CALCULATION COVER SHEET

ComEd

ZION NUCLEAR STATION

Zion Calculation No.: 22S-B-004E-166

DESCRIPTION CODE: I04

SYSTEM CODE: RC

TITLE: COMS/LTOP Pressure Instrument Loop Accuracy Calculation

REFERENCE NUMBERS

Type	Number	Type	Number
PROJ	4950		

COMPONENT EPN:

EPN Number	Compt Type	Component
1(2)PT-403		
1(2)PT-405		
1(2)PXX-403		
1(2)PXX-405		

DOCUMENT NUMBERS:

Doc Type	Document Number
DWGC	See Sections 5.3.1 - 5.3.4
PROC	See Sections 5.2.2 - 5.2.4
DATA	See Section 5.6.1
CALC	22S-B-004E-189, Rev. 1

REMARKS: Revised calculation reflects a reduced loop uncertainty.

REV. NO.	REVISION	APPROVED	DATE
1	Revised Loop Accuracy	D.P. Galanis	11-4-96
0	Original Issue	D. P. Galanis	3/5/96

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CALCULATION TITLE PAGE

CALCULATION NO. 22S-B-004E-166 PAGE NO.: 1 OF 21

☒ SAFETY RELATED ☐ REGULATORY RELATED ☐ NON- SAFETY RELATED

CALCULATION TITLE:

COMS/LTOP Pressure Instrument Loop Accuracy Calculation

STATION/UNIT: ZION / 1&2 SYSTEM ABBREVIATION: RC

EQUIPMENT NO.

1(2)PT-403
1(2)PT-405
1(2)PXX-403
1(2)PXX-405

PROJECT NO. 4950

REV: 1 STATUS: Approved QA SERIAL NO. OR CHRON NO. N/A DATE: N/A

PREPARED BY: Chuck Hallett *CW Hallett* DATE: *11/4/96*

REVISION SUMMARY: Revised Assumption 3.1 to include reference to ComEd methodology document. Added Assumption 3.6 for maximum containment temperature. Added reference 5.1.6 to ISA-S67.04-1982. Recalculated module temperature effects as random variables as vendor specifies. Relocated drift consideration from bistable module to new channel drift section. Added statements that transmitter and bistable drift are 2σ random variables.

ELECTRONIC CALCULATION DATA FILES REVISED:
(Name ext/size/date/hour:min/verification method/remarks)

4-166R1.DOC/316416/11/4/96/5:21:12pm

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

REVIEWED BY: P. VandeVisse *CW Hallett For P. VandeVisse* DATE: *11/4/96*
REVIEW METHOD: *Detailed Review* COMMENTS (C, NC OR CI): *CI*

APPROVED BY: Dean Galanis *D.G. Galanis* DATE: *11-4-96*

COMMONWEALTH EDISON COMPANY
CALCULATION REVISION PAGE

CALCULATION NO. 22S-B-004E-166 PAGE NO.: 2 OF 21

REV: 0 STATUS: Approved QA SERIAL NO. OR CHRON NO. N/A DATE: 3/5/96

PREPARED BY: C. Hallett DATE: 1/18/96

REVISION SUMMARY: Initial Issue

ELECTRONIC CALCULATION DATA FILES REVISED: NONE
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DO ANY ASSUMPTIONS IN THIS CALCULATION REQUIRE LATER VERIFICATION
YES☐ NO☒

1. REVIEWED BY: S. McCarthy DATE: 3/1/96
2. REVIEW METHOD: Detailed Review COMMENTS (C, NC, CI): NC

3. APPROVED BY: D. Galanis DATE: 3/5/96

REV: STATUS: QA SERIAL NO. OR CHRON NO. DATE:

PREPARED BY: DATE:

REVISION SUMMARY:

ELECTRONIC CALCULATION DATA FILES REVISED:
(Name ext/size/date/hour:min/verification method/remarks)

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

1. REVIEWED BY: DATE:
2. REVIEW METHOD: COMMENTS (C, NC, CI): ______

3. APPROVED BY: DATE:

COMMONWEALTH EDISON COMPANY
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1. PURPOSE / OBJECTIVE

1.1 This calculation will determine the accuracy of the Core Over-pressurization Mitigation System (COMS) instrument channel; formerly known as Low Temperature Over-pressure Protection (LTOP). This calculation includes the combined sensor and Eagle-21 bistable uncertainties under normal environmental conditions only. The results are intended for use in separate setpoint calculations.

2. METHODOLOGY / ACCEPTANCE CRITERIA

2.1 The methodology used for this calculation is presented in TID-E/I&C-10, "Analysis of Instrument Channel Setpoint Error and Instrument Loop Accuracy" Rev. 0 [5.1.1] and TID-E/I&C-20, "Basis For Analysis of Instrument Channel Setpoint Error and Instrument Loop Accuracy", Rev.0 [5.1.2]. References 5.1.1 and 5.1.2 are consistent with the methodology within ISA S67.04-1982 [5.1.6].

2.2 The format for this calculation differs from that of TID-E/I&C-10 Rev 0 Exhibit B in order to comply with the format set forth in NEP-12-02, Rev 1.

2.3 Some instrument channels at nuclear power generating facilities perform functions that are critical for assuring the reactivity process is terminated, the reactor is safely shutdown, and the essential safety feature systems are initiated in a timely manner to mitigate the consequences of design basis accidents or transient events. For these channels, a very high confidence level in the estimation of total instrument channel error is appropriate for assuring that the instrument channel setpoint is established in a manner that allows the channel to perform its protective action during those events before critical safety limits are reached.

Other instrument channels perform functions that provide reactor operators with information that allows them to assess the readiness of safety systems by monitoring various system parameters and allowing operators to verify whether the reading indicates that the system meets certain acceptance criteria depicted in the plant technical specifications. These functions require only a moderate confidence level in the estimation of total instrument channel error.

Accordingly, a graded approach methodology, has been established where instrument channels are first classified into one of four levels (Level 1, Level 2, Level 3, and Level 4) according to the highest function served by the instrument channel. Then the errors in the channel modules are identified, documented, and propagated. Finally, the total error for the channel is determined by combining the errors using one of four methods, appropriate to channel level classification. Additionally, where applicable, the setpoint and/or allowable value and allowance for spurious trips (AST), are determined in the manner appropriate for the instrument channel classification

The methodology used in evaluating the accuracy of the loop process measurements and setpoints differ from TID-E/I&C-10 Rev 0 in the following areas:

Magnitude of confidence interval estimates

Method of determining Calibration Uncertainty

Method of combining non-random error terms

Application of Drift Error

These differences are in accordance with a Level 3 graded approach methodology. Level 3 is used for calculating setpoints or loop accuracies, where the instrument functions are utilized for EOP-non-operator actions and RG 1.97 Type B, C, D, and E parameters and Technical Specification Compliance Channels.

2.3.1 Magnitude of confidence interval estimates:

Total error is defined in Exhibit A of Reference 5.1.2 as: $Te = t\sigma \pm \Sigma e$

Where: t = confidence interval

σ = the total random error that affects the loop output

Σe = the sum of the positive or negative non-random errors that affect the loop output, whichever is applicable

For this calculation a value of 1 will be used for **t**.

2.3.2 Method of determining Calibration Uncertainty (CAL)

Calibration Standard errors (STD) are insignificant and will not be included in determining the Calibration Uncertainty (CAL).

Reference Accuracy to M&TE Calibrated Accuracy (RA:CAMTE) ratios must be less than 4:1 before being factored into the calibration uncertainty (CAL). If RA:CAMTE is 4:1 or greater, M&TE reading errors (REMTE), Temperature errors (TEMTE) and Other errors (OTHERMTE) are insignificant contributors to CAL and will be considered negligible.

When more than one item of M&TE is used to calibrate an instrument, the total reference accuracy of each item of M&TE must be summed algebraically to determine if RA:CAMTE ≥ 4:1

Determination of RA:CAMTE ratios may be achieved by review of M&TE available for use in the Instrument Maintenance Department inventory. Where alternate choices of M&TE are available, the uncertainty of one of a kind or specialized test equipment will not be considered a limiting value.

2.3.3 Method of combining Non-Random Symmetrical Error Terms

Non-random symmetrical error terms will be combined utilizing the square-root-sum-of-the-squares (SRSS) method rather than the algebraic method.

2.3.4 Application of Drift Error

The definition of the drift error term is changed to refer to the time dependent error associated with the performance of the entire instrument channel, rather than the performance of individual components within an instrument channel. The drift term (D) is combined with the channel accuracy to obtain a total channel accuracy. The minimum instrument channel drift error term (D) will be the greater of the known drift value or ±1% of span per year (2σ).

2.4 Acceptance Criteria

Not applicable to instrument uncertainty calculations

3. ASSUMPTIONS AND LIMITATIONS

3.1 In accordance with Reference 5.1.2, unless specific information is available to indicate otherwise,published instrument vendor accuracy specifications are assumed to be random, normally distributed, 2σ uncertainties; equivalent to a 95.5% probability the device error will be bound by the vendors accuracy term.

3.2 Temperature, humidity, normal radiation, pressure, static pressure and over-pressure effects have been incorporated when provided by the manufacturer. Otherwise, these errors are assumed to be small and capable of being adjusted out each time the instrument is calibrated. Therefore, unless specifically provided, errors can be assumed to be included within the instrument reference accuracy.

3.3 Power supply variations (eV) are assumed to be negligible due to the regulated and highly reliable sources of power supplied to the safety-related instrument busses.

3.4 Current leakage errors (eIRn) will be considered negligible due to the high insulation resistance values of instrument cable in normal (non-harsh) environments.

3.5 Measuring & Test Equipment Limitations

3.5.1 Pressure Transmitter input pressure is measured by a precision test gauge or digital indicator. Each specification given in Section 6.3.1.2 is the most conservative (greatest uncertainty) of the Heise Analog Series C & CM or Digital Series 7 and 9 available at Zion Station. These specifications do not include uncompensated analog gauges. Their ±0.1% full scale error per 5°F deviation from reference temperature preclude their use in a high temperature environment.

3.5.2 M&TE error is based upon use of the Fluke 8842A. The applicable calibration procedures References 5.2.1, 5.2.2 and 5.2.4 require use of a Fluke 8842A Digital Multimeter for DC voltage measurements.

3.6 Containment temperature is limited to an upper temperature of 120°F [Table 2] during normal plant operation. LTOP/COMS is active only with the plant shutdown and RCS temperature in the range of 60°F to 320°F. Under LTOP/COMS operating conditions, where heat is not added by the reactor, containment temperatures should approach ambient. Ambient temperature would be limited to a nominal summer high temperature of 90°F and therefore it is assumed that transmitter temperature should not exceed 90°F for the purpose of determining temperature effects related to LTOP/COMS.

4. DESIGN INPUT

4.1 The calibration interval for PT-403/405 from Reference 5.6.2 is 550 days (18 months), with an "increase interval" of 0 days. These values are the equivalents, respectively, to the terms "Surveillance Interval" and "Late Factor" of Reference 5.1.2.

4.2 Process Racks are the analog or digital modules downstream of the transmitter or sensing device which condition a signal and act upon it prior to input to a voting logic. For digital functions this includes; conversion resistor, transmitter power supply, signal conditioning A/D converter and CPU.

The Westinghouse Eagle-21 Process Rack design values from Reference 5.1.4 and equivalent ComEd designation are listed below:

4.2.1 Rack Calibration Accuracy = Reference Accuracy = ±0.2% span

4.2.2 Rack Comparator Setting Accuracy = Setting Tolerance = Not Applicable for digital processor

4.2.3 Rack Drift = Drift = ±0.3% span for 90 days for digital channels

4.2.4 Rack Temperature Effect = Temp. Effect = ±0.25% span

4.2.5 Seismic effects on process racks are included in Environmental Allowance
Environmental Allowance ⇒ Rack Seismic Effect = 0% span.

4.3 LOOP ELEMENT DATA

	MODULE #1 PT-403/405 [5.5.1]	MODULE #2 EAGLE-21 PXX-403/405 [5.1.4]
Manufacturer	Rosemount Inc.	Westinghouse
Model number	1154-GP9-RA	Eagle 21
Calibrated Span	Upper Range Limit (URL) 3000 psig Input 0 to 3000 psig Output 4 to 20 mAdc	Input 4 to 20 mAdc across 49.5717Ω Output - Contact Logic
Reference Accuracy	±0.25% of calibrated span	±0.20% span [4.2.1]
Stability (Drift)	±0.2% of URL / 30 months	±0.3% span / 3 months [4.2.3]
Humidity Limits	0 to 100% Relative Humidity	Not Specified
Temp. Effect	±(0.75% URL + 0.5% span) per 100°F	±0.25% span [4.2.4]
Radiation Effect	Not Specified for Non-accident condition	Not Specified
Seismic Effect	0.5% URL (7 g's)	0% span [4.2.5]
Static Pressure	N/A to non-differential pressure devices	N/A to electrical devices
Pressure Effect	Not Specified	N/A to electrical devices
Over Pressure Effect	0% @ <4500 psig	N/A to electrical devices
Power Supply Effect	<0.005% output span / volt	Included in Reference Accuracy

Table 1

4.4 LOCAL SERVICE ENVIRONMENT

	MODULE #1 PT-403/405 [5.4.1]	MODULE #2 PXX-403/405 [5.4.1]
EQ Zone	C1	A1
Location	Containment	Auxiliary Building 642' Col.: 27 Row: J
	NORMAL CONDITIONS	
Temperature Range	65°F to 120°F	74°F to 76°F
Pressure	14.7 psia -0.1 +0.3	Atmospheric
Humidity	10 to 50% RH	35 to 45% RH
Radiation	2×10^6 RAD Maximum integrated exposure [40 years + DBE]	1×10^4 RAD Total maximum integrated dose

Table 2

4.5 CALIBRATION PROCEDURE DATA

	MODULE #1 PT-403/405 [5.2.2]	MODULE #2 PC-403D [5.2.4]
Calibrated Input Range	0 to 3000 psig	4 to 20 mAdc (0.1983 to 0.9914 Vdc across 49.5717Ω)
Input Span	3000 psi	0.7931 Vdc
Output Range	0.1983 to 0.9914 Vdc (4 to 20 mAdc across 49.5717Ω input)	N/A - Logic Output
Output Span	0.7931 Vdc	N/A - Logic Output
Setting Tolerance	±0.004 Vdc (±0.5% span)	N/A [4.2.2]

Table 3

5. REFERENCES

5.1 METHODOLOGY

5.1.1 TID-E/I&C-10 Rev. 0, "Analysis of Instrument Channel Setpoint Error & Instrument Loop Accuracy",

5.1.2 TID-E/I&C-20 Rev. 0, "Basis for Analysis of Instrument Channel Setpoint Error & Loop Accuracy",

5.1.3 TID-E/I&C-26, "Evaluation of Measurement and Test Equipment Equivalency", Rev. 1

5.1.4 WCAP-12582 "Westinghouse Setpoint Methodology for Protections Systems, Zion Units 1 and 2, EAGLE 21 Version", dated August 1991 (Westinghouse Proprietary Version)

5.1.5 International Society for Measurement and Control Recommended Practice ISA-RP67.04 Part II "Methodologies for the Determination of Setpoints for Nuclear Safety-Related Instrumentation"

5.1.6 Instrument Society of America Standard ISA-S67.04-1982 "Setpoints for Nuclear Safety-Related Instrumentation Used in Nuclear Power Plants"

5.2 ZION STATION PROCEDURES

5.2.1 Zion Procedure IMAP-01 Rev. 11 "Procedure/Instructions/Cal Sheet Guidance"

5.2.2 Zion Procedure IMTS-1P-403 Rev. 1 "Reactor Coolant Wide Range Pressure Transmitter (Rack 1)"

5.2.3 Zion Procedure IMAS-1P-403 Rev. 3 "Reactor Coolant Wide Range Pressure Eagle Automatic Calibration (Rack 1)"

5.2.4 Zion Procedure IMMS-1P-403 Rev. 2 "Reactor Coolant Wide Range Pressure Eagle Manual Calibration (Rack 1)"

5.3 ZION STATION DRAWINGS

5.3.1 22E-1-4945A Rev. Y "Loop Schematic Diagram Reactor Coolant System Part 1"

5.3.2 22E-1-4945P Rev. S "Loop Schematic Diagram Reactor Coolant System Part 13"

5.3.3 22E-2-4945A Rev. Y "Loop Schematic Diagram Reactor Coolant System Part 1"

5.3.4 22E-2-4945P Rev. Q "Loop Schematic Diagram Reactor Coolant System Part 13"

5.4 ENVIRONMENTAL PARAMETERS

5.4.1 Zion Station Environmental Qualification Report; Appendix B - Plant Environmental Conditions Table, Revision 9

5.5 VENDOR PRODUCT INFORMATION

5.5.1 Rosemount Product Data Sheet 2514 Rev. 4/87 for Model 1154 Alphaline Nuclear Pressure Transmitters

5.5.2 Heise Bulletin HE-1 "Precision Pressure Gauges "

5.5.3 Heise Bulletin DP-1 "Series 7 Digital Pressure Indicators"

5.5.4 Heise Bulletin S9-1 "Series 9 Digital Pressure Instrument"

5.5.5 Fluke 8842A Digital Multimeter Instruction Manual, Rev. 2 6/86

5.6 OTHER REFERENCES

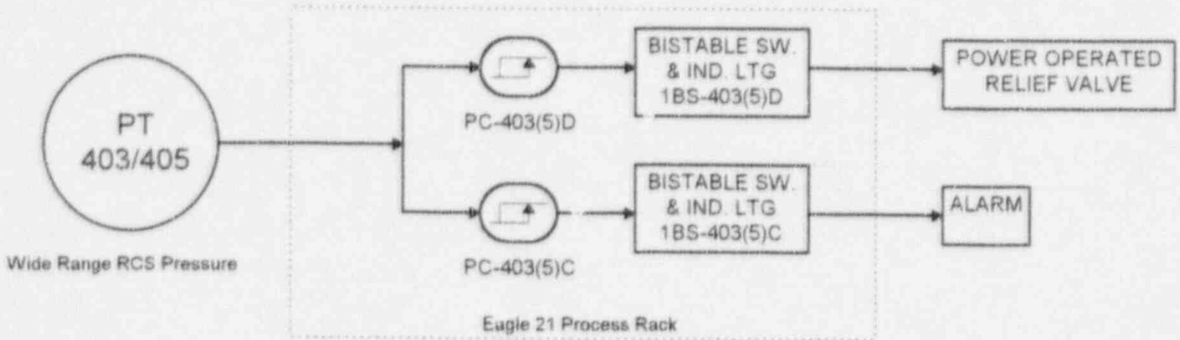
5.6.1 ComEd Instrument Database IDATA, Specific Verified Data Sheet, and Verified Supplemental Data Sheet for the following instruments:

1PT-403	Rev. C
1PT-405	Rev. C
2PT-403	Rev. C
2PT-405	Rev. C

5.6.2 Computer Data base GSIN - Instrumentation System Version 0.4

6. CALCULATIONS

6.1 INSTRUMENT CHANNEL CONFIGURATION AND DESCRIPTION



Pressure Transmitters PT-403 & 405, located inside containment, sense Reactor Coolant System (RCS) pressure. The transmitter outputs are routed through containment penetrations to the Eagle-21 Process Racks located in the Auxiliary Electric Room where they are converted from analog to digital signals. The digital pressure signals are compared to programmed values in the Eagle-21 processor memory. Bistable logic signals are generated whenever RCS pressure exceeds a programmed value (setpoint) to open the Power Operated Relief Valves (PORVs)

6.2 PROCESS PARAMETERS

The pressure transmitters sense RCS pressure and are scaled for 0 to 3000 psig. Uncompensated static head bias due to transmitter elevations versus tap location will be factored into a separate setpoint calculation, and are not accounted for in this calculation.

6.3 CALCULATION OF MODULE ERRORS

6.3.1 MODULE 1 ERRORS

6.3.1.1 RA (Reference Accuracy)

Transmitter output is measured at the Eagle-21 Process Rack

Output span = 793.1×10^{-3} Vdc [5.2.2]

$$Accuracy = \pm 0.25\% \text{ of Span} \bullet \text{Output Span} = \pm 0.0025 \bullet 0.7931 \text{ Vdc}$$ [Table 1]

$$= \pm 1983 \times 10^{-3} \text{ Vdc}$$

$$RA = \frac{Accuracy}{2} = \frac{\pm 1983 \times 10^{-3} \text{ Vdc}}{2}$$

$$= \pm 9915 \times 10^{-6} \text{ Vdc}$$

RA = ± 991.5x10^{-6} Vdc

6.3.1.2 CAL (Calibration Equipment Errors)

6.3.1.2.1 Input MTE1

0 - 3000 psig Pressure Gauge [5.5.2]

6.3.1.2.1.1 Station Calibration Accuracy **CAMTE**

$CAMTE = \pm 0.1\%\ \text{span} \bullet 3000\ \text{psi}$

$\pm 3\ \text{psi}$ [5.5.2]

CAMTE = ± 3 psi

6.3.1.2.1.2 Temperature error of M&TE **TEMTE**

Temp error specification $TE = \frac{\pm 0.004\%\ \text{span}}{°F > 95°}$ [5.5.3, 5.5.4]

Table 2Containment $Temp_{Max} = 90°F$ [3.6]

TEMTE = 0

6.3.1.2.1.3 Other M&TE Errors **OTHERMTE**

No further M&TE errors are identified

OTHERMTE = 0

6.3.1.2.1.4 Reading error of M&TE **REMTE**

$REMTE = \pm \frac{1}{4}$ smallest division on analog gauge

$= \pm \frac{1}{4} \bullet 5\ \text{psi}$ [5.1.3]

$= \pm 125\ \text{psi}$

REMTE = ± 1.25 psi

6.3.1.2.1.5 Sensor Transfer Function

$$\frac{\delta out}{\delta_{in}} = \frac{0.7931\ \text{Vdc}}{3000\ \text{psi}}$$ [5.2.2]

6.3.1.2.1.6 $MTE1_{prop}$

$$MTE1_{prop} = \pm\left[\left(\left(\frac{CAMTE}{2}+\frac{TEMTE}{2}+\frac{OTHERMTE}{2}\right)^2+REMTE^2\right)\bullet\left(\frac{\delta_{out}}{\delta_{in}}\right)^2\right]^{1/2}$$

$$= \pm\left[\left(\left(\frac{3\ psi}{2}+\frac{0}{2}+\frac{0}{2}\right)^2+(125\ psi)^2\right)\bullet\left(\frac{0.7931\ Vdc}{3000\ psi}\right)^2\right]^{1/2}$$

$$= \pm 516.2\times10^{-6}\ Vdc$$

$MTE1_{prop}$ = ±516.2x10^{-6} Vdc

6.3.1.2.2 Output M&TE2

Fluke Model 8842A DMM 0 to 2 Vdc Scale [5.5.5]

6.3.1.2.2.1 Station Calibration Accuracy **CAMTE**

Accuracy = ±0.0030% Rdg + 2 counts (fast speed) [5.5.5]

Resolution = 100 μV

$$CAMTE = \pm(0.003\% \bullet 1\ Vdc\ +\ 2 \bullet 100\mu Vdc)$$

$$= \pm\left(30\times10^{-6}+200\times10^{-6}\right)\ Vdc$$

$$= \pm 230.0\times10^{-6}\ Vdc$$

CAMTE = ±230.0X10^{-6} Vdc

6.3.1.2.2.2 Temperature error of M&TE **TEMTE**

The transmitter output is measured at the Eagle 21 racks in the Aux. Electric Room where temperature is controlled between 74 and 76°F [Table 2], falling within the DMM's certified temperature range of 73.4 ±9°F; therefore

TEMTE = 0

6.3.1.2.2.3 Other M&TE Errors **OTHERMTE**

No further M&TE errors are identified, therefore;

OTHERMTE = 0

6.3.1.2.2.4 Reading error of M&TE **REMTE**

REMTE = LSD (Least Significant Digit)

LSD = 100 μV

REMTE = 100x10^{-6} Vdc

6.3.1.2.2.5 MTE2

$$MTE2 = \pm\left[\left(\left(\frac{CAMTE}{2} + \frac{TEMTE}{2} + \frac{OTHERMTE}{2}\right)^2 + REMTE^2\right)\right]^{1/2}$$

$$= \pm\left[\left(\frac{230.0\times10^{-6}\ Vdc}{2} + \frac{0}{2} + \frac{0}{2}\right)^2 + \left(100\times10^{-6}\ Vdc\right)^2\right]^{1/2} = \pm152.4\times10^{-6}\ Vdc$$

MTE2 = ±152.4x10^{-6} Vdc

6.3.1.2.3 Calibration Error **CAL**

$CAL = \pm[(MTE1)^2 + (MTE2)^2]^{1/2}$

$= \pm[(516.2\text{x}10^{-6}\ Vdc)^2 + (152.4\text{x}10^{-6}\ Vdc)^2]^{1/2}$

CAL = ±538.2x10^{-6} Vdc

6.3.1.3 Calibration Setting Tolerance Uncertainty **ST**

$ST_{3\sigma} = \pm0.004\ Vdc$

$$ST = \frac{ST_{3\sigma}}{3} = \frac{\pm0.004\ Vdc}{3} = \pm1.333\times10^{-3}\ Vdc$$ [Table 3]

ST = ±1.333x10^{-3} Vdc

6.3.1.4 Sensor Temperature Effect **STE**

$$STE_{2\sigma} = \pm\frac{(0.75\%\ URL + 0.5\%\ Calibrated\ Span)}{100\ ^\circ F}$$ [5.5.1]

$$= \pm\frac{(0.0075 \bullet 3000\ psi + 0.005 \bullet 3000\ psi)}{100\ ^\circ F}$$

$$= \pm\frac{37.5\ psi}{100\ ^\circ F}$$

$$\Delta T = T_{max_{normal}} - T_{min\ normal}$$ [3.6]

$$= 90^\circ F - 65^\circ F = 25^\circ F$$

$$\frac{\delta_{out}}{\delta_{in}} = \frac{793.1\times10^{-3}\ Vdc}{3000\ psi}$$

$$STE_{2\sigma} = \pm\Delta T \bullet error \bullet \frac{\delta_{out}}{\delta_{in}}$$

$$= \pm 25°F \bullet \frac{37.5\ psi}{100°F} \bullet \frac{793.1 \times 10^{-3}\ Vdc}{3000\ psi}$$

$$= \pm 2.478 \times 10^{-3}\ Vdc$$

$$STE = \frac{STE_{2\sigma}}{2} = \frac{\pm 2.478 \times 10^{-3}\ Vdc}{2}$$

$$= \pm 1.239 \times 10^{-3}\ Vdc$$

STE = ± 1.239x10^{-3} Vdc

6.3.1.5 Module Drift **D**

In accordance with Methodology Section 2.3.4, drift is determined on a channel basis and will not be included in determining the individual module uncertainty.

6.3.1.6 Determination of Random Errors σ**1**

$\sigma 1 = \pm\ [RA^2 + CAL^2 + ST^2 + STE^2]^{1/2}$

$= \pm\ [(991.5 \times 10^{-6}\ Vdc)^2 + (538.2 \times 10^{-6}\ Vdc)^2 + (1.333 \times 10^{-3}\ Vdc)^2 + (1.239 \times 10^{-3}\ Vdc]^{1/2}$

$\sigma 1$ = ± 2.141x10^{-3} Vdc

6.3.1.7 Determination of Non-random Errors Σ**e1**$^+$ and Σ**e1**$^-$

6.3.1.7.1 Humidity Error **eH**

eHn = 0 [3.1]

6.3.1.7.2 Seismic Error **eS**

$$error = \pm 0.5\%\ URL$$

$$eSnsym = error \bullet \frac{\delta_{out}}{\delta_{in}}$$

$$= (0.5\% \bullet 3000\ psi) \bullet \frac{793.1 \times 10^{-3}\ Vdc}{3000\ psi}$$

$$= \pm 3.966 \times 10^{-3}\ Vdc$$

eSnsym = ± 3.966x10^{-3} Vdc

6.3.1.7.3 Over Pressure Error **eOP**

eOP = 0 [Table 1]

6.3.1.7.4 Power Supply Error **eV**

eVn = 0 [3.3]

6.3.1.7.5 Total Positive Non-random Error $\Sigma en1^+$

$$\Sigma en1^+ = \left[(eHn^+)^2 + (eSn^+)^2 + (eOPn^+)^2 + (eVn^+)^2\right]^{1/2}$$

$$= \left[0^2 + (3.966 \times 10^{-3}\ \text{Vdc})^2 + 0^2 + 0^2\right]^{1/2}$$

$$= +3.966 \times 10^{-3}\ \text{Vdc}$$

$\Sigma en1^+ = +3.966 \times 10^{-3}$ Vdc

6.3.1.7.6 Total Negative Non-random Error $\Sigma en1^-$

$$\Sigma en1^- = -\left[(eHn^-)^2 + (eSn^-)^2 + (eOPn^-)^2 + (eVn^-)^2\right]^{1/2}$$

$$= -\left[0^2 + (3.966 \times 10^{-3}\ \text{Vdc})^2 + 0^2 + 0^2\right]^{1/2}$$

$$= -3.966 \times 10^{-3}\ \text{Vdc}$$

$\Sigma en1^- = -3.966 \times 10^{-3}$ Vdc

6.3.2 MODULE 2 ERRORS

6.3.2.1 RA (Reference Accuracy)

Accuracy = ±0.2% span [5.1.4]

= ±0.002 • 0.7931 Vdc

= $\pm 1.586 \times 10^{-3}$ Vdc

$$RA = \frac{Accuracy}{2} = \frac{\pm 1586 \times 10^{-3}\ \text{Vdc}}{2}$$

$$= \pm 7931 \times 10^{-6}\ \text{Vdc}$$

RA = $\pm 793.1 \times 10^{-6}$ Vdc

6.3.2.2 CAL (Calibration Equipment Errors)

M&TE Error

Reference 5.2.3 required test equipment is a Fluke 8842A DMM, the same as required to calibrate the sensor. Only this DMM is used to verify accuracy of the EAGLE-21 Rack, therefore CAL = MTE2. From 6.3.1.2.2.5; MTE2 = $\pm 152.4 \times 10^{-6}$ Vdc, therefore;

RA:CAL = 793.1×10^{-6} Vdc : 152.4×10^{-6} Vdc = 5.2:1

Therefore, per Section 2.3.2;

CAL = ±0 Vdc

6.3.2.3 σ2input (Random Error at Module Input)

σ2input = ± 2.141×10^{-3} Vdc [6.3.1.4]

6.3.2.4 Rack Temperature Effect **RTE**

$$RTE_{2\sigma} = \pm 0.25\% \text{ span} \bullet 0.7931 \text{ Vdc span}$$

$$= \pm 1.983 \times 10^{-3} \text{ Vdc}$$

$$\text{RTE} = \frac{RTE_{2\sigma}}{2} = \frac{\pm 1.983 \times 10^{-3} \text{ Vdc}}{2}$$ [Table 1]

$$= 991.5 \times 10^{-6} \text{ Vdc}$$

RTE = ± 991.5×10^{-6} VdcTable 1

6.3.2.5 D (Module Drift)

In accordance with Methodology Section 2.3.4, drift is determined on a channel basis and will not be included in determining the individual module uncertainty.

6.3.2.6 Determination of Random Errors (σ2)

$$\sigma 2 = \pm [RA^2 + CAL^2 + \sigma 2input^2 + RTE^2]^{1/2}$$

$$= \pm [(793.1\times10^{-6} \text{ Vdc})^2 + (0 \text{ Vdc})^2 + (2.141\times10^{-3} \text{ Vdc})^2 + (991.5\times10^{-6} \text{ Vdc})^2]^{1/2}$$

σ2 = ± 2.489×10^{-3} Vdc

Converting Vdc to psi

$$\sigma 2 = \frac{\pm 2.489 \times 10^{-3} \text{Vdc}}{\frac{\delta_{out}}{\delta_{in}}} = \frac{\pm 2.489 \times 10^{-3} \text{Vdc}}{\frac{793.1 \times 10^{-3} \text{Vdc}}{3000 \text{ psi}}}$$

$$= \pm 9.415 \text{ psi}$$

6.3.2.7 Determination of Non-random Errors ($\Sigma e2^+$ and $\Sigma e2^-$) under Normal Operating Conditions

6.3.2.7.1 Seismic Error **eS**

eSn = 0 [Table 1]

6.3.2.7.2 Power Supply Error **eV**

eVn = 0 [3.3]

6.3.2.7.3 Non-random Errors Present in Input Signals **e2inputn**

$$e2inputn^{+} = \Sigma en1^{+}$$
$$= +3.966 \times 10^{-3} \text{ Vdc}$$ [6.3.1.7.5]

e2inputn⁺ = +3.966x10⁻³ Vdc

$$e2inputn^{-} = \Sigma en1^{-}$$
$$= -3.966 \times 10^{-3} \text{ Vdc}$$ [6.3.1.7.6]

e2inputn⁻ = −3.966x10⁻³ Vdc

6.3.2.7.4 Total Positive Non-random Error **$\Sigma en2^{+}$**

$$\Sigma en2^{+} = \left[\left(eSn^{+}\right)^{2} + \left(eVn^{+}\right)^{2} + \left(e2inputn^{+}\right)^{2}\right]^{1/2}$$
$$= \left[0^{2} + 0^{2} + \left(3.966 \times 10^{-3} \text{ Vdc}\right)^{2}\right]^{1/2}$$
$$= +3.966 \times 10^{-3} \text{ Vdc}$$

$\Sigma en2^{+} = +3.966 \times 10^{-3}$ Vdc

6.3.2.7.5 Total Negative Non-random Error **Σen2⁻**

$$\Sigma en2^- = -\left[\left(eSn^-\right)^2 + \left(eVn^-\right)^2 + \left(e2inputn^-\right)^2\right]^{1/2}$$

$$= -\left[0^2 + 0^2 + \left(3.966 \times 10^{-3}\ \text{Vdc}\right)^2\right]^{1/2}$$

$$= -3.966 \times 10^{-3}\ \text{Vdc}$$

$\Sigma en2^- = -3.966 \times 10^{-3}$ Vdc

6.3.2.7.6 Converting $\Sigma en2^{+/-}$ to psi

$$\Sigma en2^{+/-} = \frac{\pm 3.966 \times 10^{-3}\text{Vdc}}{\frac{\delta_{out}}{\delta_{in}}} = \frac{\pm 3.966 \times 10^{-3}\text{Vdc}}{\frac{793.1 \times 10^{-3}\text{Vdc}}{3000\ \text{psi}}}$$

$$= \pm 15.002\ \text{psi}$$

6.4 TOTAL INSTRUMENT CHANNEL ERROR

6.4.1 Channel Error

Positive Normal Channel Error (Cen^+)

$$Cen^+ = 1 \bullet \left(+\sigma 2\right) + \Sigma en2^+ = 1 \bullet +9.415\ \text{psi} + 15.002\ \text{psi}$$

$$= +24.417\ \text{psi}$$

$Cen^+_{psi} = +24.417$ psi

Negative Normal Channel Error (Ten^-)

$$Cen^- = 1 \bullet \left(-\sigma 2\right) + \Sigma en2^- = 1 \bullet -9.415\ \text{psi} + \left(-15.002\ \text{psi}\right)$$

$$= -24.417\ \text{psi}$$

$Cen^-_{psi} = -24.417$ psi

6.4.1 Channel Drift

6.4.1.1 Transmitter Drift

Vendor specifies the transmitter drift to be a 2σ random variable equal to ±0.2% of the Upper Range Limit (URL). The transmitter URL and calibrated span are both equal to 3000 psi, therefore the drift term is equivalent to ±0.2% span.

The 30 month interval specified by the vendor bounds the 18 month surveillance interval, therefore;

$$D_{xmtr} = \frac{Drift_{2\sigma}}{2} = \frac{\pm 0.2\%\ \text{span}}{2} = \pm 0.1\%\ \text{span}$$

6.4.1.2 Rack Drift

Vendor treats Eagle 21 rack drift as a 2σ random variable in Reference 5.1.4

Rack Drift = Drift = ±0.3% span for 90 days for digital channels

$$Drift_{2\sigma} = \pm\left[(0.3\%\ \text{span})^2 \bullet \left(\frac{18\ \text{months} \bullet 125\%}{3\ \text{months}}\right)\right]^{1/2}$$

$$= \pm 0.822\%\ \text{span}$$

$$D_{rack} = \frac{Drift_{2\sigma}}{2} = \frac{0.822\%\ \text{span}}{2} = \pm 0.411\%\ \text{span}$$

6.4.1.3 Channel Drift

Since both the transmitter vendor and the Rack vendor identify their respective drift error terms as random, it is considered reasonable to consider the $D_{channel}$ as random.

$$D_{calculated} = \pm\left(D_{xmtr}^2 + D_{rack}^2\right)^{1/2}$$

$$= \pm\left((0.1\%)^2 + (0.411\%)^2\right)^{1/2}$$

$$= \pm 0.423\%\ \text{span}$$

Per Methodology Section 2.3.4, the equivalent 1σ 22.5 month Channel Drift equals;

$$Drift_{min} = \pm \frac{\left[(1.0\%\ \text{span})^2 \bullet \left(\frac{18\ \text{months} \bullet 125\%}{12\ \text{months}}\right)\right]^{1/2}}{2}$$

$$= \pm 0.685\%\ \text{span}$$

The minimum channel drift error proscribed in Section 2.3.4 is greater than calculated drift and therefore conservative, therefore

$$D_{Channel} = \pm 0.685\%\ \text{span} \bullet 3000\ \text{psi}$$

$$= \pm 20.550\ \text{psi}$$

6.4.2 Total Instrument Channel Error

$$Ten^{+} = 1 \bullet \left((\sigma 2)^2 + (D_{Channel})^2 \right)^{1/2} + \Sigma en2^{+}$$

$$= 1 \bullet \left((9.417 \text{ psi})^2 + (20.550 \text{ psi})^2 \right)^{1/2} + 15.002 \text{ psi}$$

$$= +37.607 \text{ psi}$$

$$Ten^{-} = -1 \bullet \left((\sigma 2)^2 + (D_{Channel})^2 \right)^{1/2} + \Sigma en2^{-}$$

$$= -1 \bullet \left((9.416 \text{ psi})^2 + (20.550 \text{ psi})^2 \right)^{1/2} + (-15.002 \text{ psi})$$

$$= -37.607 \text{ psi}$$

$Ten^{\pm} = \pm 37.607$ psi ≈ ±38 psi

7. SUMMARY AND CONCLUSIONS

The Total Loop Error to be considered in determining Low Temperature Over-pressurization Protection Eagle-21 Setpoints is ± 38 psi; based upon pressure signals from PT-403 and PT-405 under normal operating conditions.

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