1.3.G, the Expanded Tolerance for the transmitter calibration is determined as follows (consistent with the method used to calculate ET for the ITS project):

$$ET = \pm\,[0.7 * (au_{P}(2\sigma) - ST)] + ST \quad \text{(where ST is } 2\sigma)$$

$$ST2(3\sigma) = \pm\,0.08 \text{ mA} \qquad [4.5]$$

$$ST2(2\sigma) = 2*(ST2(3\sigma)/3) = 2*(\pm\,0.08 \text{ mA})/3 = \pm\,0.05333 \text{ mA}$$

For the calibration of the transmitter alone, au_{xmtr} is conservatively based on the $\sigma 2AV$ from 6.2.1.11, where $\sigma 2AV = \pm 0.10924$ mA (1σ).

$$au_{xmtr}(2\sigma) = 2 * \sigma 2AV = 2 * (0.10924 \text{ mA}) = 0.21848 \text{ mA}$$

$$ET = \pm\,[0.7 * (0.21848 \text{ mA} - 0.05333 \text{ mA})] + 0.05333 \text{ mA} = \pm\,0.16894 \text{ mA}$$

ET = ± 0.16 mA (conservatively rounded)

The transmitter ET must exceed the 3σ value of the transmitter ST, from 4.5.

In mA: **ET (0.16 mA) > ST (0.08 mA) PASS**

7.0 RESULTS & CONCLUSION

The calibration information used to support the results of this calculation is defined below. In addition, the calibration values and expanded tolerances are identified.

7.1 Main Steam Line High Flow – Instrument Loop Setpoint Requirements:

	% Rated Flow (Note 1)	Process Differential Pressure	Trip Unit Calibration
Analytical Limit (AL)	≤ 140 %	≤ 292.45 psid	
Allowable Value (AV)	≤≈ 134 %	≤ 248.1 psid	≤ 17.23 mA
Setpoint (SPc)	≈ 133 % ↑	244.0 psid ↑	17.01 mA ↑
Rated Flow	100 %	111.06 psid	

Note 1: Approximate % rated steam flow values for AV and SPc were calculated using the equations in Section 6.0 and are provided here for reference only.

Note 2: Section 6.1.1.1 utilized a conservative Base Uncertainty for the Flow Element that bounds the reference accuracy value of FE 2-0261-1A defined in References 5.16 and 5.17. As a result, the setpoint of the associated DPIS 2-0261-2A-1 is not affected and no change is required.

Note 3: An amendment to the Quad Cities Technical Specifications is required prior to implementation of the above setpoint requirements. Technical Specification Table 3.3.6.1-1 Item 1.d and Table 3.3.7.1-1 Item 3 must be revised to specify the Allowable Value for Main Steam Line Flow – High as ≤ 248.1 psid and to add a surveillance requirement for trip unit calibrations on a 92 day frequency.

7.2 Surveillance Intervals, Setting Tolerances and Expanded Tolerances:

	Surveillance Interval	Setting Tolerance	Expanded Tolerance
Transmitter Calibration	24 months	± 0.08 mA	± 0.16 mA
Loop Calibration:	24 months	± 3.0 psid	± 3.4 psid
Trip Unit Calibration:	92 days	± 0.08 mA	± 0.08 mA

7.3 Transmitter and Trip Unit Calibration Requirements:

The following values define the calibration requirements for transmitters DPT 1(2)-0261-2A through -2S (excluding -2I, -2O, -2Q), including a static pressure correction for the 1005 psig steam line maximum operating pressure:

% of Span	Transmitter Input	Transmitter Output
0	0.0 psid	4.00 mA
25	75.0 psid	8.05 mA
50	150.0 psid	12.10 mA
75	225.0 psid	16.15 mA
Setpoint	240.9 psid	17.01 mA
Allowable Value	245.0 psid	17.23 mA
100	300.0 psid	20.20 mA

The following values define the calibration requirements for functional testing of trip units DPIS 1(2)-0261-2A-1 through -2S-1 (excluding -2I-1, -2O-1, -2Q-1):

% of Span	MTU Input	MTU Indication
0	4.00 mA	0.0 psid
25	8.00 mA	75.0 psid
50	12.00 mA	150.0 psid
75	16.00 mA	225.0 psid
Setpoint	17.01 mA	Not Applicable
Allowable Value	Not Applicable	Not Applicable
100	20.00 mA	300.0 psid

7.4 Due to the replacement of the DPISs with Rosemount transmitters and Master Trip Units, upon implementation of ECs 345323 and 345324, the current versions of the applicable calibration procedures (References 5.4 & 5.5) shall be revised to follow a similar approach as that used for the other analog trip loops. Specifically, in order for the results of this calculation to remain valid, the following must be true:

7.4.1 For the channel surveillance, after calibration of the transmitter, the actuation of the trip unit must be verified by observation of MTU trip based on increasing pressure input to the transmitter, using the setting tolerance given in 7.2 above.

7.4.2 For the master trip unit surveillance, a certified digital readout assembly for the Rosemount 710DU Trip/Calibration system must be used to generate an increasing stable current and to observe the trip current, to the setting tolerance given in 7.2 above.

7.4.3 The pressure input to the transmitter must be measured with either the M&TE listed below, or other M&TE of equal or better accuracy than the worst case unit (Heise CMM - 400 psig).

M&TE	Accuracy at 104°F (Ref. 5.9)
Heise CMM (400 psig)	± 1.744484 psig
Druck DPI 601 (500 psig)	± 0.730068 psig

8.0 ATTACHMENTS

Attachment A – GE SIL 438, Rev. 1 (Ref. 5.6) - 3 pages
Attachment B – BIF Vendor Information (Ref. 5.18) – 4 pages
Attachment C – BIF Vendor Letter (Ref. 5.17) – 3 pages
Attachment D – Rosemount Letter (Ref. 5.22) – 2 pages
Attachment E – Rosemont Telecon (Ref. 5.23) – 2 pages

Final
[Last Page]

MAY 1 3 1994

GE Nuclear Energy

SIL
Services Information Letter

Main steam line high flow trip setting

SIL No. 438
Revision 1

May 5, 1994

The original SIL 438 was written because a review of the MSL high flow trip setpoint for an operating BWR disclosed an inconsistency between the actual setting and that specified in the plant technical specifications. The difference was attributed to the use of design steam flow conditions rather than rated conditions in the original setpoint calculation. The original SIL 438 informed BWR owners of this potential inconsistency and provided a method for determining the proper setpoint for the MSL high flow trip.

This Revision 1 to SIL 438 corrects an error in the equation for calculating the MSL high flow trip setpoint. Using the uncorrected equation found in the original SIL 438 could result in a non-conservatism of approximately 3% steam flow when calculating the analytic limit or trip setpoint.

Discussion

The Main Steam Line (MSL) high flow sensors detect and isolate breaks in the main steam lines outside the reactor containment. The high flow trip initiates reactor isolation by closing the main steam isolation valves (MSIV) to minimize potential release of radioactive materials to the environment.

The trip signal for the MSL high flow isolation is taken from differential pressure instruments in the flow limiters (venturis) in each steam line. The venturis also limit the maximum flow loss from a steam line break to approximately 200 % of rated steam flow for that steam line. The maximum setpoint for the MSL high flow trip must be less than the maximum flow (choke flow) calculated for each steam line, and the minimum setpoint should be sufficiently above 100 % of rated steam flow for each steam line to prevent spurious trips. A typical setpoint (analytical limit) is 140 % Nuclear Boiler Rated (NBR) steam flow. This setpoint permits on-line testing of the MSIVs, because closing one valve would result in each of the remaining three steam lines carrying approximately 133 % of its normal flow at 100% power.

Many plant technical specifications specify a setpoint for the MSL high flow trip based on an upper analytical limit of equivalent to 140% NBR steam flow. The actual setpoint is then calculated as a maximum pressure drop across the differential pressure sensing device.

An inconsistency was discovered in one instance in which the calculated differential pressure setpoint was based on the design steam flow conditions for the turbine (105% NBR steam flow) rather than the rated, licensed power conditions for the nuclear boiler. This resulted in a differential pressure setpoint that corresponded to approximately 147 % NBR steam flow, which is inconsistent with the plant technical specifications.

The safety significance of this potential inconsistency is a slight increase in the maximum detectable steam line break size as detected by the steam line differential pressure sensors. There are additional leakage detection monitors which would also initiate steam line isolation. Without reliance on these additional monitors, a conservative evaluation of the high setpoint demonstrates that the setpoint difference results in less than a ten percent increase in released radioactive material, which is significantly less than the 10CFR100 limits. Because there is no significant change in the margin to allowable limits, the higher setpoint is not a safety concern.

Recommended action

GE Nuclear Energy recommends that owners of GE BWRs verify that the proper instrument trip setpoint has been established. The following method is recommended for determining whether there is an inconsistency between plant technical specifications and actual trip setpoints. The calculated differential pressure at the flow rate corresponding to the MSL high flow trip setpoint allowed by the technical specifications may be checked against the actual trip setpoint. The equation for calculating this flow rate is shown in Attachment 1.

To receive additional information on this subject or for assistance in implementing a recommendation, please contact your local GE Nuclear Energy Service Representative.

This SIL pertains only to GE BWRs. The conditions under which GE Nuclear Energy issues SILs are stated in SIL No. 001 Revision 3, the provisions of which are incorporated into this SIL by reference.

Product reference

B21—Nuclear Boiler

Technical source

M. E. Driscoll

Issued by

RM Fairfield

R. M. Fairfield, Program Manager
Service Information Communications
GE Nuclear Energy
175 Curtner Avenue, San Jose, CA 95125

Calculation of main steam line high flow trip setpoint

The equation[1] for calculating the main steam line high flow trip setpoint is:

$$W = 1890.07\frac{CYd^2F_a}{(1-B^4)^{1/2}}(\rho\,\Delta P)^{1/2}$$

where:

$$Y = \left[r^{2/k} \times \frac{k}{k-1} \times \frac{1-r^{\frac{k-1}{k}}}{1-r} \times \frac{1-B^4}{1-\left(B^4 r^{2/k}\right)}\right]^{1/2}$$

W = steam flow rate at desired analytic limit or trip setpoint (lbm / hr)

C = coefficient of discharge (0.995 for a venturi tube with a machined entrance cone) (ratio)

B = ratio of throat to pipe inside diameter, d / D

D = pipe inside diameter (in)

d = throat inside diameter (in)

F_a = area thermal expansion factor (ratio) (Approximately 1.0092 for 300 series stainless steel primary element thermal expansion from 68°F to 550°F)

ρ = upstream fluid density (lbm/ft^3). (rated condition of dry, saturated steam)

r = ratio of throat static pressure to inlet static pressure $\frac{P_1 - \Delta P}{P_1}$ (absolute pressures)

k = ratio of specific heats of fluid, $\frac{C_p}{C_v}$ (isentropic exponent for ideal gas, approximately 1.255 for dry, saturated steam at 1050 psia and 550°F)

ΔP = differential pressure across venturi $P_1 - P_2$ (psid)

Y = expansion factor for a gas (ratio)

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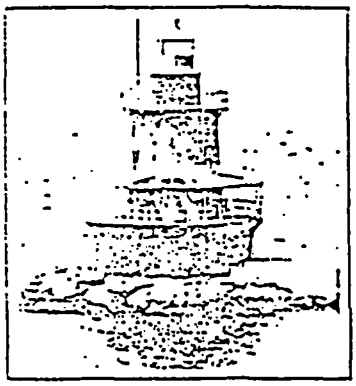
[1] American Society of Mechanical Engineers, "Report of ASME Research Committee on Fluid Meters", Sixth Edition, 1971, P. 233, and May 1974 Errata.

B A SHORT I HISTORY F

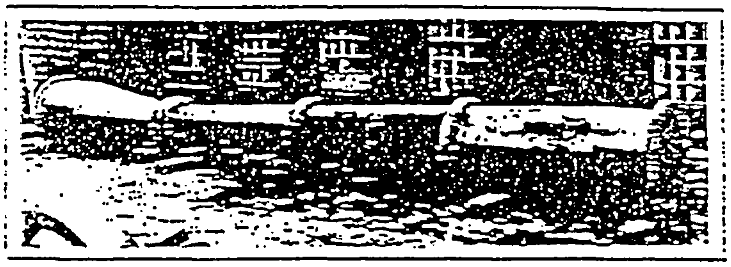
The High Street Furnace Company, was little more than a blacksmith shop when it began producing iron plows in Providence around 1820. Sold to the newly incorporated Builder's Iron Foundry in 1853, the new owners added products which held more promise of growth and which reflected their own areas of expertise.

BIF's stated purpose at incorporation was the "manufacture of iron fonts for houses and other castings for builders and other uses." Examples of the ornamental iron work produced by BIF during the mid 1800's can still be seen on the Library of Congress Building in Washington. Other products produced by BIF during that period included cylinders for bridge piers and prefabricated lighthouses which were installed around the world.

The demand for BIF's architectural iron declined as steel came into more widespread use and decorative iron fell out of fashion. Less resourceful firms might have folded, but BIF responded by entering into markets needing products which could be manufactured with methods and materials similar to those BIF had been using. One of the logical transitions BIF made at that time included changing production from iron architectural columns to water pipes.


A BIF lighthouse, at Plum Island, in Narragansett Bay, near Newport, RI. Installed in 1899 and operational for over 50 years.

In 1887 Clemens Herschel introduced the Herschel Standard Venturi, by far the most accurate flowmeter available over the ensuing 80 years. In 1893 the Chief Engineer at BIF, F. N. Connet, perfected the necessary metering instruments to enable use of the BIF Venturi tube as a flow measurement tool. Venturi tubes and meters have been two of BIF's most important products ever since. A continuing dedication to upgrading these products led to BIF's research and development of the Universal Venturi® Tube in 1970. At the time of its introduction, the UVT was the result of thousands of hours of design engineering and rigorous hydraulic testing. The UVT greatly increased the reliability and accuracy of flow measurement. At the same time, the UVT reduced costs of both lead-in piping and surrounding structures by eliminating the previous requirement for long runs of straight pipe into a Venturi.


Venturi Meter Tube Number One for East Jersey Water Co.

More than 160 years have passed since the High Street Furnace company produced its first iron plow. Its successor, BIF, has successfully designed, manufactured, and marketed a steadily evolving product line for over 13 decades. Today BIF, a Unit of General Signal, is recognized worldwide as a leader in automatic flow control, in controlled feeding and weighing of liquids and solids, and in wastewater and water treatment systems.


Clemens Herschel

THE RIGHT FLOWMETER FOR EACH APPLICATION

Calculation QDC-0200-I-1369, Rev. 0
Attachment B Page B2 of B4

BIF has the experience and expertise to approach any application with the confidence that we have solved the problem before. We can handle the job economically and reliably. We do not consider any application too difficult or too simple, too large or too small.

Here is a partial list of applications where BIF flowmeters are working:

- Water intake metering for New York City; 96" line size
- Primary metering equipment for the first fertilizer plant built in the People's Republic of China
- Chilled water metering in the World Trade Center's air conditioning system
- Boiler feed water metering in nuclear reactors
- Compressor surge control in air reduction systems
- Air flow measurement in heating ducts
- Fire protection systems to provide the ability to verify pump outputs during flow tests
- BIF UVTs are used by the majority of pump manufacturers to insure the accuracy of their pump test stands

Builders Iron Foundry,
Providence, RI,
about 1885.

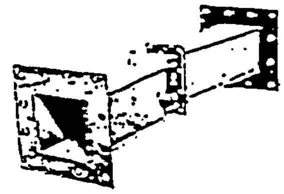
UVT designs and constructions available

Standard Sizes 180

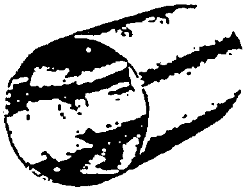
Range from 2" on up. Information on smaller or larger units furnished on request. Three standard Beta ratios (approximately .46; .6; and .725) are available. Materials of construction include: cast iron-bronze liner; cast iron-stainless steel liner; fiberglass reinforced plastic; special high-temperature fiberglass reinforced plastic; carbon steel plate, forging, or casting with stainless steel trim; all stainless steel. Other materials available.

Rectangular UVT

Patented rectangular versions, incorporating all the outstanding performance advances of the standard UVT, have been developed to meter preheated air supplied to power plant boilers for combustion. Tests prove these new rectangular units superior to other rectangular flow metering devices.



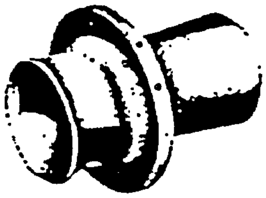
Model 183 Weldment Type



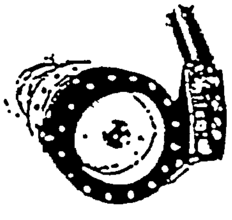
Welded construction provides the combination of structural strength with a wide selection of corrosion resistant metals. Surfaces are precisely machined to UVT formula for accurate prediction of flow characteristics. UVT weldments are available in six basic configurations and rectangular design.

Plastic UVT Insert Model 182

When low head loss, highest accuracy requirements are needed for fluid flow measurement. Standard sizes for basic lines from 2" to 60". Specials available for any line and throat size. 150 or 300 psig standard maximum – higher pressure on request. Corrosion resistant, low cost fiberglass reinforced polyester installed within the pipeline at any flanged pipe joint – no special equipment or foundations required.



Wide Range Metering Systems

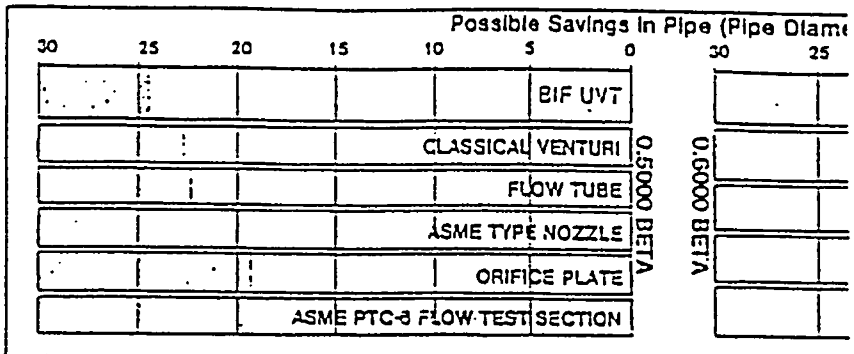


The Universal Venturi Metering Valve in series with a Universal Venturi Tube provides 30:1 metering range. Common flow transmitter responds to pressure differentials produced by the UVT and metering valve. Transmitter is connected to an indicating, totalizing and recording instrument. Rates up to 10% of full scale are measured by the Universal Venturi in the disc of the metering valve. A contact in the recorder opens the valve for flows over 10% full scale which are measured by the UVT. Accuracy up to ±1% of flow for valve and UVT.

CHARACTERISTICS OF THE UVT

The Universal Venturi Tube is the primary meter which provides the best performance characteristics found in other flow meters.

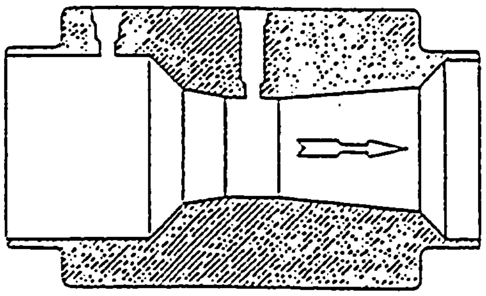
- Heavily documented accuracy
- Low head loss and therefore lower operating cost
- Short laying lengths; approximately 2.5 pipe diameters long
- Low installed cost; reduced amount of upstream pipe and associated laying costs
- Various materials of construction available
- Meters liquids and gases – the only meter with documentation available; verified at Colorado Engineering Experiment Station, Nunn, Colorado
- No line size limit



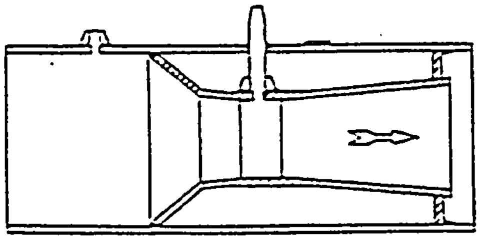
Comparison of meter run lengths required for unaffected performance of various types of primary d

	BIF's UVT	Classical Venturi	Flow Tubes	Averaging Pitots	Orifice Plates	Flow Nozzles	Magnetic Flow Meter	Sonic Flow Meter	Doppler Flow Meter
Documented Accuracy	●	○			○	○			
Wide Range	●	○				○	○	○	○
Energy Efficient	●	○	○	○			○	○	○
Negligible Installation Effect	●	○				○			
Adaptable to Gaseous Flow	●	○		○	○	○			
Field Certifiable	●	○			○	○			
Stable Signal	●	○				○			
Insensitive to Aging	●	○							
Experienced Manufacturer	●	○	○		○	○	○		
Use on Solids Bearing Fluids	●						○	○	○

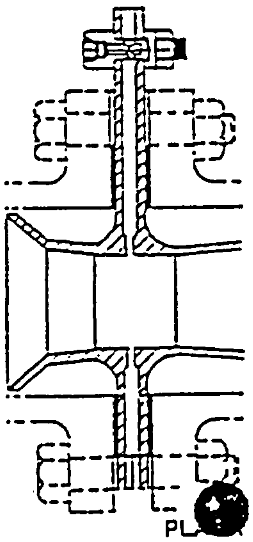
Calculation QDC-C200-I-1369, Rev. 0
Attachment B Page B3 of B4



INLINE BARSTOCK
Line Sizes: 1" through 6"



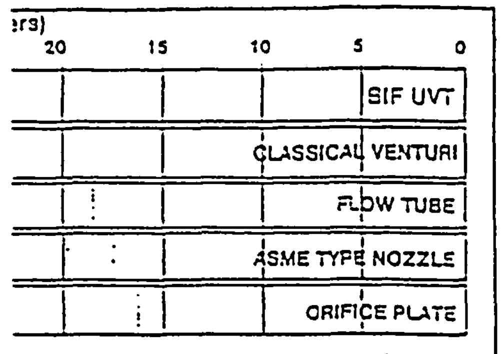
INSERT DESIGN IN CONTAINING PIPE
Line Sizes: 8" and larger



PL
Line Sizes:

1235 D-12

FLOW CONDITIONING: THE KEY TO RELIABLE FLOW METERING

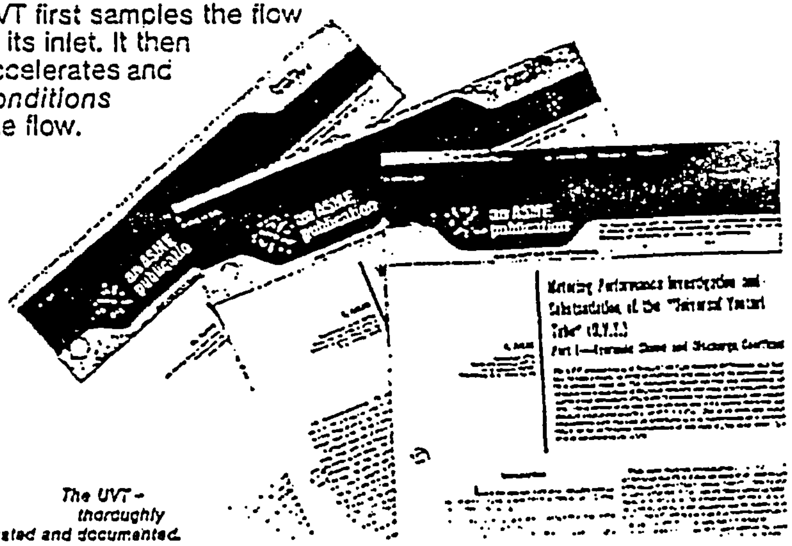


es when installed downstream of a short radius elbow.

UVT's unique, patented internal hydraulic contour conditions fluid flow, providing accuracy and reliability not previously possible in primary meters. The UVT design builds in flow conditioning; flow is hydraulically cushioned to provide a strong, stable, predictable, low-noise signal. BIF UVT's guarantee accuracy of ±0.5% without calibration, and we have documentation to prove this.

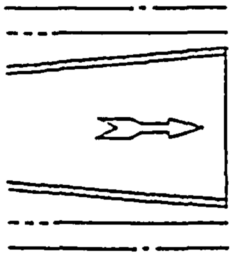
Unlike other differential producing meters, the UVT doesn't have to accept the inconsistencies of poor velocity profiles in a flow line. The UVT first samples the flow in its inlet. It then accelerates and *conditions* the flow.

Finally, it re-examines flow in its throat section. This error-purging process provides a measurement resulting from the difference in the *kinetic energy* of the flow at the inlet and the throat.

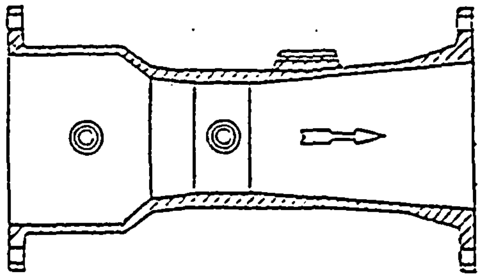


The UVT - thoroughly investigated and documented.

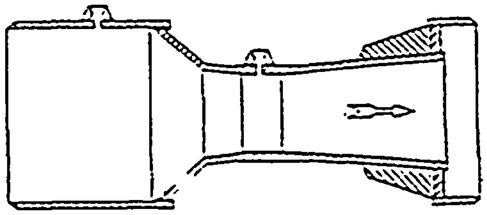
Calculation QDC-0200-I-1369, Rev. 0
Attachment B Page B4 of B4



I[illegible]RT
through 60"



INLINE CAST IRON
Line Sizes: 2" and larger



INLINE FABRICATED
Line Sizes: 8" and larger

1236 0-13

B I F®
Engineered Flow Applications

QDC-0200-I-1369 Rev. 0
Attachment C
Page C1 of C3

July 17, 2002

Mr. Jeffrey Drowley
Mechanical Engineering Manager
Exelon Nuclear
4300 Winfield Road Suite 300
Warrenville, IL 60555

Mr. Drowley,

After phone discussions with Mr. Joseph Basak and yourself on Friday July 12th and Saturday July 13th regarding the damages to the Alpha Steam line Venturi at Quad Cities II Nuclear Plant, I was asked to come on site. The on-site stay was to expedite the assessment of impact on the Choke Flow requirements, the safety set point requirements and the flow measurement requirements of the BIF supplied Venturi as a result of a Dryer Part Separation.

While on site I have had discussions with several plant personnel, contractor service people and GE Team people working on this outage. I have reviewed, for several hours, movies taken of the Venturi impact areas and of pieces that were lodged in the Venturi or that passed through the Venturi. Movies were taken with two different cameras. Much of the upstream pipe, the Venturi element itself and the area downstream on the Venturi were made visible. Most importantly the Venturi hydraulic shape was visible. Initial viewing was of the Venturi with a piece of foreign material lodged in the throat. In this movie several impact areas were visible on the surface of the elliptical approach section. In later movies we saw the same impact areas and areas further downstream of the Alpha Steam line Venturi. We also saw movies of the Bravo Steam line Venturi. The views of both Venturi were from just above the High Pressure Piezometer through the Venturi to past the Hydraulic Shape downstream weld that supports the shape.

The impact damage area of the Alpha Steam line Venturi lies mostly within the elliptical approach section. The damage ranges from what were categorized as stains (no discernable depth) to slight scratches (0.0005" to 0.005" depth) to pits (diameters of ~3/32" with depths of 0.01" to 0.02") and gouges (long lengths up to 2.5" long with depths of 0.02" to 0.10"). The dimensions shown above are estimates based on other known items within the camera view and were not physically taken.

No impact damage was discernable within the Venturi throat itself. However an unidentifiable discoloration of about 3" diameter existed around the throat piezometer hole. Although unidentifiable this does not appear to be a result of the recent damage and will not affect the performance of this Venturi.

QDC-0200-I-1369 Rev. 0
Attachment C
Page C2 of C3

There appeared to be a few slight scratches in the recovery cone of the Venturi, which have no real impact on performance.

The Venturi Flow Equation contains several terms covering density, pressure differential, expansion factors, flow rate, throat diameter, inlet diameter and Discharge Coefficient. The throat diameter and inlet diameters were not changed as a result of this damage. The density and expansion factors will be whatever they are as a result of the steam temperature from normal operations. The pressure differential and flow rate are related to each other via the Discharge Coefficient. The pressure differential is read with instrumentation and the flow rate calculated for that pressure differential using the Discharge Coefficient. The Discharge Coefficient, however, is what will be impacted by this damage. Both the general diversion of the normal flow-streamlines expected into the nozzle, and the increase in the frictional resistance loss between the Inlet Piezometer and the Throat Piezometer, cause this. It is important to know that the most sensitive area of the Venturi is the Throat Piezometer hole area. Sensitivity decreases as you move upstream from the throat toward the upstream edge of the hydraulic shape. Similarly, the Inlet Piezometer area would also be sensitive but not as sensitive as the Throat Piezometer area.

It is my experience as a result of reviewing thousands of laboratory calibrations of Venturis with varying frictional characteristics and shapes that this total damage (Attachment 1) will not cause more than a ±0.5% change in the uncertainty to the normal assigned discharge coefficient uncertainty level. The damage that I view as having the greatest impact is what we are referring to as Gouge 1. While not near the sensitive area of the throat, it is in a direct line with the Throat Piezometer hole and would have the largest effect.

The impact on overall permanent pressure loss across the Venturi as a result of the damage is undetectable and should not impact plant performance.

There appears to be a minor circumferential depression at the entrance to the elliptical section. I believe that this was caused by impingement of condensate on this surface over the past thirty years of service. There appears to be no depression near the pipe wall, in the boundary layer region. Most of the depression occurs as you move beyond the boundary layer into the ellipse but still at a severe elliptical angle. As the elliptical angle relaxes, the material depression reduces back to the original shape, as it is no longer visible. This appeared in movies of the Alpha Steam line as well as the Bravo Steam line. This shows that this depression is not caused by the Dryer Incident.

My experience with Venturi at BIF, The Foxboro Company and Westfall Manufacturing covers 25 years with Venturi and Flow Meters of many types, configuration and service. I worked for BIF and certified the flow calculations for this Venturi when it was originally supplied to General Electric for this plant.

BIF®
Engineered Flow Applications

QDC-0200-I-1369 Rev. 0
Attachment C
Page C3 of C3

I do have some concerns regarding accelerated erosion of the material as a result of this recent surface damage. However, in discussion with members of the GE Team, they believe that the material is sufficient and specifically chosen for its erosion resistance.

I recommend that a comparison of flow signals be performed at known power levels and any changes trended to indicate potential problems. These trends may be used to trigger a closer inspection of the impact damage area at the next scheduled outage with comparison to the pictures documented during this outage for any changes. The same people should review any visual inspection, if at all possible. As a result of that visual examination, a disposition may then be made to either replace the Venturi, perform another visual check at the next planned outage or to skip the next planned outage and do the visual inspection within the following planned outage.

Recommendations:

The normal Discharge Coefficient uncertainty be increased by 0.5%.

During the next startup, look at the hydraulic noise level of the flow signal of the Alpha Steam line Venturi. Compare it to that of the Bravo, Charlie and Delta Steam lines. Compare it to what the experience was before the initial event that triggered this shut down. This may be used to confirm the effect on sensitivity and make appropriate setpoint changes as required.

Compare the flow readings of the most recent startup to the next startup as the unit comes up to full power, being sure that the flow rates look normal considering hydraulic noise as well.

Consider having a replacement Venturi for the Alpha Steam line available as a contingency for the next outage. Although I do not believe a replacement is necessary at this time, this Venturi will take time to manufacture and that time would impact the length of the outage. I estimate that the expedited lead time for a replacement Venturi would be 9 to 12 weeks after Purchase Order and design release to manufacturer.

BIF was very happy to help with this outage and if we can be of any assistance in the future please do not hesitate to call.

Sincerely,

Joseph M. Motta
Senior Flow Engineer

Rosemount Nuclear Instruments

Rosemount Nuclear Instruments, Inc.
12001 Technology Drive
Eden Prairie, MN 55344 USA
Tel 1 (612) 828-8252
Fax 1 (612) 828-8280

4 April 2000

Ref: Grand Gulf Nuclear Station message on INPO plant reports, subject Rosemount Instrument Setpoint Methodology, dated March 9, 2000

Dear Customer:

This letter is intended to eliminate any confusion that may have arisen as a result of the reference message from Grand Gulf. The message was concerned with statistical variation associated with published performance variables and how the variation relates to the published specifications in Rosemount Nuclear Instruments, Inc.(RNII) pressure transmitter models 1152, 1153 Series B, 1153 Series D, 1154 and 1154 Series H. According to our understanding, the performance variables of primary concern are those discussed in GE Instrument Setpoint Methodology document NEDC 31336, namely

1. Reference Accuracy
2. Ambient Temperature Effect
3. Overpressure Effect
4. Static Pressure Effects
5. Power Supply Effect

It is RNII's understanding that GE and the NRC have accepted the methodology of using transmitter testing to insure specifications are met as a basis for confirming specifications are $\pm 3\sigma$. The conclusions we draw regarding specifications being $\pm 3\sigma$ are based on manufacturing testing and screening, final assembly acceptance testing, periodic (e.g., every 3 months) audit testing of transmitter samples and limited statistical analysis. Please note that all performance specifications are based on zero-based ranges under reference conditions. Finally, we wish to make clear that no inferences are made with respect to confidence levels associated with any specification.

1. <u>Reference Accuracy</u>.

   All (100%) RNII transmitters, including models 1152, 1153 Series B, 1153 Series D, 1154 and 1154 Series H, are tested to verify accuracy to $\pm 0.25\%$ of span at 0%, 20%, 40%, 60%, 80% and 100% of span. Therefore, the reference accuracy published in our specifications is considered $\pm 3\sigma$.

2. <u>Ambient Temperature Effect</u>

   All (100%) amplifier boards are tested for compliance with their temperature effect specifications prior to final assembly. All sensor modules, with the exception of model 1154, are temperature compensated to assure compliance with their temperature effect specifications. All (100%) model 1154, model 1154 Series H and model 1153 gage and absolute pressure transmitters are tested following final assembly to verify compliance with specification. Additionally, a review of audit test data performed on final assemblies of model 1152 and model 1153 transmitters not tested following final assembly indicate

CALCULATION QDC-0200-I-1369
REV. 0
ATTACHMENT D
PAGE D1 OF D2

conformance to specification. Therefore, the ambient temperature effect published in our specifications is considered ±3σ.

3. **Overpressure Effect**

   Testing of this variable is done at the module stage. All (100%) range 3 through 8 sensor modules are tested for compliance to specifications. We do not test range 9 or 10 modules for overpressure for safety reasons. However, design similarity permits us to conclude that statements made for ranges 3 through 8 would also apply to ranges 9 and 10. Therefore, the overpressure effect published in our specifications is considered ±3σ.

4. **Static Pressure Effects**

   All (100%) differential pressure sensor modules are tested for compliance with static pressure zero errors. Additionally, Models 1153 and 1154 Ranges 3, 6,7 and 8 are 100% tested after final assembly for added assurance of specification compliance. Audit testing performed on ranges 4 and 5 have shown compliance to the specification. Therefore, static pressure effects published in our specifications are considered ±3σ.

5. **Power Supply Effect**

   Testing for conformance to this specification is performed on all transmitters undergoing sample (audit) testing. This variable has historically exhibited extremely small performance errors and small standard deviation (essentially a mean error of zero with a standard deviation typically less than 10% of the specification). All transmitters tested were found in compliance with the specification. Therefore, power supply effect published in our specifications is considered ±3σ.

Should you have any further questions, please contact Jerry Edwards at (612) 828-3951.

Sincerely,

Jerry Edwards

Jerry L. Edwards
Manager, Sales, Marketing and Contracts
Rosemount Nuclear Instruments, Inc.

CALCULATION QDC-0200-I-1369
REV. 0
ATTACHMENT D
PAGE D2 OF D2

Telephone Call

				Copies	
By	Neil Archambo	Of	Bechtel		
To	Tim Layer	Of	Rosemount		
Date	June 16, 1993	Time	10:00 am		
Subject	Rosemount Model 710DU Trip/ Calibration Unit Specifications			Job No.	N/A
				File No.	N/A

Mr. Layer was contacted in order to clarify the specifications listed in the Rosemount Trip/Calibration System Model 710DU Operations Manual. Clarification was required for the following:

- Master Trip Unit (MTU)
    - Analog Output Accuracy (Normal Conditions)
    - Trip Output Repeatability (Normal Conditions)
- Slave Trip Unit (STU)
    - Trip Output Repeatability (Normal Conditions)
- Calibration Unit Accuracy

The equation listed for the MTU Analog Output Accuracy is as follows:

±0.15% (60° to 90°F) ±0.35%/100°F

According to Mr. Layer, the above equation is to be used in the following manner:

- For ambient temperatures in the range of 60° to 90°F,

  Analog Output Accuracy = ±0.15%(SPAN)

- For ambient temperatures above 90°F,

  Analog Output Accuracy = ±(0.15%(SPAN) + (0.35%)(SPAN)/100°F)(ΔT))

  Where: ΔT = Ambient Temperature - 90°F

CALCULATION QDC-0200-I-1369 REV. 0
ATTACHMENT E
PAGE E2 OF E2

For example, suppose the ambient temperature at the trip unit location is 120°F. The associated trip unit analog output accuracy would be:

$$\text{Analog Output Accuracy} = \pm(0.15\%(\text{SPAN}) + (0.35\%)(\text{SPAN})/100^\circ\text{F})(\Delta T))$$

$$\text{Analog Output Accuracy} = \pm(0.15\%(4\ \text{Vdc}) + (0.35\%)(4\ \text{Vdc})/100^\circ\text{F})(30^\circ\text{F}))$$

$$\text{Analog Output Accuracy} = \pm 0.0102\ \text{Vdc}$$

The trip output repeatability for both the MTU and STU is calculated in the manner listed above. The equations are clarified below for ambient temperatures above 90°F:

MTU Trip Output Repeatability (MTU_{TOR}):

$$MTU_{TOR} = \pm(0.13\%(\text{SPAN}) + (0.2\%)(\text{SPAN})/100^\circ\text{F})(\Delta T))$$

STU Trip Output Repeatability (STU_{TOR}):

$$STU_{TOR} = \pm(0.2\%(\text{SPAN}) + (0.35\%)(\text{SPAN})/100^\circ\text{F})(\Delta T))$$

In addition, Mr. Layer stated that the trip setpoint repeatability equations listed above include reference accuracy, temperature effects, and drift. The equations are accurate for 6 months. Based on calibration procedure DIS 1400-02, the trip units are calibrated every three months. However, Mr. Layer stated that the errors would not be reduced by calibrating more frequently than 6 months.

The MTU and STU trip setpoints are calibrated using the calibration unit supplied with the Model 710DU. Mr. Layer stated that errors associated with the calibration unit are included in the repeatability error equations listed above. Therefore, no additional error evaluations are required for the calibration of the MTU and STU.