ATTACHMENT J

CALCULATION NO. L-001443, Rev. 0, Dated November 21, 1997

REACTOR WATER CLEANUP HIGH FLOW ISOLATION ERROR ANALYSIS

# CALCULATION TITLE PAGE

**ComEd**

**LaSalle**

Calculation No. L-001443

DESCRIPTION CODE: I03 (Setpoint/Settings/Margin)

DISCIPLINE CODE: I (Instrumentation & Control)

SYSTEM CODE: G33

TITLE: Reactor Water Cleanup High Flow Isolation Error Analysis

X Safety Related ___ Augmented Quality ___ Non-Safety Related

## REFERENCE NUMBERS

| Type | Number | Type | Number |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

**COMPONENT EPN :**

| EPN | Compt Type |
|---|---|
| 1-G33-N504 | Venturi Flow Nozzle |
| 1-G33-N041A,B | ΔP Transmitter |
| 1-G33-N609A,B | Trip Unit |

**DOCUMENT NUMBERS:**

| Doc Type/Sub Type | Document Number |
|---|---|
| | |
| | |
| | |

**REMARKS:**

| REV. NO. | REVISING ORGANIZATION | APPROVED PRINT/SIGN | DATE |
|---|---|---|---|
| 0 | ComEd | R.M. SCHIAVONI / [signature] | 11/20/97 |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

# COMMONWEALTH EDISON COMPANY
## CALCULATION REVISION PAGE

CALCULATION NO. L-001443 

## REVISION SUMMARIES

REV: 0

REVISION SUMMARY:

Initial Issue

ELECTRONIC CALCULATION DATA FILES REVISED:
(Program Name, Version, File name ext/size/date/hour: min)

PREPARED BY: VIKRAM R. SHAH [signature] DATE: ~~11-06-97~~ 11/20/97
Print/Sign

REVIEWED BY: Joe Basak Joseph R Basak DATE: 11/20/97
Print/Sign

Type of Review
☒ Detailed ☐ Alternate ☐ Test

DO ANY ASSUMPTIONS IN THIS CALCULATION REQUIRE LATER VERIFICATION
☒ YES ☐ NO

Tracked by: ____________________

REV:

REVISION SUMMARY:

ELECTRONIC CALCULATION DATA FILES REVISED:
(Program Name, Version, File name ext/size/date/hour: min)

PREPARED BY: ____________________ DATE: __________
Print/Sign

REVIEWED BY: ____________________ DATE: __________
Print/Sign

Type of Review
☒ Detailed ☐ Alternate ☐ Test

DO ANY ASSUMPTIONS IN THIS CALCULATION REQUIRE LATER VERIFICATION
☐ YES ☒ NO

Tracked by: ____________________

# COMMONWEALTH EDISON COMPANY
# CALCULATION TABLE OF CONTENTS

| CALCULATION NO. L-001443 | REV. NO. 0 | PAGE NO. 3 OF 53 |
|---|---|---|
| DESCRIPTION | PAGE NO. | SUB-PAGE NO. |

# COMMONWEALTH EDISON COMPANY
# CALCULATION TABLE OF CONTENTS (continued)

| CALCULATION NO. L-001443 | REV. NO. 0 | PAGE NO. 4 OF 53 |
|---|---|---|
| DESCRIPTION | PAGE NO. | SUB-PAGE NO. |
| ATTACHMENTS | | |
| A Telecon between V. Shah of Signals & Safeguards, Inc. and B. Bejlovec of CECo, regarding maintenance of Rosemount transmitter static pressure correction at LaSalle County Station, dated 9-9-94. | A-1 | |
| B Correspondence from T.J. Layer, Rosemount App. Eng., to E. Kaczmarski, CECo, regarding "Pressure Transmitter Performance Specifications", dated 6/24/91. | B-1 thru B-5 | |
| C Telecon between N. Archambo of Bechtel and T. Layer of Rosemount, clarifying the accuracy specifications for the Rosemount 710DU Trip/Calibration System, dated 6-16-93. | C-1 thru C-2 | |
| D Letter from T. Layer of Rosemount, Inc. to V. Shah of Signals & Safeguards, Inc., clarifying specifications for Model 510DU/710DU Trip Unit and Model 1154 Series H Transmitter, dated 9/30/93. | D-1 thru D-2 | |
| E Sargent & Lundy Design Information Transmittal LAS-FNDIT-0536, Upgrade 0, dated 11/10/97, regarding, "Setpoint With New Flow Transmitter and Trip Unit in RWCU Recirc Line." | E-1 thru E-2 | |

## COMMONWEALTH EDISON COMPANY



### 1.0 PURPOSE/OBJECTIVE OF CALCULATION

The purpose of this calculation is to determine the Instrument setpoint and Allowable Value, for the instrument loops that initiate an inboard and outboard logic channel trip upon detection of high flow.

This calculation is performed to support DCP 9700532, which adds high flow break detection instrumentation into RWCU isolation logic. This logic will detect high energy line break.

The calculation evaluates normal operating and accident environmental conditions for the following instruments:

1-G33-N504 1-G33-N041A,B 1-G33-N609A,B

COMMONWEALTH EDISON COMPANY



2.0 METHODOLOGY AND ACCEPTANCE CRITERIA

2.1 Methodology

The methodology used for this calculation is presented in the NES-EIC-20.04, "Analysis Of Instrument Channel Setpoint Error And Instrument Loop Accuracy", Rev. 0 (References 3.2).

2.2 Acceptance Criteria

The acceptance criteria for this calculation is based on the Reference 3.2 as follows:

(1) New determined setpoint provides 95/95 assurances that the Analytical Limit will not be violated,

(2) New determined setpoint provides reasonable assurance that spurious actuation will not occur during normal operation.

# COMMONWEALTH EDISON COMPANY



REFERENCES

3.1 ISA-S67.04, Part 1, "Setpoints for Nuclear Safety Related Instruments", Approved August 24, 1995

ISA-RP67.04-Part II-1994, "Methodologies for the Determination of Setpoints for Nuclear Safety Related Instrumentation", Approved September 30, 1994

3.2 NES-EIC-20.04, "Analysis of Instrument Channel Setpoint Error And Instrument Loop Accuracy."

3.3 LaSalle Station UFSAR, Rev 6, EQ Zone Maps, Table 3.11-7, 8, 16, 17, dated April 1990.

3.4 LaSalle Station Procedures

<u>LIS-RT-106A</u> (Rev. 0), "Unit 1 Reactor Water Cleanup High Inlet Differential Flow Division 1 Isolation Calibration".

<u>LIS-RT-106B</u> (Rev. 0), "Unit 1 Reactor Water Cleanup High Inlet Differential Flow Division 2 Isolation Calibration".

3.5 Rosemount Operational Manual 4471-1, Rev. A, "Model 710DU Trip/Calibration System", VETIP J-0756

Rosemount Product Data Sheet 2471, Model 710DU Trip/Calibration System, Rev. 4/87.

3.6 Rosemount Instruction Manual 4631, March 1996, "Model 1154 Series H Alphaline Pressure Transmitters for Nuclear Service", VETIP J-0223

3.7 Pipe Fitters Manual - Tube Turns, Weldings, Fittings, and Piping Components, 1981

3.8 Commonwealth Edison Company Calculation No. NED-I-EIC-0255, "Measurement & Test Equipment Accuracy Calculation For Use with CECo BWRs", Rev. 0, CHRON # 208597.

3.9 Commonwealth Edison Company Instrument Database (EWCS) for the following instruments:

1G33-N504

COMMONWEALTH EDISON COMPANY



3.10 Sargent & Lundy P&ID/C&I drawings will revise per ECNs 001368E (ESSI) and 001369E (F S2)

| Drwg # | Sht# | Revision | Dated |
|---|---|---|---|
| M-2097 | 2 | G | 01/15/86 |

3.11 ANSI/AMSE PTC 6 Report, "Guidance for Measurement Uncertainty in Performance Tests of Steam Turbines", Tables 4.10, 4.11, Figures 4.5, 4.6, 4.7, 4.8 and 4.9, dated 1935.

3.12 Sargent & Lundy single line piping drawings depicting "as-built" field arrangements

| Drwg # | Sht# | Revision | Dated |
|---|---|---|---|
| M-840 | 8 | X | 07/09/96 |

3.15 Vendor Drawing 73927-1, -21, Rev. 1. J2961 Specification.

3.16 ASME Steam Tables, 6th Edition, dated 1997

3.17 Instrument Engineers Handbook, Process Measurement and Analysis by Bela G. Liptak, Third edison.

3.18 Sargent & Lundy Report SL-4493, "Final Report on Insulation Resistance and Its Presumed Effects on Circuit Accuracy LaSalle County Station", dated October 12, 1988.

3.19 Sargent & Lundy Calculation CID-MISC-01, "Instrument Loop Evaluation for Parasitic Resistance", Rev. 0, dated 2/3/87.

COMMONWEALTH EDISON COMPANY



4.0 DESIGN INPUTS

4.1 Telecon between V. Shah of Signals & Safeguards, Inc. and B. Bejlovec of CECo, regarding maintenance of Rosemount transmitter static pressure correction at LaSalle County Station, dated 9-9-94. (ATTACHMENT A)

4.2 Correspondence from T.J. Layer, Rosemount App. Eng., to E. Kaczmarski, CECo, regarding "Pressure Transmitter Performance Specifications", dated 6/24/91. (ATTACHMENT B)

4.3 Telecon between N. Archambo of Bechtel and T. Layer of Rosemount, clarifying the accuracy specifications for the Rosemount 710DU Trip/Calibration System, dated 6-16-93. (ATTACHMENT C)

4.4 Letter from T. Layer of Rosemount, Inc. to V. Shah of Signals & Safeguards, Inc., clarifying specifications for Model 510DU/710DU Trip Unit and Model 1154 Series H Transmitter, dated 9/30/93. (ATTACHMENT D)

4.5 Sargent & Lundy Design Information Transmittal LAS-ENDIT-0536, Upgrade 0, dated 11/10/97, regarding, "Setpoint With New Flow Transmitter and Trip Unit in RWCU Recirc Line." (ATTACHMENT E) This Design Input provides following information:

Analytical Limit = 600 GPM
Process Calibration Range = 0 to 700" GPM corresponding to 0 to 200" W.C.
Calibration Range = 18 months (Every Refuling Outage)
Inaddition, it also provides Manufacturer, Model no, EQ Zone, and instrument Location.

COMMONWEALTH EDISON COMPANY



5.0 ASSUMPTIONS

5.1 Published instrument and M&TE vendor specifications are considered to be 2 sigma values unless specific information is available to indicate otherwise.

5.2 Humidity, power supply and ambient pressure errors have been incorporated when provided by the manufacturer. Otherwise, these errors are assumed to be included within the manufacturer's reference accuracy specification.

5.3 In accordance with Reference 3.6, it is assumed that the M&TE listed in Section 9.0 is calibrated to the required manufacturer's recommendations and within the manufacturer's required environmental conditions.

5.4 ComEd LaSalle Technical Surveillance Procedure LTS-1000-44, "General Area Reactor building Temperature Surveillance."- data collection from 03/88 thru 12/89. Based on the data reviewed from LTS-1000-44, the Minimum normal temperature in the reactor building will be assumed to be 60°F.

5.5 Per Reference 3.2, an additional flow uncertainty of 0.5% span will be used to account for modelling and process uncertainty (i.e. Pressure & temperature Spikes, Pressure loss, and head loss) of the flow nozzle.

5.6 As stated in Note 1 of ANSI/ASME PTC 6 Report - 1985, the overall uncertainty value of the flow element is acceptable for flow elements in service for less than six months. Further, Section 4.17 of this report states that the base uncertainty for flow elements in service for more than six months is likely to change much less with time than indicated for the initial six months. It is therefore assumed that any additional error due to damage or deposits on the flow element will have a negligible impact on the overall loop uncertainty. Since the flow element has been in service greater than six months, for conservatism, the largest Group 2 base uncertainty from Table 4.10 will be used to evaluate the overall flow element error for flow nozzle.

Assumptions 5.1 thru 5.6 do not require verification. These assumptions are based on the industry practice and engineering judgement.

5.7 The instrument department will develop a instrument surveillance procedure to account for high line static pressure effect. The procedure should use setting tolerance based on this calculation.

Assumption 5.7 is an unverified assumption.

## 6.0 INSTRUMENT CHANNEL CONFIGURATION

Per Reference 3.10, the Instrument Loops each consist of a flow element, differential pressure transmitter, and master trip unit.

The Instrument Loop initiates RWCU isolation when RWCU inlet flow and the corresponding differential pressure increases to the calibrated setpoint.

## 7.0 PROCESS PARAMETERS

From References 3.9,

For 1G33-N504 (RWCU Inlet Flow)

| | |
|---|---|
| Fluid: | Water |
| Maximum Process Pressure: | 1025 PSIG |
| Maximum Process Temperature | 550°F |
| Normal Process Pressure: | 1005 PSIG |
| Minimum Process Temperature: | 533°F |

COMMONWEALTH EDISON COMPANY



8.0 LOOP ELEMENT DATA

8.1 **Module 1, Venturi Flow Nozzle**

1G33-N504 (RWCU System Inlet Flow) (Reference 3.9, and 3.15)

| | |
|---|---|
| Manufacturer: | BIF |
| Normal Flow | 352 GPM |
| DP @ Design Flow: | 101.62" W.C. @ 500 GPM (This does not include the zero pressure static shift compensation) |
| Design Temperature: | 575°F |
| Design Pressure: | 1250 PSIG |
| Pipe Size/Schedule: | 6" Diameter, 120 |
| Throat Diameter (d): | 2.438 inches |
| Pipe Diameter (D): | 4.876 inches (Reference 3.7) |
| Beta Ratio(d/D): | 0.50 |

Per Reference 3.12,

The only upstream and downstream obstructions are single 90° bends. Upstream and downstream straight pipe lengths are as follows.

Upstream pipe length = 82.375 inches
Downstream pipe length = 42.0 inches

# COMMONWEALTH EDISON COMPANY



8.2 Module 2, Rosemount Model 1154DH5R Differential Pressure Transmitter (Reference 3.15)

<u>1G33-N041A, B</u>

From Reference 3.6,

| | |
|---|---|
| Upper Range Limit (URL) | 0-750" W.C. |
| Accuracy [3σ] | ±0.25% calibrated span (Includes effects of Linearity, Hysteresis, and Repeability) |
| Temperature Effect [3σ] | ±(0.75% URL + 0.50% span)/100°F between 40°F and 200°F (Design input 4.4) |
| Static Pressure Effect | |
| Zero [3σ] | ±0.2% URL/1000 psi |
| Span [3σ] | ±0.5% reading/1000 psi |
| Overpressure Limits [2σ] | ±1% URL (Zero shift after 2000 PSI) |
| Power Supply Effect | <0.005% output span per volt |
| Drift [2σ] | ±0.2% URL for 30 months |
| Radiation Effect [2σ] | ± (0.5% URL + 1% span) after 55 Mreds TID<br>± (0.75% URL + 1% span) after 110 Mreds TID gamma radiation exposure. |
| Seismic Effect [2σ] | ±0.5% URL with Horizontal ZPA of 8.5g's, and Vertical ZPA of 5.2g's |

COMMONWEALTH EDISON COMPANY



Environmental Data for Transmitter Location

Transmitter Locations, Reactor Building (Design Input 4.5):

| Switch Tag Numbers | Panel Number | EQ Zone |
|---|---|---|
| 1G33-N041A | 1H22-P010 | H4A |
| 1G33-N041B | Locally mounted | H4A |

Normal Operating Conditions for Environmental Zone H4A (Reference 3.3, Assumption 5.4)

| | |
|---|---|
| Temperature: | 60°F-118°F |
| Pressure: | -0.4" W.G. |
| Radiation: | 2 x $10^6$ Rads (40-Year Dose) |
| Relative Humidity: | 25 - 35% |

Accident Conditions for Environmental Zone H4A (Reference 3.3, Assumption 5.4)

| | |
|---|---|
| Temperature: | 60°F-145°F |
| Pressure: | -0.25" W.G. |
| Radiation: | 1 x $10^7$ Rads (40-Year Dose) |
| Relative Humidity: | 20 - 95% |

# COMMONWEALTH EDISON COMPANY



Module 3 Rosemount Model 710DU - MTU (Reference 3.15)

1G33-N609A,B

From References 3.5, Design Inputs 4.2, 4.3, and 4.4

| | |
|---|---|
| Repeatability (Normal) | ±0.13%(SPAN) (60°F to 90°F)for 6 months<br>±0.20%(SPAN)/100°Ffor 6 months |
| Repeatability (Accident) | ±0.40%(SPAN)for 6 months |
| Radiation Effect | None Within Limits Stated Below |
| Seismic Effect | None Within Limits Stated Below |
| Temperature Effect | Included in Repeatability Errors (Design Input 4.3) |
| Stability | Included in Repeatability Errors for 6 months (Design Input 4.3) |
| Temperature Limits | 60°F to 90°F (Normal)<br>160°F (24 hrs, once/year)<br>185°F (Accident for 6 hrs)<br>150°F (Accident for 8 hrs) |
| Humidity Limits | 40-50% RH (Normal)<br>90% (24 hrs, once/year)<br>90% (Accident for 14 hrs) |
| Radiation Limits | ≤$10^5$ RADS (air) 20 yr TID (normal)<br>2 x $10^5$ RADS 24 hr TID (Accident) |
| Seismic Limits (ZPA) | 1.17 g OBE, 1.75 g SSE (During & After) |

**Environmental Conditions (Reference 3.3):**

EQ Zone C1B, Auxiliary Electric Equipment Room

Normal and Accident Conditions:

| | |
|---|---|
| Maximum Temperature | 80°F |
| Minimum Temperature | 72°F |
| Pressure | +0.25" W.G. |
| Humidity | 45% RH |
| Radiation | 1.0 x $10^3$ RADS (40 years) |

9.0 CALIBRATION INSTRUMENT DATA

9.1 Calibration Method

The following devices may potentially be used as measurement and test equipment when performing calibrations on the devices within the subject instrument loop.

The Calibration Error for each module consists of three random components:

- M&TE Error ($MTE_{IN}$) present at input
- M&TE or Reading Error/Least Significant Digit ($MTE_{OUT}$ or RE/LSD) used to measure output
- Calibration Standard Accuracy (STD) which is negligible per Assumption 5.3

9.2 Transmitter Calibration (MTE2)

The transmitter is calibrated using a pressure gauge for $MTE2_{IN}$ and a digital multimeter for $MTE2_{OUT}$.

9.1 Calibration Method

From Reference 3.8,

| | |
|---|---|
| Manufacturer: | Wallace & Tiernan |
| Model: | 62A-4C-0280 |
| Range: | 0 to 280" W.C. |
| Calibrated Accuracy: | ± 0.50" W.C. |
| Minor Division: | 0.5 PSIG |
| Temp. Effect: | ± 0.1% Range/10°C referred to 25°C |

Pressure gauge calibration accuracy (CAMTE2) is the manufacturer's reference accuracy, and is rounded up to nearest minor division.

CAMTE2 = 0.50" W.C.

Per Reference 3.8, the standard deviation of calibration accuracy ($CAMTE2_{(1\sigma)}$) is CAMTE2/2. Therefore,

$CAMTE2_{(1\sigma)}$ = ± 0.50" W.C. / 2 = ± 0.25" W.C.

## COMMONWEALTH EDISON COMPANY



The reading error of an analog gauge is given as ¼ of the smallest division on the gauge. From the data above,

$$REMTE2 = (1/4)(0.50\text{" W.C.}) = \pm 0.125\text{" W.C.}$$

The temperature error is a degradation of the specified accuracy and is not considered an additional random error. From the data above, TEMTE2 refers to 25°C.

Since the pressure transmitter input pressure is monitored at the transmitter, the temperature error is evaluated using the transmitter environment. From Section 8.2.1 the minimum temperature at the transmitter location under normal operating conditions is 60°F (15.6°C). Therefore,

$$\Delta T_{min} = 15.6°C - 25°C = 9.4°C$$

From Section 8.2.1 the maximum temperature at the transmitter location under normal operating conditions is 118°F (47.8°C). Therefore,

$$\Delta T_{max} = 47.8°C - 25°C = 22.8°C$$

Therefore, $\Delta T_{max}$ is the maximum transmitter location temperature.

$$TEMTE2 = (0.1\%\ FS/10°C)\Delta T$$

$$= [(0.001)\cdot(280\text{" W.C.})/10°C][22.8°C]$$

$$= \pm 0.63840\text{" W.C.}$$

Per Reference 3.8, the standard deviation of temperature effect ($TEMTE2_{(1\sigma)}$) is TEMTE2/2. Therefore,

$$TEMTE2_{(1\sigma)} = \pm 0.63840\text{" W.C.} / 2$$

$$= \pm 0.31920\text{" W.C.}$$

Therefore,

$$MTE2_{IN} = [(CAMTE2_{(1\sigma)} + TEMTE2_{(1\sigma)})^2 + (REMTE2)^2]^{0.5}$$

$$= [(0.25\text{" W.C.} + 0.31920\text{" W.C.})^2 + (0.125\text{" W.C.})^2]^{0.5}$$

$$= \pm 0.582764\text{" W.C.}$$

9.1.1 Calibration Standard Error (STD1)

The error due to calibration accuracy of calibration equipment is assumed to be negligible (Reference 3.2). Therefore,

$$STD1 = 0$$

9.1.2 Determination of Transmitter Input Calibration Error Propagated through the Transmitter ($CALI_{prop}$)

The M&TE error (± 0.582764" W.C.) was determined in Section 9.1. The transfer function is determined in Section 11.1.1. Therefore,

$$MTEI_{prop} = \pm[(MTE1)^2 \cdot (dT/dP)^2]^{0.5}$$

$$= \pm[(0.582764\text{" W.C.})^2 \bullet (0.08\text{ mA/" W.C.})^2]^{0.5}$$

$$= \pm 0.046621\text{ mA}$$

9.2.2 Digital Multimeter Error ($MTE2_{OUT}$)

9.2.2.1 Digital Multimeter Error ($MTE2_{OUT1}$)

Per Reference 3.8,

| | |
|---|---|
| Manufacturer: | Fluke |
| Model: | 8500A |
| Range: | 10 Vdc (5½ Digit Resolution) |

From Section 8.2.1, the temperature range is 60 (15.6°C) to 118°F (47.8°C). Reference 3.8 provides the following specifications:

| | |
|---|---|
| Reference Accuracy (RA) | = ±(0.002%(RDG) + 1(digits)) |
| Resolution (RES) | = 0.0001 Vdc |
| Temperature Effect (TE) | = ±(0.0002%(RDG) + 0.5(digit))/°C)(ΔT) |

$$\Delta T = (47.8 - 28.0)°C = 19.8°C$$

At a reading of 5.0 Vdc

$$MTE2_{OUT1} = \pm[(RA/2 + TE/2)^2 + RES^2]^{0.5}$$

$$= \pm[(0.0002\text{ Vdc}/2 + 0.001188\text{ Vdc}/2)^2 + (0.0001\text{ Vdc})^2]^{0.5}$$

$$= \pm 0.000701\text{ Vdc}$$

# COMMONWEALTH EDISON COMPANY



9.2.2.2 Digital Multimeter Error ($MTE2_{OUT2}$)

Per Reference 3.8,

Manufacturer: Fluke
Model: 8500A
Range: 10 Vdc (6½ Digit Resolution)

From Section 8.2.1, the temperature range is 60 (15.6°C) to 118°F (47.8°C). Reference 3.8 provides the following specifications:

Reference Accuracy (RA) = ±(0.002%(RDG) + 9(digits))
Resolution (RES) = 0.00001 Vdc
Temperature Effect (TE) = ±(0.0002%(RDG) + 0.5(digit))/°C)(ΔT)

$\Delta T = (47.8 - 28.0)°C = 19.8°C$

At a reading of 5.0 Vdc

$MTE2_{OUT2} = \pm[(RA/2 + TE/2)^2 + RES^2]^{0.5}$

$= \pm[(0.00019\ Vdc/2+0.000297\ Vdc/2)^2+(0.00001\ Vdc)^2]^{0.5}$

$= \pm\ 0.000244\ Vdc$

9.2.2.3 Digital Multimeter Error ($MTE2_{OUT3}$)

Per Reference 3.8,

Manufacturer: Fluke
Model: 8505A
Range: 10 Vdc (Normal Mode)

From Section 8.2.1, the temperature range is 60 (15.6°C) to 118°F (47.8°C). Reference 3.8 provides the following specifications:

Reference Accuracy (RA) = ±(0.0019%(RDG) + 8.9(digits))
Resolution (RES) = 0.00001 Vdc
Temperature Effect (TE) = ±(0.0002%(RDG) + 0.5(digit))/°C)(ΔT)

$\Delta T = (47.8 - 28.0)°C = 19.8°C$

At a reading of 5.0 Vdc

$MTE2_{OUT3} = \pm[(RA/2 + TE/2)^2 + RES^2]^{0.5}$

$= \pm[(0.000184Vdc/2+0.000297\ Vdc/2)^2+(0.00001\ Vdc)^2]^{0.5}$

$= \pm\ 0.000241\ Vdc$

## COMMONWEALTH EDISON COMPANY



9.2.2.4 Digital Multimeter Error ($MTE2_{OUT4}$)

Per Reference 3.8,

| | |
|---|---|
| Manufacturer: | Fluke |
| Model: | 8505A |
| Range: | 10 Vdc (Average Mode) |

From Section 8.2.1, the temperature range is 60 (15.6°C) to 118°F (47.8°C). Reference 3.8 provides the following specifications:

Reference Accuracy (RA) = ±(0.00152%(RDG) + 69(digits))
Resolution (RES) = 0.000001 Vdc
Temperature Effect (TE) = ±(0.0002%(RDG) + 5(digit))/°C)(ΔT)

$\Delta T = (47.8 - 28.0)°C = 19.8°C$

At a reading of 5.0 Vdc

$MTE2_{OUT4} = \pm[(RA/2 + TE/2)^2 + RES^2]^{0.5}$

$= \pm[(0.000145 Vdc/2+0.000297\ Vdc/2)^2+(0.000001\ Vdc)^2]^{0.5}$

$= \pm\ 0.000221$ Vdc

9.2.2.5 Digital Multimeter Error ($MTE2_{OUT5}$)

Per Reference 3.8,

| | |
|---|---|
| Manufacturer: | Fluke |
| Model: | 8600A |
| Range: | 20 Vdc |

From Section 8.2.1, the temperature range is 60 (15.6°C) to 118°F (47.8°C). Reference 3.8 provides the following specifications:

Reference Accuracy (RA) = ±(0.02%(RDG) + 0.005%(RNG))
Resolution (RES) = 0.001 Vdc
Temperature Effect (TE) = ±(0.001%(RDG) + 0.0005%(RNG))/°C)(ΔT)

$\Delta T = (47.8 - 35.0)°C = 12.8°C$

At a reading of 5.0 Vdc

$MTE2_{OUT5} = \pm[(RA/2 + TE/2)^2 + RES^2]^{0.5}$

$= \pm[(0.002 Vdc/2+0.00192\ Vdc/2)^2+(0.001\ Vdc)^2]^{0.5}$

$= \pm\ 0\ 00220$ Vdc

9.2.2.6 Digital Multimeter Error ($MTE2_{OUT6}$)

Per Reference 3.8,

| | |
|---|---|
| Manufacturer: | Fluke |
| Model: | 8050A |
| Range: | 20 Vdc |

From Section 8.2.1, the temperature range is 60 (15.6°C) to 118°F (47.8°C). Reference 3.8 provides the following specifications:

| | |
|---|---|
| Reference Accuracy (RA) | = ±(0.03%(RDG) + 2(digits)) |
| Resolution (RES) | = 0.001 Vdc |
| Temperature Effect (TE) | = ±(0.1(Accuracy Spec)/°C)(ΔT) |

$$\Delta T = (47.8 - 28.0)°C = 19.8°C$$

At a reading of 5.0 Vdc

$$MTE2_{OUT6} = \pm[(RA/2 + TE/2)^2 + RES^2]^{0.5}$$

$$= \pm[(0.0035 Vdc/2 + 0.00035\ Vdc/2)^2 + (0.001\ Vdc)^2]^{0.5}$$

$$= \pm\ 0.002169\ Vdc$$

9.2.2.6 Worst Case $MTE2_{OUT}$

The greatest DMM error occurs with the Fluke 8600A. Therefore,

$$MTE2_{OUT} = \pm\ 0.00220\ Vdc$$

Convert $MTE2_{OUT}$ from 1 to 5 Vdc to 4 to 20mA by dividing with 250Ω resistor,

$$MTE2_{OUT} = \pm\ (0.00220\ Vdc/250\Omega)$$

$$= \pm\ 0.0088\ mA$$

9.2.2.7 Calibration Standard Error (STD2)

The error due to calibration accuracy of calibration equipment is assumed to be negligible (Reference 3.2). Therefore,

$$STD2 = 0$$

9.2.2.8 Determination of CAL2

$$CAL2 = [(MTEI_{prop})^2 + (MTE2_{OUT})^2 + (STD1)^2 + (STD2)^2]^{½}$$

$$= \pm[(0.046621\ mA)^2 + (0.0088\ mA)^2 + (0)^2 + (0)^2]^{½}$$

$$= \pm\ 0.047444\ mA$$

COMMONWEALTH EDISON COMPANY



## 10.0 CALIBRATION PROCEDURE DATA

The design Input 4.5 provide the following:

Flow Element FE-1G33-N504 (RWCU Inlet Flow)

Range: 0 to 700 GPM = 0 to 200" W.C.

Transmitter FT-1G33-N041A,B

Calibrated Range: 0 to 200" W.C. (4 - 20 mAdc)
Output Span: 1 to 5 Vdc (See Note 1)
Calib. Tolerance: ± 0.02 Vdc

Trip Unit FDS-1G33-N042A,B

Setting Tolerance: ± 0.012 Vdc

Per Design Input 4.5,

Analytical Limit: 600 GPM

Calibration Frequency (Design Input 4.5)

Transmitters, Trip Unit: 18 months

Late Factor: 4.5 months

Note 1: The input to the signal converter from the transmitter is measured as a 1-5 Vdc signal developed across a MTU (Master Trip Unit), Further, the method used to calibrate the transmitter and the Master Trip Unit is to apply current from the transmitter through this MTU while measuring the DP input to the transmitter and simultaneously monitoring the voltage developed across this same MTU. The SRU used for this loops are 0.1% precision resistor. The accuracy effect of this SRU is small compare to other error terms, and are considered to be negligible.

11.0 FLOW ELEMENT ERRORS (MODULE 1)

The flow element has an analog input and an analog output. Therefore, it is classified as an analog module.

11.1 Random Error, Normal Operating Conditions ($\sigma 1n$)

Flow element accuracy is the only random error affecting the flow element. The flow element is not a calibratable device. As such, there is no setting tolerance (ST1) applicable for this device. The calibration error for this device is included in the reference accuracy of the flow element. Additionally, the flow element is the first module in the instrument loop.

11.1.1 Flow Element Reference Accuracy (RA1n)

The error associated with the reactor water cleanup flow element is calculated per the methodology contained in Reference 3.11 (see Assumption 5.6). Reference 3.11 classifies the error terms calculated here as random errors. The overall flow element measurement uncertainty (RA1) is calculated as follows:

$$RA1 = \pm [U_B^2 + U_{LNS}^2 + U_6^2 + U_{DSL}^2]^{1/2}$$

Base Uncertainty ($U_B$) For Flow Nozzle

The base uncertainty is determined from Table 4.10 of Reference 3.11. Per Assumption 5.6, the Group 2 base uncertainty for uncalibrated flow nozzle is 3.20% flow. This value will be used to maintain conservatism in the calculation.

$$U_{B\ Nozzle} = \pm 3.20\%\ flow$$

Minimum Upstream Straight Run Uncertainty ($U_{LNS}$)

From Section 8.1, the pipe size is 6 inches, schedule 120, and the inner pipe diameter is 4.876 inches. From Section 8.1, the limiting upstream straight run is approximately 82.375"/4.876" = 16.89 pipe diameters, the beta ratio is 0.50, and the closest upstream flow obstruction is a single 90° bend. From Table 4.11 of Reference 3.11, the denominator for the upstream length ratio is from column 1 and is 7.0 diameters. The upstream length ratio is then:

straight length ratio = 16.89 diameters/7.0 diameters

= 2.41

The minimum straight run uncertainty ($U_{LNS}$) is taken from Figure 4.5 of Reference 3.11 as 1.0% of flow.

COMMONWEALTH EDISON COMPANY



<u>Beta Ratio Uncertainty</u> ($U_\beta$)

From Section 8.1, the beta ratio is 0.50. From Figure 4.6 of Reference 3.11, the beta ratio effect ($U_\beta$) for a calibrated flow element is 0% of flow.

<u>Minimum Downstream Straight Run Uncertainty</u> ($U_{DSL}$)

From Section 8.1, the limiting downstream straight run is 42"/4.876" = 8.61 pipe diameters. From Table 4.11 of Reference 3.11, the denominator for the downstream length ratio is taken from column 7 and is 3.5 diameters. The downstream length ratio is then:

straight length ratio = 8.61 diameters/3.5 diameters

= 2.46

The minimum straight run uncertainty ($U_{DSL}$) is taken from Figure 4.9 of Reference 3.11 as 0.05% of flow.

$$RA1n_{Nozzle} = \pm [U_{B\ Nozzle}^2 + U_{LNS}^2 + U_\beta^2 + U_{DSL}^2]^{1/2}$$

$$= \pm [(3.2\%)^2 + (1.0\%)^2 + (0\%)^2 + (0.05\%)^2]^{1/2} \text{ Flow}$$

$$= \pm 3.352984\% \text{ Flow}$$

As stated in Section 11.1, CAL1 = 0, ST1 = 0, and $\sigma1in$ = 0. Therefore,

Determination of Random Error For Flow Nozzle ($\sigma1n_{Nozzle}$)

$$\sigma1n_{Nozzle} = \pm ((RA1n_{Nozzle}/ 2)^2 + (CAL1)^2 + (ST1)^2 + (\sigma1in)^2)^{0.5}$$

$$= \pm ((3.352984\% \text{ Flow}/ 2)^2 + (0)^2 + (0)^2 + (0)^2)^{0.5}$$

$$= \pm 1.676492\% \text{ Flow} \quad [1\sigma]$$

11.2 Random Error, Accident Conditions ($\sigma1a$)

The random error for the flow elements is the same for normal and accident conditions since none of the error terms are affected by the accident, therefore:

$$\sigma1a_{Nozzle} = \pm 1.676492\% \text{ Flow} \quad [1\sigma]$$

## COMMONWEALTH EDISON COMPANY



11.3 Non-Random Error, Normal and accident Operating Conditions

The flow element is a mechanical device that is not affected by the following non-random errors:

| | |
|---|---|
| Humidity Errors: | e1H = 0 |
| Ambient Temperature Error | e1T = 0 |
| Radiation Error: | e1R = 0 |
| Seismic Error: | e1S = 0 |
| Static Pressure Effects: | e1SP = 0 |
| Ambient Pressure Errors: | e1AP = 0 |
| Power Supply Effects: | e1V = 0 |

11.3.1 Process Error (e1P)

From Section 7.0, the process error can very from a normal pressure of 1005 PSIG and 533°F to 1025 PSIG and 550°F. As pressure and temperature changes, the density of the fluid changes. This change in density results in a change in the flow.

The error will be evaluated at design flow of 500 GPM and at DP of 101.62" WC described in the Reference 3.15. This process conditions are calculated at 1005 PSIG and temperature of 533°F. Using the basis flow equation from Reference 3.17

$$Q = k\sqrt{\frac{dP}{\rho}}$$

where: Q = flow
k = constant
dP = differential pressure
ρ = density of fluid

Per Reference 3.16, the normal pressure of 1005 PSIG and temperature of 533°F, the density $\rho = 47.116472\ lbm/ft^3$.

solving for k:

$$k = \frac{Q}{\sqrt{\frac{dP}{\rho}}}$$

$$= \frac{500\ GPM}{\sqrt{\frac{101.62\ INWC}{47.12\ lbm/ft^3}}}$$

$$= 340.473292$$

Per Reference 3.16 at the temperature of approximately 550°F, and maximum pressure of 1025 PSIG, ρ = 46.01085 lbm/ft³.

$$Q_{550°F,\ 1025\ psig} = k\sqrt{\frac{dP}{\rho}}$$

$$= (340.473292)\sqrt{\frac{101.62\ INWC}{46.012\ lbm/ft^3}}$$

$$= 505.984\ GPM$$

$$\Delta Q = 505.984356\ gpm - 500\ gpm$$

$$= 5.984356\ GPM$$

Calculation of flow error due to variation in the pressure and temperature:

e1p = ± 5.984356 GPM • (100% flow span/500 GPM)

e1p = ± 1.1969% flow span

11.3.3 Process Error Due To Unknown Uncertainty ($e1p_{Unknown}$)

Per Assumption 5.5, the unknown uncertainty is equal to

$e1p_{Unknown}$ = ± 0.50% flow span

COMMONWEALTH EDISON COMPANY



11.3.4 Total Non-Random Errors, Normal Operating Condition ($\Sigma e1n$)

The error calculated under normal operating condition is used to determine Allowable Value (AV). Only errors that effect the "as-found" setpoint value will be calculated under Normal Operating Conditions.

The total non-random errors for the flow element is given by the sum of the individual errors. Therefore:

$$\Sigma e1n = \pm(e1Hn + e1Tn + e1Rn + e1Sn + e1SPn + e1APn + e1Pn + e1Vn + D + e1pn_{Unknown})$$

$$= \pm(0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0)$$

$$= 0$$

11.3.5 Total Non-Random Errors, Accident Operating Condition ($\Sigma e1a$)

The total non-random errors for the flow element is given by the sum of the individual errors. Therefore:

$$\Sigma e1a = \pm(e1Ha + e1Ta + e1Ra + e1Sa + e1SPa + e1APa + e1Pa + e1Va + D + e1pa_{Unknown})$$

$$= \pm(0 + 0 + 0 + 0 + 0 + 0 + 1.1969\% \text{ flow span} + 0 + 0 + 0.50\% \text{ flow span})$$

$$= \pm 1.6969\% \text{ flow span}$$

11.4 Module 2- Flow Transmitter Error

These loops consists of the flow element, the flow transmitter, and the master trip unit.

11.4.1 Transfer Function Derivation

The error in the transmitter output due to the input random and/or non-random errors is calculated using the partial derivative method per Reference 3.2, as follows,

$$T = K(dP - dP_o) + C$$

where: $K$ = transmitter gain (mA/" W.C.)
$dP$ = analog input signal (" W.C.)
$dP_o$ = minimum value of calibrated span (" W.C.)
$C$ = transmitter output offset (mA)

The process span of 0 to 700 GPM corresponds to a DP of 0 to 200" WC, and the transmitter output will be 4-20 mA. The transfer function of the transmitter can be written as,

For FT-1G33-N041 A, B, the transmitter input span is 200" W.C.

$$T = (16\ mA/\ 200"\ W.C.)(dP - 0) + 4\ mA$$

The partial derivative of T with respect to dP yields:

$$\delta T/\delta dP = (16\ mA/200"\ W.C.) = 0.08\ mA/"\ W.C.$$

11.4.2 Random Errors, Normal Operating Conditions

11.4.2.1 Transmitter Reference Accuracy (RA2)

From Section 8.2, the transmitter accuracy is ± 0.25% calibrated span. The output span of the transmitter is 16 mA. Therefore,

$$RA2 = \pm 0.25\%\ span$$

$$= \pm (0.25\%)(16\ mA) = \pm 0.04\ mA$$

The vendor's specification for accuracy is a $3\sigma$ value. Therefore,

$$RA2_{(1\sigma)} = \pm 0.04\ mA/3 = \pm 0.013333\ mA \quad [1\sigma]$$

11.4.2.2 Transmitter Calibration Error (CAL2)

Per Section 9.2.2.8,

the calibration error CAL2 = ± 0.047444 mA

11.4.2.3 Transmitter Setting Tolerance (ST2)

From data given in Section 9.0, calibration tolerance for the transmitter is ± 0.02 Vdc. Therefore, per Section 10.0,

$ST2_{(1\sigma)}$ = ± 0.02 Vdc/3

= ± 0.006666 Vdc

Using the Ohm's Law, 1-5 Vdc will be converted to 4-20 mA by, using the 250Ω resistor,

$ST2_{(1\sigma)}$ = ± (0.006666 Vdc /250Ω)

= ± 0.02666 mA

11.4.2.4 Temperature Error (eT2n)

Per Design Input 4.2, the vendor has determined that, the temperature error is considered to be a random error. Based on Reference 3.5, and Assumption 5.5, the ambient temperature at the transmitter location varies from a minimum of 60°F to a maximum of 118°F. From Section 8.1, the temperature effect on the transmitter within this temperature range is determined below:

e1Tn = ±((0.75%(URL) + (0.5%(SPAN))/100°F)(ΔT)

=± [(0.0075•750"WC + 0.005•200.00"WC)/100°F]•(118°F-60°F)

= ± 3.8425" W.C.

From Design Input 4.4, Temperature error is considered as a 3σ value, therefore $e1Tn_{(1\sigma)}$ = e1Tn/3.

$e1Tn_{(1\sigma)}$ = 3.8425" W.C./3 = ± 1.280833" W.C.

Using the transfer function determined in Section 11.4.1, The temperature error term converted in terms of mA is as follows:

$eT2n_{c(1\sigma)}$ = ± $(eT2n_{(1\sigma)})$ • (dT/dP)

= ±(1.280833" W.C.)•(0.08 mA/" W.C.)
= ± 0.102467 mA

11.4.2.5 Radiation Error (eR2n)

Per Design Input 4.2, the vendor has determined that the radiation error is considered to be a random error. From Section 8.2, radiation effects are described for exposure during and after $5.5x10^7$ rads. Per Section 8.2.1, the transmitter is located in the reactor building which has a 40 year TID of $2.0x10^6$ rads. Therefore,

eR2n = 0

11.4.2.6 Seismic Error (eS2n)

Per Design Input 4.2, the vendor has determined that the seismic error is considered to be a random error. A seismic event defines a particular type of accident condition. Errors included on the instrument due to seismic vibrations are defined only for accident conditions and therefore, are not applicable during normal plant conditions.

eS2n = 0

11.4.2.7 Static Pressure Effect (eSP2n)

Per Design Input 4.2, the vendor has determined that, the Static Pressure error is considered to be a random error. The instrument is valved out during calibration, and therefore, does not experience any effect of high line pressure. The evaluation of the static pressure error is under accident condition since, only errors that effect the as-found setpoint value will be calculated under normal operating conditions. Therefore,

e1SPn = 0

11.4.2.8 Pressure Error (eP2n)

Per Design Input 4.2, the vendor has determined that the pressure error is considered to be a random error. Per Section 7.0, the maximum static pressure is 1025 PSIG, which is below the published specification. Therefore, Overpressure effect will not be considered. Therefore,

e1Pn = 0

11.4.2.9 Drift (D2)

Per Design Input 4.2, the vendor has determined that the drift error is considered to be a random error. From Section 8.2, drift is ±0.2% URL for 30 months. From Section 10.0 the transmitter calibration frequency is 18 months plus 25% late factor. Vendor also states that the Drift is not time dependent, and error will not reduce if the transmitter is calibrated more frequently. Therefore,

D2 = [(IDE)]

= [(0.2%•(750" WC))]

= ± 1.5" W.C.

From Design Input 4.2, drift error is considered as a 2σ value, therefore,

$D2_{1\sigma}$ = ± 1.5" W.C./2

= ± 0.75" W.C.

Using the transfer function determined in Section 11.4.1, The drift error term converted in terms of mA is as follows:

$D2_{(1\sigma)}$ = $\pm(D2_{(1\sigma)})$ • (dT/dP)

= ±(0.75" W.C.)•(0.08 mA/" W.C.)

= ± 0.060 mA

11.4.2.10 Random Input Error (σ2inn)

The random error present at the input to the transmitter is due to the flow element and was calculated in Section 11.1.1

$\sigma 2inn = \sigma 1_{Nozzle} = \pm 1.676492\%$ of flow span

From Section 8.2, the dp span is 200" W.C.. Per Reference 3.2, % flow span to % dp span is converted as below:

Evaluating at maximum flow of 700 GPM:

$$\%\ flow\ span\ error = \frac{\%\ dp\ span}{2} \cdot \frac{maximum\ flow}{normal\ flow}$$

$$\pm 1.676492\%\ flow\ span = \frac{\%\ dp\ span}{2} \cdot \frac{700\ GPM}{700\ GPM}$$

$$\%\ dp\ span = \pm 3.352984\%$$

$\sigma 2inn_{@\,700\,GPM}$ = ± 3.352984% span • (200" W.C./100% span)

= ± 6.705968" W.C.

This error is propagated through the transmitter using the derivative of the transfer function determined in Section 11.4.1, as follows:

$\sigma 2inn_{PROP}$ = ±($\sigma 2inn_{@\,700\,GPM}$)($\delta T/\delta P$)

= ±(6.705968" W.C.)(0.08 mA/" W.C.)

= ± 0.536477 mA

11.4.2.11 Determination of Transmitter Random Error ($\sigma 2n$)

$\sigma 2n = \pm[(RA2)^2 + (CAL2)^2 + (ST2)^2 + (eT2n)^2 + (eR2n)^2 + (eS2n)^2 + (eSP2n)^2 + (eP2n)^2 + (D2)^2 + (\sigma 2inn_{PROP})^2]^{0.5}$

$\sigma 2n = \pm[(RA2)^2 + (CAL2)^2 + (ST2)^2 + (eT2n)^2 + (eR2n)^2 + (eS2n)^2 + (eSP2n)^2 + (eP2n)^2 + (D2)^2 + (\sigma 2inn_{PROP})^2]^{0.5}$

$= \pm[(0.013333\ mA)^2 + (0.047444\ mA)^2 + (0.026666\ mA)^2 + (0.102467\ mA)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0.060\ mA)^2 + (0.536477\ mA)^2]^{0.5}$

= ± 0.552310 mA

COMMONWEALTH EDISON COMPANY



11.5 Random Error, Accident Conditions (σ2a)

11.5.1 Transmitter Reference Accuracy (RA2)

The transmitter reference accuracy specification is dependent only on the calibrated span and is not a function of the transmitter environment. Therefore, for the purpose of this calculation, the reference accuracy determined for normal operating conditions (Section 11.4.2.1) is the same error that would occur during accident conditions.

RA2 = ± 0.013333 mA

11.5.2 Calibration Error (CAL2)

Per Section 9.2.2.8,

the calibration error CAL2 = ± 0.047444 mA

11.5.3 Transmitter Setting Tolerance (ST2)

Calibration of the transmitter takes place during normal plant conditions, Therefore, The setting tolerance for normal and accident conditions are the same. From Section 11.4.2.3:

ST2 = ± 0.02666 mA

11.5.4 Transmitter Drift Error (D2)

Instrument Drift is a function of time, and is not dependent on environmental conditions. Therefore, The Drift error for normal and accident conditions are the same. From Section 11.4.2.9:

D2 = ± 0.060 mA

11.5.5 Temperature Error under Accident Conditions (e2Ta)

Per Design Input 4.2, the vendor has determined that, the temperature error is considered to be a random error. Based on Reference 3.3 and Assumption 5.5, the ambient temperature range at the transmitter location during accident conditions varies from a minimum of 60°F to a maximum of 145°F. From Section 8.1, the temperature effect on the transmitter within this temperature range is determined below:

$$e2Ta = \pm[(0.75\%(URL) + 0.5\%(SPAN))/100°F](\Delta T)$$

$$= \pm[(0.0075(750"WC) + 0.005(200"WC))/100°F](145° - 60°F)$$

$$= \pm 5.63125" WC$$

Per Design Input 4.4, the temperature effect is a 3σ value. therefore $e2Ta_{(1\sigma)} = \pm 2Ta/3$.

$$e2Ta_{(1\sigma)} = (1/3)(\pm 5.63125" WC) = \pm 1.877083" WC$$

Using the transfer function determined in Section 11.4.1, The temperature error term expressed as transmitter output is as follows:

$$e2Ta_{(1\sigma)} = \pm(e2Ta_{(1\sigma)}) \bullet (dT/dP)$$

$$= \pm(1.877083" WC) \bullet (0.08 mA/" W.C.)$$

$$= \pm 0.150167 mA$$

11.5.6 Radiation Error (e2Ra)

Per Design Input 4.2, the vendor has determined that, the radiation error is considered to be random error. As noted in the vendor specification, the radiation effect on the transmitter is given for both low and high values of radiation. From Reference 3.3, the worst case radiation level within the transmitter environment during accident condition is $1 \times 10^7$ RADS (Gamma Integrated). Within this range, the radiation effect equation used is for low level radiation as given below:

$$e2Ra = \pm 0.5\%(URL) + 1.0\% Span$$

$$= \pm 0.005 (750" WC) + 0.01 (200" WC)$$

$$= \pm 5.75" WC$$

Per Design Input 4.2, the Radiation effect is considered to be a 2σ value, therefore, $e2Ra_{(1\sigma)}$ = e2Ra/2.

$e2Ra_{(1\sigma)}$ = ± 5.75" WC/2 = ± 2.875" WC

Using the transfer function determined in Section 11.4.1, The radiation error term expressed as transmitter output is as follows:

$e2Ra_{(1\sigma)}$ = ±($e2Ra_{(1\sigma)}$) • (dT/dP)

= ±(2.875" WC)•(0.08 mA/" W.C.)

= ± 0.23 mA

11.5.7 Static Pressure Error (e2SPa)

Per Design Input 4.2, the vendor has determined that, the Static Pressure error is considered to be a random error. From Section 7.0, the systems maximum operating pressure is 1025 psig. Therefore,

$eSP2a_{ZERO}$ = ± 0.2% URL/1000 psig
= ± (0.2%)(750 INWC) • 1025 psig/1000 psig
= ± 1.5375" W.C.

$eSP2a_{SPAN}$ = ± 0.5% rdg/1000 psig
= ± (0.5%)(200" W.C.)• 1025 psig/1000 psig
= ± 1.025" W.C.

eSP2a = ± $[(eSP2a_{ZERO})^2 + (eSP2a_{SPAN})^2]^{0.5}$
= ± $[(1.5375\text{" W.C.})^2 + (1.025\text{" W.C.})^2]^{0.5}$
= ± 1.847845" W.C.

From Design Input 4.2, Static Pressure error is considered as a 3σ value, therefore $eSP2a_{(1\sigma)}$ = eSP2a/3.

$eSP2a_{(1\sigma)}$ = 1.847845" W.C./ 3 = ± 0.615948" W.C.

Using the transfer function determined in Section 11.4.1, the static pressure error term converted in terms of mA is as follows:

$eSP2a_{(1\sigma)}$ = ±($eSP2a_{(1\sigma)}$) • (dT/dP)

= ±(0.615948" W.C.)•(0.08 mA/" W.C.)

= ± 0.049276 mA

11.5.8 Seismic Error (e2Sa)

Per Design Input 4.2, the vendor has determined that, the seismic error is considered to be a random error. As noted in the vendor's specifications listed in Section 8.2, the seismic effect on the transmitter is given for the ZPA of 8.5 g's, and the vertical ZPA of 5.2 g's. Therefore, the seismic effect on the transmitter during accident conditions is:

$$e2Sa = \pm\ 0.5\%(URL)$$

$$= \pm\ 0.005(750"\ WC)$$

$$= \pm\ 3.75"\ WC$$

From Design Input 4.2, Seismic error is considered as a 2σ value, therefore $e2Sa_{(1\sigma)} = e2Sa/2$.

$$e2Sa_{(1\sigma)} = 3.75"\ W.C./2$$

$$= \pm\ 1.875"\ W.C.$$

Using the transfer function determined in Section 11.4.1, The Seismic error term expressed as transmitter output is as follows:

$$e2Sa_{(1\sigma)} = \pm(e2Sa_{(1\sigma)}) \bullet (dT/dP)$$

$$= \pm(1.875"\ W.C.)\bullet(0.08\ mA/"\ W.C.)$$

$$= \pm\ 0.15\ mA$$

11.5.9 Pressure Effect (e2Pa)

Per Design Input 4.2, the vendor has determined that the pressure error is considered to be a random error. Per Section 7.0, the maximum static pressure is 1025 PSIG, which is well below the published specification. Therefore, Overpressure effect will not be considered. Therefore,

$$e2Pa = 0$$

## COMMONWEALTH EDISON COMPANY



11.5.10 Random Input Error ($\sigma 2ina$)

Per Section 11.4.2.10, The input error from the flow element for accident condition is determined to be same as normal random error. Therefore,

$$\sigma 2ina_{PROP} = \pm\ 0.536477 \text{ mA}$$

11.5.11 Determination of Transmitter Random Error ($\sigma 2a$)

$$\sigma 2a = \pm[(RA2)^2 + (CAL2)^2 + (ST2)^2 + (eT2a)^2 + (eR2a)^2 + (eS2a)^2 + (eSP2a)^2 + (eP2a)^2 + (D2)^2 + (\sigma 2ina_{PROP})^2]^{0.5}$$

$$\sigma 2a = \pm[(RA2)^2 + (CAL2)^2 + (ST2)^2 + (eT2a)^2 + (eR2a)^2 + (eS2a)^2 + (eSP2a)^2 + (eP2a)^2 + (D2)^2 + (\sigma 2ina_{PROP})^2]^{0.5}$$

$$= \pm[(0.013333 \text{ mA})^2 + (0.047444 \text{ mA})^2 + (0.02666 \text{ mA})^2 + (0.150167 \text{ mA})^2 + (0.23 \text{ mA})^2 + (0.15 \text{ mA})^2 + (0.049276 \text{ mA})^2 + (0)^2 + (0.060 \text{ mA})^2 + (0.536477 \text{ mA})^2]^{0.5}$$

$$= \pm\ 0.628431 \text{ mA}$$

11.6 Non-Random Errors for Normal Operating Conditions ($\sum e2n$)

11.6.1 Humidity Error (e2Hn)

The transmitter humidity limit is 100% RH per vendor specifications listed in Sections 8.2. From Section 8.2, the humidity range at the transmitter location during normal operation is 25-35% RH. Therefore:

$$e2Hn = 0$$

11.6.2 Pressure Error (e2Pn)

There are no ambient pressure errors described in the vendor's specifications for this device. Based on Assumption 5.2, ambient pressure effects associated with the transmitter are included in instrument reference accuracy, Therefore:

$$e2Pn = 0$$

11.6.3 Power Supply Effects (e2Vn)

Per Section 8.1, $e2Vn = 0.005\%$ span/volt

Per Reference 3.5, table 3, the maximum and minimum operating voltage available to drive the transmitters are 26 Vdc and 22 Vdc, respectively. Therefore, the maximum voltage variation possible for operating the transmitter is 4 Vdc.

$$e2Vn = 0.00005 \bullet (200\text{" W.C.}) \bullet 4V\ )/1V$$

$$= \pm 0.04\text{" W.C.}$$

Using the transfer function determined in Section 11.4.1, The power supply error term expressed as transmitter output is as follows:

$$e2Vn_{(1\sigma)} = \pm(e2Vn_{(1\sigma)}) \bullet (dT/dP)$$

$$= \pm(0.04\text{" W.C.}) \bullet (0.08\text{ mA/" W.C.})$$

$$= \pm\ 0.0032\text{ mA}$$

11.6.4 Process Error (e2pn)

Process measurement errors are associated with the flow element and were evaluated under Section 11.3.1. There are no additional process errors associated with the transmitter. Therefore,

$$e2pn = 0$$

COMMONWEALTH EDISON COMPANY



11.6.5 Insulation Resistance Error (e2IRn)

References 3.1 and 3.2, under conditions of high humidity and temperature associated with high energy line breaks (HELB), insulation resistance may be reduced. This reduction results in signal error that is experienced during harsh environmental conditions, hence IR is not applicable during normal plant conditions. Therefore;

$$e2IRn = 0$$

11.6.6 Non-Random Input Error (e2inn)

The non-random error present at the input to the transmitter is due to the flow element and was calculated in Section 11.3.3

$$e2inn = e1n = 0$$

11.6.7 Transmitter Total Non-Random Error ($\sum e2n$)

$$\sum e2n = (e2Hn + e2Pn + e2Vn + e2pn + e2IRn + e2inn)$$

$$= \pm(0 + 0 + 0.0032 \text{ mA} + 0 + 0 + 0)$$

$$= \pm 0.0032 \text{ mA}$$

11.7 Non-Random Errors for Accident Operating Conditions ($\sum e2a$)

11.7.1 Humidity Error (e2Ha)

The transmitter humidity limit is 100% RH per vendor specifications listed in Sections 8.2. From Section 8.2, the maximum humidity at the transmitter location during accident operation is 95% RH. Therefore:

$$e2Ha = 0$$

11.7.2 Pressure Error (e2Pa)

There are no ambient pressure errors described in the vendor's specifications for this device. Based on Assumption 5.2, ambient pressure effects associated with the transmitter are included in instrument reference accuracy, Therefore:

$$e2Pa = 0$$

11.7.3 Power Supply Effects (e2Va)

Per Section 8.1, $e2Vn = 0.005\%$ span/volt

Per Reference 3.5, table 3, the maximum and minimum operating voltage available to drive the transmitters are 26 Vdc and 22 Vdc, respectively. Therefore, the maximum voltage variation possible for operating the transmitter is 4 Vdc.

$$e2Va = 0.00005 \bullet (200\text{" W.C.}) \bullet 4V)/1V$$

$$= \pm 0.04\text{" W.C.}$$

Using the transfer function determined in Section 11.4.1, The power supply error term expressed as transmitter output is as follows:

$$e2Va_{(1\sigma)} = \pm(e2Va_{(1\sigma)}) \bullet (dT/dP)$$

$$= \pm(0.04\text{" W.C.}) \bullet (0.08\text{ mA/" W.C.})$$

$$= \pm 0.0032\text{ mA}$$

11.7.4 Process Error (e2pa)

Process measurement errors are associated with the flow element and were evaluated under Section 11.3.1. There are no additional process errors associated with the transmitter. Therefore,

$$e2pa = 0$$

11.7.5 Insulation Resistance Error (e2IRa)

Per References 3.18 and 3.19, the insulation resistance error is considered negligible with respect to other error terms, Therefore,

$$e2IRa = 0$$

11.7.6 Non-Random Input Error (e2ina)

The non-random error present at the input to the transmitter is due to the flow element and was calculated in Section 11.3.3

$$e2ina = e1 = \pm 1.6969\% \text{ of flow span}$$

From Section 8.2, the dp span is 200" W.C.. Per Reference 3.2, % flow span to % dp span is converted as below:

Evaluating at maximum flow of 700 GPM:

$$\%\ flow\ span\ error = \frac{\%\ dp\ span}{2} \cdot \frac{maximum\ flow}{normal\ flow}$$

$$\pm 1.6969\%\ flow\ span = \frac{\%\ dp\ span}{2} \cdot \frac{700\ GPM}{700\ GPM}$$

$$\%\ dp\ span = \pm 3.3938\%$$

$$e2ina_{@\ 700\ GPM} = \pm 3.3939\% \text{ span} \bullet (200\text{" W.C.}/100\% \text{ span})$$

$$= \pm 6.7876\text{" W.C.}$$

This error is propagated through the transmitter using the derivative of the transfer function determined in Section 11.5.1, as follows:

$$e2ina_{PROP} = \pm(e2ina_{@\ 700\ GPM})(\delta T_A/\delta P)$$

$$= \pm(6.7876\text{" W.C.})(0.08\ mA/\text{" W.C.})$$

$$= \pm 0.543008\ mA$$

11.7.7 Transmitter Total Non-Random Error ($\sum e2a$)

$$\sum e2a = (e2Ha + e2Pa + e2Va + e2pa + e2IRa + e2ina_{PROP})$$

$$= \pm(0 + 0 + 0.0032\ mA + 0 + 0 + 0.543008\ mA)$$

$$= \pm 0.546208\ mA$$

COMMONWEALTH EDISON COMPANY



11.8 MASTER TRIP UNIT ERRORS (MODULE 3)

Module 3 Has an analog input with a discrete output, classified as a bistable module.

11.8.1 Random Error - Bistable Module ($\sigma_3$) (Master Trip Unit)

11.8.1 MTU Trip Point Repeatability (RPT2)

The vendor repeatability specification listed in Section 8.2 defines a 2σ value that is accurate for 6 months (Design Inputs 4.3, 4.4). The calibration frequency (SI) is 18 months and the late factor (LF) is 4.5 months. Therefore,

The maximum temperature at the MTU location is 80°F (which is within the vendor's 60°F to 90°F repeatability spec.) and the input span is 4.0 Vdc.

RPT3n = ±(0.13% of span /100°F)/6 months)(SI)(1 + LF/SI)

RPT3n = ±([0.0013•(4.0 Vdc)]/6months)•(18 months)•(1+ 4.5/18)

= ± 0.0195 Vdc

The vendor's specification for accuracy is a 2σ value. Therefore, the standard deviation for reference accuracy is as follows,

$RPT3n_{(1\sigma)}$ = (± 0.0195 Vdc) / 2

= ± 0.00975 Vdc

11.8.2 MTU Calibration Error (CAL3)

11.8.2.1 Calculation of $MTE3_{IN}$

From Section 9.2.2.6, The worst case MTE used to measure the input to the MTE is

$MTE3_{IN}$ = ± 0.00220 Vdc

11.8.2.2 Calculation of STD3

The error due to calibration accuracy of calibration equipment is assumed to be negligible. Therefore,

STD3 = 0

The calibration error is determined as follows:

$$CAL3 = [(MTE3_{IN})^2 + (STD3)^2]^{n}$$

$$= \pm[(0.00220\ Vdc)^2 + (0)^2]^{½}$$

$$= \pm\ 0.00220\ Vdc$$

11.8.3 Setting Tolerance (ST3)

The master trip unit setpoint setting tolerance is given in Section 10.^.

$$ST2 = \pm\ 0.012\ Vdc$$

Per Section 2.1.a, ST1 is considered as a 3σ value, therefore $ST_{3(1\sigma)} = ST_3/3$.

$$ST_{3(1\sigma)} = \pm\ 0.012\ Vdc/3 \qquad = \pm 0.004\ Vdc$$

11.8.4 Random Input Errors (σ3inn)

The random error present at the input to the MTU is due to the transmitter and was calculated in Section 11.4.2.11. Calculation of $\sigma2_{Prop}$ is equivalent to the scaling conversion due to the Linearity of the devices. The value for σ2n determined for the transmitter is provided in terms of the transmitter output. Therefore,

$$\sigma3inn = \sigma2_{Prop} \approx \pm\sigma2n$$

$$\sigma3ina = \pm\ 0.551936\ mA$$

Convert σ3ina from 4 to 20mA to 1 to 5 Vdc by multiplying with 250Ω resistor,

$$\sigma3inn = \pm\ (0.552310\ mA) \bullet (250\Omega)$$

$$= \pm\ 0.138078\ Vdc$$

11.8.5 Drift Error (D3)

Based on Design Input 4.3, the drift error associated with the MTU is included in the repeatability. Therefore:

$$D3 = 0$$

11.8.6 Temperature Error (e3Tn)

Based on Design Input 4.3, the temperature error associated with the MTU is included in the repeatability. Therefore:

$$e3Tn = 0$$

11.8.7 Determination of MTU Random Errors ($\sigma 3n$)

$$\sigma 3n = [(RPT3_{(1\sigma)})^2 + (CAL3)^2 + (ST3)^2 + (\sigma 3inn)^2 + (D3)^2 + (e3Tn)^2]^{0.5}$$

$$= [(0.00975\ Vdc)^2 + (0.00220\ Vdc)^2 + (0.004\ Vdc)^2 + (0.138078\ Vdc)^2 + (0)^2 + (0)^2]^{0.5}$$

$$\sigma 3n = \pm\ 0.138497\ Vdc$$

COMMONWEALTH EDISON COMPANY



11.9 Random Error, Accident Conditions ($\sigma3a$)

11.9.1 MTU Trip Point Repeatability (RPT3a)

The vendor does provide accident condition specifications for the MTU. However, the MTU is located in a controlled environmental area such that Normal Operating Conditions and Accident Conditions are the same (Section 8.2). From Section 11.8.1,

RPT3a = RPT3n = ± 0.00975 Vdc

11.9.2 MTU Calibration Error (CAL3)

Calibration of the MTU takes place during normal plant conditions. Therefore, The calibration error for normal and accident conditions are the same. From Section 11.8.2:

CAL3 = ± 0.00220 Vdc

11.9.3 MTU Setting Tolerance (ST3)

Calibration of the MTU takes place during normal plant conditions. Therefore, The setting tolerance for normal and accident conditions are the same. From Section 11.8.3:

ST3 = ± 0.004 Vdc

11.9.4 Drift Error (e3D)

Based on Design Input 4.3, the drift error associated with the MTU is included in the repeatability error. Therefore:

e3D = 0

11.9.5 Temperature Error (e2Ta)

Based on Design Input 4.3, the temperature error associated with the MTU is included in the repeatability error. Therefore:

e3Ta = 0

## COMMONWEALTH EDISON COMPANY



11.9.6 Random Input Errors ($\sigma 3ina$)

The random error present at the input to the MTU is due to the transmitter and was calculated in Section 11.5.11. Calculation of $\sigma 2_{Prop}$ is equivalent to the scaling conversion due to the linearity of the devices. The value for $\sigma 2a$ determined for the transmitter is provided in terms of the transmitter output. Therefore,

$$\sigma 3ina = \sigma 2_{Prop} = \pm \sigma 2a$$

$$\sigma 3ina = \pm 0.628431 \text{ mA}$$

Convert $\sigma 3ina$ from 4 to 20mA to 1 to 5 Vdc by multiplying with 250Ω resistor,

$$\sigma 3ina = \pm (0.628431 \text{ mA}) \bullet (250\Omega)$$

$$= \pm 0.157108 \text{ Vdc}$$

11.9.7 Determination of MTU Random Errors ($\sigma 3a$)

$$\sigma 3a = [(RPA3_{(1\sigma)})^2 + (CAL3)^2 + (ST3)^2 + (\sigma 3ina)^2 + (D3)^2 + (e3Ta)^2]^{0.5}$$

$$= [(0.00975 \text{ Vdc})^2 + (0.00220 \text{ Vdc})^2 + (0.004 \text{ Vdc})^2 + (0.157108 \text{ Vdc})^2 + (0)^2 + (0)^2]^{0.5}$$

$$\sigma 3a = \pm 0.157476 \text{ Vdc}$$

11.10 Non-Random Errors for Normal Operation ($\sum$e3n)

11.10.1 Humidity Error (e3Hn)

There are no humidity related errors described in the vendor's specifications for this device. Based on assumption 5.2, humidity effects associated with the MTU are included in the repeatability error. Therefore:

e3Hn = 0

11.10.2 Radiation Error (e3Rn)

Based on Reference 3.5, the radiation level within the MTU environment during accident plant conditions is < 1 x $10^3$ RADS TID. From Reference 3.8, the accuracy of the MTU will remain within its stated repeatability within radiation levels $\leq$ 1 x $10^5$ RADS TID. Therefore:

e3Rn = 0

11.10.3 Seismic Error (e3Sn)

A seismic event defines a particular type of accident condition. Errors included on the instrument due to seismic vibrations are defined only for accident conditions and therefore, are not applicable during normal plant conditions.

e3Sn = 0

11.10.4 Static Pressure Error (e3SPn)

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

e3SPn = 0

11.10.5 Pressure Error (e3Pn)

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

e3Pn = 0

11.10.6 Power Supply Error (e3Vn)

There are no power supply variation effects stated in the vendor's specifications for this device. Based on Assumption 5.2, error effects associated with power supply fluctuations are included in the repeatability error. Therefore:

$e3Vn = 0$

11.10.7 Process Error (e3pn)

The MTU is an electrical device and as such is not affected by process errors. Therefore:

$e3pn = 0$

11.10.8 Non-Random Input Error (e3inn)

The non-random error present at the input to the trip unit, is due to the transmitter and was calculated in Section 11.6.7:

$e3inn = \Sigma e2n$

$= \pm 0.0032$ mA

Convert e3inn from 4 to 20mA to 1 to 5 Vdc by multiplying with 250Ω resistor,

$e3inn = \pm (0.0032 \text{ mA}) \bullet (250\Omega)$

$= \pm 0.0008$ Vdc

11.10.9 Insulation Resistance Error (e3IRn)

Insulation resistance error is not applicable during normal plant conditions, which have a small controlled range of temperature and humidity conditions, and there is no effect applicable as noted below:

$e3IRn = 0$

11.10.10 Total Non-Random Error (Σe3n)

The total non-random error for the MTU under normal operating conditions is determined below.

$\Sigma e3n = \pm(e3Hn + e3Rn + e3Sn + e3SPn + e3Pn + e3Vn + e3pn + e3inn + e3IRn)$

$= \pm(0 + 0 + 0 + 0 + 0 + 0 + 0 + 0.0008 \text{ Vdc} + 0)$

$= \pm 0.0008$ Vdc

COMMONWEALTH EDISON COMPANY



11.11 Non-Random Errors for Accident Operation (∑e3a)

11.11.1 Humidity Error (e3Ha)

There are no humidity related errors described in the vendor's specifications for this device. Based on assumption 5.4, humidity effects associated with the MTU are included in the repeatability error. Therefore:

e3Ha = 0

11.11.2 Radiation Error (e3Ra)

Based on Reference 3.5, the radiation level within the MTU environment during accident plant conditions is $< 1 \times 10^3$ RADS TID. From Reference 3.8, the accuracy of the MTU will remain within its stated repeatability within radiation levels $\leq 1 \times 10^5$ RADS TID. Therefore:

e3Ra = 0

11.11.3 Seismic Error (e3Sa)

From Section 8.2, and Reference 3.16, the MTU will remain within its stated repeatability when subjected to seismic vibrations with a ZPA of 1.17 g OBE and 1.75 g SSE, Which is well above the station guidelines of 0.02g. Therefore:

e3Sa = 0

11.11.4 Static Pressure Error (e3SPa)

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

e3SPa = 0

11.11.5 Pressure Error (e3Pa)

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

e3Pa = 0

11.11.6 Power Supply Error (e3Va)

There are no power supply variation effects stated in the vendor's specifications for this device. Based on Assumption 5.2, error effects associated with power supply fluctuations are included in the repeatability error. Therefore:

e3Va = 0

11.11.7 Process Error (e3pa)

The MTU is an electrical device and as such is not affected by process errors. Therefore:

e3pa = 0

11.11.8 Non-Random Input Error (e3ina)

The non-random error present at the input to the trip unit, ∑e2a, is due to the transmitter and was calculated in Section 11.7.7:

e3ina = ∑e2a

e3ina = ± 0.546208 mA

Convert e3inn from 4 to 20mA to 1 to 5 Vdc by multiplying with 250Ω resistor,

e3ina = ± (0.546208 mA) • (250Ω)

= ± 0.136552 Vdc

11.11.9 Insulation Resistance Error (e3IRa)

Per References 3.18 and 3.19, the insulation resistance error is considered negligible with respect to other error terms, Therefore,

e3IRa = 0

11.11.10 Total Non-Random Error (Σe3a)

The total non-random error for the MTU under accident operating conditions is determined below.

∑e3a = (e3Ha + e3Ra + e3Sa + e3SPa + e3Pa + e3Va + e3pa + e3ina + e3IRa)

= (0 + 0 + 0 + 0 + 0 + 0 + 0 + 0.136552 Vdc + 0)

∑e3a = ± 0.136552 Vdc

COMMONWEALTH EDISON COMPANY



12.0 TOTAL ERROR, NORMAL OPERATING AND ACCIDENT CONDITIONS (TE3)

Per Reference 3.2 methodology, the total error is defined as;

$TE3 = 2\bullet(\sigma 3) + \Sigma e3$

where: $\sigma 3$ = total randon error
$\Sigma\epsilon 3$ = total non-random error

12.1 Total Error, Normal Operating Conditions (TE3n)

From Section 11.8.7, $\sigma 3n = \pm\ 0.138403$ Vdc
From Section 11.10.10, $\Sigma e3n = \pm\ 0.0008$ Vdc

TE3n $= \pm\ (2 \bullet 0.138497$ Vdc) + 0.0008 Vdc

$= \pm\ 0.277794$ Vdc [$2\sigma$]

Converting Total error (TE3n) in to process error (GPM),

Per Section 10.0, 0 to 700 GPM corresponds to 4 to 20 mA, which converts to 1 to 5 Vdc signal input to trip unit. Therefore, the transfer function of the trip unit can be written as,

T = (700 GPM/ 4 Vdc)(dP - 0) + 1 Vdc

The partial derivative of T with respect to dP yields:

**$\delta T/\delta dP$ = (700 GPM/4 Vdc) = 175 GPM/ Vdc**

TE3n $= \pm$ (0.277794 Vdc)$\bullet$(175 GPM/Vdc)

$= \pm\ 48.61395$ GPM $= \pm\ 50$ GPM [$2\sigma$]

12.2 Total Error, Accident Conditions (TE3a)

From Section 11.9.7 $\sigma 3a = \pm\ 0.157457$ Vdc
From Section 11.11.10, $\Sigma e3a = \pm\ 0.136552$ Vdc

TE3a $= \pm\ (2 \bullet 0.157476$ Vdc) + 0.136552 Vdc

$= \pm\ 0.451504$ Vdc [$2\sigma$]

Converting Total error (TE3a) in to process error (GPM),

TE3a $= \pm$ (0.451504 Vdc)$\bullet$(175 GPM/Vdc)

$= \pm\ 79.0132 = \pm\ 80$ GPM [$2\sigma$]

13.0 ERROR ANALYSIS

13.1 **DETERMINATION OF ALLOWABLE VALUE AND NOMINAL TRIP SETPOINT.**

From Section 10.0,

Analytical Limit (AL) = 600 GPM

13.2 **DETERMINATION OF NOMINAL TRIP SETPOINT (NTSP)**

From Section 12.2, total error TE3a = ± 80 GPM

For conservatism, an additional margin of ±1% of AL will be added for the determination of the setpoint.

MAR = ± (0.01) (600 GPM) = ± 6 GPM

From Reference 3.2, the nominal trip setpoint is calculated for the actuation on a increasing process parameter is given as,

NTSP = AL - (TE3a + MAR)

= 600 GPM - [80 GPM + 6 GPM]

= 514 GPM, This value be rounded down to 500 GPM

13.3 **DETERMINATION OF ALLOWABLE VALUE (AV)**

From Section 12.1, total error TE3n = ± 50 GPM

From Reference 3.2, the allowable value is calculated for the actuation on a increasing process parameter is given as,

AV = (NTSP + TE3n)

= (500 GPM + 50 GPM)

= 550 GPM

COMMONWEALTH EDISON COMPANY



## 14.0 ERROR ANALYSIS SUMMARY AND CONCLUSIONS

This calculation determined the allowable value (AV) and the Nominal Trip Setpoint (NTSP) for the Reactor Water Clean up system high flow break detection isolation.

The setpoint and allowable value are determined based on the Analytical limit of 600 GPM. The setpoint of 500 GPM, and an Allowable Value of 550 GPM provides 95/95 assurances that it will not exceed design and licensing bases.

The acceptance criteria, as defined in Section 2.2, has been met.

This calculation indicates with a high degree of confidence, for the following instruments, that the Tech Spec LCO (Allowable Value) and Analytical Limit will not be exceeded under accident and normal conditions respectively, when the transmitter/trip unit are calibrated to the new determined setpoint, and using the test equipment specified in Section 9.0.

1G33-N041A,B    1G33-N609A,B

THE INSTRUMENT MAINTENANCE DEPARTMENT SHOULD DEVELOP A PROCEDURE TO ACCOUNT FOR HIGH LINE STATIC PRESSURE EFFECT. THIS CALCULATION IS PREPARED WITH A PROCESS RANGE OF 0 TO [illegible]0 GPM CORRESPONDING TO A DP OF 0 TO 200" W.C. THIS RANGE DOES NOT ACCOUNT FOR HIGH LINE PRESSURE EFFECT. THIS SETTING TOLERANCE FOR THE TRANSMITTER SHOULD BE ± 0.02 Vdc, and THE MASTER TRIP UNIT SHOULD BE ± 0.012 Vdc.

[FINAL]

A-1 (FINAL)
Calculation L-001443,
Rev. 0

# RECORD OF TELEPHONE CONVERSATION

Date 09/09/94

Between Vikram Shah and B. Bejlovec
of Signals & Safeguards of CECo.
Telephone 815-357-6761, Ext. 2673 Subject Calibration of Rosemount Transmitters and the Span & Zero Adjustment For LaSalle Station. Station LaSalle Station Units 1 and 2

Memorandum:

I explained to Mr. Bejlovec the purpose of my call. I asked him if the LaSalle Instrument Mechanic Department have been instructed to chaeck the zero and span adjustment at he time of the calibration.

Answer

Mr.Bejlovec has stated that it is a general practice that every rosemount transmitters are check for the static and span correction at the time of the calibration. They have been asked to follow the manufacturer's instruction to perform the adjustment on the span & zero adjustment.

L-001443, Rev.0 ~~Design Input~~
Attachment B-1

ROSEMOUNT® Measurement Control Analytical Valves

Rosemount Inc.
12001 Technology Drive
Eden Prairie, MN 55344 U.S.A.
Tel (612) 941-5560
Telex 4310012
Fax (612) 828-3088

June 24, 1991

| Post-it™ brand fax transmittal memo 7671 | # of pages ▸ 5 |
|---|---|
| To Tom Herring | From Ed Kaczmorski |
| Co. S & S | Co. CECo |
| Dept. | Phone # (708) 515-7262 |
| Fax # (708) 255-5821 | Fax # |

Mr. Ed Kaczmorski
Commonwealth Edison Co.
Nuclear Engineering
1400 OPUS Place, Suite 400
Downers Grove, IL 60515

Re: Pressure Transmitter Performance Specifications

Dear Mr. Kaczmorski,

Per your request, the following information is forwarded to clarify the performance specifications of Rosemount commercial grade and nuclear qualified instrumentation.

Nuclear Qualified Instrumentation:

Rosemount Nuclear Qualified instrumentation applicable to Commonwealth Edison Plants are the Model 1152, 1153 Series B, 1153 Series D, 1154 and 1154 Series H Pressure Transmitters; Model 353C Conduit Seals; and the Model 710DU Trip/Calibration System. The specifications referenced in Rosemount literature are separated into 'Nuclear Specifications' which include the DBE simulation and 'Performance Specifications' which include transmitter performance under plant reference conditions.

The 'Nuclear Specifications' which include Radiation, Seismic, LOCA/HELB, and Post DBE are derived from the Type Testing completed on each model type. Due to the limited sample size in the Type Tests, these specifications are based on worst case errors plus margin as referenced in IEEE 323-1974 (1983). For most practical purposes, these specifications are considered 2-sigma. (Two standard deviations).

The 'Performance Specifications' are determined from testing completed on large samples of each model type. In addition, all manufactured units are tested to insure meeting published specifications prior to shipment. Therefore, these specifications are considered 3-sigma. (Three standard deviations).

There is one exception to this rule. The Point Drift Specification of ±.20% URL for 24 Months which replaces the Stability Specification of +/-.25% URL for 6 months for all nuclear transmitters is considered to be 2-sigma based on the sample size used during testing.

Rosemount Inc.
12001 Technology Drive
Eden Prairie, MN 55344 U.S.A.



Commercial Grade Instrumentation:

The specifications published for Rosemount commercial grade instrumentations are considered to be 3-sigma. All Model 1151 Transmitters, 444 Temperature Transmitters and related hardware specifications were based on testing of very large sample sizes. In addition, most all specifications are verified during manufacturing of the instruments.

Specifications written as +/- for both Nuclear and Commercial Grade instrumentation implies random uncertainty allowances within the specification band. These specifications are normally distributed for most practical purposes.

We anticipate this information will assist you in the interpretation of Rosemount specifications. If we can be of further assistance, please do not hesitate to contact us.

Sincerely,

Timothy J. Layer
Marketing Engineer
Rosemount Nuclear Products

cc: N. Hyrniw #7

TJL

# STATIC PRESSURE EFFECTS ON ROSEMOUNT NUCLEAR TRANSMITTERS

To obtain the highest accuracy flow and pressure measurements an understanding of the effects of high static pressure is needed. The purpose of this data sheet is to explain the effects of high static pressure on Rosemount nuclear pressure transmitters.

Static pressure affects the δ-*cell* in two different and independent ways. These effects are known as the zero effect and the span effect.

The first effect occurs with zero input differential to the cell. In this case, the effect of the static pressure on both the high and low side tend to cancel each other. The slight remaining shift in output is called the static pressure effect on zero or zero effect. While the maximum magnitude of the zero effect is predictable, its direction is not. However, the effect is repeatable for an individual transmitter and can be eliminated by simply re-zeroing the transmitter at line pressure.

To understand the second effect of static pressure, called the span effect, it is necessary to understand the inner workings of the δ-*cell*.

The δ-*cell* is a variable capacitance device. In the cell, differential pressure moves the sensing diaphragm between two fixed capacitor plates. See Figure 1. The varying capacitance between the sensing diaphragm and the plates is converted electronically to a 4-20 mA dc output that it is directly proportional to the differential pressure.

In the actual cell design the sensing diaphragm is stretched between the fixed plates and welded to the cylindrical body of the cell.

When high pressure is applied to both sides of the cell a slight deformation takes place, increasing tension radially in the sensing diaphragm. See Figure 2. The net effect of the increased tension is that the sensing diaphragm moves away from its nearer wall or capacitor plate, (this only happens at pressures other than zero differential pressure). As the static pressure increases, the tension increases causing a greater movement of the diaphragm. The movement of the diaphragm is always toward the zero differential pressure, or center position. With this in mind you can see the effect is to decrease output as static pressure is increased. In other words as static pressure increases, a slightly higher differential pressure is required to move the sensing diaphragm a given amount.

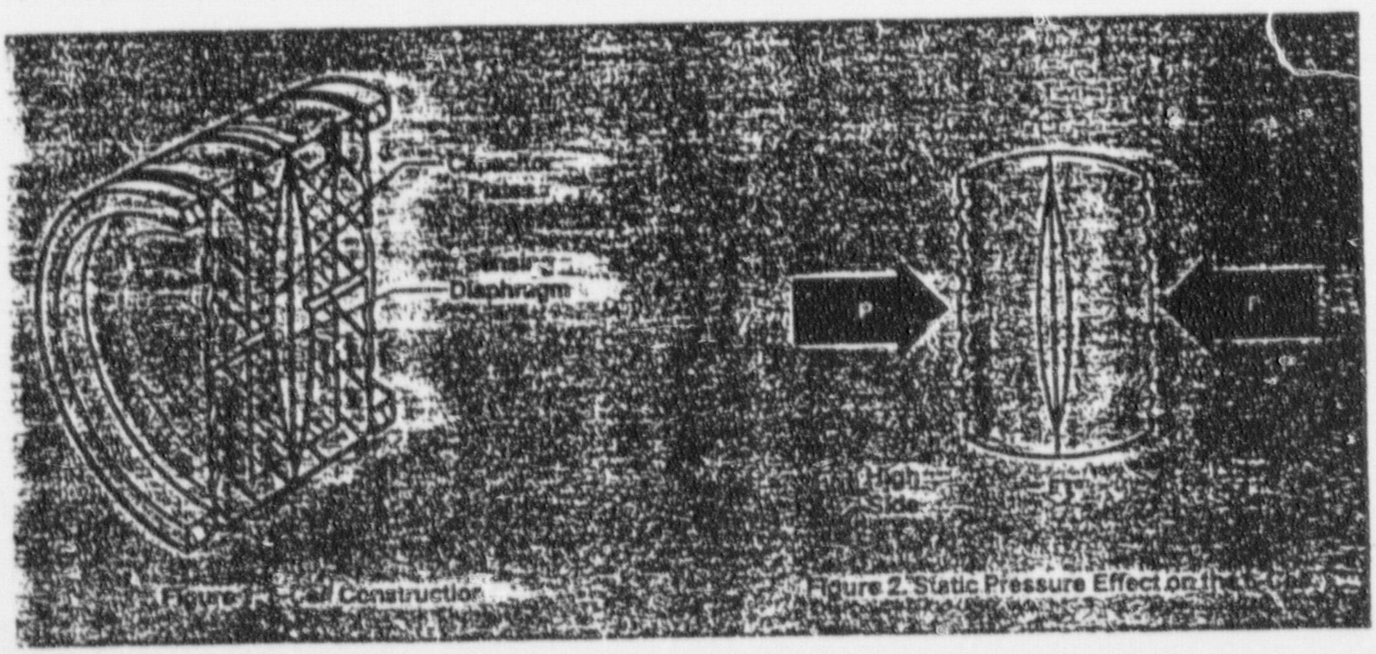


Figure 1. δ-*cell* Construction

Figure 2. Static Pressure Effect on the δ-Cell

When zero is elevated, or a higher pressure is applied to the low side than to the high side, the effect is to increase output as static pressure increases. This is easier to understand if you remember that in an elevated zero situation the position of the diaphragm at 4 mA is to the left of center. Note Figure 2. As process differential pressure increases, the diaphragm moves back toward the center position. The radial tension created by the static pressure causes the diaphragm to move even closer to the center position, thus increasing output.

The shift is called the static pressure effect on span or span effect, and is systematic or predictable, repeatable, and linear. Because the effect is systematic it can be calibrated out for any given static pressure and calibrated span. Testing done at Rosemount Inc., using a DeGranges differential dead-weight tester, and by others has confirmed the correction factors Rosemount Inc. specifies. There is an uncertainty associated with the correction, but this uncertainty is typically less than the published specification of ±0.5% of reading per 1000 psi.

SPAN CORRECTION SAMPLE PROCEDURE

The following is an example of how to correct for the effect of static pressure. The correction procedure uses the case of a Range Code 5 calibrated −100 in$H_2O$ to +300 in$H_2O$ with 1200 psi line pressure. Note that steps 2-5 are omitted for ranges based at zero differential pressure. From the instruction manual, the correction factor for Range Code 5 is 0.75% of input per 1000 psi static pressure. To start, use the standard calibration procedures to calibrate the unit so that its output is 4 mA at −100 in. and 20 mA at +300 in$H_2O$. Then use the following procedure to correct for the static pressure effect.

1. Calculate correction factor:
   0.75%/1000 psi × 1200 psi = 0.9% of differential pressure input.
2. Calculate 4 mA or zero point adjustment correction in terms of pressure: 0.9% of −100 in$H_2O$ = −0.9 in$H_2O$.
3. Convert zero point correction from pressure to percent of input span: −0.9 in$H_2O$/400 in. input span = −0.225% span.
4. Calculate zero point correction in terms of output span (mA): −0.225% of 16 mA span = −0.036 mA.
5. Arithmetically add zero correction to ideal zero output (4 mA). This is the corrected ideal zero output. 4.00 mA − 0.036 = 3.964 mA.
6. Calculate full scale or 20 mA point adjustment correction in terms of pressure: 0.9% of 300 in$H_2O$ = 2.7 in$H_2O$.
7. Repeat step 3 with the results of step 6: 2.7 in. per 400 in. input span = 0.675% span.
8. Repeat step 4 using the result of step 7: 0.675% of 16 mA = 0.108 mA.
9. Arithmetically add full scale correction to ideal full scale output (20 mA). This is the corrected ideal full scale output: 20.00 mA + 0.108 = 20.108 mA.
10. Readjust zero and span adjustments for corrected outputs:
    3.964 mA at −100 in$H_2O$
    20.108 mA at +300 in$H_2O$

ZERO CORRECTION

The static pressure zero effect can be trimmed out after installation with the unit at operating pressure. Equalize pressure to both process connections, and turn the zero adjustment until the ideal output at zero differential input is observed. Do not readjust the span pot. This completely eliminates the zero effect of line pressure. Please note that re-zeroing the transmitter will shift all of the calibration points the same amount toward the correct reading.

L-001443, Rev. C
B-5
FINAL

# STATIC PRESSURE EFFECTS ON ROSEMOUNT NUCLEAR TRANSMITTERS ZERO EFFECT CORRECTION PROCEDURE

The zero effect (or zero shift) associated with a static line pressure applied to a differential transmitter will be repeatable for a given transmitter, and can be eliminated by simply re-zeroing the transmitter at line pressure with zero DP across the unit.

If however the transmitter does not include zero DP within its calibrated span, the zero effect or zero correction can be determined before the unit is suppressed or elevated to eliminate the zero effect after correcting for the span effect.

The following procedure illustrates how to eliminate the zero effect for a non-zero DP based calibration. The example uses a Range Code 5 calibrated 100 $inH_2O$ to 500 $inH_2O$ with 1200 psi static line pressure.

1. Using standard calibration procedures calibrate the unit to the required span, with the 4 mA or ZERO point corresponding to zero DP:

   4 mA at 0 $inH_2O$ and 20 mA at 400 $inH_2O$

2. Apply static pressure to both H and L process connections with zero DP across the transmitter, and note the zero correction (zero shift). For example, if the output reads 4.006 mA, the zero correction is calculated as:

   4.00 mA - 4.006 mA = -0.006 mA

   Note the sign associated with this correction as this result will be algebraically added when determining the final, ideal transmitter output.

3. Remove static pressure and correct for the span effect by following the procedures as outlined in the transmitter instruction manual. Recalibrate the unit to the calculated output values. If, for example, the span correction procedure yielded 4.029 mA and 20.144 mA, calibrate the unit for:

   4.029 mA at 100 $inH_2O$
   20.144 mA at 500 $inH_2O$

4. Next, algebraically add the zero correction found in Step 2 (-0.006 mA) to the ideal zero point value calculated in Step 3.

   4.029 mA + (-0.006 mA) = 4.023 mA

5. To eliminate the zero effect, readjust only the zero pot so that the ouput reads the ideal zero point calculated in Step 4 (do not readjust the span pot). Note that all the calibration points will shift the same amount toward the correct reading. The example output is now 4.023 mA at 100 $inH_2O$.

   The transmitter output will now be 4-20 mA over its calibrated span when the unit is operated at 1200 psi static line pressue. There is an uncertainty associated with the span correction, but this is typically less than the published specification of ± 0.5% of reading per 1000 psi.

Rosemount Inc.
12001 TECHNOLOGY DRIVE EDEN PRAIRIE, MINNESOTA 55344 U.S.A.
PHONE: (612) 941-5560 TELEX: 4310024, 4310012 CABLE: ROSEMOUNT

# 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

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

Analog Output Accuracy = $\pm(0.15\%(SPAN) + (0.35\%)(SPAN)/100°F)(\Delta T))$

Analog Output Accuracy = $\pm(0.15\%(4\ Vdc) + (0.35\%)(4\ Vdc)/100°F)(30°F))$

Analog Output Accuracy = $\pm 0.0102$ 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 ($MTU_{TOR}$):

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

STU Trip Output Repeatability ($STU_{TOR}$):

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

In addition, Mr. Layer stated that the trip setpoint repeatability equations listed above include reference accuracy, temperature effects, and 'ft. The equations are accurate for 6 months. Based on calibration ,cedure 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.

**ROSEMOUNT**

L-001443, Rev. 0
Attachment D-1

Rosemount Aerospace Inc
1256 Trapp Road
Eagan MN 55121 USA
Tel (612) 681-8900
Telex 4310050
Fax (612) 681-8909

September 30, 1993

Mr. Victor Shah
Signals & Safegaurds
3375 N. Arlington Heights Road
Suite C
Arlington Heights, IL 60004

Subj: Nuclear Qualified Instrumentation Confidence Levels
Ref.: June 24, 1991 Letter to E. Kazcmarski of Commonwealth Edison

Dear Mr. Shaw,

The above referenced letter directed to E. Kazcmarski of Commonwealth Edison Co. was issued to state the confidence levels of Rosemount nuclear qualified pressure transmitter and nuclear qualified trip/calibration system specifications.

As we discussed, one correction and one clarification to the information supplied in the letter is required.

The correction to the above referenced letter is that the Model 510DU and/or 710DU Trip/Calibration System performance specifications should be considered a two-sigma confidence specification. The reason is that the Trip Point Repeatability Specification is a time-based specification over a six month period. Since Rosemount does not test 100% of trip units over a six month period to verify compliance with the specification, and since the qualification testing used a statistically small sample size, we cannot state a three-sigma confidence.

The clarification required involves the Model 1154 Series H Transmitter Ambient Temperature Effect Specification. The Model 1154 Series H has two Ambient Temperature Effect Specifications as follows:

Three-sigma:
± (0.75% URL + 0.50% Span) per 100 F over the Range 40 to 200 F.

Two-sigma:
± (0.15% URL + 0.35% Span) per 50 F over the Range 40 to 130 F.

Rosemount Inc.
Aerospace Division
1256 Trapp Road
Eagan, MN 55121 U.S.A.

D-2
L-0[illegible] Rev. 0
(FINAL)



As we discussed, Rosemount issued a 10CFR21 notification alerting users of Model 1154 Series H Transmitters that some units may not meet the two-sigma Ambient Temperature Effect Specification. All units met the three-sigma specification. The 10CFR21 notification listed a interim specification which should be used until more detailed evaluation is completed by Rosemount. (Reference Notification dated May 27, 1993).

The corrective action Rosemount is implementing in response to this issue is to review the production data for all transmitters shipped to determine;

1.0 Units meet the two-sigma specification
2.0 Units meet the interim specification
3.0 All new production units (100%) will be tested to the two-sigma specification, thus, resulting in a three-sigma confidence for new units ordered.

The evaluation of data for units shipped to the LaSalle Station should be completed in the next two weeks. Results will be issued to Mr. Seckenger at LaSalle and CECO Engineering.

Sincerely,

Timothy J. Layer
Sr. Marketing Engineer
Rosemount Nuclear Products

TJL/

# COMED NUCLEAR DESIGN INFORMATION TRANSMITTAL

| | | |
|---|---|---|
| ☑ SAFETY-RELATED<br>☐ NON-SAFETY-RELATED<br>☐ REGULATORY RELATED | Originating Organization<br>Section: ICPED<br>Company: Sargent & Lundy | **NDIT No.: LAS-ENDIT-0536**<br>Upgrade: 0<br>Page 1 of 2 |

Station: LaSalle County Units: 1

Design Change Authority No N/A

System: RT

To: Shah, Vikram - ComEd,

**Subject:**
Setpoint with new flow transmitter and trip unit in RWCU Recirc Line

| Name | Position | Signature | Date |
|---|---|---|---|
| Byskosh, Roman E. (Preparer) | Project Engineer | [signature] | 11/8/97 |
| Florian, Robert A. (Reviewer) | Project Engineer | Robert A. Florian | 11/8/97 |
| Gilautra, Vinod K. (Approver) | Senior Project Engineer | Vinod Gilautra | 11/10/97 |

**Status of Information:** ☑ Approved for Use ☐ Unverified ☐ Engineering Judgement

Verification Method N/A

Schedule:

**Purpose of Issuance**

Perform setpoint calculation to support the addition of RWCU high flow instrumentation in accordance with DCP 9700532, ECNs 001368E (ESSI) and 001369E (ESS2).

**Source of Information**

1) Vendor Drawing (Spec. J2961) 73927-1, -21, Rev. 1
2) UFSAR Section 3, Table 3.11-25 (AEER), Figure 3.11 - 1
   Table 3.11-6 (Rx Bldg.), Figure 3.11 - 1, 3.11 - 3

**Description of Information**

The following flow monitoring instruments are being added to improve the response time for detecting and isolating a break in the RWCU Recirculation Line for EQ purposes.

| Instrument | Manufacturer | Model No. | Location | Elec. Div. | EQ Zone |
|---|---|---|---|---|---|
| Transmitter (FT-1G33-N041A) | Rosemount | 1154 DH 5R | 1H22-P010 (Rx Bldg) (Elev. 710'-6") (Col. 14-E) | 1 | H4A |
| Master Trip Unit (FS-1G33-N609A) | Rosemount | 710 DU | 1H13-P629 (AEER) | 1 | C1B |

**Distribution:** SEAC

Jones, Gary C - Sargent & Lundy,
Gilautra, Vinod K. - Sargent & Lundy, ICPED
Murskyj, Mark P. - ComEd, DE-E
ComEd Microfilming
S&L Home Office

WIN No.: 2560

FINAL E-2

# COMED NUCLEAR DESIGN INFORMATION TRANSMITTAL

| | | |
|---|---|---|
| ☐ SAFETY-RELATED | Originating Organization | NDIT No.: LAS-ENDIT-0536 |
| ☐ NON-SAFETY-RELATED | Section: ICPED | Upgrade: 0 |
| ☐ REGULATORY RELATED | Company: Sargent & Lundy |  |

| | | | | | |
|---|---|---|---|---|---|
| Transmitter (FT-1G33-N041B) | Rosemount | 1154 DH 5R | Locally Mtd next to 1H22-P010 (Reactor Bldg) | 2 | H4A |
| Master Trip Unit (FS-1G33-N609B) | Rosemount | 710 DU | 1H13-P631 (AEER) | 2 | C1B |

The analytical limit has been set at 600 gpm at normal operating inlet process conditions. The basis for this limit is to detect break flow prior to exceeding area EQ limits, but high enough to avoid spurious actuations during system transients. Gary C. Jones 10 NOV.

Per source 1, the process calibrated DP at 1020PSIA & 533 Deg. F will be approximately 0-200 in WC corresponding to a flow of 0 700 gpm.

The flow monitoring instrument loop will be calibrated every refuel cycle.

The instrument loop is considered safety-related and has to be operable following a design basis accident.

The EQ zones are established per Source 2.

DP @ Design Flow is 101.62 in WC corresponding to 500 gpm. This does not include correction for high line pressures.