

CALCULATION COVER SHEET



ZION NUCLEAR STATION

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

Title.: COMS/LTOP Pressure Instrument Loop
Accuracy Calculation

Project Title: I&C Setpoint Program

PURPOSE: Determine the instrument loop uncertainty for use in further calculations for the PORV Core Overpressurization Mitigation System setpoint.

CALCULATION TYPE: IS **SR SOFTWARE USED:** None

PLANT DESIGN

CHANGE NUMBER: N/A **PROJECT NUMBER:** 4950

RELATED/REFERENCED

CALCULATIONS: None

**COMPONENT
IDENTIFICATION
NUMBERS:**

1/2PT-403

1/2PT-405

1/2PXX-403

1/2PXX-405

DRAWING

NUMBERS: 22E-1-4945A Rev. V

22E-1-4945P Rev. S

22E-2-4945A Rev. W

22E-2-4945P Rev. Q

REMARKS:

CHRON # 0313950

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CALCULATION TITLE PAGE

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<input checked="" type="checkbox"/> SAFETY RELATED <input type="checkbox"/> REGULATORY RELATED <input type="checkbox"/> NON- SAFETY RELATED			
CALCULATION TITLE: LTOP Pressure Instrument Loop Accuracy Calculation			
STATION/UNIT: ZION / 1&2		SYSTEM ABBREVIATION: RC	
EQUIPMENT NO. PT-403 PXX-403 PT-405 PXX-405		PROJECT NO. 4950	
REV: 0 STATUS: Approved		QA SERIAL NO. OR CHRON NO. 0313950	DATE: 1/18/96
PREPARED BY: Chuck Hallett		DATE: 1/18/96	
REVISION SUMMARY: Rev. 0 - INITIAL ISSUE			
ELECTRONIC CALCULATION DATA FILES REVISED: None (Name ext/size/date/hour:min/verification method/remarks)			
DO ANY ASSUMPTIONS IN THIS CALCULATION REQUIRE LATER VERIFICATION YES <input type="checkbox"/> NO <input checked="" type="checkbox"/>			
REVIEWED BY: Steve McCarthy		DATE: 3/1/96	
REVIEW METHOD: Detailed Review		COMMENTS (C OR NC): NC	
APPROVED BY: D. S. Galani		DATE: 3-5-96	

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1 PURPOSE / OBJECTIVE			
1.1	This calculation will determine the accuracy of the Core Overpressurization Mitigation System (COMS) instrumentation; 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].		
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	<p>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.</p> <p>Other instrument channels perform functions that provide reactor operators with information that allow 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.</p> <p>Accordingly, a graded approach methodology, has been established, following industry recommended practice [5.1.5, 5.1.6], 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</p> <p>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:</p> <p>Magnitude of confidence interval estimates</p> <p>Method of determining Calibration Uncertainty</p> <p>Method of combining non-random error terms</p> <p>Application of Drift Error</p>		
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<p>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."</p>		
<p>2.3.1 Magnitude of confidence interval estimates:</p> <p>Total error is defined in Exhibit A of Reference 5.1.2 as: $T_e = t\sigma \pm \Sigma e$</p> <p>Where: t = confidence interval</p> <p>σ = the total random error that affects the loop output</p> <p>Σe = the sum of the positive or negative non-random errors that affect the loop output, whichever is applicable</p> <p>For this calculation a value of 1 will be used for t.</p>		
<p>2.3.2 Method of determining Calibration Uncertainty (CAL)</p> <p>Calibration Standard errors (STD) are insignificant and will not be included in determining the Calibration Uncertainty (CAL).</p> <p>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.</p> <p>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 \geq 4:1</p> <p>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.</p>		
<p>2.3.3 Method of combining Non-Random Symmetrical Error Terms</p> <p>Non-random symmetrical error terms will be combined utilizing the square-root-sum-of-the-squares (SRSS) method rather than the algebraic method.</p>		
<p>2.3.4 Application of Drift Error</p> <p>The definition of the drift error term is changed to refer to the time dependent error associated with the performance of entire instrument channels, rather than the performance of individual components within an instrument channel. The drift term (D) is applied only in the calculation of total random error for the last module of the instrument channel. The minimum instrument channel drift error term (D) will be the greater of the known drift value or $\pm 1\%$ of span per year (2σ).</p>		
<p>2.4 Acceptance Criteria</p> <p>Not applicable to instrument uncertainty calculations</p>		
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3. ASSUMPTIONS AND LIMITATIONS			
3.1	Published instrument vendor specifications are considered to be random, normally distributed 2σ values unless specific information is available to indicate otherwise.		
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 $\pm 0.1\%$ 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.		
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 = $\pm 0.2\%$ span		
4.2.2	Rack Comparator Setting Accuracy = Setting Tolerance = Not Applicable for digital processor		
4.2.3	Rack Drift = Drift = $\pm 0.3\%$ span for 90 days for digital channels		
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4.2.4 Rack Temperature Effect = Temp. Effect = $\pm 0.25\%$ span4.2.5 Seismic effects on process racks are included in Environmental Allowance
Environmental Allowance \Rightarrow 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 49.5717 Ω Output - Contact Logic
Reference Accuracy	$\pm 0.25\%$ of calibrated span	$\pm 0.20\%$ span [4.2.1]
Stability (Drift)	$\pm 0.25\%$ of URL / 6 months	$\pm 0.3\%$ span / 3 months [4.2.3]
Humidity Limits	0 to 100% Relative Humidity	Not Specified
Temp. Effect	$\pm (0.75\% \text{ URL} + 0.5\% \text{ span})$ per 100°F	$\pm 0.25\%$ 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 105°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 x 10 ⁸ RAD Maximum integrated exposure [40 years + DBE]	1 x 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 49.5717 Ω)
Input Span	3000 psi	0.7931 Vdc
Output Range	0.1983 to 0.9914 Vdc (4 to 20 mAdc across 49.5717 Ω input)	N/A - Logic Output
Output Span	0.7931 Vdc	N/A - Logic Output
Setting Tolerance	± 0.004 Vdc ($\pm 0.5\%$ span)	N/A [4.2.2]

Table 3

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<u>5. REFERENCES</u>			
5.1 METHODOLOGY			
5.1.1 TID-E/I&C-10, "Analysis of Instrument Channel Setpoint Error & Instrument Loop Accuracy", Rev. 0			
5.1.2 TID-E/I&C-20, "Basis for Analysis of Instrument Channel Setpoint Error & Loop Accuracy", Rev. 0			
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 International Society for Measurement and Control Draft Technical Report ISA-dTR67.04.09 "Graded Approaches to Setpoint Determination" Draft 1, 1994			
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. 0 "Reactor Coolant Wide Range Pressure Transmitter (Rack 1)"			
5.2.3 Zion Procedure IMAS-1P-403 Rev. 2 "Reactor Coolant Wide Range Pressure Eagle Automatic Calibration (Rack 1)"			
5.2.4 Zion Procedure IMMS-1P-403 Rev. 0 "Reactor Coolant Wide Range Pressure Eagle Manual Calibration (Rack 1)"			
5.3 ZION STATION DRAWINGS			
5.3.1 22E-1-4945A Rev. V "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. W "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			
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5.5 VENDOR PRODUCT INFORMATION

5.5.1 Rosemount Product Data Sheet 2514 Rev. 4/87 for Model 1154 Alkaline 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

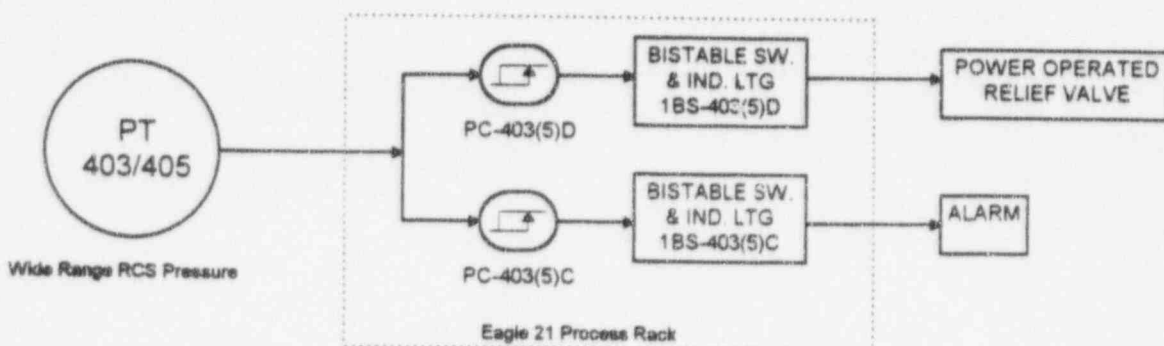


FIGURE 1

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).

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<p>6.2 PROCESS PARAMETERS</p> <p>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.</p> <p>6.3 CALCULATION OF MODULE ERRORS</p> <p>6.3.1 MODULE 1 ERRORS</p> <p>6.3.1.1 RA (Reference Accuracy)</p> <p>Transmitter output is measured at the Eagle-21 Process Rack</p> <p>Output span = 793.1×10^{-3} Vdc [5.2.2]</p> <p>Accuracy = $\pm 0.25\%$ of Span • Output Span = $\pm 0.0025 \cdot 0.7931$ Vdc [Table 1]</p> <p>$= \pm 1983 \times 10^{-3}$ Vdc</p> $RA = \frac{\text{Accuracy}}{2} = \frac{\pm 1983 \times 10^{-3} \text{ Vdc}}{2}$ <p>$= \pm 9915 \times 10^{-6}$ Vdc</p> <p>RA = $\pm 991.5 \times 10^{-6}$ Vdc</p> <p>6.3.1.2 CAL (Calibration Equipment Errors)</p> <p>6.3.1.2.1 Input MTE1</p> <p>0 - 3000 psig Pressure Gauge [5.5.2]</p> <p>6.3.1.2.1.1 Station Calibration Accuracy CAMTE</p> <p>CAMTE = $\pm 0.1\% \text{span} \cdot 3000$ psi [5.5.2]</p> <p>$= \pm 3$ psi</p> <p>CAMTE = ± 3 psi</p> <p>6.3.1.2.1.2 Temperature error of M&TE TEMTE</p> <p>Temp error specification $TE = \frac{\pm 0.004\% \text{ span}}{^{\circ}F > 95^{\circ}}$ [5.5.3, 5.5.4]</p> <p>$\Delta T = \text{Containment Temp}_{\text{max}} - \text{Reference Temp.}$ [Table 2]</p> <p>$\Delta T = 105^{\circ}F - 95^{\circ}F = 10^{\circ}F$</p> <p>$TEMTE = TE \cdot \Delta T \cdot \text{span}$</p> $= \frac{\pm 0.004\% \text{ span}}{^{\circ}F} \cdot 10^{\circ}F \cdot \frac{3000 \text{ psi}}{\text{span}}$ <p>$= \pm 12$ psi</p> <p>TEMTE = ± 1.2 psi</p>		
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<p>6.3.1.2.1.3 Other M&TE Errors OTHERMTE</p> <p>No further M&TE errors are identified</p> <p>OTHERMTE = 0</p>		
<p>6.3.1.2.1.4 Reading error of M&TE REMTE</p> $REMTE = \pm \frac{1}{4} \text{ smallest division on analog gauge}$ $= \pm \frac{1}{4} \cdot 5 \text{ psi}$ $= \pm 125 \text{ psi}$ <p>REMTE = ± 1.25 psi</p>		
<p>6.3.1.2.1.5 Sensor Transfer Function</p> $\frac{\delta_{out}}{\delta_{in}} = \frac{0.7931 \text{ Vdc}}{3000 \text{ psi}}$		
<p>6.3.1.2.1.6 MTE1_{prop}</p> $MTE1_{prop} = \pm \left[\left(\left(\frac{CAMTE}{2} + \frac{TEMTE}{2} + \frac{OTHERMTE}{2} \right)^2 + REMTE^2 \right) \cdot \left(\frac{\delta_{out}}{\delta_{in}} \right)^2 \right]^{1/2}$ $= \pm \left[\left(\left(\frac{3 \text{ psi}}{2} + \frac{1.2 \text{ psi}}{2} + \frac{0}{2} \right)^2 + (125 \text{ psi})^2 \right) \cdot \left(\frac{0.7931 \text{ Vdc}}{3000 \text{ psi}} \right)^2 \right]^{1/2}$ $= \pm 646.1 \times 10^{-6} \text{ Vdc}$ <p>MTE1_{prop} = ±646.1x10⁻⁶ Vdc</p>		
<p>6.3.1.2.2 Output M&TE2</p> <p>Fluke Model 8842A DMM 0 to 2 Vdc Scale</p>		
<p>6.3.1.2.2.1 Station Calibration Accuracy CAMTE</p> <p>Accuracy = ±0.0030% Rdg + 2 counts (fast speed)</p> <p>Resolution = 100 μV</p> $CAMTE = \pm (0.003\% \cdot 1 \text{ Vdc} + 2 \cdot 100 \mu\text{Vdc})$ $= \pm (30 \times 10^{-6} + 200 \times 10^{-6}) \text{ Vdc}$ $= \pm 230.0 \times 10^{-6} \text{ Vdc}$ <p>CAMTE = ±230.0x10⁻⁶ Vdc</p>		
<p>6.3.1.2.2.2 Temperature error of M&TE TEMTE</p> <p>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</p> <p>TEMTE = 0</p>		
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<p>6.3.1.2.2.3 Other M&TE Errors OTHERMTE</p> <p>No further M&TE errors are identified, therefore;</p> <p>OTHERMTE = 0</p> <p>6.3.1.2.2.4 Reading error of M&TE REMTE</p> <p>REMTE = LSD (Least Significant Digit)</p> <p>LSD = 100 μV</p> <p>REMTE = 100×10^{-6} Vdc</p> <p>6.3.1.2.2.5 MTE2</p> $MTE2 = \pm \left[\left(\frac{CAMTE}{2} + \frac{TEMTE}{2} + \frac{OTHERMTE}{2} \right)^2 + REMTE^2 \right]^{1/2}$ $= \pm \left[\left(\frac{230.0 \times 10^{-6} \text{ Vdc}}{2} + \frac{0}{2} + \frac{0}{2} \right)^2 + (100 \times 10^{-6} \text{ Vdc})^2 \right]^{1/2} = \pm 152.4 \times 10^{-6} \text{ Vdc}$ <p>MTE2 = $\pm 152.4 \times 10^{-6}$ Vdc</p> <p>6.3.1.2.3 Calibration Error CAL</p> $CAL = \pm [(MTE1)^2 + (MTE2)^2]^{1/2}$ $= \pm [(646.1 \times 10^{-6} \text{ Vdc})^2 + (152.4 \times 10^{-6} \text{ Vdc})^2]^{1/2}$ <p>CAL = $\pm 663.8 \times 10^{-6}$ Vdc</p> <p>6.3.1.3 Calibration Setting Tolerance Uncertainty ST</p> $ST_{3\sigma} = \pm 0.004 \text{ Vdc}$ $ST = \frac{ST_{3\sigma}}{3} = \frac{\pm 0.004 \text{ Vdc}}{3} = \pm 1333 \times 10^{-3} \text{ Vdc}$ <p>[Table 3]</p> <p>ST = $\pm 1.333 \times 10^{-3}$ Vdc</p> <p>6.3.1.4 Determination of Random Errors σ_1</p> $\sigma_1 = \pm [RA^2 + CAL^2 + ST^2]^{1/2}$ $= \pm [(991.5 \times 10^{-6} \text{ Vdc})^2 + (663.8 \times 10^{-6} \text{ Vdc})^2 + (1.333 \times 10^{-3} \text{ Vdc})^2]^{1/2}$ <p>$\sigma_1 = \pm 1.789 \times 10^{-3}$ Vdc</p> <p>6.3.1.5 Determination of Non-random Errors Σe_1^+ and Σe_1^-</p> <p>6.3.1.5.1 Humidity Error eH</p> <p>eHn = 0</p> <p>[3.2]</p>		
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6.3.1.5.2 Temperature Error eT

$$\text{error} = \pm \frac{(0.75\% \text{ URL} + 0.5\% \text{ Calibrated Span})}{100^\circ \text{F}} \quad [5.5.1]$$

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

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

$$\Delta T = T_{\text{max normal}} - T_{\text{min normal}}$$

$$= 105^\circ \text{F} - 65^\circ \text{F} = 40^\circ \text{F}$$

[Table 2]

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

$$eT_{\text{nsym}} = \pm \Delta T \cdot \text{error} \cdot \frac{\delta_{\text{out}}}{\delta_{\text{in}}}$$

$$= \pm 40^\circ \text{F} \cdot \frac{37.5 \text{ psi}}{100^\circ \text{F}} \cdot \frac{793.1 \times 10^{-3} \text{ Vdc}}{3000 \text{ psi}}$$

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

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

6.3.1.5.3 Seismic Error eS

$$\text{error} = \pm 0.5\% \text{ URL}$$

$$eS_{\text{nsym}} = \text{error} \cdot \frac{\delta_{\text{out}}}{\delta_{\text{in}}}$$

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

[Table 1]

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

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

6.3.1.5.4 Over Pressure Error eOP

$$eOP = 0$$

[Table 1]

6.3.1.5.5 Power Supply Error eV

$$eV_n = 0$$

[3.3]

6.3.1.5.6 Total Positive Non-random Error Σe_{n1^+}

$$\Sigma e_{n1^+} = \left[(eH_{n^+})^2 + (eT_{n^+})^2 + (eS_{n^+})^2 + (eOP_{n^+})^2 + (eV_{n^+})^2 \right]^{1/2}$$

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

$$= +5.609 \times 10^{-3} \text{ Vdc}$$

$$\Sigma e_{n1^+} = +5.609 \times 10^{-3} \text{ Vdc}$$

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

$$\begin{aligned}\Sigma en1^- &= -\left[(eHn^-)^2 + (eTn^-)^2 + (eSn^-)^2 + (eOPn^-)^2 + (eVn^-)^2\right]^{V2} \\ &= -\left[0^2 + (3.966 \times 10^{-3} \text{ Vdc})^2 + (3.966 \times 10^{-3} \text{ Vdc})^2 + 0^2 + 0^2\right]^{V2} \\ &= -5.609 \times 10^{-3} \text{ Vdc} \\ \Sigma en1^- &= -5.609 \times 10^{-3} \text{ Vdc}\end{aligned}$$

6.3.2 MODULE 2 ERRORS

6.3.2.1 RA (Reference Accuracy)

$$\text{Accuracy} = \pm 0.2\% \text{ span}$$

[5.1.4]

$$= \pm 0.002 \bullet 0.7931 \text{ Vdc}$$

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

$$RA = \frac{\text{Accuracy}}{2} = \frac{\pm 1.586 \times 10^{-3} \text{ Vdc}}{2}$$

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

$$RA = \pm 793.1 \times 10^{-3} \text{ Vdc}$$

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 = $\pm 152.4 \times 10^{-6} \text{ Vdc}$, therefore;

$$RA:CAL = 793.1 \times 10^{-6} \text{ Vdc} : 152.4 \times 10^{-6} \text{ Vdc} = 5.2:1$$

Therefore, per Section 2.3.2;

$$CAL = \pm 0 \text{ Vdc}$$

6.3.2.3 $\sigma 2_{\text{input}}$ (Random Error at Module Input)

$$\sigma 2_{\text{input}} = \pm 1.789 \times 10^{-3} \text{ Vdc}$$

[6.3.1.4]

6.3.2.4 D (Module Drift)

From Section 4.2.3;

Rack Drift = Drift = $\pm 0.3\%$ span for 90 days for digital channels

Rack Drift is normalized to 1 year by:

$$\begin{aligned} \text{VendorDrift}_{2\sigma} &= \pm \left[(0.3\% \text{ span})^2 \cdot \left(\frac{12 \text{ months}}{3 \text{ months}} \right) \right]^{1/2} \\ &= \pm 0.6\% \text{ span per 12 months} \end{aligned}$$

Vendor Drift is less than 1% span / 12 months, therefore, per Section 2.3.4 drift for the final element in a loop = $\pm 1\%$ span / 12 months.

$$\begin{aligned} \text{Drift}_{2\sigma} &= \pm \left[(1\% \text{ span})^2 \cdot \left(\frac{18 \text{ months}}{12 \text{ months}} \right) \right]^{1/2} \cdot \text{span} \\ &= \pm 12247\% \text{ span} \cdot 793.1 \times 10^{-3} \text{ Vdc} = \pm 9.713 \times 10^{-3} \text{ Vdc} \\ D &= \frac{\text{Drift}_{2\sigma}}{2} = 4.857 \times 10^{-3} \text{ Vdc} \end{aligned}$$

$$D = \pm 4.857 \times 10^{-3} \text{ Vdc}$$

6.3.2.5 Determination of Random Errors (σ_2)

$$\begin{aligned} \sigma_2 &= \pm [RA^2 + CAL^2 + \sigma_{2\text{input}}^2 + D^2]^{1/2} \\ &= \pm [(793.1 \times 10^{-6} \text{ Vdc})^2 + (0 \text{ Vdc})^2 + (1.789 \times 10^{-3} \text{ Vdc})^2 + (4.857 \times 10^{-3} \text{ Vdc})^2]^{1/2} \\ \sigma_2 &= \pm 5.236 \times 10^{-3} \text{ Vdc} \end{aligned}$$

6.3.2.6 Determination of Non-random Errors (Σe_2^+ and Σe_2^-) under Normal Operating Conditions6.3.2.6.1 Temperature Error e_T

$$e_{T\text{nsym}} = \pm 0.25\% \text{ span} \cdot 0.7931 \text{ Vdc span}$$

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

[Table 1]

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

6.3.2.6.2 Seismic Error e_S

$$e_{S\text{n}} = 0$$

[Table 1]

6.3.2.6.3 Power Supply Error e_V

$$e_{V\text{n}} = 0$$

[3.3]

6.3.2.6.4 Non-random Errors Present in Input Signals $e2inputn$

$$e2inputn^+ = \Sigma e1^+ \quad [6.3.1.5.6]$$

$$= +5.609 \times 10^{-3} \text{ Vdc}$$

$$e2inputn^+ = +5.609 \times 10^{-3} \text{ Vdc}$$

$$e2inputn^- = \Sigma e1^- \quad [6.3.1.5.7]$$

$$= -5.609 \times 10^{-3} \text{ Vdc}$$

$$e2inputn^- = -5.609 \times 10^{-3} \text{ Vdc}$$

6.3.2.6.5 Total Positive Non-random Error $\Sigma en2^+$

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

$$= \left[(1.983 \times 10^{-3} \text{ Vdc})^2 + 0^2 + 0^2 + (5.609 \times 10^{-3} \text{ Vdc})^2 \right]^{1/2}$$

$$= +5.949 \times 10^{-3} \text{ Vdc}$$

$$\Sigma en2^+ = +5.949 \times 10^{-3} \text{ Vdc}$$

6.3.2.6.6 Total Negative Non-random Error $\Sigma en2^-$

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

$$= - \left[(1.983 \times 10^{-3} \text{ Vdc})^2 + 0^2 + 0^2 + (5.609 \times 10^{-3} \text{ Vdc})^2 \right]^{1/2}$$

$$= -5.949 \times 10^{-3} \text{ Vdc}$$

$$\Sigma en2^- = -5.949 \times 10^{-3} \text{ Vdc}$$

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6.4 TOTAL INSTRUMENT CHANNEL ERROR

Positive Normal Total Instrument Channel Error (Ten^+)

$$Ten^+ = 1 \cdot (+\sigma_2) + \Sigma en_2^+ = 1 \cdot +5.236 \times 10^{-3} \text{ Vdc} + 5.949 \times 10^{-3} \text{ Vdc}$$

$$= 11.185 \times 10^{-3} \text{ Vdc}$$

$$Ten_{psi}^+ = \frac{Ten_{Vdc}}{\frac{\delta_{out}}{\delta_{in}}} = \frac{+11185 \times 10^{-3} \text{ Vdc}}{\frac{793.1 \times 10^{-3} \text{ Vdc}}{3000 \text{ psi}}}$$

$$= +42.3 \text{ psi}$$

$$Ten_{psi}^+ = +42.3 \text{ psi}$$

Negative Normal Total Instrument Channel Error (Ten^-)

$$Ten^- = 1 \cdot (-\sigma_2) + \Sigma en_2^- = 1 \cdot -5.236 \times 10^{-3} \text{ Vdc} + (-5.949 \times 10^{-3} \text{ Vdc})$$

$$= -11.185 \times 10^{-3} \text{ Vdc}$$

$$Ten_{psi}^- = \frac{Ten_{Vdc}}{\frac{\delta_{out}}{\delta_{in}}} = \frac{-11185 \times 10^{-3} \text{ Vdc}}{\frac{793.1 \times 10^{-3} \text{ Vdc}}{3000 \text{ psi}}}$$

$$= -42.3 \text{ psi}$$

$$Ten_{psi}^- = -42.3 \text{ psi}$$

7. SUMMARY AND CONCLUSIONS

The Total Loop Error to be considered in determining Low Temperature Overpressurization Protection Eagle-21 Setpoints is ± 42.3 psi; based upon pressure signals from PT-403 and PT-405 under normal operating conditions.

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