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Exelon Nuclear

RS-03-123

June 26, 2003

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D C 20555

Subject: LaSalle County Station, Units 1 and 2
Facility Operating License Nos. NPF-11 and NPF-18
NRC Docket Nos. 50-373 and 50-374

Response to Request for Additional Information to Support Request for Amendment to Technical Specifications Table 3.3.5.1-1, "Emergency Core Cooling System Instrumentation"

References:

(1) Letter from K. R. Jury (EGC) to the NRC, "Request for Amendment to Technical Specifications Table 3.3.5.1-1, 'Emergency Core Cooling System Instrumentation,'" dated March 31, 2003

(2) Letter from W. A. Macon Jr. (NRC) to J. L. Skolds (EGC), "LaSalle County Station, Units 1 and 2 – Request for Additional Information (TAC Nos. MB8198 and MB8199)," dated May 30, 2003

Exelon Generation Company (EGC), LLC, in Reference 1, requested a change to the Technical Specifications (TS) of LaSalle County Station (LSCS) Units 1 and 2. Specifically, the proposed change would increase the upper limit associated with TS Table 3.3.5.1-1, "Emergency Core Cooling System Instrumentation," Function 3.e, "HPCS System Flow Rate – Low (Bypass)," Allowable Value from less than or equal to (≤) 1704 gallons per minute (gpm) to ≤ 2194 gpm. The NRC in Reference 2 requested additional information to support their review of the submittal. Attached to this letter is the requested information.

A001

Should you have any questions concerning this matter, please contact Mr. T. W. Simpkin at (630) 657-2821.

I declare under penalty of perjury that the foregoing is true and correct.

Respectfully,

Executed on 6/26/03

T. W. Simpkin
Manager – Licensing
Mid-West Regional Operating Group

cc: Regional Administrator – NRC Region III
NRC Senior Resident Inspector – LaSalle County Station
Office of Nuclear Facility Safety – Illinois Department of Nuclear Safety

ATTACHMENT 1

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION TO SUPPORT REQUEST FOR AMENDMENT TO TECHNICAL SPECIFICATIONS TABLE 3.3.5.1-1

Question 1
On Page 4 of the submittal there is a reference to loss of coolant (LOCA) analyses. The staff requests the licensee to identify the evaluation models used for the LOCA analyses. In the analyses, the maximum assumed injection flow is 5400 gallons per minute (gpm). In Technical Specifications Surveillance Requirement 3.5.1.5, the tested flow rates are 6250 gpm for Unit 1 and 6200 gpm for Unit 2. The staff requests the licensee to describe in detail how the analyses value of 5400 gpm is verified during the periodic test with the increased minimum flow value of 2194 gpm.

Response 1
The following LOCA methodologies are applicable for LaSalle County Station (LSCS).

- "GESTR-LOCA and SAFER Models for the Evaluation of the Loss-of-Coolant Accident," Volumes I, II and III, NEDE-23785-1-P-A, dated February 1985.
- Advanced Nuclear Fuels Corporation Methodology for Boiling Water Reactors EXEM BWR Evaluation Model, ANF-91-048(P)(A), January 1993.
- BWR Jet Pump Model Revision for RELAX, ANF-91-048(P)(A), Supplement 1 and Supplement 2, Siemens Power Corporation, October 1997.

LaSalle Station Procedure LOS-HP-Q1/2, "HPCS System Inservice Test," delineates the specific steps to verify the High Pressure Core Spray (HPCS) pump performance in accordance with American Society of Mechanical Engineers (ASME) Section XI Inservice Tests and Technical Specification requirements.

After completion of valve line-ups and verification that the system is filled the following general sequence is followed. Refer to the attached simplified sketch on page 3 of HPCS.

- HPCS pump is started.
- Verify HPCS minimum Flow Valve (1/2E22-F012) OPENS.
- Throttle open HPCS Suppression Pool valve (1/2E22-F023) to establish a flow rate of 6300 gallons per minute (gpm) as indicated on 1/2E22-R603, HPCS Pump Flow Indicator. Note input to the recorder is from a flow orifice in the HPCS pump discharge line downstream of the minimum bypass line but upstream of the full test line.
- Verify HPCS minimum Flow Valve (1/2E22-F012) CLOSES
- Using HPCS Suppression Pool valve (1/2E22-F023) set flow rate to 6300 to 6400 gpm as indicated on 1/2E22-R603, HPCS Pmp Flow and Record flow.
- Allow HPCS pump to run a minimum of 5 minutes
- When 5 minutes stabilization period is complete, CHECK flow on 1/2E22-R603, HPCS Pmp Flow between 6300 and 6400 gpm.
- Record flow from 1/2E22-R603, HPCS Pmp Flow 6300 to 6400 gpm (i.e., acceptance criteria)
- Record HPCS Pump discharge pressure as indicated by the process computer point A807, HPCS Pump Discharge Pressure:
- Required Value $\geq$ 370 psig (TS SR 3.5.1.5 and SR 3.5.2.5)

As noted above, the measurement of the ASME IST and TS flow rate is downstream of the minimum flow bypass line and recorded after the valve in the bypass line closes. As stated in our submittal of March 31, 2003, our analyses indicates that if the minimum flow valve (i.e., 1/2E22-F012) was to remain open, the flow to the vessel would exceed 5400 gpm at 370 pounds per square inch gauge (psig). The basis of these analyses is previous testing of the HPCS system with the minimum flow valve open. Located downstream of the minimum flow valve is an orifice which limits the flow in the minimum flow line in proportion to the HPCS line pressure. At 370 psig the flow through the minimum flow line is approximately 582 gpm. Therefore, the surveillance minimum acceptance criteria of 6300 gpm minus a potential 582 gpm bypassed results in 5710 gpm to the reactor pressure vessel (RPV), which is greater than the LOCA analysis of 5400 gpm at 370 psig.

In addition, when the flow into the RPV is 2194 gpm, with the minimum flow valve open, the HPCS pump discharge pressure is approximately 1080 psig; the corresponding pump flow is approximately 3100 gpm with 909 gpm going through the minimum flow line. As shown in Updated Final Safety Analysis (UFSAR) Figure 6.3-10, the required flow into the RPV at 1080 psig is approximately 1300 gpm. Therefore, there is an excess flow into the RPV of approximately 900 gpm (i.e., 2194 gpm-1300 gpm).

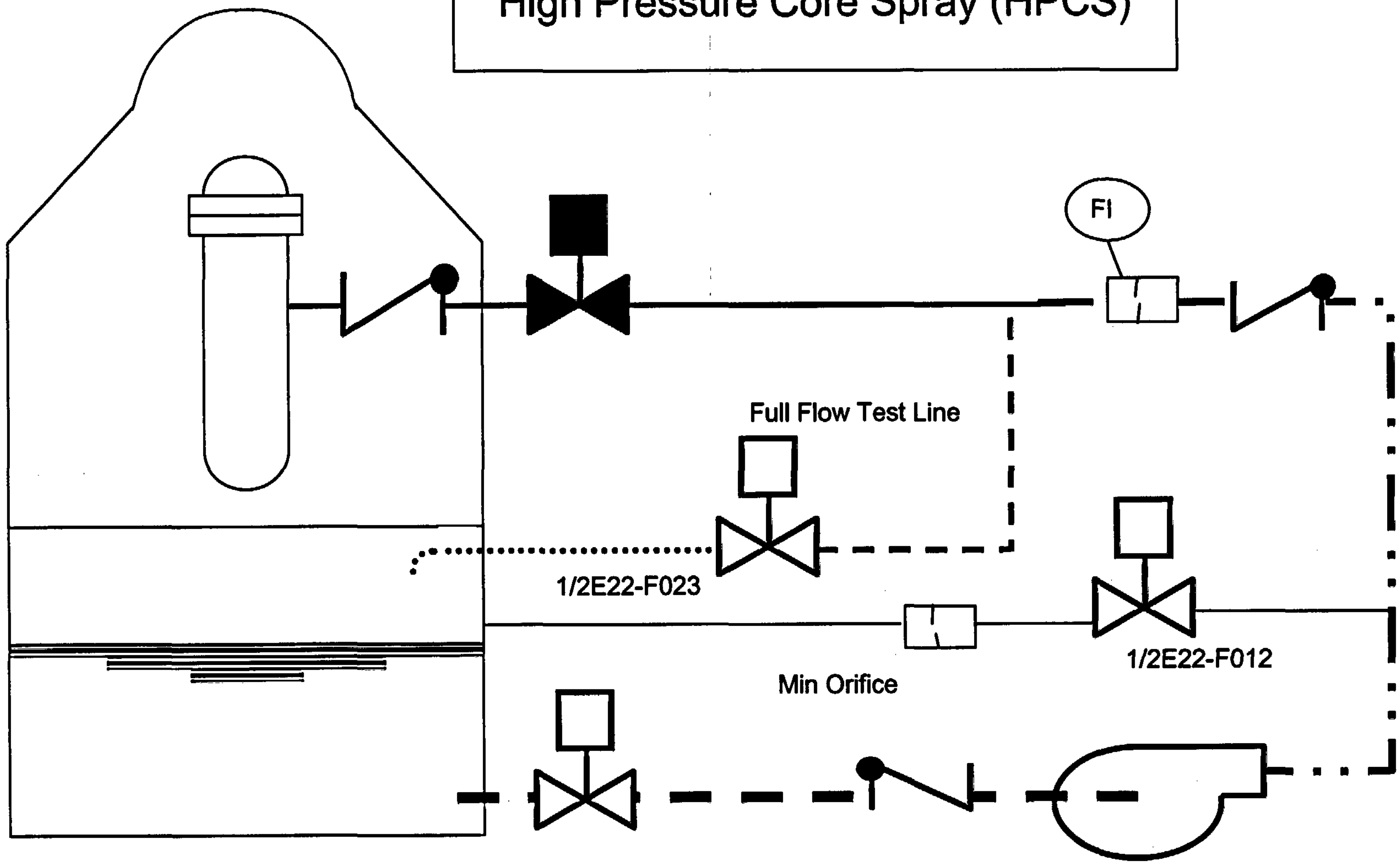
In conclusion, LSCS's HPCS system design basis is for the minimum flow valve to close at 2194 gpm and is tested in that configuration. The test acceptance value of 6300 gpm is greater than both the TS SR of 6250 (Unit 1) and the LOCA analysis requirement of 5400 gpm at 370 psig.

Question 2
The staff requests the licensee to provide the setpoint methodology calculations used in determining the revised upper Allowable Value limit (≤ 2194 gpm). Please include all the historical calibration and performance data used in these calculations. It is recommended that any Standards and Guides that are used in the calculations be referenced.

Response 2
The calculation for the setpoint change and Engineering Standard for setpoint methodology used at LSCS are identified below and are contained in Attachments 2 and 3 to this submittal.

- Revision 1E of NED-I-EIC-0198, HPCS, LPCS and LPCI Discharge Min Flow Bypass Differential Pressure Switch Setpoint Error Analysis evaluated the setpoint change to the HPCS Bypass flow setpoint and allowable value. The revision includes a table of the historical data for the HPCS Bypass flow switches.
- NES-EIC-20.04 revision 3, Analysis of Instrument Channel Setpoint Error and Instrument Loop Accuracy.

Simplified Sketch
High Pressure Core Spray (HPCS)



ATTACHMENT 2

REVISION 1E OF NED-I-EIC-0198, HPCS, LPCS AND LPCI DISCHARGE MIN FLOW BYPASS DIFFERENTIAL PRESSURE SWITCH SETPOINT ERROR ANALYSIS

DESIGN ANALYSIS NO.: NED-I-EIC-0198 PAGE NO. 1
Major REV Number: 001 Minor Rev Number: E

[ ] BRAIDWOOD STATION
[ ] BYRON STATION
[ ] CLINTON STATION
[ ] DRESDEN STATION
[X] LASALLE CO. STATION
[ ] QUAD CITIES STATION
Unit: [ ] 0 [X] 1 [X] 2 [ ] 3

DESCRIPTION CODE:(C018) I03
DISCIPLINE CODE: (C011) I
SYSTEM CODE: (C011) E12, E22, E22

TITLE: HPCS, LPCS and LPCI Discharge Min Flow Bypass Differential Pressure Switch Setpoint Error Analysis

[X] Safety Related [ ] Augmented Quality [ ] Non-Safety Related

ATTRIBUTES (C016)

TYPE	VALUE	TYPE	VALUE
Elevation			
Software			

COMPONENT EPN: (C014 Panel)

EPN	TYPE
1(2)E12-N014A,B,C	FE
1(2)E21-N002	FE
1(2)E22-N007	FE
1(2)E12-N010AA,BA,CA	PDS
1(2)E21-N004	FS
1(2)E22-N006	FS

DOCUMENT NUMBERS: (C012 Panel) (Design Analyses References)

Type/Sub	Document Number	Input (Y/N)
DCD/DCR	DCR 990838	
DCD/DCR	DCR 991051	
DCD/DCR	DCR 992235	
DCD/DCR	DCR 992279	
DCD/EVAL	EC 338226 Rev 0	
/		
/		

REMARKS:

CC-AA-309 - ATTACHMENT 1 - Design Analysis Approval
Page 2 of 2

DESIGN ANALYSIS NO.	**NED-I-EIC-0198**	**REV: 001E**	**PAGE NO. 2**

Revision Summary (including EC's incorporated): A minor revision was made to the calculation for the Module 2A, HPCS Flow Bypass switches, 1(2)E22-N006, based on historical data of the SOR switches for this function. Revised Setpoints and Allowable values were determined for the upper and lower functions of the switch. In addition, a minimum value for the Upper Analytical Limit value was determined that is to be provided as an input for LOCA calculations. A Technical Specification change will be required to implement the revised setpoints. This revision affects sections 2.4, 3.22, 3.26, 4.6, 10, 12.1, 12.2, 12.3, 12.4, 13.1, 13.2, 15, 16 and 17. Sections 2.5, 2.6, 2.7, 3.26, 3.27, 4.8, 4.9, 4.10, 4.11, 5.12, 15A, 16A and Attachment A are added. N1-A3

Electronic Calculation Data Files:
(Program Name, Version, File Name extension/size/date/hour/min)

Design impact review completed? [X] Yes [ ] N/A, Per EC#: 338226 Rev 0
(If yes, attach impact review sheet)

Prepared by: W. Kirchhoff / [signature] / 9/17/02
Print / Sign / Date

Reviewed by: V. Shah / [signature] / 9/17/02
Print / Sign / Date

Method of Review: [X] Detailed [ ] Alternate [ ] Test

This Design Analysis supersedes: ______________________ **in its entirety.**

Supplemental Review Required? [ ] Yes [X] No

[ ] Additional Review [ ] Special Review Team

Additional Reviewer or Special Review Team Leader: ________ / ________ / ________
Print / Sign / Date

Special Review Team: (N/A for Additional Review)

Reviewers: 1) ________ / ________ / ________ 2) ________ / ________ / ________
Print / Sign / Date Print / Sign / Date

3) ________ / ________ / ________ 4) ________ / ________ / ________
Print / Sign / Date Print / Sign / Date

Supplemental Review Results:

Approved by: Mark Morsky / [signature] / 9/18/02
Print / Sign / Date

External Design Analysis Review (Attachment 3 Attached)

Reviewed by: ________ / ________ / ________
Print / Sign / Date

Approved by: ________ / ________ / ________
Print / Sign / Date

Do any ASSUMPTIONS / ENGINEERING JUDGEMENTS require later verification? [ ] Yes [X] No
Tracked By: AT#, EC# etc.) ______________________

CALCULATION TABLE OF CONTENTS

CALCULATION NO. NED-I-EIC-0198	REV. NO. 001E	PAGE NO. 3

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Purpose/Objective

The purpose of this minor revision is to revise the calculation for the Module 2A, HPCS Flow Bypass switches, based on using historical data of the SOR switches for this function. Revised Setpoints and Allowable values will be determined for the upper function of the switch based on maintaining the current Allowable Value for the lower function, and on ensuring that the revised Setpoint for the switch lower function maintains acceptable margin from the lower Analytical Limit. In addition, a minimum value for the Upper Analytical Limit value will be determined that may be applicable as an input for LOCA calculations if credit is taken for the minimum flow valve closing. A Technical Specification change will be required to implement the revised setpoints. The setpoint change will be implemented with an EC that is separate from the scope of this calculation.

Methodology and Acceptance Criteria

Revise 2.4 and add 2.5, 2.6 and 2.7

2.4 Expanded as-found tolerances will be computed for each switch. The methodology for this determination is within Reference 3.23 or 3.26.

2.5 Historical data, which has been collected for the HPCS Min Flow switches, will be evaluated for setpoint and deadband drift, in accordance with Appendix J, Guideline for the Analysis and Use of As-found / As-left Data of Reference 3.22. The results of the drift analysis will be used in the calculation in place of vendor supplied data for the switch relating to drift and tolerance. Because historical data is being used for determination of the drift error, the random error determined for drift is the standard deviation of the drift multiplied times a multiplier (k) to provide a 95% / 95% confidence for tolerance. The multiplier used is listed in Design Input 4.9.

2.6 A new setpoint will be determined for the Lower switch function based on the current Technical Specification Lower Allowable Value. The calculated value of the lower Analytical Limit will be determined using the total uncertainty errors and the revised setpoint of the lower switch function. The calculated Analytical Limit will be verified to be conservative to the true Analytic Limit of the switch. A revised Upper setpoint value will be determined based on the historical data of the switch deadband. A proposed Upper Analytical and Allowable Values will be determined based on the total uncertainty errors of the switch using the historical drift data, following the methodology of Reference 3.22. The acceptance criteria is that positive margin is achieved between the proposed setpoints and the Analytical Limits and Allowable Values.

2.7 Attachment A, HPCS Bypass Flow Switch Historical Data, is an EXCEL spreadsheet, which was used to evaluate the past performance of the applicable switches for setpoint

and Deadband drift. The data entered from Design Input 4.8 and all arithmetic functions performed by the program have been verified by the Reviewer to be correct.

Assumptions / Engineering Judgments

Add 5.12

5.12 Based on Engineering judgement, no time dependence is evaluated for the HPCS Flow Switch setpoint calculation because the historical data which was used for determining drift, was predominantly on the same quarterly frequency that is to be used for the new settings.

Design Inputs

Delete Design Input 4.6 associated with HPCS.

Add Design Inputs 4.8, 4.9, 4.10 and 4.11.

4.8 OE01-0017 Rev 1, Operability Determination, HPCS Flow Switch 1(2)E22-N006 found out of Tech Spec Allowable tolerance, Attachment of 1(2)E22-N006 Data.

4.9 95/95 Percent Tolerance Factor (k) for sample size of 100 is equal to 2.23 from Table 6-1, Tolerance Factors for Normal Distributions of Reference 3.27

4.10 An Outlier multiplier of 3.38 is applicable for a sample size of 100 based on NES-EIC-20.04 Rev 3, Table J1, Critical Values for T (Reference 3.22)

4.11 LaSalle Units 1 and 2 Technical Specification, Table 3.3.5.1-1 Emergency Core Cooling System Instrumentation, Function 3.e, HPCS System Flow Rate - Low (Bypass), lower Allowable Value is ≥ 1380 gpm.

References

Revise reference 3.22

3.22 NES-EIC-20.04, "Analysis of Instrument Channel Setpoint error and Instrument Loop Accuracy," Rev 3.

Add references 3.26 and 3.27

3.26 ER-AA-520, Rev 2, Instrument Performance Trending

3.27 TR-103335-R1, EPRI - Guidelines for Instrument Calibration Extension/Reduction-Revision 1, Statistical Analysis of Instrument Calibration Data

Calculations

1. Section 10.0 Calibration Procedure Data is revised to remove data for HPCS Flow Bypass (Module 2A) 1(2)E22-N006, which is being superseded by this revision to the calculation. Replace Section 10.0 for HPCS Flow Bypass (Module 2A) 1(2)E22-N006 with the following:

   Data which had been compiled for the HPCS Flow Switches 1(2)E22-N006 for an operability determination (Design Input 4.8) was evaluated on an EXCEL spreadsheet for Setpoint Drift, Reset Drift, Deadband and As-found Deadband. See Attachment A.

   An Outlier check was performed on the data using a multiplier of 3.38 (Design Input 4.10). The results of the spreadsheet calculation for the HPCS Flow Switches was:

   Setpoint Average Drift = 0.191316 inches w.c.
   Setpoint Drift Standard Deviation = 1.435288 inches w.c.
   Deadband Average (as-found) = 9.310391 inches w.c.
   Deadband Standard Deviation (as-found) = 1.279217 inches w.c.

   The Calibration Frequency and Late Factor specified in section 10.0 for the HPCS Flow Bypass Module 2A are not changed. The historical data is predominantly at the same 3-month frequency as the stated Calibration Frequency.

2. Errors are adjusted using the drift values from the data reduction while eliminating the uncertainties for Reference Accuracy, M&TE, power supply effects, normal operational temperature error, setting tolerance and drift, as recommended in Appendix J, section 2.7 of Reference 3.22.

   Section 12.1.1 Random Error, Normal Operating Conditions ($\sigma 2n$), is then revised to use the drift data uncertainty in place of Reference Accuracy, Calibration Error (M&TE), temperature error, Setting Tolerance and Vendor Drift Uncertainty.

   The random drift error is equal to the Setpoint Drift Standard Deviation multiplied times a multiplier (k) from Design Input 4.9. This error is a two-sigma uncertainty since it represents a 95/95 confidence level.

   $e2D_{(2\sigma)}$ = 2.23 x 1.435288 inches w.c.
   = 3.200692 inches w.c

   12.1.6.1 Determination of Module 2A Total Random Errors ($\sigma 2n_A$)

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This term is a one-sigma error. The drift error must be adjusted by dividing the term by two.

$\sigma 2n_A = \pm [(e2inn_A)^2 + (e2D_{(2\sigma)} / 2)^2]^{1/2}$

$\sigma 2n_A = \pm [(0 \text{"wc})^2 + (3.200692 / 2)^2]^{1/2}$

$\sigma 2n_A = \pm 1.600346$" wc (1 sigma)

Section 12.2 Random Error, Accident Conditions ($\sigma 2a$), is then revised to use the drift data uncertainty in place of Reference Accuracy, Calibration Error (M&TE), Setting Tolerance and Vendor Drift Uncertainty.

12.2.3 Determination of Total Random Error, Accident Conditions ($\sigma 2a$)

$\sigma 2a = \pm [(e2Ta)^2 + (e2ina)^2 + (e2D_{(2\sigma)} / 2)^2]^{1/2}$

$\sigma 2a = \pm [(0.6384 \text{" wc})^2 + (.882347 \text{"wc})^2 + (3.200692 / 2)^2]^{1/2}$

$\sigma 2a = \pm 1.935768$" wc (1 sigma)

Section 12.3 Non-Random Errors Normal Operating Conditions ($\Sigma e2n$) is revised to add the drift bias.

Section 12.3.8 Drift Bias

The Drift Bias (e2Dbn) is equal to the Average setpoint drift from the Data Spreadsheet.

e2Dbn = 0.191316 inches w.c.

Section 12.3.10 Total Non-Random Error Normal Operating Conditions ($\Sigma e2n$)

$\Sigma e2n$ = e2Hn + e2Rn + e2Sn + e2SPn + e2Pn + e2pn + e2Vn +e2inn + e2Dbn

= 0 +0 +0 ± 5" wc +0 +0+0 +0+0.191316 " w.c

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= + 5.191316 / -4.808684 " w.c

For conservatism, the smaller magnitude error will be used in both directions because this error is used in establishing the Allowable Value limit beyond the setpoint.

Σe2n = $\pm$ 4.808684 " w.c

Section 12.4 Non-Random Errors Accident Conditions (Σe2a) is revised to add the drift bias.

Section 12.4.8 Drift Bias

The Drift Bias (e2Dba) is equal to the Average setpoint drift from the Data Spreadsheet.

e2Dba = 0.191316 inches w.c.

Section 12.4.10 Total Non-Random Error Accident Conditions (Σe2a)

Σe2a = e2Ha + e2Ra + e2Sa+ e2SPa + e2Pa+ e2pa + e2Va +e2ina + e2Dba

= ($\pm$ 0.3808 $\pm$ 1.0302 $\pm$ 0.3196 $\pm$ 5" +0 + 0+ 0 $\pm$ 0.274 + 0.191316) " w.c

= + 7.195916 / -6.813284 "w.c

For conservatism, the larger magnitude error will be used in both directions because this error provides margin between the Analytical limit and the setpoint.

Σe2a = $\pm$ 7.195916 " w.c

3. Section 13.0 Total Error, Normal Operating and Accident Conditions (TE2) is revised to incorporate the changes to Section 12 for Module 2A.

From references 3.2 and 3.3, TE2 = 2 x (σ2)+ Σe2

13.1 Total Error, Normal Operating Conditions (TE2n)

For Modules 1A & 2A, HPCS Min. flow Bypass:

From Section 12.1.6.1, $\sigma 2n_A = \pm 1.600346$ " w.c (1 sigma)

From Section 12.3.10, $\Sigma e2n = \pm 4.808684$ " w.c

$TE2n_A = \pm[(2 \times 1.600346\text{" wc}) + 4.808684]$ " w.c

$TE2n_A = \pm 8.009376$ " w.c

13.2 Total Error, Accident Conditions (TE2a)

For Modules 1A & 2A, HPCS Min. flow Bypass:

From Section 12.2.3, $\sigma 2a_A = \pm 1.935768$ " w.c (1 sigma)

From Section 12.4.10, $\Sigma e2a = \pm 7.195916$ " w.c

$TE2a = \pm[(2 \times 1.935768\text{" wc}) + 7.195916]$ " w.c

$TE2a = \pm 11.067452$ " w.c

4. Section 15.0 Determination of Limiting Setpoints and Allowable Values and section 16.0 Determination of Expanded Tolerance (Administrative As Found Limit) are superseded for discussion related to Module 1A & 2A HPCS Flow Bypass with the following:

15A.0 Determination of Limiting Setpoints, Allowable Values and the minimum value for the Maximum Flow Bypass Analytical Limit for Module 1A & 2A HPCS Flow Bypass.

15A.1 Determination of the Limiting Setpoint for Module 1A & 2A HPCS Flow Bypass.

15A.1.1 HPCS Minimum Flow Bypass Analytical Limit AL_{min} and Allowable Value, AV_{min}

The HPCS Minimum Flow Bypass Analytical Limit, AL_{min} Flow, is defined as 1000 gpm in Reference 3.14.

The HPCS Minimum Flow Bypass Allowable Value, AV_{min} Flow is defined as ≥ 1380 gpm by Design Input 4.11.

Section 11.1.2 Overall Flow Element Uncertainty provides the relation for the Module 1A HPCS Flow Orifice as: $K_A = Q/(dP)^{1/2}$
with K_A = 321 [gpm / ("wc) $^{1/2}$], Q= Flow in gpm, and dP = Flow orifice differential pressure in inches of water column.

Then dP = $[Q/321]^2$ " wc

The corresponding dP Analytical Limit AL_{min} = $[1000/321]^2$ = 9.704875" wc

The corresponding dP Allowable Value, AV_{min} = $[1380/321]^2$ = 18.481963 " wc

15A.1.2 From Reference 3.22

Allowable Value Low (AV_{low}) = SP_{low} - Total Error, Normal Operating Conditions (TE2n)

Therefore, SP_{low} = AV_{low} + TE2n

SP_{low} = 18.481963 +8.009376 " w.c

SP_{low} = 26.491339 " w.c

Rounding for usability **AV_{low} = 18.5" w.c**
AV_{low} Flow = 1380 gpm

SP_{low} = 26.5" wc
SP_{low} Flow = 1652 gpm

15A.1.3 Verifying margin against the true Analytical Limit

Setpoint Low (SP_{low}) > AL_{min} + TE2a

26.5" wc > 9.704875" wc + 11.067452 " w.c
>20.772327" w.c

The margin is acceptable.

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15A.1.3 The Setpoint High is the reset of the switch in the increasing direction. The reset of the switch has a non-adjustable Deadband. The statistical relation between the Setpoint Low and the reset has been determined by historical data evaluated on Attachment A. The Deadband Uncertainty is equal to the Deadband Average (as-found) plus the Deadband Standard Deviation (as-found) times the multiplier.

From Attachment A:
Deadband Average (as-found) = 9.310391" w.c.
Deadband Standard Deviation = 1.279217 " w.c.
Multiplier (k) = 2.23 (Design Input 4.9)

Deadband Uncertainty = 9.310391+2.23 x 1.279217
= 12.163045" w.c

15A.1.4 $SP_{high} > SP_{low}$ + Deadband Uncertainty

$SP_{high} >$ 26.5" wc + 12.163045" w.c

> 38.663045" w.c

Rounding for usability **SP_{high}= 38.7" wc**
SP_{high} Flow = 1997 gpm

15A.2 Determination of the Limiting Allowable Value for Module 1A & 2A HPCS Flow Bypass.

15A.2.1 From Reference 3.22

Allowable Value High (AV_{high}) = SP_{high} + Total Error, Normal Operating Conditions (TE2n)

AV_{high} = 38.7" wc + 8.009376 " w.c

AV_{high} = 46.709376 " wc

Rounding for usability

AV_{high} = 46.7" w.c
AV_{high} Flow = 2194 gpm

15A.3 Determination of the minimum acceptable Analytical Limit of maximum flow for Module 1A & 2A HPCS Flow Bypass.

From Reference 3.22, Setpoint High (SP_{high}) < AL_{max} - TE2a

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Therefore the $AL_{max} > SP_{high} + TE2a$

$AL_{max} > 38.7\text{" wc} + 11.067452\text{" wc}$

$AL_{max} > 49.767452\text{" wc}$

Therefore, a minimum Analytical Limit of 49.6" wc is acceptable

AL_{max} = 49.8" wc
AL_{max} Flow = 2265 gpm

16A.0 Determination of Expanded Tolerance (Administrative As Found Limit) of the Module 2A HPCS Flow Bypass

The Expanded Tolerance (ET) of the Module 2A HPCS Flow Bypass is calculated using the guidance of Attachment 1 of Reference 3.26, which states that the ET should be the Allowable Value or some percentage of the Allowable Value. For conservatism, 0.7 of the difference between the AV and Setpoint will be used. Since the AV was determined using the Total Error, Normal Operating Conditions (TE2n), it follows that:

ET = 0.7 x TE2n

ET = 0.7 x 8.009376 " w.c

= 5.606563

Rounding for usability:

ET = 5.6" w.c

Summary and Conclusions

Replace Section 17.0 Summary and Conclusions discussion of the HPCS Flow Bypass switches with the following:

The recommended values for the HPCS Flow Bypass switches are as summarized in the Table below.

EPN		AV		SP		ET
1(2)E22-N006	Reset	46.7" wc	2194 gpm	38.7" wc	1997 gpm	5.6" wc
	Set	18.5" wc	1380 gpm	26.5" wc	1652 gpm	5.6" wc

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Based on evaluation of historical data of the HPCS Flow Bypass switches, revised setpoints, Allowable Values and an Upper Analytical Limit were determined. The new switch setpoints and Allowable values provide the required margin from the upper and lower analytical limits as determined.

$(SP_{low} = 26.5\text{" wc}) > (AV_{low} = 18.5\text{ " w.c}) > (AL_{min} = 9.7\text{" wc})$

$(SP_{low}Flow = 1652\text{ gpm}) > (AV_{low}Flow = 1380\text{ gpm}) > (AL_{min}\ Flow = 1000\text{ gpm})$

$(SP_{high} = 38.7\text{" wc}) < (AV_{high} = 46.7\text{ " w.c}) < (AL_{max} = 49.8\text{" wc})$

$(SP_{high}\ Flow = 1997\text{ gpm}) < (AV_{high}Flow = 2194\text{ gpm}) < (AL_{max}\ Flow = 2265\text{ gpm})$

Attachments

Attachment A, HPCS Flow Bypass Switch Historical Data

Final
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Attachment A
HPCS Flow Bypass Switch Historical Data

												Raw Data				Outlier Checks	3.38	Sigma						
EPN	DATE	AS-Found Trip	AS-Found Reset	AS-Left Trip	AS-Left Reset	Interval	Set Drift	Reset Drift	Dead Band	As-Found Dead Band		Set Drift	Reset Drift	Dead Band	As-Found Dead Band	Set Drift	Reset Drift	Dead Band	As-Found Dead Band		Set Drift	Reset Drift	Dead Band	As-Found Dead Band
	09/15/1986	NEW	NEW	23.1	31.1		0.2	-0.1	8		Average	0.164741	0.900259	8.451387	9.211078	0.2	-0.1	8		Average	0.191316	0.909912	8.553886	9.310391
	10/10/1986	23.3	31	23.2	31	25	-0.4	1.3	7.8	7.7	StdDev	1.82652	2.130483	1.758703	1.66322	-0.4	1.3	7.8	7.7	StdDev	1.435288	1.877013	1.365086	1.279217
	01/09/1987	22.8	32.3	22.8	29.4	91	1.9	3.5	6.6	9.5	Count	116	116	119	116	1.9	3.5	6.6	9.5	Count	114	114	118	115
	04/10/1987	24.7	32.9	22.9	30	91	-0.2	-2	7.1	8.2	Max	7.2	8.2	12.8	14.2	-0.2	-2	7.1	8.2	Max	3.7	4.8	12.8	14.2
	07/17/1987	22.7	28	22.7	28	98	2	4	5.3	5.3						2	4	5.3	5.3					
	10/06/1987	24.7	32	22.9	29.4	83	-2.4	1.2	6.5	7.3						-2.4	1.2	6.5	7.3					
	01/11/1988	20.5	30.6	23.3	30.3	95	2.3	3.5	7	10.1						2.3	3.5	7	10.1					
	05/10/1988	25.6	33.6	22.9	29.8	120	1.7	4.7	6.9	8.2						1.7	4.7	6.9	8.2					
	08/11/1988	24.6	34.5	22.8	30	93	-0.2	1.8	7.2	9.9						-0.2	1.8	7.2	9.9					
	11/09/1988	22.6	31.8	22.6	31.8	90	-2.2	-4.2	9.2	9.2						-2.2	-4.2	9.2	9.2					
	02/08/1989	20.4	27.6	23.1	29.9	91	-0.1	3.3	6.8	7.2						-0.1	3.3	6.8	7.2					
	05/11/1989	23	33.2	23	33.2	92	0.4	-1.8	10.2	10.2						0.4	-1.8	10.2	10.2					
	08/10/1989	23.4	31.4	23.4	31.4	91	2.3	4.6	8	8						2.3	4.6	8	8					
	11/11/1989	25.7	36	22.9	31.4	93	-0.1	1.4	8.5	10.3						-0.1	1.4	8.5	10.3					
	02/13/1990	22.8	32.8	22.8	32.8	94	-1.7	-1.5	10	10						-1.7	-1.5	10	10					
	05/16/1990	21.1	31.3	23.2	30.6	92	1.8	3.2	7.4	10.2						1.8	3.2	7.4	10.2					
	08/06/1990	25	33.8	23	30.8	82	-0.6	1.2	7.8	8.8						-0.6	1.2	7.8	8.8					
	10/31/1990	22.4	32	22.4	32	86	0.8	-2.4	9.6	9.6						0.8	-2.4	9.6	9.6					
	01/25/1991	23.2	29.6	23.2	29.6	86	2.2	4	6.4	6.4						2.2	4	6.4	6.4					
	04/27/1991	25.4	33.6	22.6	29.2	92	0.2	4.3	6.6	8.2						0.2	4.3	6.6	8.2					
	07/08/1991	22.8	33.5	22.8	33.5	72	-0.2	-1.5	10.7	10.7						-0.2	-1.5	10.7	10.7					
	09/30/1991	22.6	32	22.6	32	84	0.8	-0.3	9.4	9.4						0.8	-0.3	9.4	9.4					
	12/23/1991	23.4	31.7	23.4	31.7	84	-0.2	0.3	8.3	8.3						-0.2	0.3	8.3	8.3					
	03/16/1992	23.2	32	23.2	32	84	-1.25	-0.95	8.8	8.8						-1.25	-0.95	8.8	8.8					
	06/08/1992	21.95	31.05	22.91	28.95	84	0.69	4.05	6.04	9.1						0.69	4.05	6.04	9.1					
	08/31/1992	23.6	33	23	30	84	-1.3	4.2	7	9.4						-1.3	4.2	7	9.4					
	11/12/1992	21.7	34.2	23.3	29.9	73			6.6	12.5								6.6	12.5					
	02/16/1993	NEW	NEW	23.4	32.7	96	-0.5	1.3	9.3							-0.5	1.3	9.3						
	03/15/1993	22.9	34	22.9	34	27	-0.5	-1.3	11.1	11.1						-0.5	-1.3	11.1	11.1					
	05/10/1993	22.4	32.7	22.4	32.7	56	1	-0.7	10.3	10.3						1	-0.7	10.3	10.3					
	08/05/1993	23.4	32	23.4	32	87	-2	0	8.6	8.6						-2	0	8.6	8.6					
	10/29/1993	21.4	32	23	32.5	85	2	1.4	9.5	10.6						2	1.4	9.5	10.6					
	01/17/1994	25	33.9	22.6	30.8	80	1.2	1.2	8.2	8.9						1.2	1.2	8.2	8.9					
	04/23/1994	23.8	32	23.25	30.66	96	2.15	3.44	7.41	8.2						2.15	3.44	7.41	8.2					
	08/01/1994	25.4	34.1	22.8	29.9	100	-2.3	1.6	7.1	8.7						-2.3	1.6	7.1	8.7					
	10/25/1994	20.5	31.5	23.3	31	85	-0.7	1.5	7.7	11						-0.7	1.5	7.7	11					
	01/19/1995	22.6	32.5	22.6	32.5	86	2.4	0.9	9.9	9.9						2.4	0.9	9.9	9.9					
	04/10/1995	25	33.4	23.1	31.2	81	2.8	2.8	8.1	8.4						2.8	2.8	8.1	8.4					
	07/03/1995	25.9	34	23.1	30.1	84	2.2	4.3	7	8.1						2.2	4.3	7	8.1					
	09/27/1995	25.3	34.4	23.5	31	86	-2.2	-1.6	7.5	9.1						-2.2	-1.6	7.5	9.1					
	12/20/1995	21.3	29.4	23	30.5	84	7.2	8.2	7.5	8.1								7.5	8.1					
	03/14/1996	30.2	38.7	23	30.4	85	-0.57	0.1	7.4	8.5						-0.57	0.1	7.4	8.5					
	04/09/1996	22.43	30.5	22.43	30.5	26	2.17	3.3	8.07	8.07						2.17	3.3	8.07	8.07					
	06/04/1996	24.6	33.8	22.7	30.5	56	-1.34	1.66	7.8	9.2						-1.34	1.66	7.8	9.2					
	01/21/1998	21.36	32.16	23.2	30.8	596	-0.04	0.7	7.6	10.8						-0.04	0.7	7.6	10.8					
	04/16/1998	23.16	31.5	23.16	31.5	85	-0.36	0.5	8.34	8.34						-0.36	0.5	8.34	8.34					
	06/29/1998	22.8	32	22.8	32	74	0.31	1.04	9.2	9.2						0.31	1.04	9.2	9.2					
	09/30/1998	23.11	33.04	23.11	33.04	93	0.33	-1.3	9.93	9.93						0.33	-1.3	9.93	9.93					
	06/01/1999	23.44	31.74	23.44	31.74	244	-3.54	0.06	8.3	8.3						-3.54	0.06	8.3	8.3					
	10/16/1999	19.9	31.8	23	31.9	139	0.2	0.9	8.9	11.9						0.2	0.9	8.9	11.9					
	07/24/2000	23.2	32.8	23.2	32.8	280	-0.7	-0.3	9.6	9.6						-0.7	-0.3	9.6	9.6					
	10/18/2000	22.5	32.5	22.5	32.5	86	0.58	0.88	10	10						0.58	0.88	10	10					
	01/08/2001	23.08	33.38	23.08	33.38	82	0.88	-0.22	10.3	10.3						0.88	-0.22	10.3	10.3					
	04/02/2001	23.96	33.16	22.9	31.21	84	-1.12	0.99	8.31	9.2						-1.12	0.99	8.31	9.2					
	05/03/2001	21.78	32.2	19.66	27.19	31	2.24	-7.5	7.53	10.42						2.24		7.53	10.42					
	07/23/2001	21.9	19.69	30.5	26.88	81	-9.9	4.32	-3.62	-2.21							4.32							
	10/19/2001	20.6	31.2	19.1	26.7	88			7.6	10.6								7.6	10.6					

Attachment A
HPCS Flow Bypass Switch Historical Data

EPN	DATE	AS-Found Trip	AS-Found Reset	AS-Left Trip	AS-Left Reset	Interval	Set Drift	Reset Drift	Dead Band	As-Found Dead Band
	07/30/1986	NEW	NEW	23.2	32.4		0.4	0	9.2	
	08/15/1986	23.6	32.4	23.6	31.6	16	-0.2	2.4	8	8.8
	11/15/1986	23.4	34	23.4	34	92	-0.4	-1.3	10.6	10.6
	04/10/1987	23	32.7	23	32.7	146	0.8	3.3	9.7	9.7
	07/09/1987	23.8	36	23	35.8	90	0.6	0.4	12.8	12.2
	10/09/1987	23.6	36.2	23.6	36.2	92	1.4	-1.8	12.6	12.6
	01/11/1988	25	34.4	22.6	32.2	94	1.6	1.8	9.6	9.4
	02/10/1988	24.2	34	23	31.8	30	-4.5	1.1	8.6	9.8
	04/12/1988	18.6	32.7	FAIL	FAIL	62				14.2
	04/14/1988	NEW	NEW	22.6	30	2	-0.6	1	7.4	
	05/13/1988	22	31	23.4	29.2	29	-3	1.8	5.8	9
	07/13/1988	20.4	31	23.3	30	61	-0.3	1	6.7	10.6
	08/12/1988	23	31	23	31	30	0.5	1	8	8
	10/13/1988	23.5	32	23.4	32	62	-0.4	-2.4	8.6	8.5
	01/13/1989	23	29.6	23	29.6	92	1	3.4	6.6	6.6
	04/17/1989	24	33	23	30.5	94	0.4	3.1	7.5	9
	07/18/1989	23.4	33.6	23.4	33.6	92	2.4	-0.1	10.2	10.2
	10/17/1989	25.8	33.5	23	34	91	3.2	-0.8	11	7.7
	11/17/1989	26.2	33.2	FAIL	FAIL	31				7
	11/18/1989	NEW	NEW	23	31	1	-1	0	8	
	12/18/1989	22	31	23.2	31.2	30	1.5	2.8	8	9
	01/19/1990	24.7	34	23	31	32	-0.7	-0.8	8	9.3
	02/20/1990	22.3	30.2	23	30.4	32	-1.2	1.8	7.4	7.9
	04/18/1990	21.8	32.2	23	31.2	57	0.4	1.8	8.2	10.4
	07/11/1990	23.4	33	23.4	33	84	0.9	0.5	9.6	9.6
	10/05/1990	24.3	33.5	22.7	31.5	86	-0.1	0.7	8.8	9.2
	12/27/1990	22.6	32.2	22.6	32.2	83	0.6	-0.1	9.6	9.6
	03/23/1991	23.2	32.1	23.2	32.1	86	1	1.3	8.9	8.9
	06/11/1991	24.2	33.4	23.1	31.2	80	-0.3	0	8.1	9.2
	09/03/1991	22.8	31.2	22.8	31.2	84	-0.2	-0.5	8.4	8.4
	11/26/1991	22.6	30.7	23.2	31.7	84	0	2.8	8.5	8.1
	02/12/1992	23.2	34.5	23.2	34.5	78	0.6	-2.5	11.3	11.3
	03/24/1992	23.6	32	22.95	31	41	-0.45	0.7	8.05	8.2
	06/09/1992	22.5	31.7	22.5	31.7	77	0.5	-0.3	9.2	9.2
	09/03/1992	23	31.4	23	31.4	86	-0.3	-0.2	8.4	8.4
	11/27/1992	22.7	31.2	22.7	31.2	85	-0.2	1.2	8.5	8.5
	02/17/1993	22.5	32.4	22.5	32.4	82	0.65	-0.4	9.9	9.9
	05/11/1993	23.15	32	23.15	32	83	-1.2	-0.25	8.85	8.85
	08/05/1993	21.95	31.75	22.65	31.9	86	0.43	0.1	9.25	9.8
	10/18/1993	23.08	32	23.08	32	74	-0.28	0	8.92	8.92
	01/20/1994	22.8	32	22.8	32	94	-1.4	0.6	9.2	9.2
	04/14/1994	21.4	32.6	22.9	31.5	84	-0.5	1	8.8	11.2
	07/06/1994	22.4	32.5	22.4	32.5	83	1.1	0.1	10.1	10.1
	09/26/1994	23.5	32.6	23.5	32.6	82	-1.6	-0.6	9.1	9.1
	12/21/1994	21.9	32	22.6	31.3	86	0.88	2.15	8.7	10.1
	03/21/1995	23.48	33.45	23.48	33.45	90	0.84	0.52	9.97	9.97
	05/05/1995	24.32	33.97	22.71	31.6	45	3.69	4.8	8.89	9.65
	07/31/1995	26.4	36.4	23.4	33.8	87	-2.7	-4.1	10.4	10
	10/23/1995	20.7	29.7	22.9	31.6	84	3.7	4.3	8.7	9
	01/15/1996	26.6	35.9	22.8	34	84	0.9	-0.3	11.2	9.3
	04/08/1996	23.7	33.7	23	31.6	84	0.9	2.07	8.6	10
	05/07/1998	23.9	33.67	22.74	32.4	759	1.36	1	9.66	9.77
	07/30/1998	24.1	33.4	22.74	30.69	84	0.42	1.52	7.95	9.3
	02/07/1999	23.16	32.21	23.16	32.21	192	-0.46	0.19	9.05	9.05
	05/07/1999	22.7	32.4	22.7	32.4	89	0.65	-0.415	9.7	9.7
	07/29/1999	23.35	31.985	23.35	31.985	83	-0.48	-0.285	8.635	8.635
	10/20/1999	22.87	31.7	22.87	31.7	83	-1.2	0.32	8.83	8.83
	01/17/2000	21.67	32.02	23	30.8	89	0.6	2.7	7.8	10.35
	06/29/2000	23.6	33.5	23.6	33.5	164	-0.03	-0.61	9.9	9.9

DATE		Raw Data				Outlier Checks	3.38	Sigma						
		Set Drift	Reset Drift	Dead Band	As-Found Dead Band	Set Drift	Reset Drift	Dead Band	As-Found Dead Band		Set Drift	Reset Drift	Dead Band	As-Found Dead Band
07/30/1986						0.4	0	9.2						
08/15/1986						-0.2	2.4	8	8.8					
11/15/1986						-0.4	-1.3	10.6	10.6					
04/10/1987						0.8	3.3	9.7	9.7					
07/09/1987						0.6	0.4	12.8	12.2					
10/09/1987						1.4	-1.8	12.6	12.6					
01/11/1988						1.6	1.8	9.6	9.4					
02/10/1988						-4.5	1.1	8.6	9.8					
04/12/1988									14.2					
04/14/1988						-0.6	1	7.4						
05/13/1988						-3	1.6	5.8	9					
07/13/1988						-0.3	1	6.7	10.6					
08/12/1988						0.5	1	8	8					
10/13/1988						-0.4	-2.4	8.6	8.5					
01/13/1989						1	3.4	6.6	6.6					
04/17/1989						0.4	3.1	7.5	9					
07/18/1989						2.4	-0.1	10.2	10.2					
10/17/1989						3.2	-0.8	11	7.7					
11/17/1989									7					
11/18/1989						-1	0	8						
12/18/1989						1.5	2.8	8	9					
01/19/1990						-0.7	-0.8	8	9.3					
02/20/1990						-1.2	1.8	7.4	7.9					
04/18/1990						0.4	1.8	8.2	10.4					
07/11/1990						0.9	0.5	9.6	9.6					
10/05/1990						-0.1	0.7	8.8	9.2					
12/27/1990						0.6	-0.1	9.6	9.6					
03/23/1991						1	1.3	8.9	8.9					
06/11/1991						-0.3	0	8.1	9.2					
09/03/1991						-0.2	-0.5	8.4	8.4					
11/26/1991						0	2.8	8.5	8.1					
02/12/1992						0.6	-2.5	11.3	11.3					
03/24/1992						-0.45	0.7	8.05	8.2					
06/09/1992						0.5	-0.3	9.2	9.2					
09/03/1992						-0.3	-0.2	8.4	8.4					
11/27/1992						-0.2	1.2	8.5	8.5					
02/17/1993						0.65	-0.4	9.9	9.9					
05/11/1993						-1.2	-0.25	8.85	8.85					
08/05/1993						0.43	0.1	9.25	9.8					
10/18/1993						-0.28	0	8.92	8.92					
01/20/1994						-1.4	0.6	9.2	9.2					
04/14/1994						-0.5	1	8.8	11.2					
07/06/1994						1.1	0.1	10.1	10.1					
09/26/1994						-1.6	-0.6	9.1	9.1					
12/21/1994						0.88	2.15	8.7	10.1					
03/21/1995						0.84	0.52	9.97	9.97					
05/05/1995						3.69	4.8	8.89	9.65					
07/31/1995						-2.7	-4.1	10.4	10					
10/23/1995						3.7	4.3	8.7	9					
01/15/1996						0.9	-0.3	11.2	9.3					
04/08/1996						0.9	2.07	8.6	10					
05/07/1998						1.36	1	9.66	9.77					
07/30/1998						0.42	1.52	7.95	9.3					
02/07/1999						-0.46	0.19	9.05	9.05					
05/07/1999						0.65	-0.415	9.7	9.7					
07/29/1999						-0.48	-0.285	8.635	8.635					
10/20/1999						-1.2	0.32	8.83	8.83					
01/17/2000						0.6	2.7	7.8	10.35					
06/29/2000						-0.03	-0.61	9.9	9.9					

Attachment A
HPCS Flow Bypass Switch Historical Data

											Raw Data					Outlier Checks	3.38	Sigma						
EPN	DATE	AS-Found Trip	AS-Found Reset	AS-Left Trip	AS-Left Reset	Interval	Set Drift	Reset Drift	Dead Band	As-Found Dead Band		Set Drift	Reset Drift	Dead Band	As-Found Dead Band	Set Drift	Reset Drift	Dead Band	As-Found Dead Band		Set Drift	Reset Drift	Dead Band	As-Found Dead Band
	12/12/2000	23.57	32.89	23.57	32.89	166	-0.17	-0.19	9.32	9.32						-0.17	-0.19	9.32	9.32					
	03/08/2001	23.4	32.7	23.4	32.7	86	-0.04	-0.2	9.3	9.3						-0.04	-0.2	9.3	9.3					
	05/03/2001	23.36	32.6	19.68	26.21	56	1.72	2.19	6.53	9.14						1.72	2.19	6.53	9.14					
	06/27/2001	21.4	28.4	19.85	26.1	55	-0.95	1.15	6.25	7						-0.95	1.15	6.25	7					
	08/24/2001	18.9	27.25	18.9	27.25	58			8.35	8.35								8.35	8.35					

ATTACHMENT 1
DESIGN ANALYSIS APPROVAL
Page 1 of 2

DESIGN ANALYSIS NO. 992279	REV: N/A	PAGE NO. 1

[ ] BRAIDWOOD STATION
[ ] BYRON STATION
[ ] DRESDEN STATION
[X] LASALLE CO. STATION
[ ] QUAD CITIES STATION

[ ] Unit 0 [X] Unit 1 [X] Unit 2 [ ] Unit 3

DESCRIPTION CODE: C018)	I03
DISCIPLINE CODE: (C011)	I
SYSTEM CODE: (C011)	E12, E21, E22
ELEVATION CODE: (C016)	Misc

TITLE: Revise NED-I-EIC-0198 Revision 1 to Shift the Field Setpoint Lower in the Acceptable Range

[X] Safety Related [ ] Augmented Quality [ ] Non-Safety Related

REFERENCE NUMBERS: (C011 Panel)

Type	Number

COMPONENT EPN: (C014 Panel) EPN	COMPONENT	DOCUMENT NUMBERS: (C012 Panel) (Calculation References) Doc Type/ Sub Type	Document Number
1(2)E12-N010AA,BA,CA		CALC/ENG	NED-I-EIC-0198 REV 1
1(2)E21-N004		DCR	990838
1(2)E22-N006		DCR	991051
		DCR	992235

REMARKS:

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ATTACHMENT 1

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ASSUMPTIONS / ENGINEERING JUDGEMENTS	N/A	
DESIGN INPUT	N/A	
REFERENCES	N/A	
CALCULATIONS	4 - 5	
SUMMARY AND CONCLUSIONS	N/A	
ATTACHMENTS	N/A	

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DESIGN ANALYSIS NO. **DCR 992279** **REV: N/A** **PAGE NO. 2**

Revision Summary:

Revised sections 15.1 and 17 to change setpoints for switches to account for wider deadband

Electronic Calculation Data Files:
(Program Name, Version, File Name extension/size/date/hour/min)

Design impact review completed? [X] Yes [ ] No
Significant design impact from results? [ ] Yes [X] No (If yes, attach impact review sheet.)

Prepared by: R. FREDRICKSEN / [signature] / 5/1/01
Print / Sign / Date

Reviewed by: E. ZACHARIAS / Elizabeth Zacharias / 5/1/01
Print / Sign / Date

Method of Review: [X] Detailed [ ] Alternate [ ] Test

This Design Analysis supersedes: DCR 992235 **in its entirety.**

Supplemental Review Required? [ ] Yes [X] No

[ ] Additional Review [ ] Special Review Team

Additional Reviewer or Special Review Team Leader: ______ / ______ / ______
Print / Sign / Date

Special Review Team: (N/A for Additional Review)

Reviewers: 1) ______ / ______ / ______ 2) ______ / ______ / ______
Print / Sign / Date Print / Sign / Date

3) ______ / ______ / ______ 4) ______ / ______ / ______
Print / Sign / Date Print / Sign / Date

Supplemental Review Results:

Approved by: F G GOGLIOTTI / [signature] / 5/1/01
Print / Sign / Date

External Design Analysis Review (Attachment 3 Attached)

Reviewed by: ______ / ______ / ______
Print / Sign / Date

Approved by: ______ / ______ / ______
Print / Sign / Date

Do any ASSUMPTIONS / ENGINEERING JUDGEMENTS require later verification? [ ] Yes [X] No
(Tracked By: AT#, etc.)______

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CALCULATION PAGE

CALCULATION NO. DCR 992279	REVISION NO. N/A	PAGE NO. 4 OF 5

Purpose/Objective

The current calculation assumes that SOR's reset deadband is 3" wc based on their published information. The historical data for these instruments at LaSalle indicates that they have significantly wider deadbands.

From the current calibration data, set and reset values indicate that the setpoint is within the ITS tolerance, while the reset is up to 12" wc off. These large reset values would not meet the criteria of the calculation.

To support these larger reset values, the setpoint for the switch needs to be lowered to the low end of the acceptable band. DCR 992235, which left the field setting at it's current setpoint should be cancelled in its entirety.

Calculations

1. Modify the field setpoint paragraph of section 15.1(as modified by DCR 991051) as shown in bold below:

Therefore for the field setpoints for each switch:

As the reset values of these switches have shown large values the setpoint will be set near the low end of the setpoint range.

Module 1A & 2A, HPCS Flow Bypass

$SP_{A(Min)}$ = 19.0 "wc

$SP_{A(Max)}$ = 27.5 "wc

Selecting a readable value near the low setpoint

Use SP_A = 19.5 "wc

SP_A = [(19.5)$^{1/2}$ * 321] = 1417.498 gpm

Use SP_A = 1417 gpm

Reset SP_A = 19.5 "wc + 3 "wc = 21.5 "wc

21.5 "wc is < 27.5 "wc so the reset will occur prior to the $SP_{A(Max)}$

Module 1B & 2B, LPCS Flow Bypass

$SP_{B(Min)}$ = 13.4" wc

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$SP_{B\,(Max)}$ = 26.8 "wc

Selecting a readable value near the low setpoint

Use SP_B = 13.5 "wc

SP_B = [(13.5)$^{1/2}$ * 349] = 1282.308 gpm

Use SP_B = 1283 gpm

Reset SP_B = 13.5 "wc + 3 "wc = 16.5 "wc

16.5 "wc is < 26.8 "wc so the reset will occur prior to the $SP_{B(Max)}$

Module 1C & 2C, LPCI Flow Bypass

$SP_{C(Min)}$ = 11.1 "wc

$SP_{C(Max)}$ = 26.4 "wc

Selecting a readable value near the low setpoint

Use SP_C = 11.5 "wc

SP_C = [(11.5)$^{1/2}$ * 412] = 1397.16 gpm

Use SP_C = 1397 gpm

Reset SP_C = 11.5 "wc + 3 "wc = 14.5 "wc

14.5 "wc is < 26.4 "wc so the reset will occur prior to the $SP_{C(Max)}$

2. Replace the table in section 17 (as modified by DCR 991051) with the following table:

EPN		AV	SP	ET
1(2) E22-N006	Reset	28.2 "wc / 1704 gpm	19.5"wc/ 1417 gpm	± 0.66 "wc
	Set	18.5 "wc / 1380 gpm		
1(2) E21-N004	Reset	27.7 "wc / 1835 gpm	13.5"wc/ 1283 gpm	± 0.79 "wc
	Set	12.6 "wc / 1240 gpm		
1(2) E12-N010 AA/BA/CA	Reset	27.1 "wc / 2144 gpm	11.5"wc/ 1397 gpm	± 0.66 "wc
	Set	10.4 "wc / 1330 gpm		

Final
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ATTACHMENT 1
DESIGN ANALYSIS APPROVAL
Page 1 of 2

DESIGN ANALYSIS NO. DCR 992235 **REV: N/A** **PAGE NO. 1**

[ ] BRAIDWOOD STATION
[ ] BYRON STATION
[ ] DRESDEN STATION
[X] LASALLE CO. STATION
[ ] QUAD CITIES STATION

[ ] Unit 0 [x] Unit 1 [x] Unit 2 [ ] Unit 3

DESCRIPTION CODE: (C018)	I03
DISCIPLINE CODE: (C011)	I
SYSTEM CODE: (C011)	E12, E21, E22
ELEVATION CODE: (C016)	Misc

TITLE: Change Setpoints in NED-I-EIC-0198 to agree with Calibration Procedure Values

[X] Safety Related [ ] Augmented Quality [ ] Non-Safety Related

REFERENCE NUMBERS: (C011 Panel)

Type	Number

COMPONENT EPN: (C014 Panel)

EPN	COMPONENT
See Calculation	

DOCUMENT NUMBERS: (C012 Panel) (Calculation References)

Doc Type/ Sub Type	Document Number
CALC/ENG	NED-I-EIC-0198 Rev 1
DCR	990838
DCR	991051
/	
/	
/	
/	

REMARKS:

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ATTACHMENT 1
DESIGN ANALYSIS APPROVAL
Page 2 of 2

DESIGN ANALYSIS NO. **DCR 992235** **REV: N/A** **PAGE NO. 2**

Revision Summary:

Sections 15.1 and 17 to change the field setpoints to agree with calibration setpoint values.

Electronic Calculation Data Files: None
(Program Name, Version, File Name extension/size/date/hour/min)

Design impact review completed? [X] Yes [ ] No
Significant design impact from results? [ ] Yes [X] No (If yes, attach impact review sheet.)

Prepared by: R. Fredricksen / [signature] / 04/02/01
Print / Sign / Date

Reviewed by: W. Kirchhoff / [signature] / 4/2/01
Print / Sign / Date

Method of Review: [X] Detailed [ ] Alternate [ ] Test

This Design Analysis supersedes: NONE **in its entirety.**

Supplemental Review Required? [ ] Yes [X] No

[ ] Additional Review [ ] Special Review Team

Additional Reviewer or Special Review Team Leader: ____ / ____ / ____
Print / Sign / Date

Special Review Team: (N/A for Additional Review)

Reviewers: 1) ____ / ____ / ____ 2) ____ / ____ / ____
Print / Sign / Date Print / Sign / Date

3) ____ / ____ / ____ 4) ____ / ____ / ____
Print / Sign / Date Print / Sign / Date

Supplemental Review Results:

Approved by: M. Murskyj / [signature] / 4/5/01
Print / Sign / Date

External Design Analysis Review (Attachment 3 Attached)

Reviewed by: ____ / ____ / ____
Print / Sign / Date

Approved by: ____ / ____ / ____
Print / Sign / Date

Do any ASSUMPTIONS / ENGINEERING JUDGEMENTS require later verification? [ ] Yes [X] No
(Tracked By: AT#, etc.)

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CALCULATION PAGE

CALCULATION NO. DCR 992235	REVISION NO.	PAGE NO. 4 of 5

Purpose/Objective

This revision is to change the field setpoints for all of the instruments to 23" wc so that there will be no required field work to implement ITS in this area. The range of acceptable setpoints encompass this value for all three systems and thus there is no additional calculations required.

Calculations

1. Modify the field setpoint paragraph of section 15.1(as modified by DCR 991051) as shown in bold below:

Therefore for the field setpoints for each switch:

Module 1A & 2A, HPCS Flow Bypass

$SP_A = (SP_{A(Min)} + SP_{A(Max)})/2$

$SP_A = (19.0\text{ "wc} + 27.5\text{ "wc})/2$

$SP_A = 23.25\text{ "wc}$

Use $SP_A = 23.0\text{ "wc}$

$SP_A = [(23.0)^{1/2} * 321] = 1539.46\text{ gpm}$

Use $SP_A = 1540\text{ gpm}$

Reset $SP_A = 23.0\text{ "wc} + 3\text{ "wc} = 26.0\text{ "wc}$

26 "wc is < 27.5 "wc so the reset will occur prior to the $SP_{A(Max)}$

Module 1B & 2B, LPCS Flow Bypass

$SP_B = (SP_{B(Min)} + SP_{B(Max)})/2$

$SP_B = (13.4\text{ "wc} + 26.8\text{ "wc})/2$

$SP_B = 20.1\text{ "wc}$

Since the current setpoint is 23.0 "wc, which is between the max and min it will be used

Use $SP_B = 23.0\text{ "wc}$

$SP_B = [(23.0)^{1/2} * 349] = 1673.745\text{ gpm}$

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CALCULATION PAGE

CALCULATION NO. DCR 992235	REVISION NO.	PAGE NO. 5 of 5

Use SP_B **= 1674 gpm**

Reset SP_B **= 23.0 "wc + 3 "wc = 26.0 "wc**

26 "wc is < 26.8 "wc so the reset will occur prior to the $SP_{B(Max)}$

<u>Module 1C & 2C, LPCI Flow Bypass</u>

$SP_C = (SP_{B(Min)} + SP_{B(Max)})/2$

SP_C = (11.1 "wc + 26.4 "wc)/2

SP_C = 18.75 "wc

Since the current setpoint is 23.0 "wc, which is between the max and min it will be used

Use SP_C **=23.0 "wc**

$SP_C = [(23.0)^{1/2} * 412] = 1975.883$ **gpm**

Use SP_C **= 1976 gpm**

Reset SP_C **=23.0 "wc + 3 "wc =26.0 "wc**

26.0 "wc is < 26.4 "wc so the reset will occur prior to the $SP_{C(Max)}$

2. Replace the table in section 17 (as modified by DCR 991051) with the following table:

EPN		AV	SP	ET
1(2) E22-N006	Reset	28.2 "wc / 1704 gpm	23.0 "wc/ 1540 gpm	± 0.66 "wc
	Set	18.4 "wc / 1377 gpm		
1(2) E21-N004	Reset	27.7 "wc / 1836 gpm	23.0 "wc/ 1674 gpm	± 0.79 "wc
	Set	12.6 "wc / 1239 gpm		
1(2) E12-N010 AA/BA/CA	Reset	27.1 "wc / 2144 gpm	23 "wc/ 1976 gpm	± 0.66 "wc
	Set	10.4 "wc / 1329 gpm		

Final
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`EDITORIAL/MINOR/TEMPORARY CALCULATION CHANGE

DCR #:991051

Affected Calc No. NED-I-EIC-0198 Rev. 1 Page No. 1 of 12

CHECK ONE: ☐ Editorial ☐ Evaluation Of Temporary Condition

☒ Minor/Administrative Changes To An Existing Calculation (Safety Margin Not Affected)

☒ SAFETY RELATED ☐ AUGMENTED QUALITY ☐ NON-SAFETY RELATED

CALCULATION TITLE: HPCS, LPCS, and LPCI Discharge Min Flow Bypass Differential Pressure Switch Setpoint Error Analysis

☐ Editorial Change Continued - see attached

STATION/UNIT: LaSalle Units 1 and 2 **SYSTEM CODE:** E12, E21, E22

EQUIPMENT NO. AND COMPONENT TYPE (if appl.): 1(2)E12-N014A-C; 1(2)E21-N002; 1(2)E22-N007; 1(2)E12-N010AA, BA, CA; 1(2)E21-N004; and 1(2)E22-N006

provals required when initiating Calc Revision in accordance with Section C.5.4

PREPARED BY: R. Fredricksen [signature] DATE: 5/12/00
PRINTED NAME/SIGNATURE [signature] 5/17/00

REVISION SUMMARY: This pending revision affects Reference 3.23, and Sections 14.3, 15.1, 15.2, 16.1, 16.2, and 17.0, as added or revised by DCR 990838 to NED-I-EIC-0198 Revision 1. The purpose of this pending revision is to incorporate a change in the method used to determine the Allowable Value (AV) and Extended Tolerance (ET). In accordance with Revision 2 of Reference 3.23, the AV is the sum of the nominal trip setpoint and the calculated drift tolerance interval (DTI_c). In addition, this change will provide both upper and lower Setpoints and Allowable Values for the applicable switches. The Extended Tolerance, based on the AV, is also recalculated. The changes associated with this pending revision and results are defined on the attached description of change.

ELECTRONIC CALCULATION DATA FILES: None
(Software name, Version, Name ext/size/date/hour/: min)
For Example: PIPSYS VERSION 2.3, SX01.dat, 63.5kb, 5/30/97, 14:23

DO ANY ASSUMPTIONS IN THIS CALCULATION REQUIRE LATER VERIFICATION?
☐ YES ☒ NO IF YES, INDICATE TRACKING NUMBER

REVIEWED BY: Joseph R. Basak [signature] DATE: 5/12/00
PRINTED NAME/SIGNATURE [signature] 5/17/00

REVIEW METHOD: Detailed Review COMMENTS (C, NC OR CI): (NC circled)

PEPP-E FORM

`EDITORIAL/MINOR/TEMPORARY CALCULATION CHANGE

DCR #:991051

APPROVED BY: Mark Murskyj / M Murskyj DATE: 5/17/00
PRINTED NAME/SIGNATURE

DESCRIPTION OF CHANGE to NED-I-EIC-0198 Revision 1 including approved pending revision DCR 990838:

1. Revise Reference 3.23 (added in DCR 990838) to read as follows:

   3.23 ComEd Document No. DG99-001245, Improved Technical Specifications (ITS) and 24-Month Technical Specifications project Technical Plan, Revision 2, April 28, 2000.

2. In section 4.5 change "18 months" to "refueling cycle".

3. In Section 12.1.5 change the "per year" to " per refueling cycle" .

4. Delete Section 14.3 (as revised in DCR 990838)

5. Replace the Section 15 and 16 added by DCR 990838 with the following:

15.0 Determination of Limiting Setpoints and Allowable Values

15.1 Determination of the Limiting Setpoint (SP_C)

There are two analytical limits or their equivalent for these switches. There is a maximum flow, which is a design input for core safety analysis. These values are from Section 4.6 (as added by DCR 990838), and are converted to inches of water column using the flow coefficient equation from Section 11.1.2:

Module 1A & 2A, HPCS Max. Flow Bypass

$$AL_{A(Max)} = [1948.0 \text{ gpm}/321 (\text{gpm}/''\text{wc}^{1/2})]^2 = 36.82713 ''\text{wc}$$

Module 1B & 2B, LPCS Max. Flow Bypass

$$AL_{B(Max)} = [2121.0 \text{ gpm}/349 (\text{gpm}/''\text{wc}^{1/2})]^2 = 36.93435 ''\text{wc}$$

Module 1C & 2C, LPCI Max. Flow Bypass

$$AL_{C(Max)} = [2463.0 \text{ gpm}/412 (\text{gpm}/''\text{wc}^{1/2})]^2 = 35.73834 ''\text{wc}$$

In addition, there are minimum flows for each of these switches, based on the minimum flow necessary to insure that the pumps will have sufficient flow to prevent overheating. These values are from Section 10.0, and are converted to inches of water column using the flow coefficient equation from Section 11.1.2:

Module 1A & 2A, HPCS Min. Flow Bypass

$AL_{A(Min)}$ = [1000.0 gpm/321 (gpm/"wc$^{1/2}$)]^2 = 9.704875 "wc

Module 1B & 2B, LPCS Min. Flow Bypass

$AL_{B(Min)}$ = [635.0 gpm/349 (gpm/"wc$^{1/2}$)]^2 = 3.310523 "wc

Module 1C & 2C, LPCI Min. Flow Bypass

$AL_{C(Min)}$ = [550.0 gpm/412 (gpm/"wc$^{1/2}$)]^2 = 1.782095 "wc

From Section 13.2, the total errors for the respective flow bypass switches are:

$TE2a_A$ = ±9.2908 "wc
$TE2a_B$ = ±10.0703 "wc
$TE2a_C$ = ±9.2797 "wc

Computing the limiting setpoint for each module will use the following formula:

Maximum Setpoints:

$SP_c \leq AL - TE_a$

Minimum Setpoints

$SP_c \geq AL + TE_a$

Module 1A & 2A, HPCS Flow Bypass

$SP_{A(Max)} \leq AL_{A(Max)} - TE2a_A$

$SP_{A(Max)} \leq$ 36.82713 "wc - 9.2908 "wc

$SP_{A(Max)} \leq$ 27.53633 "wc

Use $SP_{A(Max)} \leq$ 27.5 "wc

$SP_{A(Min)} \geq AL_{A(Min)} + TE2a_A$

$SP_{A(Min)} \geq$ 9.704875 "wc + 9.2908 "wc

$SP_{A(Min)} \geq$ 18.995675 "wc

Use	$SP_{A(Min)}$	~~≤~~ ≥	19.0 "wc (MPM 5/17/00)

<u>Module 1B & 2B, LPCS Flow Bypass</u>

	$SP_{B(Max)}$	≤	$AL_{B(Max)}$ - $TE2a_B$
	$SP_{B(Max)}$	≤	36.93435 "wc - 10.0703 "wc
	$SP_{B(Max)}$	≤	26.86405 "wc
Use	$SP_{B(Max)}$	≤	26.8 "wc
	$SP_{B(Min)}$	≥	$AL_{B(Min)}$ + $TE2a_B$
	$SP_{B(Min)}$	≥	3.310523 "wc + 10.0703 "wc
	$SP_{B(Min)}$	≥	13.380823 "wc
Use	$SP_{B(Min)}$	~~≤~~ ≥	13.4 "wc (MPM 5/17/00)

<u>Module 1C & 2C, LPCI Flow Bypass</u>

	$SP_{C(Max)}$	≤	$AL_{C(Max)}$ - $TE2a_C$
	$SP_{C(Max)}$	≤	35.73834 "wc - 9.2797 "wc
	$SP_{C(Max)}$	≤	26.45864 "wc
Use	$SP_{C(Max)}$	≤	26.4 "wc
	$SP_{C(Min)}$	≥	$AL_{C(Min)}$ + $TE2a_C$
	$SP_{C(Min)}$	≥	1.782095 "wc + 9.2797 "wc
	$SP_{C(Min)}$	≥	11.061795 "wc
Use	$SP_{C(Min)}$	~~≤~~ ≥	11.1 "wc (MPM 5/17/00)

Because the switch is designed to close on decreasing pressure, the minimum setpoints will be the ones that are controlled by the field calibration.

The maximum setpoints are, however, the safety related setpoints and these occur on the reset of the switch. Thus, both set and reset for the switch must be calibrated.

The deadband on the switch is given by the manufacturer as 3" wc (see Section 4.7) so the field setpoint must be at least 3 "wc lower than $SP_{(Max)}$ to ensure that the reset will occur within tolerances.

Therefore for the field setpoints for each switch:

<u>Module 1A & 2A, HPCS Flow Bypass</u>

$SP_A = (SP_{A(Min)} + SP_{A(Max)})/2$

$SP_A = (19.0 \text{ "wc} + 27.5 \text{ "wc})/2$

$SP_A = 23.25$ "wc

Use $SP_A = 23.0$ "wc

$SP_A = [(23.0)^{1/2} * 321] = 1539.46$ gpm

Use $SP_A = 1540$ gpm

Reset $SP_A = 23.0$ "wc + 3 "wc = 26.0 "wc

26 "wc is < 27.5 "wc so the reset will occur prior to the $SP_{A(Max)}$

<u>Module 1B & 2B, LPCS Flow Bypass</u>

$SP_B = (SP_{B(Min)} + SP_{B(Max)})/2$

$SP_B = (13.4 \text{ "wc} + 26.8 \text{ "wc})/2$

$SP_B = 20.1$ "wc

Use $SP_B = 20.0$ "wc

$SP_B = [(20.0)^{1/2} * 349] = 1560.775$ gpm

Use $SP_B = 1560$ gpm

Reset $SP_B = 20.0$ "wc + 3 "wc = 20.0 "wc

23 "wc is < 26.8 "wc so the reset will occur prior to the $SP_{B(Max)}$

Module 1C & 2C, LPCI Flow Bypass

$SP_C = (SP_{B(Min)} + SP_{B(Max)})/2$

$SP_C = (11.1 \text{ "wc} + 26.4 \text{ "wc})/2$

$SP_C = 18.75$ "wc

Use $SP_C = 18.7$ "wc

$SP_C = [(18.7)^{1/2} * 412] = 1781.632$ gpm

Use $SP_C = 1781$ gpm

Reset $SP_C = 18.7$ "wc + 3 "wc = 21.7 "wc

21.7 "wc is < 26.4 "wc so the reset will occur prior to the $SP_{C(Max)}$

15.2 Determination of the Limiting Allowable Value (AV)

To compute the Limiting Allowable Value the Limiting setpoint will be used.

For maximum setpoints the AV will add the DTI_v to the calculated setpoint value:

$AV_{(Max)} = SP_{(Max)} + DTI_v$

For minimum setpoints, the AV will subtract the DTI_v from the calculated setpoint value:

$AV_{(Min)} = SP_{(Min)} - DTI_v$

As described in Reference 3.23, the applicable uncertainty is referred to as the drift tolerance interval (DTI_v) for the ITS/24 Month Project. In addition, per Reference 3.23, the DTI_v is determined from the combination of Reference Accuracy, Drift, Setting Tolerance and Calibration Error. From Section 12 of this calculation, the applicable values for Calibration Error (CAL2), Drift (e2D), Setting Tolerance (ST2), and the Reference Accuracy, which is equal to the Repeatability (RPT2), are as follows:

RPT2 =	± 0.2 "wc	[1σ]	[Section 12.1.1.a]
$CAL2_{A/C}$	= $CAL2_{A\&C}$ = ± 0.025 "wc	[1σ]	[Section 12.1.1.d.1]
$CAL2_B$ =	± 0.267833"wc	[1σ]	[Section 12.1.1.d.2]
ST2 =	± 0.2 "wc	[1σ]	[Section 12.1.2]

$e2D =$ ± 0.2 "wc [1σ] [Section 12.1.5]

Per Section 12.1 of this calculation, all four terms used in determining the DTI_v – the Drift, Setting Tolerance, CAL, and the Repeatability – are considered as random terms. Thus, the DTI_v is calculated as follows for Modules A & C:

$$DTI_{v(A\,\&\,C)}\ (1\sigma) = [(RPT2)^2 + (e2D)^2 + (CAL2_{A\,\&\,C})^2 + (ST2)^2]^{1/2}$$

$$DTI_{v(A\&C)}\ (1\sigma) = [(0.2)^2 + (0.2)^2 + (0.025)^2 + (0.2)^2]^{1/2}$$

$$DTI_{v(A\&C)}\ (1\sigma) = \pm 0.347311 \text{ "wc}$$

$$DTI_{v(A\&C)}(2\sigma) = \pm 0.694622 \text{ "wc}$$

Similarly, the DTI_v for Module B is determined from the same equation as above, just substituting the calibration error ($CAL2_B$) for Module B into the equation, or

$$DTI_{v(B)}\ (1\sigma) = [(0.2)^2 + (0.2)^2 + (0.267833)^2 + (0.2)^2]^{1/2}$$

$$DTI_{v(B)}\ (1\sigma) = \pm 0.437875 \text{ "wc}$$

$$DTI_{v(B)}(2\sigma) = \pm 0.87575 \text{ "wc}$$

Now computing the AVs:

Module 1A & 2A, HPCS Flow Bypass

$$AV_{A(Max)} \leq SP_{A(Max)} + DTI_{v(A)}$$

$$AV_{A(Max)} \leq 27.53633 \text{ "wc} + 0.694622 \text{ "wc}$$

$$AV_{A(Max)} \leq 28.230952 \text{ "wc}$$

Use $AV_{A(Max)} \leq 28.2$ "wc

$$AV_{A(Max)} \leq [(28.2)^{1/2} * 321] = 1704.628 \text{ gpm}$$

Use $AV_{A(Max)} \leq 1704$ gpm

	$AV_{A(Min)}$	$\geq$	$SP_{A(Min)}$ - $DTI_{v(A)}$
	$AV_{A(Min)}$	$\geq$	18.995675 "wc – 0.694622 "wc
	$AV_{A(Min)}$	$\geq$	18.301053 "wc
Use	$AV_{A(Min)}$	$\geq$	18.4 "wc 18.4 mpm 5/17/00
	$AV_{A(Min)}$	$\not\leq$ $\geq$ mpm 5/17/00	$[(28.2)^{½} * 321]$ = 1376.937 gpm
Use	$AV_{A(Min)}$	$\not\leq$ $\geq$	1377 gpm

Module 1B & 2B, LPCS Flow Bypass

	$AV_{B(Max)}$	$\leq$	$SP_{B(Max)}$ + $DTI_{v(B)}$
	$AV_{B(Max)}$	$\leq$	26.86405"wc + 0.87575 "wc
	$AV_{B(Max)}$	$\leq$	27.7398 "wc
Use	$AV_{B(Max)}$	$\leq$	27.7 "wc (conservatively rounded) 27.7 mpm 5/17/00
	$AV_{B(Max)}$	$\leq$	$[(28.2)^{½} * 349]$ = 1836.815 gpm
Use	$AV_{B(Max)}$	$\leq$	1836 gpm
	$AV_{B(Min)}$	$\geq$	$SP_{A(Min)}$ - $DTI_{v(A)}$
	$AV_{B(Min)}$	$\geq$	13.380823 "wc – 0.87575 "wc
	$AV_{B(Min)}$	$\geq$	12.505073"wc
Use	$AV_{B(Min)}$	$\geq$	12.6 "wc 12.6
	$AV_{B(Min)}$	$\not\leq$ $\geq$	$[(28.2)^{½} * 349]$ = 1238.827 gpm mpm 5/17/00
Use	$AV_{B(Min)}$	$\not\leq$ $\geq$	1239 gpm

Module 1C & 2C, LPCI Flow Bypass

	$AV_{C(Max)}$	$\leq$	$SP_{C(Max)}$ + DTI_v

$AV_{C(Max)} \leq 26.45864 \text{ "wc} + 0.694622 \text{ "wc}$

$AV_{C(Max)} \leq 27.153262 \text{ "wc}$

Use $AV_{C(Max)} \leq 27.1 \text{ "wc}$ 27.1

$AV_{C(Max)} \leq [(28.2)^{½} * 412] = 2144.776 \text{ gpm}$ 27.1 mpm 5/17/00

Use $AV_{C(Max)} \leq 2144 \text{ gpm}$

$AV_{C(Min)} \geq SP_{C(Min)} - DTI_{V©}$

$AV_{C(Min)} \geq 11.061795 \text{ "wc} - 0.694622 \text{ "wc}$

$AV_{C(Min)} \geq 10.367173 \text{ "wc}$

Use $AV_{C(Min)} \geq 10.4 \text{ "wc}$

$AV_{C(Min)}$ ~~≤~~ ≥ [(~~28.2~~ 10.4)^{½} * 412] = 1328.66 gpm mpm 5/17/00

Use $AV_{C(Min)}$ ~~≤~~ ≥ 1329 gpm

16.0 Determination of Expanded Tolerance (Administrative As Found Limit)

The Expanded Tolerance (ET) for these switches, per Reference 3.23, is determined as follows:

For Maximum Setpoints

$$ET = [0.7 \times (AV - SP - ST)] + ST$$

For Minimum Setpoints:

$$ET = [0.7 \times (SP - AV - ST)] + ST$$

From Section 10.0, ST is equal to ±0.6 inches for all switches. Thus, ET is determined as,

$$ET_{Max} = [0.7 \times (AV - SP_C - 0.6)] + 0.6$$

$$ET_{Min} = [0.7 \times (SP_C - AV - 0.6)] + 0.6$$

Therefore, the Expanded Tolerance Limit is determined as follows:

Module 1A & 2A, HPCS Min. Flow Bypass

$ET_{A(Max)}$= [0.7 x (AV $_{A(Max)}$ – SP$_{A(Max)}$ – 0.6)] + 0.6 "wc

$ET_{A(Max)}$= [0.7 x (28.230952 "wc – 27.53633 "wc – 0.6)] + 0.6 "wc

$ET_{A(Max)}$= [0.7 x (.094662)] + 0.6 "wc

$ET_{A(Max)}$= 0.666235 "wc

Use $ET_{A(Max)}$= ± 0.66 "wc

$ET_{A(Min)}$= [0.7 x (SP$_{A(Min)}$ – AV $_{A(Min)}$ – 0.6)] + 0.6

$ET_{A(Min)}$= [0.7 x (18.995675 "wc –18.301053 "wc – 0.6)] + 0.6 "wc

$ET_{A(Min)}$= [0.7 x (.094662)] + 0.6 "wc

$ET_{A(Min)}$= 0.666235 "wc

Use $ET_{A(Min)}$= ± 0.66 "wc

Module 1B & 2B, LPCS Min. Flow Bypass

$ET_{B(Max)}$= [0.7 x (AV $_{B(Max)}$ – SP$_{B(Max)}$ – 0.6)] + 0.6 "wc

$ET_{B(Max)}$= [0.7 x (27.7398 "wc – 26.86405 "wc – 0.6)] + 0.6 "wc

$ET_{B(Max)}$= [0.7 x (0.27575)] + 0.6 "wc

$ET_{B(Max)}$= 0.793025 "wc

Use $ET_{B(Max)}$= ± 0.79 "wc

$ET_{B(Min)}$= [0.7 x (SP$_{B(Min)}$ – AV $_{B(Min)}$ – 0.6)] + 0.6

$ET_{B(Min)}$= [0.7 x (13.380823 "wc –12.505073 "wc – 0.6)] + 0.6 "wc

$ET_{B(Min)}$= [0.7 x (0.27575)] + 0.6 "wc

$ET_{B(Min)}$= 0.793025 "wc

Use $ET_{B(Min)}$= ± 0.79 "wc

Module 1C & 2C, LPCI Min. Flow Bypass

$$ET_{C(Max)} = [0.7 \times (AV_{C(Max)} - SP_{C(Max)} - 0.6)] + 0.6 \text{ "wc}$$

$$ET_{C(Max)} = [0.7 \times (27.153262 \text{ "wc} - 26.45864 \text{ "wc} - 0.6)] + 0.6 \text{ "wc}$$

$$ET_{C(Max)} = [0.7 \times (.094662)] + 0.6 \text{ "wc}$$

$$ET_{C(Max)} = 0.666235 \text{ "wc}$$

Use $ET_{C(Max)} = \pm 0.66$ "wc

$$ET_{C(Min)} = [0.7 \times (SP_{C(Min)} - AV_{C(Min)} - 0.6)] + 0.6$$

$$ET_{C(Min)} = [0.7 \times (11.061795 \text{ "wc} - 10.367173 \text{ "wc} - 0.6)] + 0.6 \text{ "wc}$$

$$ET_{C(Min)} = [0.7 \times (.094662)] + 0.6 \text{ "wc}$$

$$ET_{C(Min)} = 0.666235 \text{ "wc}$$

Use $ET_{C(Min)} = \pm 0.66$ "wc

Because the ET_{Max} and ET_{Min} are the same for each switch then only one ET is required for each switch.

Replace the new paragraphs added to section 17 by DCR 990838 with the following:

The following is the computed data for the switches indicated:

EPN		AV	SP	ET
1(2) E22-N006	Reset	28.2 "wc / 1704 gpm	23.0 "wc/ 1540 gpm	± 0.66 "wc
	Set	18.4 "wc / 1377 gpm		
1(2) E21-N004	Reset	27.7 "wc / 1836 gpm	20.0 "wc/ 1560 gpm	± 0.79 "wc
	Set	12.6 "wc / 1239 gpm		
1(2) E12-N010 AA/BA/CA	Reset	27.1 "wc / 2144 gpm	18.7 "wc/ 1781 gpm	± 0.66 "wc
	Set	10.4 "wc / 1329 gpm		

CALCULATION TITLE PAGE

CALCULATION NO: DCR 990838 REV. N/A
STATION/UNIT: LaSalle/1 and 2
TITLE: Change NED-I-EIC-0198 to Derive AV & ET for ITS/24 Mo. Project

DESCRIPTION CODE: I03 SYSTEM CODE: E12, E21, E22
DISCIPLINE CODE: I ELEVATION CODE: Misc.

☒ Safety Related ☐ Augmented Quality Related ☐ Non-Safety Related

REFERENCE NUMBERS:

Type	Number
PROJ	105260

COMPONENT EPN:

EPN	Comp Type
See NED-I-EIC-0198	

DOCUMENT NUMBERS:

Doc Type/ SubType		Document Number
CALC	ENG	NED-I-EIC-0198, Rev. 1

REVISION SUMMARY:

See page 3 for detailed changes to calculation NED-I-EIC-0198.

Electronic Calculation Data Files:
(Program Name, Version, File name ext/size/date/hour/:min)

Type of Review: ☒ Detailed ☐ Alternate ☐ Test ☐ Repetitive Calc Review

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

Tracked by: (NTS#, AT#, EWCS #, etc.) ____
Approvals required when initiating Calc Revision in accordance with Section C.5.4

	Print/Sign/Initial			Org.	Date
Prepared by:	R. S. Weldon	RSWeldon	RSW	Excel	2/2/00
Reviewed by:	T. W. Bolian	TW Bolian	TWB	Excel	2/2/00
Approved by	Mark Mursky	[signature]		ComEd	3/6/00

Supplemental Review Required ☐ Yes (NEP-12-05 documentation attached) ☒ No
Supervisor [signature] 3/7/00 (ComEd USE ONLY)

CALCULATION NO: DCR 990838 REV. N/A

Table of Contents

CALCULATIONS:

DETAILED DESCRIPTION OF CHANGES:

This DCR changes uncertainty calculation NED-I-EIC-0198 to derive differential pressure switch Allowable Values and Expanded Tolerance for the Improved Technical Specification Project / 24 Month Cycle Extension Project. It also incorporates into the calculation an evaluation of the differential pressure switches' reset function.

1. Replace the first paragraph of Purpose/Objective of Calculation, Section 1.0 with the following:

   The purpose of this calculation is to determine, for the instrument loops that open their respective minimum flow bypass valves, when HPCS, LPCS, or LPCI discharge flow decreases to their respective setpoints, what the total instrument loop error (uncertainty) is associated with each of these loops. In addition, this calculation addresses the impact of the loop error on the closing function of the flow bypass valves (for HPCS, LPCS, and LPCI) upon increasing flow.

   Add the following two paragraphs to the end of the Purpose/Objective of Calculation, Section 1.0:

   This calculation also derives the new Technical Specification Allowable Values for the Improved Technical Specification Project.

   Finally, this calculation computes Expanded Tolerance (administrative internal as found limit) for the above switches.

2. Delete Section 2.3 and add new Sections 2.3 and 2.4 as shown below:

   2.3 Derivation of allowable values for use in the Improved Technical Specification Project will be in accordance with the methodology of References 3.22 and 3.23.

   2.4 Expanded as-found tolerance will be computed for each switch. The methodology for this determination is within Reference 3.23.

3. Add references 3.22, 3.23, 3.24 and 3.25 as shown below.

   3.22 NES-EIC-20.04, "Analysis of Instrument Channel Setpoint Error and Instrument Loop Accuracy," Rev. 1

3.23 ComEd Document No. DG99-001245, Improved Technical Specifications (ITS) and 24-Month Technical Specifications Project Technical Plan, Revision 1, November 8, 1999

3.24 VTIP Binder J-0212, Tab 21, Static O-Ring Inc. Publication Number 215, "SOR Inc. - Instruction Manual for Differential Pressure Switches," November 1, 1984

3.25 NDIT NFM-98-00197, Containing Siemens Report EMF-95-041, Rev. 1

4. Add new Sections 4.6 and 4.7 as shown below.

4.6 Reference 3.25 assumes that the respective bypass valves for HPCS, LPCI, and LPCS begin to close on increasing system flow at the values stated below. These values represent the Analytical Limits for the maximum flows within the respective HPCS, LPCI, and LPCS bypass lines.

HPCS Bypass Flow AL (Upper):	1948.0 gpm
LPCI Bypass Flow AL (Upper):	2463.0 gpm
LPCS Bypass Flow AL (Upper):	2121.0 gpm

4.7 Reference 3.24 provides the following information:

a. Series 102 and 103 differential pressure switches have a fixed deadband (i.e., the reset point is at a fixed point about the adjustable setpoint).

b. The switching element designation within the model number (i.e., for a Model 103AS-B202-NX-JJTTX6 the "B" would be the switching element designation) identifies any applicable multiplier to the maximum deadband provided within the specifications. For the "B" switching element the multiplier is 1.5.

c. For a 103-202 series switch, the maximum specified deadband (without any multipliers) is 2.0 "wc.

d. The maximum deadband for a Model 103AS-B202-NX-JJTTX6 differential pressure switch would be 2.0 x 1.5 = 3.0 "wc.

5. Remove the 3 listings of "Tech Spec LCO" within Section 10.0.

6. Delete Sections 14.4 and 14.5 and replace Section 14.3 with the following:

14.3 Deadband/Reset Function Evaluation

From Section 4.6, the maximum flows (Analytical Limits) assumed in the accident analysis within the bypass lines when the bypass valves begin to close are as follows, converted to inches of water column using the flow coefficient equation from Section 11.1.2,

Module 1A & 2A, HPCS Max. Flow Bypass

$$AL_{A(Max)} = [1948.0 \text{ gpm}/321 (\text{gpm}/''\text{wc}^{1/2})]^2 = 36.827127 \ ''\text{wc}$$

Module 1B & 2B, LPCS Max. Flow Bypass

$$AL_{B(Max)} = [2121.0 \text{ gpm}/349 (\text{gpm}/''\text{wc}^{1/2})]^2 = 36.934352 \ ''\text{wc}$$

Module 1C & 2C, LPCI Max. Flow Bypass

$$AL_{C(Max)} = [2463.0 \text{ gpm}/412 (\text{gpm}/''\text{wc}^{1/2})]^2 = 35.738341 \ ''\text{wc}$$

From Section 10.0, the calibration setpoints for each of the flow bypass differential pressure switches is,

Modules 1A & 2A, HPCS Flow Bypass: SP = 23 "wc

Modules 1B & 2B, HPCS Flow Bypass: SP = 23 "wc

Modules 1C & 2C, HPCS Flow Bypass: SP = 23 "wc

From Section 4.7, the reset points for the specified differential pressure switches are fixed at 3 "wc from the setpoint. With the setpoint values provided above, the resulting reset points would then be the setpoint plus the 3 "wc, or:

Modules 1A & 2A, HPCS Flow Bypass: Reset = 26 "wc

Modules 1B & 2B, LPCS Flow Bypass: Reset = 26 "wc

Modules 1C & 2C, LPCI Flow Bypass: Reset = 26 "wc

From Section 13.2, the total errors for the respective flow bypass switches are:

$TE2a_A =$ ±9.2908 "wc
$TE2a_B =$ ±10.0703 "wc

$TE2a_C =$ ±9.2797 "wc

Therefore, the reset points are combined with the total errors and evaluated against the respective Analytical Limits to ensure the acceptability of the reset points:

Module 1A & 2A, HPCS Flow Bypass

$AL_{A(Max)} \geq$ Reset + $TE2a_A$

36.827127 "wc ≥ 26 "wc + 9.2908 "wc

36.827127 "wc ≥ 35.2908"wc and is thus acceptable

Module 1B & 2B, LPCS Flow Bypass

$AL_{B(Max)} \geq$ Reset + $TE2a_B$

36.934352 "wc ≥ 26 "wc + 10.0703 "wc

36.934352 "wc ≥ 36.0703"wc and is thus acceptable

Module 1C & 2C, LPCI Flow Bypass

$AL_{C(Max)} \geq$ Reset + $TE2a_C$

35.738341 "wc ≥ 26 "wc + 9.2797 "wc

35.934352 "wc ≥ 35.2797"wc and is thus acceptable

The above evaluation shows that the values for the reset points will ensure that the analytical limits for the maximum flows assumed within the bypass lines, are not exceeded.

7. Change the numbering for the existing Section "15", to section "17".

8. Add Sections 15.0 and 16.0 as shown below:

15.0 Determination of Allowable Value for Improved Technical Specification Project

15.1 Allowable Value for Decreasing Bypass Flow

Appendix C of Reference 3.22 provides the instructions for calculating an Allowable Value for a setpoint (decreasing) as:

AV = SP - applicable uncertainty(for a decreasing setpoint)

Where:

AV =	Allowable Value (as calculated for ITS project)
SP =	Calculated Trip Setpoint
Applicable = Uncertainty	a value calculated from the errors and uncertainties that have been determined to effect the trip setpoint

From Section 14 of this calculation, the calculated setpoint, SP has a value as follows:

SP = 23 "wc decreasing

In terms of flow, this calculated setpoint corresponds to the following values per Section 11.1.2 of this calculation:

$SP_{FLOW\,A}$ = SP_A = 1539.5 gpm decreasing
$SP_{FLOW\,B}$ = SP_B = 1673.7 gpm decreasing
$SP_{FLOW\,C}$ = SP_C = 1975.9 gpm decreasing

As described in Reference 3.23, the applicable uncertainty is referred to as the drift tolerance interval (DTI_v) for the ITS/24 Month Project. In addition, per Reference 3.23, the DTI_v is determined from the combination of Reference Accuracy, Drift, Setting Tolerance and Calibration Error. From Section 12 of this calculation, the applicable values for Calibration Error (CAL2), Drift (e2D), Setting Tolerance (ST2), and the Reference Accuracy which is equal to the Repeatability (RPT2) are as follows:

$RPT2 = \pm 0.2$ "wc [1σ]

$CAL2_{A/C} = CAL2_{A\&C} = \pm 0.025$ "wc [1σ]

$CAL2_B = \pm 0.267833$"wc [1σ]

$ST2 = \pm 0.2$ "wc [1σ]

$e2D = \pm 0.2$ "wc [1σ]

Per Section 12.1 of this calculation, all four terms used in determining the DTI_v - the Drift, Setting Tolerance, CAL, and the Repeatability - are considered as random terms. Thus, the DTI_v is calculated as follows for Modules A & C:

$$DTI_{v(A\&C)}(1\sigma) = [(RPT2)^2 + (e2D)^2 + (CAL2_{A\&C})^2 + (ST2)^2]^{1/2}$$

$$DTI_{v(A\&C)}(1\sigma) = [(0.2)^2 + (0.2)^2 + (0.025)^2 + (0.2)^2]^{1/2}$$

$$DTI_{v(A\&C)}(1\sigma) = \pm 0.347311 \text{ "wc}$$

$$DTI_{v(A\&C)}(2\sigma) = \pm 0.694622 \text{ "wc}$$

Similarly, the DTI_v for Module B is determined from the same equation as above, just substituting the calibration error ($CAL2_B$) for Module B into the equation, or

$$DTI_{v(B)}(1\sigma) = [(0.2)^2 + (0.2)^2 + (0.267833)^2 + (0.2)^2]^{1/2}$$

$$DTI_{v(B)}(1\sigma) = \pm 0.437875 \text{ "wc}$$

$$DTI_{v(B)}(2\sigma) = \pm 0.87575 \text{ "wc}$$

Therefore, per References 3.22 and 3.23 the AV is calculated as follows for Modules A & C:

$$AV_{(A\&C)} = SP - DTI_{v(A\&C)}$$

$$AV_{(A\&C)} = 23 \text{ "wc} - 0.694622 \text{ "wc}$$

$$AV_{(A\&C)} = 22.305378 \text{ "wc}$$

$AV_{(A\&C)} =$ 22.3 "wc (Rounded for Usability)

Converting the dP to flow using the information from Section 11.1.2 of this calculation:

$AV_{(A)}$ (flow) = $(K_A)\ (dP_{(A/C)})^{1/2}$

Where $dP_{A/C} = AV_{(A\&C)}$

$AV_{(A)}$ (flow) = (321 gpm/inwc) $(22.3 \text{ inwc})^{1/2}$

$AV_{(A)}$ (flow) = 1515.8543 gpm

$AV_{(A)}$ (flow) = 1515.9 gpm (Rounded for Usability)

Also, for Module C the AV for flow, using the information from Section 11.1.2 of this calculation:

$AV_{(C)}$ (flow) = $(K_C)(dP_{A/C})^{1/2}$

$AV_{(C)}$ (flow) = (412 gpm/inwc) $(22.3\text{inwc})^{1/2}$

$AV_{(C)}$ (flow) = 1945.5825 gpm

$AV_{(C)}$ (flow) = 1945.6 gpm (Rounded for Usability)

Similarly, the AV is calculated as follows for Module B:

$AV_{(B)} = SP - DTI_{v(B)}$

$AV_{(B)}$ =23 "wc - 0.87575 "wc

$AV_{(B)}$ =22.12425 "wc

$AV_{(B)}$ =22.1 "wc (Rounded for Usability)

Converting the dP to flow using the information from Section 11.1.2 of this calculation:

$AV_{(B)}$ (flow) = $(K_B)\ (dP_B)^{1/2}$

$AV_{(B)}$ (flow) = (349 gpm/inwc) $(22.1\text{inwc})^{1/2}$

$AV_{(B)}$ (flow) = 1640.6712 gpm

$AV_{(B)}$ (flow) = 1640.7 gpm (Rounded for Usability)

The terms included in the AV determinations were treated in the same way as they were in the setpoint determination. Therefore, adequate margin exists between the Analytical Limit and the Allowable Value, and no check calculation is required.

15.2 Allowable Value for Increasing Flow

Appendix C of Reference 3.22 provides the instructions for calculating an Allowable Value for a setpoint (increasing) as:

AV = SP + applicable uncertainty (for an increasing setpoint)

Where:

AV =	Allowable Value (as calculated for ITS project)
SP =	Calculated Trip Setpoint
Applicable = Uncertainty	a value calculated from the errors and uncertainties that have been determined to effect the trip setpoint

Based on the configuration of the bypass flow loops, for the increasing flow evaluation, the setpoint becomes the reset point. From Section 14 of this calculation, the reset point (Reset) has a value as follows:

Reset = 26 "wc increasing

From Section 15.1, the $DTI_{v(A\,\&\,C)}$ is ± 0.6946222 "wc. Therefore, for Modules A and C the Allowable Value for increasing flow (AV_{incr}) becomes,

$AV_{incr(A\&C)}$ = Reset + $DTI_{v(A\,\&\,C)}$

$AV_{incr(A\&C)}$ = 26 "wc + 0.694622 "wc

$AV_{incr(A\&C)}$ = 26.694622"wc

$AV_{incr(A\&C)} =$ 26.7 "wc (Rounded for Usability)

Converting the dP to flow using the information from Section 11.1.2 of this calculation:

$AV_{incr(A)}$ (flow) = $(K_A)\ (dP_{(A/C)})^{1/2}$

Where $dP_{A/C} = AV_{incr(A\&C)}$

$AV_{incr(A)}$ (flow) = (321 gpm/inwc) (26.7 inwc)$^{1/2}$

$AV_{incr(A)}$ (flow) = 1658.6726 gpm

$AV_{incr(A)}$ (flow) = 1658.7 gpm (Rounded for Usability)

Also, for Module C the AV_{incr} for flow, using the information from Section 11.1.2 of this calculation:

$AV_{incr(C)}$ (flow) = $(K_C)(dP_{A/C})^{1/2}$

$AV_{incr(C)}$ (flow) = (412 gpm/inwc) (26.7inwc)$^{1/2}$

$AV_{incr(C)}$ (flow) = 2128.8882 gpm

$AV_{incr(C)}$ (flow) = 2128.9 gpm (Rounded for Usability)

Similarly, the AV_{incr} is calculated as follows for Module B:

$AV_{incr(B)} =$ Reset + $DTI_{v(B)}$

$AV_{incr(B)} =$ 26 "wc + 0.87575 "wc

$AV_{incr(B)} =$ 26.87575 "wc

$AV_{incr(B)} =$ 26.9 "wc (Rounded for Usability)

Converting the dP to flow using the information from Section 11.1.2 of this calculation:

$AV_{incr(B)}$ (flow) = $(K_B)\ (dP_B)^{1/2}$

$AV_{(B)}$ (flow) = (349 gpm/inwc) (26.9 inwc)$^{1/2}$

$AV_{incr(B)}$ (flow) = 1810.0958 gpm

$AV_{incr(B)}$ (flow) = 1810.1 gpm (Rounded for Usability)

The terms included in the AV determinations were treated in the same way as they were in the setpoint determination. Therefore, adequate margin exists between the Analytical Limit and the Allowable Value, and no check calculation is required.

16.0 Determination of Expanded Tolerance (Administrative As Found Limit)

16.1 Expanded Tolerance Limit for Decreasing Flow

The Expanded Tolerance (ET) for these switches, per Reference 3.23, is determined as follows for Modules A & C for a decreasing setpoint:

$$ET_{A\&C} = [0.7 \times (SP - AV_{(A\&C)} - ST)] + ST \quad \text{(where ST is a } 2\sigma \text{ value)}$$

From Section 12.1.2, ST as a 1σ value is equal to ±0.2 inches. Therefore, when converted to a 2σ value it becomes ±0.4 inches. Thus, $ET_{A\&C}$ Is determined as,

$$= [0.7 \times (23 - 22.3 - 0.4)] + 0.4$$

$$= 0.61\text{"wc}$$

Therefore the Expanded Tolerance Limit is determined as follows for Modules A & C for the decreasing setpoint :

$$\begin{aligned} \text{ET Limit (A \&C)} &= SP - ET_{A\&C} \\ &= 23\text{ "wc} - 0.61\text{ "wc} \\ &= 22.39\text{ "wc} \\ &= 22.4\text{ "wc (Rounded for Usability)} \end{aligned}$$

Similarly, the Expanded Tolerance is determined as follows for Module B for a decreasing setpoint:

$$\begin{aligned} ET_B &= [0.7 \times (SP - AV_{(B)} - ST)] + ST \quad \text{(where ST is a } 2\sigma \text{ value)} \\ &= [0.7 \times (23 - 22.1 - 0.4)] + 0.4 \\ &= 0.75\text{"wc} \end{aligned}$$

Therefore the Expanded Tolerance Limit is determined for Module B as follows for a decreasing setpoint::

ET Limit (B) = SP - ET_B
= 23 "wc – 0.75 "wc
= 22.25 "wc
= 22.3 "wc (Rounded for Usability)

16.2 Expanded Tolerance Limit for Increasing Flow

Per Section 16.1 above, the ET for Modules A & C ($ET_{A\&C}$) is 0.61 "wc. Per Reference 3.23, the ET Limit for an increasing setpoint (which in this case is the reset point), is,

ET Limit (A &C) = Reset + $ET_{A\&C}$
= 26 "wc + 0.61 "wc
= 26.61 "wc
= 26.6 "wc (Rounded for Usability)

Similarly for Module B, using the ET for Module B (ET_B) of 0.75"wc given in Section 16.1 above, the ET Limit for Module B becomes,

ET Limit (B) = Reset + ET_B
= 26 "wc + 0.75 "wc
= 26.75 "wc
= 26.8 "wc (Rounded for Usability)

9. Delete the first sentence in the first paragraph of Section 17.0, Error Analysis Summary and Conclusions. Also, delete the term "Tech Spec LCO (Allowable Value)", and make the term "Analytical Limit" plural, within the second sentence. Add the following two paragraphs to the end of Section 17.0 as shown below:

This calculation determines the Allowable Values for the switches for use in the Improved Technical Specification Project to be as follows:

Recommended Allowable Value (for decreasing flow):

Module A: 22.3 "wc and 1515.9 gpm

Module B: 22.1 "wc and 1640.7 gpm

Module C: 22.3 "wc and 1945.6 gpm

Recommended Allowable Value (for increasing flow using the reset function):

Module A: 26.7 "wc and 1658.7 gpm

Module B: 26.9 "wc and 1810.1 gpm

Module C: 26.7 "wc and 2128.9 gpm

The Expanded Tolerance Limit (Administrative As Found Tolerance) for these switches have been determined to be as follows for the Module A & C setpoints, for decreasing flow:

ET Limit = 22.4 "wc

And for the Module B setpoint for decreasing flow:

ET Limit = 22.3 "wc

The Expanded Tolerance Limit (Administrative As Found Tolerance) for these switches have been determined to be as follows for Modules A & C for the reset points on increasing flow:

ET Limit = 26.6 "wc

And for the Module B reset point on increasing flow:

ET Limit = 26.8 "wc

Reference 3.4 (the calibration procedures) do not currently check the reset points versus any specific acceptance criteria and should be revised to check the reset points versus acceptance criteria as provided for within this calculation.

10. Change the Table of Contents to Renumber the Existing Section 15 Listing to Section 17. Add listings in the table of contents for new Sections 15 and 16, with titles as given in Step 6 above. Make adjustments to pagination as necessary to accommodate all changes.

CALCULATION TITLE PAGE

Page 1

ComEd
LaSalle

Calculation No. NED-I-EIC-0198

DESCRIPTION CODE: I03 (Setpoint/Settings/Margin)
DISCIPLINE CODE: I (Instrumentation & Control)
SYSTEM CODE: E12, E21, E22

TITLE: HPCS, LPCS and LPCI Discharge Min Flow Bypass Differential Pressure Switch Setpoint Error Analysis

_X_ Safety Related ___ Augmented Quality ___ Non-Safety Related

REFERENCE NUMBERS

Type	Number	Type	Number

COMPONENT EPN:

EPN	Compt Type
1(2)E12-N014A,B,C	ΔP Switch
1(2)E21-N002	ΔP Switch
1(2)E22-N007	ΔP Switch
1(2)E12-N010AA,BA,CA	ΔP Switch
1(2)E21-N004	ΔP Switch
1(2)E22-N006	ΔP Switch

DOCUMENT NUMBERS:

Doc Type/Sub Type	Document Number

REMARKS:

REV. NO.	REVISING ORGANIZATION	APPROVED PRINT/SIGN	DATE
0	ComEd	Pete Wicyk	12-19-96
1	Duke Engineering & Services	Larry Lawrence / [signature]	11-14-97

COMMONWEALTH EDISON COMPANY
CALCULATION REVISION PAGE

CALCULATION NO. NED-I-EIC-0198 PAGE NO.: 2 of 52

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: W. D. Crumpacker DATE: 12-13-96
Print/Sign

REVIEWED BY: S. Vanderslice (DE&S) DATE: 12-16-96
Print/Sign

Type of Review
☒ Detailed ☐ Alternate ☐ Test

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

Tracked by: ____________

REV: 1

REVISION SUMMARY:
Implement classification of Drift error (eD) as a random, 2σ error term, per Reference 3.14. Incorporate instrument specifications per NDIT No. LS-0626 (Reference 3.20). Re-evaluated flow element uncertainty due to correction of upstream/downstream lengths and incorporate process error effects. (Section 11). Re-evaluated margin with respect to Analytical Limit & Tech Spec LCO, based on calibration setpoint, as opposed to nominal trip setpoint. Incorporated NEP Rev. 5. (As a result all pages are identified as Rev. 1. However, for clarity, only those changes in calculation content are identified by "revision bars.") - Affected pages: 1-19, 21-34, 38-52

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

WordPerfect 6.1 File Name: LS0198.6R1/304KB/11-14-97/10:00am

PREPARED BY: [signature] for E. A. Kaczmarski (DE&S) DATE: 11-14-97
Print/Sign

REVIEWED BY: [signature] J. J. Galligan (DE&S) DATE: 11-14-97
Print/Sign

Type of Review
☒ Detailed ☐ Alternate ☐ Test

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

Tracked by: ____________

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ATTACHMENT B Record of Telephone Conversation between T. R. Hearing of Signals & Safeguards, Inc. and K. Perriman of LaSalle Station I.M. Department regarding available pressure gauges, 0 to 36"wc range, and their calibration accuracies, dated 11/12/93 (1 page)	B1	
ATTACHMENT C Letter from S. Burns of SOR to E. Seckinger of CECo providing static shift acceptance criteria for SOR dP pressure switches Model 103AS-B202 and 103AS-BB202, dated 10/28/92 (6 pages)	C1 - C6	

1.0 PURPOSE/OBJECTIVE OF CALCULATION

The purpose of this calculation is to determine, for the instrument loops that open their respective min flow bypass valves, when HPCS, LPCS or LPCI discharge flow decreases to their respective setpoints and whether there exists available margin between the following:

(A) The Analytical Limit (AL) and the Calibrated Trip Setpoints (SPc)

(B) The Tech Spec Allowable Value (LCO) and the Calibrated Trip Setpoints (SPc)

The calculation is valid under normal operating and accident environmental conditions and allows for all normal operating and accident errors for the following instruments:

1E22-N006	1E12-N014A	1E12-N010AA
2E22-N006	1E12-N014B	1E12-N010BA
1E22-N007	1E12-N014C	1E12-N010CA
2E22-N007	2E12-N014A	2E12-N010AA
1E21-N004	2E12-N014B	2E12-N010BA
2E21-N004	2E12-N014C	2E12-N010CA
1E21-N002		
2E21-N002		

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2.0 METHODOLOGY AND ACCEPTANCE CRITERIA

The methodology used for this calculation is presented in TID-E/I&C-20, "Basis For Analysis of Instrument Channel Setpoint Error and Instrument Loop Accuracy", Rev. 0, dated 4/6/92, and TID-E/I&C-10, "Analysis of Instrument Channel Setpoint Error and Instrument Loop Accuracy", Rev. 0, dated 4/6/92 (Reference 3.2 and 3.3).

2.1 The evaluation of errors used to determine the "Total Error" (TE) is consistent with the above methodology with the following exceptions:

a. The calibration tolerance is assumed to describe the limits of the as-left component outputs. For a random error, this corresponds to 100% of the population and can be statistically represented by a 3 sigma value. Per References 3.2 and 3.3, the "Setting Tolerance" (ST) is defined as a random error which is due to the procedural allowances given to the technician performing the calibration. For this calculation:

ST = calibration tolerance / 3

b. Per Reference 3.8, the temperature error specification for the SOR switch is considered to be a random error. Consequently, this specified effect will be treated as a random error and combined under random error SRSS methodology.

c. Per References 3.2 and 3.3, when determining the margin between the Analytical Limit and the calibrated trip setpoint, all errors present during the operating conditions under which the instrument loop is required to function are included in the total error computation. However, when determining the margin between the Allowable Value and calibrated trip setpoint, only those errors that are observable during calibration, using the applicable surveillance procedures and the required M&TE, are included in the total error computation.

d. Per Reference 3.19, the drift error is considered to be a 2σ random error. Consequently, this specified effect will be treated as a random error and combined under random error SRSS methodology.

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e. During normal operating conditions, seismic events less than or equal to an Operating basis Earthquake (OBE) are not considered to cause a permanent shift in the input/output relationship of a device. For seismic events greater than an OBE, affected instrumentation will be recalibrated as necessary prior to any subsequent accident, negating any permanent shift which may have resulted from a seismic event. As such, the seismic error for normal operating conditions is considered to be negligible with respect to other error terms.

2.2 Temperature, radiation and humidity errors, when available from the manufacturer, were evaluated with respect to the normal and accident conditions specified in the LaSalle Station EQ zones. The EQ zone requirements for each instrument was obtained from the LaSalle Station EQ Zone maps.

2.3 The acceptance criteria for this calculation is that a positive margin is required between the Analytical Limit and the calibrated trip setpoint and Allowable value and the calibrated trip setpoint.

3.0 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 1994

3.2 TID-E/I&C-20, "Basis for Analysis of Instrument Channel Setpoint Error & Loop Accuracy", Rev. 0, dated 4/6/92.

3.3 TID-E/I&C-10, "Analysis of Instrument Channel Setpoint Error and Instrument Loop Accuracy", Rev. 0, dated 4/6/92.

3.4 LaSalle County Station Instrument/Maintenance Procedures

LIS-HP-105 (Rev. 11), "Unit 1 High Pressure Core Spray Minimum Flow Bypass Calibration", dated May 30, 1997.

LIS-HP-205 (Rev. 11), "Unit 2 High Pressure Core Spray Minimum Flow Bypass Calibration", dated March 20, 1997.

LIS-LP-102 (Rev. 12), "Unit 1 LPCS Minimum Flow Bypass Quarterly Calibration", dated May 21, 1997.

LIS-LP-202 (Rev. 12), "Unit 2 LPCS Minimum Flow Bypass Quarterly Calibration", dated November 9, 1994.

LIS-RH-103A (Rev. 5), "Unit 1 RHR A (LPCI Mode) Minimum Flow Bypass Quarterly Calibration", dated August 6, 1997.

LIS-RH-103B (Rev. 5), "Unit 1 RHR B & C (LPCI Mode) Minimum Flow Bypass Quarterly Calibration", dated June 10, 1997

LIS-RH-203A (Rev. 3), "Unit 2 RHR A (LPCI Mode) Minimum Flow Bypass Quarterly Calibration", dated November 7, 1994.

LIS-RH-203B (Rev. 4), "Unit 2 RHR B & C (LPCI Mode) Minimum Flow Bypass Quarterly Calibration", dated November 7, 1994.

3.5 LaSalle Station UFSAR, Rev 11 (dated 4/8/96), EQ Zone Maps, Table 3.11-7, 8, 16, 17

3.6 SOR, Inc. Form No. 388, dated 5/92

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

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3.8 Commonwealth Edison Company Calculation No. NED-I-EIC-0172, "Determination of Ambient Temperature Error Effect associated with SOR Differential Pressure and Static Pressure Switches", Rev. 0, CHRON # 206505.

3.9 General Electric Purchase Specification Data Sheet 21A9351BB, Revision 1, "Flow Orifice Assembly Data Sheet" for Residual Heat Removal System, dated 11/8/73.

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

Drwg #	Sht#	Revision	Dated
M-838	2	AJ	2/18/93
M-839	7	N	9/21/88
M-839	12	AF	7/29/91
M-938	2	AC	6/24/92
M-939	10	AD	5/15/92
M-837	3	AJ	5/27/93
M-839	10	AC	3/26/93
M-937	3	R	7/22/92
M-939	7	S	7/13/89
M-939	12	Y	7/13/89

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 1985.

3.12 AETC Test Report 18878-84N-1, Rev. 1, "Qualification Testing of Class 1E Electrical Equipment in Accordance with IEEE Std. 323-1974, IEEE 344-1975 and NUREG 0588 for SOR, Inc. Differential Pressure Switch Model 103AS-B202-NX-JJTTX6", dated 8/30/84.

3.13 Commonwealth Edison Electronic Work Control System (EWCS), Equipment/Component Engineering Data:

1-E22-N006	Rev. 000
2-E22-N006	Rev. 000
1-E22-N007	Rev. 000
2-E22-N007	Rev. 000
1-E21-N004	Rev. 000
2-E21-N004	Rev. 000
1-E21-N002	Rev. 000
2-E21-N002	Rev. 000
1-E12-N014A	Rev. 000
1-E12-N014B	Rev. 000
1-E12-N014C	Rev. 000
2-E12-N014A	Rev. 000

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2-E12-N014B	Rev. 000
2-E12-N014C	Rev. 000
1-E12-N010AA	Rev. 000
1-E12-N010BA	Rev. 000
1-E12-N010CA	Rev. 000
2-E12-N010AA	Rev. 000
2-E12-N010BA	Rev. 000
2-E12-N010CA	Rev. 000

3.14 General Electric Report MDE-78-0686, DRF L12-00752, Class II, "Upper and Lower Setpoint Limits for Interim Operation of LaSalle Units 1 and 2", Rev. 1, dated June, 1987.

3.15 LaSalle Station Unit 1 Technical Specifications, Amendment no. 117, dated 1/29/97, and LaSalle Station Unit 2 Technical Specifications, Amendment no. 102, dated 1/19/97.

3.16 General Electric Purchase Specification Data Sheet 21A9351BE, Revision 0, "Flow Orifice Assembly Data Sheet" for High Pressure Core Spray System, dated 3/11/71.

3.17 General Electric Purchase Specification Data Sheet 21A9351BC, Revision 1, "Flow Orifice Assembly Data Sheet" for Low Pressure Core Spray System, dated 12/29/71.

3.18 General Electric System Design Specification Data Sheets 22A1483 AJ Rev. 9, dated 2/17/84 (HPCS), 22A2905 AJ, Rev. 7, dated 11/16/83 (LPCS), and 22A2817AK, Rev.7, dated 4/12/84 (LPCI).

3.19 NES Electrical I&C letter number DG 97-001088, dated 8/25/97, "Reclassification of the drift error term in the ComEd Setpoint Accuracy Methodology"

3.20 NDIT No. LS-0626, dated 9/30/97, "Instrument Setpoint Calculations"

3.21 ASME Steam Tables Sixth Edition, 1993

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4.0 DESIGN INPUTS

4.1 Reference 3.8 gives a temperature error of ± 0.42% URL/10°FΔT from 72°F to 212°F referred to 72°F for the SOR Model 103AS-B202-NX Differential Pressure Switch.

4.2 - DELETED - (Correspondence from SOR regarding SOR pressure switch repeatability not required. Information provided via Design Input 4.5).

4.3 Record of Telephone Conversation between T. R. Hearing of Signals & Safeguards, Inc. and K. Perriman of LaSalle Station I.M. Department regarding available pressure gauges, 0 to 36"wc range, and their calibration accuracies, dated 11/12/93. (ATTACHMENT B)

4.4 Letter from S. Burns of SOR to E. Seckinger of CECo providing static shift acceptance criteria for SOR dP pressure switches Model 103AS-B202 and 103AS-BB202, dated 10/28/92 (ATTACHMENT C). SOR requested that ComEd utilize an acceptance criteria of 5"wc maximum an all future purchase orders for static pressure shift for the Model 103AS switches.

4.5 Reference 3.20 provides the following information;

a. SOR differential pressure switch with suffix ending in "X6" have repeatability specification of ±1% of Upper Range Limit.

b. SOR does not provide drift error. Therefore, a default drift error of ±1% of Upper Range Limit per 18 months should be used. The drift error will be used in its entirety and not reduced for lesser calibration intervals.

c. A minimum ambient temperature of 60°F should be used to calculate switch temperature effect and Measurement & Test Equipment (M&TE) temperature error.

5.0 ASSUMPTIONS

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

5.2 Temperature, humidity and 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 - DELETED - (Assumption regarding instrument drift not required. Information provided via Reference 3.20)

5.4 - DELETED - (Assumption regarding minimum temperature not required. Information provided via Reference 3.20)

5.5 In accordance with Reference 3.7, 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. As such, it is assumed that the calibration standard accuracy error of M&TE is negligible with respect to the other terms.

5.6 - DELETED - (Assumption not required.)

5.7 Evaluation of M&TE errors is based on the assumption that the test equipment listed in Section 9.0 is used. Use of test equipment less accurate than that listed in this section will require evaluation of the effect upon the calculation results.

5.8 Radiation induced errors associated with normal environments 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 re-calibrated. Therefore, unless specifically published by the equipment vendor, the normal radiation errors can be assumed to be included within the instrument drift related errors.

5.9 Reference 3.11, Table 4.10, Note 1 indicates that the flow element base uncertainty is acceptable for flow elements in service less than six months. Reference 3.11 paragraph 4.17 further states that the base uncertainty for flow elements in service for more than six months is likely to change much less with time than for the initial six months. Therefore, any additional error due to the flow element being in service greater than six months is considered to be negligible.

5.10 Vendor information is not available to determine the flow element beta ratio (β). For orifices, these ratios vary from 0.10 to 0.75, but typically are between 0.50 and 0.70. High beta ratios produce low differential pressures and low beta ratios produce high differential pressures (high pressure losses). High beta ratios produce larger uncertainties than low beta ratios. Therefore, a beta ratio of 0.70 will be used. This is considered to to be a reasonable assumption based on common industry practice.

5.11 It is common industry practice to size an orifice plate for normal operating conditions. These values are identified as the Normal Operating Conditions pressure/temperature values, References 3.15 Section 3/4 5.1. The process error effects are determined as variations from this condition. The table below identifies the System (Normal Operating Conditions pressure/ temperature), the expected Minimum/Maximum Pressure, and the expected Minimum/Maximum Temperature. The process temperature will be conservatively evaluated as varying from 40 °F to 120 °F (120 °F is the Maximum Suppression Pool temperature, Reference 3.15) and the process pressure variations are expected to to be within ±100 PSIG.

System [Normal Operating Conditions pressure/ temperature]	Minimum/Maximum Pressure (PSIG)	Minimum/Maximum Temperature (°F)
$HPCS_{UNIT\ 1}$ [370 PSIG/ 120 °F]	270 / 470	40 / 120
$HPCS_{UNIT\ 2}$ [330 PSIG/ 120 °F]	230 / 430	40 / 120
LPCS [290 PSIG/ 120 °F]	190 / 390	40 / 120
LPCI [130 PSIG/ 120 °F]	30 / 230	40 / 120

6.0 INSTRUMENT CHANNEL CONFIGURATION

The Instrument Loops each consist of a flow element and a differential pressure switch.

The Instrument Loops open their respective min flow bypass valves when HPCS, LPCS or LPCI pumps discharge flow decrease to their respective calibrated setpoints.

EQUIPMENT FUNCTION

(2)1E22-N006 monitors HPCS flow differential. Initiates the following actions, if flow drops below Tech Spec setpoint:

a. Removes auto close interlock for Minimum Flow Bypass to Suppression Pool Valve, (2)1E22-F012.
b. Auto opens valve (2)1E22-F012.
c. Resets alarm window "HPCS PMP DSCH FLOW HI" on panel (2)1H13-P601.

(2)1E21-N004 monitors LPCS flow differential pressure. Initiates opening of LPCS Minimum Flow Bypass Valve, (2)1E21-F011, if flow drops below Tech Spec setpoint and LPCS Pump (2)1E21-C001 is running.

(2)1E12-N010AA monitors RHR A (LPCI Mode) flow differential pressure. Initiates opening of (2)1E12-F064A, A RHR Pump Minimum Flow Bypass Stop Valve, if flow drops below Tech Spec setpoint and RHR A Pump (2)1E12-C002A is running.

(2)1E12-N010BA monitors RHR B (LPCI Mode) flow differential pressure. Initiates opening of (2)1E12-F064B, B RHR Pump Minimum Flow Bypass Stop Valve, if flow drops below Tech Spec setpoint and RHR B Pump (2)1E12-C002B is running.

(2)1E12-N010CA monitors RHR C (LPCI Mode) flow differential pressure. Initiates opening of (2)1E12-F064C, C RHR Pump Minimum Flow Bypass Stop Valve, if flow drops below Tech Spec setpoint and RHR C Pump (2)1E12-C002C is running.

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7.0 PROCESS PARAMETERS

From Reference 3.13, except as noted:

HPCS Maximum Process Pressure:	1240 PSIG
HPCS Maximum Process Temperature:	170°F
HPCS Normal Operating Pressure (Reference 3.13, Section 3/4 5.1)	370 PSIG (Unit 1)
HPCS Normal Operating Temperature (Reference 3.13, Section 3/4 6.2.1)	120 °F (Unit 1)
HPCS Normal Operating Pressure (Reference 3.13, Section 3/4 5.1)	330 PSIG (Unit 2)
HPCS Normal Operating Temperature (Reference 3.13, Section 3/4 6.2.1)	120 °F (Unit 2)
LPCS Maximum Process Pressure:	525 PSIG
LPCS Maximum Process Temperature:	187°F
LPCS Normal Operating Pressure (Reference 3.13, Section 3/4 5.1)	290 PSIG
LPCS Normal Operating Temperature (Reference 3.13, Section 3/4 6.2.1)	120 °F
LPCI Maximum Process Pressure:	500 PSIG
LPCI Maximum Process Temperature:	388°F
LPCI Normal Operating Pressure (Reference 3.13, Section 3/4 5.1)	130 PSIG
LPCI Normal Operating Temperature (Reference 3.13, Section 3/4 6.2.1)	120 °F

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8.0 LOOP ELEMENT DATA

8.1 Module 1, General Electric Flow Orifice Plate

Module 1A HPCS Discharge Flow	1(2)E22-N007 (Reference 3.16)
Maximum Flow:	7800 gpm @ 212°F
dP @ Maximum Flow:	590"wc @ 68°F
Normal Flow:	6850 gpm @ 212°F
Normal Temperature:	40° to 120°F
System Design pressure/temp:	1325 PSIG/212°F
Associated Pipe Size:	16", Schedule 80

Module 1B LPCS Discharge Flow	1(2)E21-N002 (Reference 3.17)
Maximum Flow:	7800 gpm @ 212°F
dP @ Maximum Flow:	500"wc @ 68°F
Normal Flow:	6350 gpm @ 212°F
Normal Temperature:	40° to 120°F
System Design pressure/temp:	475 PSIG/212°F
Associated Pipe Size:	16", Schedule 30

Module 1C LPCI Discharge Flow	1(2)E12-N014A, B, C (Reference 3.9)
Maximum Flow:	8400 gpm @ 120°F
dP @ Maximum Flow:	415"wc @ 68°F
Normal Flow:	7450 gpm @ 120°F
Normal Temperature:	40° to 120°F
System Design pressure/temp:	500 PSIG/358°F
Associated Pipe Size:	18", Schedule 40

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8.2 Module 2A, Static "O" Ring Model 103AS-B202-NX-C1A-JJTTX6 Differential Pressure Switches (Reference 3.13)

HPCS Bypass

From Reference 3.6 and Design Inputs 4.1, 4.4, and 4.5,

Adjustable Range:	6 to 40"wc
Ref. Accuracy (Repeatability): (Design Input 4.5)	± 1% of Upper Range Limit (URL)
Drift (Design Input 4.5):	± 1% of URL/ 18 months
Ref. Operating Temp. Range:	-30 to 180°F (Ambient temp.)
Temp. Error Effect: (Design Input 4.1)	± 0.42% URL/10°FΔT from 72°F to 212°F referred to 72°F
Static Pressure Effect: (Design Input 4.4)	5"wc

8.2.1 Environmental Data for Switch Location

Switch Locations (Reference 3.13):

1(2)E22-N006 1(2)H22-P024 EQ Zone H6

Normal Operating Conditions for Environmental Zone H6 (Reference 3.5, Design Input 4.5)

Temperature	60°F-123°F
Pressure	-0.4" W.G.
Radiation	5×10^5 Rads (40-Year Dose)
Relative Humidity	20 - 29%

Accident Conditions for Environmental Zone H6 (Reference 3.5, Design Input 4.5)

Temperature	60°F-148°F
Pressure	-0.4" W.G.
Radiation	1×10^7 Rads (40-Year Dose)
Relative Humidity	20 - 90%

8.3 Module 2B, Static "O" Ring Model 103AS-B202-NX-JJTTX6 Differential Pressure Switches (Reference 3.13)

LPCS Flow Bypass

From Reference 3.6 and Design Inputs 4.1, 4.4, and 4.5,

Adjustable Range:	6 to 40"wc
Ref. Accuracy (Repeatability): (Design Input 4.5)	± 1% of Upper Range Limit (URL)
Drift (Design Input 4.5):	± 1% of URL/ 18 months
Ref. Operating Temp. Range:	-30 to 180°F (Ambient temp.)
Temp. Error Effect: (Design Input 4.1)	± 0.42% URL/10°FΔT from 72°F to 212°F referred to 72°F
Static Pressure Effect: (Design Input 4.4)	5"wc

8.3.1 Environmental Data for Switch Location

Switch Locations (Reference 3.13):

1(2)E21-N004	1(2)H22-P001	EQ Zone H5A

Normal Operating Conditions for Environmental Zone H5A (Reference 3.5, Design Input 4.5)

Temperature	60°F-124°F
Pressure	-0.4" W.G.
Radiation	5×10^5 Rads (40-Year Dose)
Relative Humidity	20 - 29%

Accident Conditions for Environmental Zone H5A (Reference 3.5, Design Input 4.5)

Temperature	60°F-212°F
Pressure	7" W.G.
Radiation	1×10^7 Rads (40-Year Dose)
Relative Humidity	Steam

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8.4 Module 2C, Static "O" Ring Model 103AS-B202-NX-JJTTX6 Differential Pressure Switches (Reference 3.13)

LPCI Flow Bypass

From Reference 3.6 and Design Inputs 4.1, 4.4, and 4.5,

Adjustable Range:	6 to 40"wc
Ref. Accuracy (Repeatability): (Design Input 4.5)	± 1% of Upper Range Limit (URL)
Drift (Design Input 4.5):	± 1% of URL/ 18 months
Ref. Operating Temp. Range:	-30 to 180°F (Ambient temp.)
Temp. Error Effect: (Design Input 4.1)	± 0.42% URL/10°FΔT from 72°F to 212°F referred to 72°F
Static Pressure Effect: (Design Input 4.4)	5"wc

8.4.1 Environmental Data for Switch Location

Switch Locations (Reference 3.13):

1(2)E12-N010AA	1(2)H22-P018	EQ Zone H6
1(2)E12-N010BA	1(2)H22-P021	EQ Zone H6
1(2)E12-N010CA	1(2)H22-P021	EQ Zone H6

Normal Operating Conditions for Environmental Zone H6 (Reference 3.5, Design Input 4.5)

Temperature	60°F-123°F
Pressure	-0.4" W.G.
Radiation	5 x 10^5 Rads (40-Year Dose)
Relative Humidity	20 - 29%

Accident Conditions for Environmental Zone H6 (Reference 3.5, Design Input 4.5)

Temperature	60°F-148°F
Pressure	-0.4" W.G.
Radiation	1 x 10^7 Rads (40-Year Dose)
Relative Humidity	20 - 90%

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9.0 CALIBRATION INSTRUMENT DATA

Per the station procedures (Reference 3.4) and the LaSalle IM Department, the following devices may potentially be used as measurement and test equipment when performing calibrations on the devices within the subject instrument loop.

Modules A & C, HPCS and LPCI Flow Bypasses

MTE1 (analog pressure gauge) (Design Input 4.3)

Manufacturer:	Dwyer
Model:	1211-72
Range:	-36"wc to 0 to 36"wc
Smallest Scale Div.:	0.1"wc

Module B, LPCS Flow Bypass

$MTE2_A$ (analog pressure gauge) (Reference 3.7)

Manufacturer:	Wallace & Tiernan
Model:	62A-2C-0125
Range:	0-125"wc
Calibration Accuracy:	± 0.2"wc
Smallest Scale Div.:	0.2"wc
Temp. Effect:	± 0.1% Range/10°C referred to 25°C

$MTE2_B$ (digital pressure gauge) (Reference 3.7)

Manufacturer:	Druck
Model:	DPI 601
Range:	0-138"wc
Reference Accuracy:	± 0.05% Range
Indication Accuracy:	± 0.003% Range
Least Significant Digit:	0.01"wc
Temp. Effect:	±0.003% of reading/°F (from 32° to 104°F referred to 73°F)

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10.0 CALIBRATION PROCEDURE DATA

The Instrument Calibration Procedures (Reference 3.4), and References 3.14 & 3.15 provide the following:

HPCS Flow Bypass (Module 2A) 1(2)E22-N006

Instrument Setpoint:	23"wc (Decr.)	
Allowable Range:	22.4 to 23.6"wc (±0.6"wc)	
NTSP[Note 1]:	1000 gpm (9.7"wc)	(Ref.3.15)
Tech Spec LCO:	≥ 7.85"wc (900 gpm)	(Ref.3.15)
Calibration Frequency:	3 months	
Late Factor:	0.75 months	
Analytical Limit[Note 1]:	1000 gpm	(Ref. 3.14)

LPCS Flow Bypass (Module 2B) 1(2)-E21-N004

Instrument Setpoint:	23"wc (Decr.)	
Allowable Range:	22.4 to 23.6"wc (±0.6"wc)	
NTSP[Note 1]:	750 gpm (4.39"wc)	(Ref.3.15)
Calibration Frequency:	3 months	
Late Factor:	0.75 months	
Tech Spec LCO:	≥ 3.19"wc (640 gpm) (Ref.3.15)	
Analytical Limit[Note]:	635 gpm	(Ref. 3.14)

LPCI Flow Bypass (Module 2C) 1(2)-E12-N010AA, BA, CA

Instrument Setpoint:	23"wc (Decr.)	
Allowable Range:	22.4 to 23.6"wc (±0.6"wc)	
NTSP[Note 1]:	1000 gpm (5.89"wc)	(Ref. 3.15)
Calibration Frequency:	3 months	
Late Factor:	0.75 months	
Tech Spec LCO:	≥ 550 gpm (1.78"wc) (Ref.3.15)	
Analytical Limit[Note 1]:	550 gpm (1.78"wc)	(Ref. 3.14)

Note 1: Neither the plant technical specifications nor the system design specification data sheets (Reference 3.18) specify an analytical limit for pump minimum flow. In 1986, ComEd requested G.E. to furnish the report listed in Reference 3.14. The G.E. report was prepared to identify the highest and lowest possible extremes for an analytical limit which can be justified in terms of supporting the plant safety system objectives. Because of this "after-the-fact" analyses, there appears to be some inconsistencies among Nominal Tech Spec Setpoints (NTSPs) and Analytical Limits (ALs). However the NTSPs listed are the original design values, whereas the ALs are representative of more current modeling and analyses. It is anticipated that ComEd will submit revised technical specifications based on the new analyses. This calculation makes use of the analytical limits presented in reference 3.14.

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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 (σ1n)

11.1.1 Flow Element Reference Accuracy (RA1n)

The flow element Reference Accuracies are determined from Table 4.10 of Reference 3.11. The Table 4.10 accuracies assume a new installation. In order to calculate the present accuracy of the flow elements, the ANSI/ASME PTC 6 Report, "Guidance for Measurement Uncertainty in Performance Tests of Steam Turbines" (Reference 3.11) was used to determine the accuracy of an orifice plate that had been calibrated, installed and not inspected thereafter. Thecalculation is as follows:

The piping drawings listing in Reference 3.10 were used to determine the smallest upstream and downstream straight lengths of piping around the flow elements. These values, in terms of number of pipe diameters, are as follows:

	Upstream Length	Downstream Length
Module 1A, 1(2)E22-N007 (HPCS)	17D	6D
Module 1B, 1(2)E21-N002 (LPCS)	14D	6D
Module 1C, 1(2)E12-N014A/B/C (LPCI)	16D	6D

The Overall Uncertainty (OU) of a flow orifice is evaluated using the equation for no flow straightener, Reference 3.11, as noted below:

Overall Uncertainty = $\pm[U_B^2 + U_{LNS}^2 + U_\delta^2 + U_{DSL}^2]^{1/2}$

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The Base Uncertainty (U_B) is determined from Table 4.10, item H for a liquid flow application with an orifice plate and an uncalibrated flow section:

	Module 1A	Module 1B	Module 1C
U_B	3.20% Flow	3.20% Flow	3.20% Flow

For Module 1A, the Minimum Upstream Straight Run Uncertainty (U_{LNS}) is determined from Figure 4.5 for $\beta = 0.7$ (Assumption 5.10) and a length ratio of 1.2. The length ratio is determined as the ratio of the upstream length of 17D, above, and the minimum straight length in Table 4.11 Column 1, of 14D. The values for Module 1B and Module 1C are similarily determined.

	Module 1A	Module 1B	Module 1C
U_{LNS}	1.90% of Flow	2.20% of Flow	1.95% of Flow

The Beta Ratio Uncertainty (U_β) is determined from Figure 4.6 for a $\beta = 0.7$ (Assumption 5.10) and an uncalibrated condition.

	Module 1A	Module 1B	Module 1C
U_β	0.70% of Flow	0.70% of Flow	0.70% of Flow

For Module 1A, the Minimum Downstream Straight Run Uncertainty (U_{DSL}) is determined from Figure 4.9 for a length ratio of 1.5, based on a downstream straight run of length 6D and the 4D minimum straight length per column 7 of table 4.11 at a β of 0.7. The values for Module 1B and Module 1C are similarily determined.

	Module 1A	Module 1B	Module 1C
U_{DSL}	0.30% of Flow	0.30% of Flow	0.30% of Flow

Using the values listed above, the overall uncertainty (OU)of each flow element is determined as follows:

$$OU_{1A} = \pm[U_B^2 + U_{LNS}^2 + U_\beta^2 + U_{DSL}^2]^{½}$$
$$= \pm[(3.20)^2 + (1.90)^2 + (0.70)^2 + (0.30)^2]^{1/2}$$
$$= \pm 3.80\% \text{ of flow}$$

$$OU_{1B} = \pm[U_B^2 + U_{LNS}^2 + U_\beta^2 + U_{DSL}^2]^{½}$$
$$= \pm[(3.20)^2 + (2.20)^2 + (0.70)^2 + (0.30)^2]^{1/2}$$
$$= \pm 3.96\% \text{ of flow}$$

$$OU_{1C} = \pm[U_B^2 + U_{LNS}^2 + U_\beta^2 + U_{DSL}^2]^{½}$$
$$= \pm[(3.20)^2 + (1.95)^2 + (0.70)^2 + (0.30)^2]^{1/2}$$
$$= \pm 3.82\% \text{ of flow}$$

11.1.2 Overall Flow Element Uncertainty (OU)

The overall flow elememt uncertainty, determined in Section 11.1, is given in terms of % of flow. This uncertainty will be evaluated at the calibrated setpoint in order to determine the flow element reference accuracy.

The setpoints listed in Section 10.0 are given in units of differential pressure ("wc) and will be converted to flow rate (gpm) in order to apply the reference accuracy determined in Section 11.1.

Using the maximum flowrate (Q) and corresponding dP listed in Section 8.1, the Flow Coefficient (K) for each flow element is determined as follows:

Module 1A:
$K_A = Q/(dP)^{½} = 7800 \text{ gpm}/(590\text{"wc})^{½} = 321 \text{ gpm}/(\text{"wc})^{½}$

Module 1B:
$K_B = Q/(dP)^{½} = 7800 \text{ gpm}/(500\text{"wc})^{½} = 349 \text{ gpm}/(\text{"wc})^{½}$

Module 1C:
$K_C = Q/(dP)^{½} = 8400 \text{ gpm}/(415\text{"wc})^{½} = 412 \text{ gpm}/(\text{"wc})^{½}$

Using the Flow Coefficient (K) for each flow element and calibrated setpoint (SPc) dPs listed in Section 10.0, the corresponding flowrate (SP_{FLOW}) is determined as follows:

$$SP_{FLOW} = (K)(dP)^{½}$$

Module 1A: $K_A = 321 \text{ gpm}/(\text{"wc})^{½}$ $SPc_A = 23\text{"wc}$

$SP_{FLOW\_A} = (K_A)(SPc_A)^{½}$
$= [321 \text{ gpm}/(\text{"wc})^{½}][23\text{"wc}]^{½}$
$= 1539.5$ gpm

Module 1B: $K_B = 349 \text{ gpm}/(\text{"wc})^{½}$ $SPc_B = 23\text{"wc}$

$SP_{FLOW\_B} = (K_A)(SPc_A)^{½}$
$= [349 \text{ gpm}/(\text{"wc})^{½}][23\text{"wc}]^{½}$
$= 1673.7$ gpm

Module 1C: $K_C = 412 \text{ gpm}/(\text{"wc})^{½}$ $SPc_C = 23\text{"wc}$

$SP_{FLOW\_C} = (K_A)(SPc_A)^{½}$
$= [412 \text{ gpm}/(\text{"wc})^{½}][23\text{"wc}]^{½}$
$= 1975.9$ gpm

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The reference accuracies for the calibrated setpoints are determined using the flow element overall uncertainty (OU) determined in Section 11.1, as follows:

$$RA1n = \pm[OU][SP_{FLOW}]$$

Calibrated Setpoint, Module 1A:

OU_{1A} = ±3.80% of flow SP_{FLOW_A} = 1539.5 gpm

$RA1n_A$ = ±[3.80%][1539.5 gpm]
= ± 58.501 gpm

Calibrated Setpoint, Module 1B:

OU_{1B} = ±3.96% of flow SP_{FLOW_B} = 1673.7 gpm

$RA1n_B$ = ±[3.96%][1673.7 gpm]
= ± 66.279 gpm

Calibrated Setpoint, Module 1C:

OU_{1C} = ±3.82% of flow SP_{FLOW_C} = 1975.9 gpm

$RA1n_C$ = ±[3.82%][1975.9 gpm]
= ± 74.479 gpm

Per Assumption 5.1, the standard deviation of reference accuracy ($RA1n_{(1\sigma)}$) is $RA1n_{(2\sigma)}/2$. Therefore:

At the Calibrated Setpoints:

$RA1n_{A(1\sigma)}$ = ± 58.501 gpm/2 = ± 29.2505 gpm

$RA1n_{B(1\sigma)}$ = ± 66.279 gpm/2 = ± 33.1395 gpm

$RA1n_{C(1\sigma)}$ = ± 74.479 gpm/2 = ± 37.2395 gpm

The reference accuracy is the only contribution to random error in Module 1, therefore:

Calibrated Setpoints:

$\sigma 1n_A$ = ± 29.2505 gpm

$\sigma 1n_B$ = ± 33.1395 gpm

$\sigma 1n_C$ = ± 37.2395 gpm

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11.1.3 Propagation of $\sigma 1$ Through Flow Element

The range of error for calibrated setpoint flow rate ($SP_{FLOW} \pm \sigma 1n$) is computed as follows:

Module 1A: 1539.5 ± 29.2505 gpm = 1510.2495 to 1568.7505 gpm
Module 1B: 1673.7 ± 33.1395 gpm = 1640.5605 to 1706.8395 gpm
Module 1C: 1975.9 ± 37.2395 gpm = 1938.6605 to 2013.1395 gpm

Then the minimum, ideal, and maximum flow rates are converted to inches of water column using the flow coefficient equation from Section 11.1.2 as follows:

<u>Module 1A</u>

		Difference
$[1510.2495 \text{ gpm}/321(\text{gpm}/\text{"wc}^{1/2})]^2$	= 22.135398"wc	
		0.86574"wc
$[1539.5 \text{ gpm}/321(\text{gpm}/\text{"wc}^{1/2})]^2$	= 23.001138"wc	
		0.882347"wc
$[1568.7505 \text{ gpm}/321(\text{gpm}/\text{"wc}^{1/2})]^2$	= 23.883485"wc	

The worst case difference occurs between the calibrated setpoint and the 1568.7505 gpm equivalent dP's. Therefore:

$\sigma 1n_{Aprop}$ = ± 0.882347"wc

<u>Module 1B</u>

		Difference
$[1640.5605 \text{ gpm}/349(\text{gpm}/\text{"wc}^{1/2})]^2$	= 22.097017"wc	
		0.901741"wc
$[1673.7 \text{ gpm}/349(\text{gpm}/\text{"wc}^{1/2})]^2$	= 22.998758"wc	
		0.919774"wc
$[1706.8395 \text{ gpm}/349(\text{gpm}/\text{"wc}^{1/2})]^2$	= 23.918532"wc	

The worst case difference occurs between the calibrated setpoint and the 1706.8395 gpm equivalent dP's. Therefore:

$\sigma 1n_{Bprop}$ = ± 0.919774"wc

<u>Module 1C</u>

		Difference
$[1938.6605 \text{ gpm}/412(\text{gpm}/\text{"wc}^{1/2})]^2$	= 22.141605"wc	
		0.8588"wc
$[1975.9 \text{ gpm}/412(\text{gpm}/\text{"wc}^{1/2})]^2$	= 23.000405"wc	
		0.875141"wc
$[2013.1395 \text{ gpm}/412(\text{gpm}/\text{"wc}^{1/2})]^2$	= 23.875546"wc	

The worst case difference occurs between the calibrated setpoint and the 2013.132082 gpm equivalent dP's. Therefore:

$\sigma 1n_{Cprop}$ = ± 0.875141"wc

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11.2 Random Error, Accident Conditions ($\sigma 1a$)

Per Section 11.1.2, reference accuracy is the only contribution to random error. Hence, random error for the flow elements is the same for normal and accident conditions, therefore:

Calibrated Setpoints

$\sigma 1a_{Aprop} = \sigma 1n_{Aprop} = \pm 0.882347$"wc

$\sigma 1a_{Bprop} = \sigma 1n_{Bprop} = \pm 0.919774$"wc

$\sigma 1a_{Cprop} = \sigma 1n_{Cprop} = \pm 0.875141$"wc

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11.3 Non-Random Error, Normal Operating Conditions ($\sum e1n$)

Per Assumption 5.9, the contribution to non-random error by the flow elements (Module 1A, 1B, and 1C) during normal operating conditions is considered negligible. Therefore,

$$\sum e1n = 0$$

11.4 Non-Random Error, Accident Conditions ($\sum e1a$)

The flow element is a mechanical device that is affected by the process medium density changes.

11.4.1 Process Pressure Error ($e1P_pa$)

11.4.1.1 Module 1A (HPCS) Unit 1 and Unit 2

From Section 7.0, the Normal Operating Condition pressure ($ND_{UNIT\ 1}$) is 370 PSIG (385 PSIA) and ($ND_{UNIT\ 2}$) is 330 PSIG (345 PSIA), and the temperature is 120 °F. For compressed water, the specific volume and corresponding density of the fluid exhibits a negligible change for variations in pressure at a constant temperature for the system pressure range defined in Section 8.1. This is demonstrated by evaluating the following specific volumes obtained from the ASME Steam Tables (Reference 3.21) for pressures of 270/230 psig , 370/330 psig, and 470/430 psig at the suppression pool temperature of 120 °F:

HPCS Unit 1

$V_{@285psia,120F}$ = 0.01619 ft^3/lbm
$V_{@385psia,\ 120F}$ = 0.01619 ft^3/lbm
$V_{@485psia,120F}$ = 0.01618 ft^3/lbm

HPCS Unit 2

$V_{@245psia,120F}$ = 0.01619 ft^3/lbm
$V_{@345psia,\ 120F}$ = 0.01619 ft^3/lbm
$V_{@445psia,120F}$ = 0.01618 ft^3/lbm

Based on the above values, the variation in specific volume and density due to pressure change is considered to be negligible; therefore:

$e1P_pn_{HPCS} = 0$

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11.4.1.2 Module 1B (LPCS)

From Section 7.0, the Normal Operating Condition pressure (ND) is 290 PSIG (305 PSIA) and the temperature is 120 °F. For compressed water, the specific volume and corresponding density of the fluid exhibits a negligible change for variations in pressure at a constant temperature for the system pressure range defined in Section 8.1. This is demonstrated by evaluating the following specific volumes obtained from the ASME Steam Tables (Reference 3.21) for pressures of 190 psig (205 psia), 290 psig (305 psia), and 390 psig (405 psia) at the suppression pool temperature of 120 °F:

$v_{@205psia,120F} = 0.01619\ ft^3/lbm$
$v_{@305psia,\ 120F} = 0.01619\ ft^3/lbm$
$v_{@405psia,120F} = 0.01618\ ft^3/lbm$

Based on the above values, the variation in specific volume and density due to pressure change is considered to be negligible; therefore:

$e1P_pn_{LPCS} = 0$

11.4.1.3 Module 1C (LPCI)

From Section 7.0, the Normal Operating Condition pressure (ND) is 130 PSIG (145 PSIA) and the temperature is 120 °F. For compressed water, the specific volume and corresponding density of the fluid exhibits a negligible change for variations in pressure at a constant temperature for the system pressure range defined in Section 8.1. This is demonstrated by evaluating the following specific volumes obtained from the ASME Steam Tables (Reference 3.21) for pressures of 30 psig (45 psia), 130 psig (145 psia), and 230 psig (245 psia) at the suppression pool temperature of 120 °F:

$v_{@45psia,120F} = 0.01620\ ft^3/lbm$
$v_{@145psia,\ 120F} = 0.01620\ ft^3/lbm$
$v_{@245psia,120F} = 0.01619\ ft^3/lbm$

Based on the above values, the variation in specific volume and density due to pressure change is considered to be negligible; therefore:

$e1P_pn_{LPCI} = 0$

11.4.2 Process Temperature Error ($e1P_Ta$)

11.4.2.1 Module 1A (HPCS) Unit 1 and Unit 2

Process Temperature Error ($e1P_Ta$)

From Section 8.1, the normal process temperature can vary from the minimum process temperature of 40°F to a maximum process temperature of 120 °F. From Assumption 5.11, the Normal Operating Condition pressure (ND) is 270 PSIG (285 PSIA) for Unit 1 and 230 PSIG (245 PSIA) for Unit 2 and the temperature is 120 °F. As the process temperature changes, the density of the process medium (water) changes which causes the indicated flow to change.

The following specific volumes were obtained from the ASME Steam Tables (Reference 3.21) for 40 °F and 120 °F at an operating pressure of 270 PSIG (285 PSIA) and inverted to provide the associated densities identified in the table below.

HPCS Unit 1

Temperature/ Pressure	ν (FT^3/LBM)	ρ (LBM/FT^3)	Comments
40°F/385PSIA	0.01600	62.5	CD1
120°F/385PSIA	0.01619	61.7665	ND

The % change in density from the Normal Operating Condition pressure (ND) to Condition 1 (CD1) is determined as follows:

$\% \text{ Change}_{ND \text{ to Condition 1}}$ = $[(\rho_{ND} - \rho_{CD1})/\rho_{ND}]* 100$ % density
= [(61.7665 - 62.5)/61.7665] *100% density
= -1.19 % density

The % Change will be conservatively applied as a ± error even though it is applicable to the full range of operating temperature. A bounding value of ±1.19 % will be used. The percent change in fluid density, due to temperature change, is proportional to differential pressure and will be converted to a ΔP error at the setpoint (SP_{FLOW_A}) as follows:

$e1P_Ta$ = ±1.19% * (transmitter ΔP SP_{FLOW_A})
= ±1.19% * (23 "WC)

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= ±0.274 "WC

The % Change will be conservatively applied as a ± error even though it is applicable to the full range of operating temperature. A bounding value of ±1.19 % will be used. The percent change in fluid density, due to temperature change, is proportional to differential pressure and will be converted to a ΔP error at the setpoint (SP_{FLOW_A}) as follows:

$e1P_Ta$ = ±1.19% * (transmitter ΔP SP_{FLOW_A})
= ±1.19% * (23 "WC)
= ±0.274 "WC

<u>HPCS Unit 2</u>

The process temperature error for Unit 2 HPCS is similarly calculated from the following table:

Temperature/ Pressure	ν (FT^3/LBM)	ρ (LBM/FT^3)	Comments
40°F/345PSIA	0.01600	62.5	CD1
120°F/345PSIA	0.01619	61.7665	ND

The % change in density from the Normal Operating Condition pressure (ND) to Condition 1 (CD1) is determined as follows:

% $Change_{ND\ to\ Condition\ 1}$ = $[(\rho_{ND} - \rho_{CD1})/\rho_{ND}]$ * 100 % density
= [(61.7665-62.5)/61.7665] *100% density
= -1.19 % density

The % Change will be conservatively applied as a ± error even though it is applicable to the full range of operating temperature. A bounding value of ±1.19 % will be used. The percent change in fluid density, due to temperature change, is proportional to differential pressure and will be converted to a ΔP error at the setpoint (SP_{FLOW_A}) as follows:

$e1P_Ta$ = ±1.19% * (transmitter ΔP SP_{FLOW_A})
= ±1.19% * (23 "WC)
= ±0.274 "WC

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11.4.2.2 Module 1B (LPCS)

The process temperature error for LPCS is similarly calculated from the following table:

Temperature/ Pressure	ν (FT^3/LBM)	ρ (LBM/FT^3)	Comments
40°F/305PSIA	0.01600	62.5	CD1
120°F/305PSIA	0.01619	61.7665	ND

The % change in density from the Normal Operating Condition pressure (ND) to Condition 1 (CD1) is determined as follows:

$$\% \text{ Change}_{ND \text{ to Condition } 1} = [(\rho_{ND} - \rho_{CD1})/\rho_{ND}] * 100 \% \text{ density}$$
$$= [(61.7665-62.5)/61.7665] * 100\% \text{ density}$$
$$= -1.19 \% \text{ density}$$

The % Change will be conservatively applied as a ± error even though it is applicable to the full range of operating temperature. A bounding value of ±1.19 % will be used. The percent change in fluid density, due to temperature change, is proportional to differential pressure and will be converted to a ΔP error at the setpoint (SP_{FLOW_B}) as follows:

$$e1P_Ta = \pm 1.19\% * (\text{transmitter } \Delta P \; SP_{FLOW\_B})$$
$$= \pm 1.19\% * (23 \text{ "WC})$$
$$= \pm 0.274 \text{ "WC}$$

11.4.2.3 Module 1C (LPCI)

The process temperature error for LPCI is similarly calculated from the following table:

Temperature/ Pressure	ν (FT^3/LBM)	ρ (LBM/FT^3)	Comments
40°F/145PSIA	0.01601	62.4610	CD1
120°F/145PSIA	0.01620	61.7284	ND

The % change in density from the Normal Operating Condition pressure (ND) to Condition 1 (CD1) is determined as follows:

$$\% \text{ Change}_{ND \text{ to Condition } 1} = [(\rho_{ND} - \rho_{CD1})/\rho_{ND}]*100\ \% \text{ density}$$
$$= [(61.7284-62.4610)/61.7284]*100\% \text{ density}$$
$$= -1.19\ \% \text{ density}$$

The % Change will be conservatively applied as a ± error even though it is applicable to the full range of operating temperature. A bounding value of ±1.19 % will be used. The percent change in fluid density, due to temperature change, is proportional to differential pressure and will be converted to a ΔP error at the setpoint (SP_{FLOW_C}) as follows:

$$e1P_Ta = \pm 1.19\% * (\text{transmitter } \Delta P\ SP_{FLOW\_C})$$
$$= \pm 1.19\% * (23\ \text{"WC})$$
$$= \pm 0.274\ \text{"WC}$$

11.4.3 Total Non-Random Errors for Accident Conditions ($\sum e1a$)

The total non-random errors under normal conditions for the flow element is given by the sum of the individual errors.

11.4.3.1 Module 1A

$$\sum e1a = \pm(e1P_Pa + e1P_Ta)$$
$$= \pm(0+0.274\ \text{"WC})$$
$$= \pm 0.274\ \text{"WC}$$

11.4.3.2 Module 1B

$$\sum e1a = \pm(e1P_Pa + e1P_Ta)$$
$$= \pm(0+0.274\ \text{"WC})$$
$$= \pm 0.274\ \text{"WC}$$

11.4.3.3 Module 1C

$$\sum e1a = \pm(e1P_Pa + e1P_Ta)$$
$$= \pm(0+0.274\ \text{"WC})$$
$$= \pm 0.274\ \text{"WC}$$

12.0 SWITCH ERRORS (MODULE 2)

The switch has an analog input and a discrete output. Therefore, it is classified as a bistable module.

12.1.1 Random Error, Normal Operating Conditions ($\sigma 2n$)

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12.1.1.a Module 2 Trip Point Repeatability (RPT2)

Reference accuracy (1% of Upper Range Limit) and switch range (6 to 40"wc) is given in Sections 8.2, 8.3 and 8.4. Therefore,

$$RPT2 = 0.01(40"wc) = \pm 0.4"wc$$

As per Assumption 5.1, the standard deviation for reference accuracy ($RPT2_{(1\sigma)}$) is RPT2/2, therefore:

$$RPT2_{(1\sigma)} = \pm (0.4"wc)/2$$

$$= \pm 0.2"wc$$

12.1.1.b Calibration Error (CAL2)

The instrument is calibrated by applying a test pressure to the switch while measuring the pressure with a pressure gauge listed in Section 9.0, and recording the pressure at which the switch contact changes state. Modules 2A and 2C are calibrated using a -36" to 0 to 36"wc manometer while Module 2B is calibrated using a 0 to 125"wc pressure gauge.

12.1.1.b.1 Measurement & Test Equipment Error (MTE1)

The M&TE calibration error determination for Modules A and C and for Module B are performed below.

(A) MTE1 Dwyer Tube Manometer (Range -36" to +36"wc)

The only contribution to error for a manometer is reading error. Per Reference 3.3, the reading error for an analog gauge is ¼ of the smallest division. Therefore, from Section 9.0:

$$RE1 = \tfrac{1}{4}(0.1"wc) = 0.025"wc$$

$$MTE1 = \pm [((RA/2) + (TE/2))^2 + (RE1)^2]^{½}$$

$$= \pm [((0) + (0))^2 + (0.025"wc)^2]^{½}$$

$$= \pm 0.025"wc$$

(B) $MTE2_A$ W&T Analog Pressure Gauge (Range 0-125"wc)

Pressure gauge calibrated accuracy is a 2σ value. From the data in Section 9.0,

$$CA2_A = \pm 0.2"wc$$

The standard deviation for reference accuracy ($CA2_{A(1\sigma)}$) is $CA2_A/2$, therefore:

$$CA2_{A(1\sigma)} = \pm 0.2\text{"wc} / 2 = \pm 0.1\text{"wc}$$

Per Reference 3.2, the reading error of an analog gauge is ¼ the smallest division on the gauge. From data in Section 9.0,

$$RE2_A = \pm \tfrac{1}{4} (0.2\text{"wc}) = \pm 0.05\text{"wc}$$

From Section 9.0, TE2 is referred to the M&TE calibration temperature of 25°C. Since the pressure switch input pressure is monitored at the switch, the temperature error is evaluated using the switch environment. From Section 8.2, the worst case temperature at the switch location can be as high as 124°F (51.1°C) and as low as 60°F (15.6°C). Therefore,

$$\Delta T_1 = 51.1°C - 25°C = 26.1°C$$
$$\Delta T_2 = 25°C - 15.6°C = 9.4°C$$

The worst case temperature change is $\Delta T_1 = 26.1°C$

Therefore, from the data in Section 9.0 and evaluating the temperature effect at full scale (125"wc, Section 9.0),

$$TE2_A = (0.1\%\ \text{Full Scale}/10°C)\Delta T$$

$$= [(0.001)(125\text{"wc})/10°C][26.1°C]$$

$$= \pm 0.32625\text{"wc}$$

The standard deviation of temperature effect ($TE2_{A(1\sigma)}$) is $TE2_A/2$. Therefore,

$$TE2_{A(1\sigma)} = \pm 0.32625\text{"wc} / 2 = \pm 0.163125\text{"wc}$$

$$MTE2_A = [(CA2_{A(1\sigma)} + TE2_{A(1\sigma)})^2 + (RE2_A)^2]^{1/2}$$

$$= [(0.1\text{"wc} + 0.163125\text{"wc})^2 + (0.05\text{"wc})^2]^{1/2}$$

$$= \pm 0.267833\text{"wc}$$

(C) $MTE2_B$ Druck Digital Pressure Gauge

For the Druck digital gauges

$$MTE2_B = [(RAMTE2 + IAMTE2 + TEMTE2)^2 + LSD2^2]^{1/2}$$

RA2 - Reference accuracy

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IA2 - Indication accuracy

LSD2 - Least Significant Digit

TE2 - Temperature error

From the data in Section 9.0,

RA2 = 2(± 0.05% Full Scale) = 2(±0.0005)(138"wc)

= ± 0.138"wc

IA2 = 2(± 0.003% Full Scale) = 2(±0.00003)(138"wc)

= ± 0.00828"wc

The standard deviation for reference accuracy and indication accuracy are $RA2_{(1\sigma)}$ is RA2/2 and $IA2_{(1\sigma)}$ is IA2/2 respectively, therefore:

$RA2_{(1\sigma)}$ = ± 0.138"wc/2 = ± 0.069"wc

$IA2_{(1\sigma)}$ = ± 0.00828"wc/2 = ± 0.00414"wc

From the data in Section 9.0,

LSD2 = 0.01"wc

From Section 9.0, the Druck temperature effect is over a range of 32° to 104°F. The worst case temperature change is ΔT_1 = 104°F - 73°F = 31°F.

Therefore, from the data in Section 9.0 and evaluating the temperature effect at the highest acceptable calibration setpoint (Section 10.0, 23.6"wc), temperature effect is as follows:

$TE2_B$ = 2(0.003% of reading/°F)ΔT

= 2[(0.00003)(23.6"wc)/°F](31°F)

= ± 0.043896"wc

The standard deviation of temperature effect $TE2_{(1\sigma)}$ is TE2/2. Therefore:

$TE2_{B(1\sigma)}$ = ± 0.043896"wc/2 = ± 0.021948"wc

Therefore,

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$$MTE2_B = [(RA2 + IA2 + TE2_B)^2 + LSD2^2]^{1/2}$$

$$= \pm[(0.069"wc + 0.00414"wc + 0.021948"wc)^2 + (0.01"wc)^2]^{1/2}$$

$$= \pm\ 0.095612"wc$$

12.1.1.c Calibration Standard Error (STD2)

The error due to calibration accuracy of calibration equipment is assumed to be negligible (Assumption 5.5) Therefore,

$$STD2 = 0$$

12.1.1.d Determination of CAL2

$$CAL2 = [MTE2^2 + STD2^2]^{1/2}$$

12.1.1.d.1 Calibration Error for Modules 2A and 2C ($CAL2_{A/C}$)

From Section 12.1.1.b.1.A, the M & TE error that occurs with the Dwyer, -36" to +36"wc is ± 0.05"wc. Therefore,

$$CAL2_{A/C} = \pm[(0.025"wc)^2 + 0]^{1/2}$$

$$= \pm\ 0.025"wc$$

12.1.1.d.2 Calibration Error For Module 2B ($CAL2_B$)

From Sections 15.1.2.a.2 and .3, the worst case M & TE error occurs with the Wallace & Tiernan, 0 to 125"wc ($MTE2_A$ = ± 0.267833"wc). Therefore,

$$CAL2_B = \pm[(0.267833"wc)^2 + 0]^{1/2}$$

$$= \pm\ 0.267833"wc$$

12.1.2 Setting Tolerance (ST2)

Per data in Section 10.0, the setting tolerance for all three loops is as follows:

$$ST2 = \pm\ 0.6"wc$$

Per Section 2.1.a, ST2 is considered a 3σ value, therefore $ST2_{(1\sigma)}$ = ST2/3.

$$ST2_{(1\sigma)} = \pm (0.6\text{"wc})/3 = \pm 0.2\text{"wc}$$

12.1.3 Temperature Error (e2Tn)

The temperature effect is listed in Sections 8.2, 8.3 and 8.4 along with the upper range limit (URL) of 40"wc. The normal operating ambient temperature at the switch locations are 60° to 123°F and 60° to 124°F (Sections 8.2.1, 8.3.1, and 8.4.1), from which the maximum temperature difference (ΔT = 124° - 72° = 52°F) can be determined. Therefore,

$$e2Tn = \pm [0.42\%\ URL/10°F]\Delta T$$

$$= \pm [(0.0042)(40\text{"wc})/10°F]52°F$$

$$= \pm 0.8736\text{"wc}$$

Per Design Input 4.1, the standard deviation of temperature effect ($e2Tn_{(1\sigma)}$) is e2Tn/2. Therefore,

$$e2Tn_{(1\sigma)} = \pm 0.8736\text{"wc}/2 = \pm 0.4368\text{"wc}$$

12.1.4 Random Input Error (σ2inn)

The random input error of the switch is due to the flow element random error calculated in Section 11.1.2. Per Section 2.1.c methodology, when determining the margin between the Allowable Value and calibrated trip setpoint, only those error that are observable during calibration are included in the total error computation. During the calibration conditions, the loop is valved out of service from the process, and the effects of the flow element are not being measured. Therefore,

$$\sigma 2inn_A = 0$$

$$\sigma 2inn_B = 0$$

$$\sigma 2inn_C = 0$$

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12.1.5 Drift (e2D)

Drift is not described in the vendor's specification for the pressure switch. Per Design Input 4.5, instrument drift effect (IDE) is ±1% of Upper Range Limit per year and will be used in its entirety and not reduced for lesser calibration intervals. From the data in Section 8.2, 8.3 & 8.4, the switch upper range limit is 40"wc. Therefore,

$$e2D = \pm 1\% \text{ URL} = \pm (0.01 \bullet 40\text{"wc})$$

$$= \pm 0.4\text{"wc}$$

Per Reference 3.19, drift is considered a 2σ value, therefore $e2D_{(1\sigma)} = e2D/2$.

$$e2D_{(1\sigma)} = \pm (0.4\text{"wc})/2 = \pm 0.2\text{"wc}$$

12.1.6 Determination of Total Random Errors, Normal Operating Conditions (σ2n)

Per Section 2.1 methodology, the total random error is defined as

$$\sigma 2n = [(RPT2_{(1\sigma)})^2 + (CAL2)^2 + (ST2_{(1\sigma)})^2 + (e2Tn_{(1\sigma)})^2 + (e2D_{(1\sigma)})^2 + (\sigma 2inn_A)]^{½}$$

12.1.6.1 Determination of Module 2A Total Random Errors ($\sigma 2n_A$)

$$\sigma 2n_A = \pm[(0.2\text{"wc})^2 + (0.025\text{"wc})^2 + (0.2\text{"wc})2 + (0.4368\text{"wc})^2 + (0.2\text{"wc})^2 + (0\text{"wc})^2]^{½}$$

$$= \pm 0.558049\text{"wc}$$

12.1.6.2 Determination of Module 2B Total Random Error ($\sigma 2n_B$)

$$\sigma 2n_B = \pm[(0.2\text{"wc})^2 + (0.267833\text{"wc})^2 + (0.2\text{"wc})^2 + (0.4368\text{"wc})^2 + (0.2\text{"wc})^2 + (0\text{"wc})^2]^{½}$$

$$= \pm 0.618489\text{"wc}$$

12.1.6.3 Determination of Module 2C Total Random Errors ($\sigma 2n_C$)

$$\sigma 2n_C = \pm[(0.2\text{"wc})^2 + (0.025\text{"wc})^2 + (0.2\text{"wc})^2 + (0.4368\text{"wc})^2 + (0.2\text{"wc})^2 + (0\text{"wc})^2]^{½}$$

$$= \pm 0.558049\text{"wc}$$

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12.2 Random Error, Accident Conditions ($\sigma 2a$)

The only random error specification that is effected by accident conditions is temperature error. Therefore, for the purpose of this calculation, the new temperature error terms will be determined below and then combined as was done in Sections 12.1.6

12.2.1 Temperature Error (e2Ta)

12.2.1.a Module 2A and 2C Temperature Error ($e2Ta_{A/C}$)

The temperature effect is listed in Section 8.2, and 8.4 along with the upper range limit (URL) of 40"wc. The ambient temperature at the switch location for accident conditions is 60° to 148°F (Section 8.2.1, and 8.4.1), from which the maximum temperature difference (ΔT = 148° - 72° = 76°F) can be determined. Therefore,

$e2Ta_{A/C}$ = ± [0.42% URL/10°F] ΔT

= ± [(0.0042)(40"wc)/10°F]76°F

= ± 1.2768"wc

Per Design Input 4.1, the standard deviation of temperature effect ($e2Ta_{A/C(1\sigma)}$) is $e2Ta_{A/C}/2$. Therefore,

$e2Ta_{A/C(1\sigma)}$ = ± 1.2768"wc/2 = ± 0.6384"wc

12.2.1.b Modules 2B Temperature Error ($e2Ta_B$)

The temperature effect is listed in Sections 8.3 along with the upper range limit (URL) of 40"wc. The ambient temperature at the switch location for accident conditions is 60° to 212°F (Sections 8.3.1), from which the maximum temperature difference (ΔT = 212° - 72° = 140°F) can be determined. Therefore,

$e2Ta_B$ = ± [0.42% URL/10°F] ΔT

= ± [(0.0042)(40"wc)/10°F]140°F

= ± 2.352"wc

Per Design Input 4.1, the standard deviation of temperature effect ($e2Ta_{B(1\sigma)}$) is $e2Ta_B/2$. Therefore,

$e2Ta_{B(1\sigma)}$ = ± 2.352"wc/2 = ± 1.176"wc

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

The random input error is due to flow element and was calculated in Section 11.2.:

$$\sigma 2ina_A = \sigma 1n_{Aprop} = \pm\ 0.882347"wc$$

$$\sigma 2ina_B = \sigma 1n_{Bprop} = \pm\ 0.919774"wc$$

$$\sigma 2a_{ina} = \sigma 1n_{Cprop} = \pm\ 0.875141"wc$$

12.2.3 Determination of Total Random Errors, Accident Conditions ($\sigma 2a$)

Per Section 2.1 methodology, the total random error is defined as

$$\sigma 2a = [(RPT2_{(1\sigma)})^2 + (CAL2)^2 + (ST2_{(1\sigma)})^2 + (e2Ta_{(1\sigma)})^2 + (e2D_{(1\sigma)})^2 + (\sigma 2ina_A)]^{½}$$

12.2.3.1 Determination of Module 2A Total Random Errors ($\sigma 2n_A$)

$$\sigma 2a_A = \pm[(0.2"wc)^2 + (0.025"wc)^2 + (0.2"wc)2 + (0.6384"wc)^2 + (0.2"wc)^2 + (0.882347"wc)^2]^{½}$$

$$= \pm\ 1.143117"wc$$

12.2.3.2 Determination of Module 2B Total Random Error ($\sigma 2n_B$)

$$\sigma 2a_B = \pm[(0.2"wc)^2 + (0.267833"wc)^2 + (0.2"wc)^2 + (1.176"wc)^2 + (0.2"wc)^2 + (0.919774"wc)^2]^{½}$$

$$= \pm\ 1.532836"wc$$

12.2.3.3 Determination of Module 2C Total Random Errors ($\sigma 2n_C$)

$$\sigma 2a_C = \pm[(0.2"wc)^2 + (0.025"wc)^2 + (0.2"wc)^2 + (0.6384"wc)^2 + (0.2"wc)^2 + (0.875141"wc)^2]^{½}$$

$$= \pm\ 1.137564"wc$$

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12.3 Non-Random Errors Normal Operating Conditions (Σe2n)

12.3.1 Humidity Error (e2Hn)

There are no humidity errors described in the Vendor's specifications for the pressure switches. These errors are assumed to be included in instrument reference accuracy. (Assumption 5.2). Therefore,

$$e2Hn = 0$$

12.3.2 Radiation Error (e2Rn)

There are no radiation errors described in the Vendor's specifications for the pressure switches. These errors are assumed to be included in instrument drift related errors or are negligible (Assumption 5.8). Therefore,

$$e2Rn = 0$$

12.3.3 Seismic Error (e2Sn)

Per Section 2.1.e, the seismic error for normal operating conditions is considered to be negligible with respect to other error terms. Also, the instrument is not subjected to vibrational errors as its mounting location (Section 8.2.1, 8.3.1, 8.4.1) is not subject to vibrations during normal operating conditions. Therefore,

$$e2Sn = 0$$

12.3.4 Static Pressure Offset (e2SPn)

The static pressure offset errors described by the Vendor (Design Input 4.4) for the pressure switches is as follows:

$$e2SPn = \pm 5.0\text{"wc}$$

12.3.5 Pressure Error (e2Pn)

There are no ambient pressure errors described in the Vendor's specification for the pressure switch. These errors are assumed to be included in instrument reference accuracy (Assumption 5.2). Therefore,

$$e2Pn = 0$$

12.3.6 Process Error (e2pn)

Per Section 2.1.c methodology, when determining the margin between the Allowable Value and calibrated trip setpoint, only those error that are observable during calibration are included in the total error computation. During the calibration surveillance conditions, the loop is valved out of service from the process, and the effects of the process are not being measured. Therefore,

$$e2pn = 0$$

12.3.7 Power Supply Effects (e2Vn)

There is no power supply required to operate this instrument, Therefore,

$$e2Vn = 0$$

12.3.8 - DELETED -
(Per Reference 3.19, Drift is now defined as a random error and is evaluated in Section 12.1.6)

12.3.9 Non-Random Input Error (e2inn)

The non-random input error due to the flow element is calculated in Section 11.3. Therefore,

$$e2inn = e1n = 0$$

12.3.10 Total Non-Random Error Normal Operating Conditions (Σe2n)

$$\Sigma e2n = e2Hn + e2Rn + e2Sn + e2SPn + e2Pn + e2pn + e2Vn + e2inn$$

$$= 0 + 0 + 0 \pm 5\text{"wc} + 0 + 0 + 0 \pm 0\text{"wc}$$

$$= \pm 5\text{"wc}$$

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12.4 Non-Random Errors Accident Conditions (Σe2a)

12.4.1 Humidity Error (e2Ha)

Humidity error is determined based upon post-HELB functional test data shown in Reference 3.12 for switch model 103AS-B202. From the data, the maximum deviation at the setpoint in reference to the switch span on decreasing pressure is:

D_{max} = 7.48" - 7.10"wc = 0.38"wc

D_{max}% span = [0.38"wc/(40"-6"wc)100 = 1.12% of span

Therefore, humidity error is as follows:

e2Ha = 1.12% of span

= 0.0112 (40" - 6"wc)

= 0.3808"wc

12.4.2 Radiation Error (e2Ra)

Radiation error is determined based upon post-radiation functional test data shown in Reference 3.12 for switch model 103AS-B202. From the data, the maximum deviation at the setpoint in reference to the switch span on decreasing pressure is:

D_{max} = 7.48" - 6.45"wc = 1.03"wc

D_{max}% span = [1.03"wc/(40"-6"wc)100 = 3.03% of span

Therefore, radiation error is as follows:

e2Ra = 3.03% of span

= 0.0303 (40" - 6"wc)

= 1.0302"wc

12.4.3 Seismic Error (e2Sa)

Seismic error is determined based upon post-seismic functional test data shown in Reference 3.12 for switch model 103AS-B202. From the data, the maximum deviation at the setpoint in reference to the switch span on decreasing pressure is:

D_{max} = 7.48" - 7.16"wc = 0.32"wc

D_{max}% span = [0.32"wc/(40"-6"wc)100 = 0.94% of span

Therefore, seismic error is as follows:

e2Sa = 0.94% of span
= 0.0094 (40" - 6"wc)
= 0.3196"wc

12.4.4 Static Pressure Offset (e2SPa)

The static pressure offset errors described by the Vendor (Design Input 4.4) for the pressure switches is as follows:

e2SPa = ± 5.0"wc

12.4.5 Pressure Error (e2Pa)

There are no ambient pressure errors described in the Vendor's specification for the pressure switch. These errors are assumed to be included in instrument reference accuracy (Assumption 5.2). Therefore,

e2Pa = 0

12.4.6 Process Error (e2pa)

Per Reference 3.2, changes in process density is the primary source of process measurement errors for static pressure measurement applications. Fluctuations in process temperature and pressure can effect the density of the process media and thereby introduce measurement errors. In the case of a differential pressure switch measuring fluid pressure, the instrument sensing lines would be routed together through the same environment. As such, the temperature and pressure changes that occur under accident conditions would affect each sensing line the same and produce a minimal variance in the measured differential pressure. Therefore, the process error is considered negligible with respect to other error terms.

e2pa = 0

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12.4.7 Power Supply Effects (e2Va)

There is no power supply required to operate this instrument, Therefore,

$$e2Va = 0$$

12.4.8 - DELETED -
(Per Reference 3.19, Drift is now defined as a random error and is evaluated in Section 12.1.6)

12.4.9 Non-Random Input Error (e2ina)

The non-random input error due to the flow element is calculated in Section 11.4. for all flow elements (Modules 1A, 1B, and 1C). Therefore,

$$e2ina = \sum e1a = \pm 0.274\text{"wc}$$

12.4.10 Total Non-Random Error Accident Conditions ($\sum$e1a)

$$\sum e2a = e2Ha + e2Ra + e2Sa + e2SPa + e2Pa + e2pa + e2Va + e2ina$$

$$= \pm 0.3808\text{"wc} \pm 1.0302\text{"wc} \pm 0.3196\text{"wc} \pm 5.0\text{"wc} +0+0+0 \pm 0.274\text{"wc}$$

$$= \pm 7.0046\text{"wc}$$

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13.0 TOTAL ERROR, NORMAL OPERATING AND ACCIDENT CONDITIONS (TE2)

From References 3.2 and 3.3,

$$TE2 = 2 \bullet (\sigma 2) + \Sigma e2n$$

13.1 Total Error, Normal Operating Conditions (TE2n)

For Modules 1A & 2A, HPCS Min. Flow Bypass:

From Section 12.1.6.1, $\sigma 2n_A = \pm\ 0.558049$"wc

From Section 12.3.10, $\Sigma e2n = \pm\ 5$"wc

$$TE2n_A = \pm\ (2 \bullet 0.558049\text{"wc}) + 5\text{"wc}$$

$$= \pm\ 6.116098\text{"wc}$$

For Modules 1B & 2B, LPCS Min. Flow Bypass:

From Section 12.1.6.2, $\sigma 2n_B = \pm\ 0.618489$"wc

From Section 12.3.10, $\Sigma e2n = \pm\ 5$"wc

$$TE2n_B = \pm\ (2 \bullet 0.618489\text{"wc}) + 5\text{"wc}$$

$$= \pm\ 6.236978\text{"wc}$$

For Modules 1C & 2C, LPCI Min. Flow Bypass:

From Section 12.1.6.3, $\sigma 2n_C = \pm\ 0.558049$"wc

From Section 12.3.10, $\Sigma e2n = \pm\ 5$"wc

$$TE2n_C = \pm\ (2 \bullet 0.558049\text{"wc}) + 5\text{"wc}$$

$$= \pm\ 6.116098\text{"wc}$$

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13.2 Total Error, Accident Conditions (TE2a)

For Modules 1A & 2A, HPCS Min. Flow Bypass:

From Section 12.2.3.1 $\sigma 2a_A$ = ± 1.143117"wc

From Section 12.4.10, $\Sigma e2a$ = ± 7.0046"wc

$TE2a_A$ = ± (2 • 1.143117"wc) +7.0046"wc

= ± 9.2908"wc

For Modules 1B & 2B, LPCS Min. Flow Bypass:

From Section 12.2.3.2, $\sigma 2a_B$ = ± 1.532836"wc

From Section 12.4.10, $\Sigma e2a$ = ± 7.0046"wc

$TE2a_B$ = ± (2 • 1.532836"wc) +7.0046"wc

= ± 10.0703"wc

For Modules 1C & 2C, LPCI Min. Flow Bypass:

From Section 12.2.3.3, $\sigma 2a_A$ = ± 1.137564"wc

From Section 12.4.10, $\Sigma e2a$ = ±7.0046"wc

$TE2a_A$ = ± (2 • 1.143117"wc) +7.0046"wc

= ± 9.2797"wc

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14.0 ERROR ANALYSIS

14.1 Calibration Setpoint

From Section 10.0:

Modules 1A & 2A, HPCS Min. Flow Bypass: SP_C = 23"wc

Modules 1B & 2B, LPCS Min. Flow Bypass: SP_C = 23"wc

Modules 1C & 2C, LPCI Min. Flow Bypass: SP_C = 23"wc

14.2 Analytical Limit

From Section 10.0,

Modules 1A & 2A, HPCS Min. Flow Bypass: AL_A = 1000 gpm

Modules 1B & 2B, LPCS Min. Flow Bypass: AL_B = 635 gpm

Modules 1C & 2C, LPCI Min. Flow Bypass: AL_C = 550 gpm

The Analytical Limit flow rates are converted to inches of water column using the flow coefficient equation from Section 11.1.2 as follows:

Module 1A & 2A, HPCS Min. Flow Bypass

$$AL_A = [1000\ \text{gpm}/321(\text{gpm}/\text{"wc}^{½})]^2 = 9.70\text{"wc}$$

Module 1B & 2B, LPCS Min. Flow Bypass

$$AL_B = [635\ \text{gpm}/349(\text{gpm}/\text{"wc}^{½})]^2 = 3.31\text{"wc}$$

Module 1C & 2C, LPCI Min. Flow Bypass

$$AL_C = [550\ \text{gpm}/412(\text{gpm}/\text{"wc}^{½})]^2 = 1.78\text{"wc}$$

14.3 Tech Spec Allowable Value (LCO)

From Section 10.0,

Modules 1A & 2A, HPCS Min. Flow Bypass: LCO_A = 900 gpm = 7.85"wc

Modules 1B & 2B, LPCS Min. Flow Bypass: LCO_B = 640 gpm = 3.19"wc

Modules 1C & 2C, LPCI Min. Flow Bypass: LCO_C = 550 gpm = 1.78"wc

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14.4 Determination of Margin Between Analytical Limit (AL) and the Calibrated Trip Setpoints (SPc)

From References 3.2 & 3.3, the margin (MAR) for actuation on decreasing process parameter is given as,

$$MAR = (SP_C + TE2a^-) - AL$$

The margin is converted to gpm per Section 11.1.2 methodology, as follows:

$$MAR_{gpm} = [SP_C - TEa]^{1/2}(K) - AL_{gpm}$$

14.4.1 Module 1A & 2A, HPCS Min. Flow Bypass

From Section 13.2, $TE2a_A = \pm 9.29"wc$

Therefore,

$$MAR_{AL\_A} = [23"wc + (-9.29"wc)] - 9.7"wc)$$
$$= + 4.01"wc$$

$$= +(23"wc - 9.29"wc)^{1/2}(321gpm/"wc^{1/2}) - 1000gpm$$
$$= + 189\ gpm$$

14.4.2 Module 1B & 2B, LPCS Min. Flow Bypass

From Section 13.2, $TE2a_B = \pm 10.07"wc$

Therefore,

$$MAR_{AL\_B} = [23"wc + (-10.07"wc)] - 3.31"wc)$$
$$= + 9.62"wc$$

$$= + (23"wc - 10.07"wc)^{1/2}(349gpm/"wc^{1/2}) - 635gpm$$
$$= + 620gpm$$

14.4.3 Module 1C & 2C, LPCI Min. Flow Bypass

From Section 13.2, $TE2a_C = \pm 9.28"wc$

Therefore,

$$MAR_{AL\_C} = [23"wc + (-9.28"wc)] - 1.78"wc)$$
$$= + 11.94"wc$$

$$= +(23"wc - 9.28"wc)^{1/2}(412gpm/"wc^{1/2}) - 550gpm$$
$$= + 976gpm$$

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14.5 Determination of Margin Between Tech Spec Allowable Value (LCO) and the Calibrated Trip Setpoints (SPc)

From References 3.2 & 3.3, the margin (MAR) for actuation on decreasing process parameter is given as,

$$MAR = (SP_C + TE2n^-) - LCO$$

The margin is converted to gpm per Section 11.1.2 methodology, as follows:

$$MAR_{gpm} = [SP_C - TEn]^{1/2}(K) - LCO_{gpm}$$

14.5.1 Module 1A & 2A, HPCS Min. Flow Bypass

From Section 13.1, $TE2n_A = \pm 6.12"wc$

Therefore,

$$MAR_{LCO\_A} = [23"wc + (-6.12"wc)] - 7.85"wc)$$
$$= + 9.03"wc$$

$$= + (23"wc - 6.12"wc)^{1/2}(321 \text{ gpm}/"wc^{1/2}) - 900\text{gpm}$$
$$= + 419 \text{ gpm}$$

14.5.2 Module 1B & 2B, LPCS Min. Flow Bypass

From Section 13.1, $TE2n_B = \pm 6.24"wc$

Therefore,

$$MAR_{LCO\_B} = [23"wc + (-6.24"wc)] - 3.19"wc)$$
$$= + 13.57"wc$$

$$= + (23"wc - 6.24"wc)^{1/2}(349 \text{ gpm}/"wc^{1/2}) - 640\text{gpm}$$
$$= + 789 \text{ gpm}$$

14.5.3 Module 1C & 2C, LPCI Min. Flow Bypass

From Section 13.1, $TE2n_C = \pm 6.12"wc$

Therefore,

$$MAR_{LCO\_C} = [23"wc + (-6.12"wc)] - 1.78"wc)$$
$$= + 15.1"wc$$

$$= + (23"wc - 6.12"wc)^{1/2}(412 \text{ gpm}/"wc^{1/2}) - 550\text{gpm}$$
$$= + 1143 \text{ gpm}$$

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15.0 ERROR ANALYSIS SUMMARY & CONCLUSIONS

The acceptance criteria has been met. This calculation indicates with a high degree of confidence, for the following instruments, that the Analytical Limit and the Tech Spec LCO (Allowable Value) will not be exceeded under accident and normal conditions respectively, when the switches are calibrated to the existing calibration setpoint, and using the test equipment specified in Section 9.0 (Assumption 5.7).

HPCS Flow Bypass	LPCS Flow Bypass
1-E22-N006	1-E21-N004
2-E22-N006	2-E21-N004

LPCI Flow Bypass

1-E12-N010AA	2-E12-N010AA
1-E12-N010BA	2-E12-N010BA
1-E12-N010CA	2-E12-N010CA

NOTE: From Section 2.1.E methodology and Section 12.3.3, this calculation states that the instruments affected by seismic events less than of equal to an OBE are considered to have no permanent shift in the input/output relationship of the device. For seismic events greater than an OBE, affected instrumentation will be recalibrated as necessary prior to any subsequent accident, negating any permanent shift which may have resulted from a post-seismic shift.

- FINAL -

SOR

14685 West 105th Street
Lenexa, Kansas 66215 USA
Tel. 913-888-2630 • Fax 913-888-0767

January 30,1992

AB IMPELL

Attention: Michelle Brandt

Subject: Definition of terms

Per our telephone conversation of Jan. 30,1992 concerning Repeatability and Accuracy as they apply to SOR pressure switches.

REPEATABILITY: Repeatability on our pressure switches will be smaller than 1% of full scale per ANSI/ISA S51.1.

ACCURACY: Accuracy does not apply to a bi-stable electromechanical device. The only accuracy involved would be the accuracy of the pressure gauge used in calibration and the ability of the person doing the calibration.

The "N" Housing designator is obsolete and if ordered the "N6" cast iron housing would be provided.

If I can be of any further assistance please feel free to contract me.

Regards,

Steve Smith

Steve Smith
Inside Sales

ATTACHMENT A
NED-I-EIC-0198, Rev. 1
PAGE A1 of A1

- FINAL -

RECORD OF TELEPHONE CONVERSATION

Date 11/12/93

Between Thomas Hearing and Kevin Perriman
of Signals & Safeguards of LaSalle Station IM Department
Telephone 815-357-6761 ex. 2593 Subject 0 to 35" WC Range Manometers
Station LaSalle Station Units 1 and 2

Memorandum:

I explained to Kevin Perriman the purpose of my call. I needed to know the available 0 to 35" WC range manometers with an accuracy of at least ± 0.1" WC.

Answer

Mr. Perriman provided the following information:

Manufacturer:	Dwyer
Model:	1211-36
Range:	-36" to 0 to +36" WC
Calibrated Accuracy:	N/A
Smallest Scale Div.:	0.1" WC

14685 West 105th Street
Lenexa, Kansas 66215 USA
Tel. 913-888-2630 • Fax 913-888-0767

DATE: 28 October 1992

TO: Ed Seckinger
Commonwealth Edison Co.

FAX: 708-515-7299

TOTAL PAGES: 6

SUBJECT: Acceptance Criteria for SOR 8601-025
CECO P.O. 346179
SOR Order 169037

Dear Mr. Seckinger:

Per our telephone conversation yesterday I am transmitting the Static Influence Test results for the switches on the subject order for your review.

SOR requests the acceptance criteria for the static shift, for this and all future orders, be changed to 5" WC maximum.

On the dead bands, SOR requests the acceptance criteria be changed to 6" WC max for model 103AS-B202-NX-JJTTX6 and 9" WC max for model 103AS-BB202-NX-JJTTX6.

If you have any questions, please feel free to let us know.

Regards,

Sherry Burns

Sherry Burns
Nuclear Coordinator

Attachments

cc: Jane Peternel - SOR

ATTACHMENT C
NED-I-EIC-0198, Rev. 1
PAGE C1 of C6

P.O. BOX 591 11705 BLACKBOB ROAD
OLATHE, KANSAS 66061

SOR Static O Ring /Control Devices

DRAWING NO. 8601-025

STATIC INFLUENCE TEST

Customer: Commonwealth Edison
SOR Sales Order: 164037
Customer P.O.: 346179
Serial No. 92-5-7881
Tag No.: ~~103AS-B202-NX-JTTTX6~~
Item No.: 2
Model No. 103AS-B202-NX-JTTTX6
Set Point: ___ Inc. 23"w Dec.

Date/Time of Reading	Static Pressure	~~Minimum~~ Max. ΔP	~~Increasing~~ Dec. Set Point	~~Maximum~~ Min. ΔP	~~Decreasing~~ Inc. Set Point
7/29/92 11:39AM	0	35	23.7	23.7	27.8
7/29/92 11:45AM	1000	35	20.6	20.6	25.0
7/30/92 12:40PM	1000	35	19.4	19.4	24.8
7/30/92 12:45PM	0	35	23.5	23.5	27.5

24-Hour Test Begin: Time 11:45 am Date 7/29/92

24-Hour Test End: Time 12:45 Date 7/30/92

Static Shift = 4.3" W.C.

Acceptance Limit = 3.1" W.C.

Engineering: ______________________ Date: ____________

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SHEET 1 FOR REVISIONS

TITLE	BY	DATE	DRAWING NO.	REV
Performance Test - Differential Pressure Switch	Drix	12/1/87	8601-025	7
	RCD	12/1/87	SHEET 8 OF 12	

P.O. BOX 591 11705 BLACKBOB ROAD
OLATHE, KANSAS 66061

SOR

Static O Ring /Control Devices

8601-025

STATIC INFLUENCE TEST

Customer: Commonwealth Edison
SOR Sales Order: 169037

Customer P.O.: ______

Serial No. 92-5-7834

Tag No.: ______

Item No.: ______

Model No. 10345-6222

Set Point: ___ Inc. ___ Dec.

Date/Time of Reading	Static Pressure	~~Minimum~~ max ΔP	~~Increasing~~ Dec Set Point	~~Maximum~~ min ΔP	~~Decreasing~~ Inc. Set Point
9-11-92 6:46AM	0	35	22.7	22.7	26.8
9-11-92 6:47AM	1000	35	19.4	19.4	23.8
9-12-92 7:00AM	1000	35	18.3	18.3	23.8
9-12-92 7:06AM	0	35	22.3	22.3	26.8

24-Hour Test Begin: Time 6:55 Am Date 9-11-92

24-Hour Test End: Time 7:00 A-M Date 9-12-92

Static Shift = 4.4" w.c.

Acceptance Limit = 3.1" w.c.

Engineering: ______ Date: ______

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SEE SHEET 1 FOR REVISIONS

TITLE	BY	DATE	DRAWING NO.	REV
Performance Test - Differential Pressure Switch	Dick	1/4/87	8601-025	7
	RC1	3/7/92	SHEET 8 OF 12	

P.O. BOX 591 11705 BLACKBOB ROAD
OLATHE, KANSAS 66061

SOR Static O Ring /Control Devices

STATIC INFLUENCE TEST

Customer: Commonwealth Edison

SOR Sales Order: 169037

Customer P.O.: 346179

Serial No. 92-5-7835

Tag No.:

Item No.: 2

Model No. 105AS-B202-NX-JJTTX6

Set Point: ___ Inc. 23" wc Dec.

Date/Time of Reading	Static Pressure	~~Minimum~~ Max ΔP	~~Increasing~~ Dec. Set Point	~~Maximum~~ Min. ΔP	~~Decreasing~~ Inc. Set Point
8/24/92 12:39Pm	0	35	23.4	23.4	27.7
8/24/92 12:42Pm	1000	35	19.7	19.7	25.0
8/25/92 12:55Pm	1000	35	18.9	18.9	25.3
8/25/92 1:10Pm	0	35	22.9	22.9	28.0

24-Hour Test Begin: Time 12:42 Pm Date 8-24-92

24-Hour Test End: Time 12:55 Pm Date 8-25-92

Static Shift = 4.5" w.c.

Acceptance Limit = 3.1" w.c.

Engineering: __________ Date: __________

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DRAWING NO. 8601-025

SEE SHEET 1 FOR REVISIONS

TITLE	DR	DATE	DRAWING NO.	REV
Performance Test - Differential Pressure Switch	Drix	12/1/87	8601-025	7
	RCD	12/7/87	SHEET 8 OF 12	

P.O. BOX 591 11705 BLACKBOB ROAD
OLATHE, KANSAS 66061

SOR Static O Ring /Control Devices

STATIC INFLUENCE TEST

Customer: Commonwealth Edison | SOR Sales Order: 169037

Customer P.O.: ______ | Serial No. 92-5-7856

Tag No.: ______ | Item No.: 2

Model No. 103AS-B202-NX-JJTTY6 | Set Point: ___ Inc. 23"wc Dec.

Date/Time of Reading	Static Pressure	~~Minimum~~ MAX ΔP	~~Increasing~~ Dec Set Point	~~Maximum~~ MIN ΔP	~~Decreasing~~ INC Set Point
8/20/92 2:17Pm	0	35	23.1	23.1	26.9
8/20/92 2:20Pm	1000	35	19.4	19.4	24.5
8/21/92 2:20Pm	1000	35	19.2	19.2	24.6
8/21/92 2:34Pm	0	35	22.8	22.8	26.7

24-Hour Test Begin: Time 2:20 Pm Date 8-20-92

24-Hour Test End: Time 2:20 Pm Date 8-21-92

Static Shift = 3.9 "w.c

Acceptance Limit = 3.1"w.c

Engineering: ______ Date: ______

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DRAWING NO. 8601-025

TITLE	BY	DATE	DRAWING NO.	REV
Performance Test - Differential Pressure Switch	Dixie	12/1/87	8601-025	7
	RCD	12/7/87	SHEET 8 OF 12	

C

P.O. BOX 591 11705 BLACKBOB ROAD
OLATHE, KANSAS 66061

Static O Ring / Control Devices

8601-025 DRAWING

STATIC INFLUENCE TEST

Customer: Commonwealth Edison

SOR Sales Order: 164637

Customer P.O.: ____

Serial No. 92-S-7837

Tag No.: ____

Item No.: 2

Model No. 103AS-B203-NX-JJTTX6

Set Point: ___ Inc. 23½ Dec.

Date/Time of Reading	Static Pressure	~~Minimum~~ max ΔP	~~Increasing~~ Dec Set Point	~~Maximum~~ min ΔP	~~Decreasing~~ Inc Set Point
8/20/92 2:08Pm	0	35	23.0	23.0	26.6
8/20/92 2:12 Pm	1000	35	20.3	20.3	25.2
8/21/92 2:24Pm	1000	35	19.0	19.0	24.7
8/21/92 2:29Pm	0	35	22.5	22.5	26.7

24-Hour Test Begin: Time 2:12 Pm Date 8-20-92

24-Hour Test End: Time 2:24Pm Date 8-21-92

Static Shift = 4 "wc

Acceptance Limit = 3.1"wc..

Engineering: ____ Date: ____

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- FINAL -

SEE SHEET 1 FOR REVISIONS

TITLE	BY	DATE	DRAWING NO.	REV.
Performance Test - Differential Pressure Switch	DRK	12/1/87	8601-025	7
	RCD	12/1/87	SHEET 8 OF 12	

ATTACHMENT 3

NES-EIC-20.04 REVISION 3
ANALYSIS OF INSTRUMENT CHANNEL SETPOINT ERROR AND INSTRUMENT LOOP ACCURACY

ANALYSIS OF INSTRUMENT CHANNEL SETPOINT ERROR AND INSTRUMENT LOOP ACCURACY

If this standard does not address your particular application, or is not appropriate to your application, contact the Engineering Administration group.

Rev No	Description	Prepared by	Reviewed by	Approved by
0	Initial Issue: 10/14/97	P. Vandevisse	D. Ugorcak	T. B. Thorsell
1	Revised References, Appendix A, E, I and Added Appendix J	W. D. Crumpacker	D. Ugorcak	T. B. Thorsell
2	Revised Appendix A, I, J and References. Approved for use 5/10/00	R. Fredricksen	D. Ugorcak	T. Thorsell
3	Revised Appendix I and J. Updated References. Approved for use 10/23/00	R. Fredricksen	D. Ugorcak	R. Beavers

Latest Revision indicated by a bar in right hand margin

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1.0 PURPOSE

This engineering standard defines a methodology for the determination of instrument setpoints, allowable values and instrument loop accuracy, that is consistent with ANSI/ISA-67.04.01-2000 (reference 3.1). This standard may be used to:

- combine instrument uncertainties and errors used in the determination of instrument channel and setpoint accuracy,
- develop a basis for establishing instrument setpoints with respect to applicable acceptance criteria, and
- provide criteria to ensure that setpoints are maintained within specified limits.

ANSI/ISA RP67.04.02-2000 (reference 3.2) shall be used when this document does not provide the necessary guidance for a particular application.

Upon issue, this document replaces in their entirety: TID-E/I&C-10, Analysis of Instrument Channel Setpoint Error and Instrument Loop Accuracy, rev. 0, and TID-E/I&C-20, Basis for Analysis of Instrument Channel Setpoint Error and Instrument Loop Accuracy, rev. 0.

2.0 SCOPE

This standard defines an acceptable method for establishing the uncertainties associated with instruments, instrument loops, and instrument setpoints and for applying these uncertainties in the determination of instrument loop accuracy, allowable values and calculated setpoints at ComEd nuclear stations. This document shall be used when establishing specific values for loop accuracy, allowable values, and instrument setpoints.

This standard shall be utilized by qualified ComEd personnel, non-ComEd organizations and integrated teams in the development of uncertainty analyses for the purpose of:

- establishing new setpoints (both safety and non-safety related),
- evaluation or justification of existing setpoints,
- determining instrument indication uncertainties and indication accuracies, and
- performing uncertainty analyses as required by other engineering evaluations.

3.0 REFERENCES

3.1 ANSI/ISA-67.04.01-2000, Setpoints for Nuclear Safety-Related Instrumentation, Approved February 29, 2000

3.2 ISA- RP67.04.02-2000, Methodologies for the Determination of Setpoints for Nuclear Safety-Related Instrumentation, Approved January 1, 2000

3.3 ISA-TR67.04.08-1996, Setpoints for Sequenced Actions, Approved March 21, 1996

3.4 ISA-dTR67.04.09-1996, Graded Approaches to Setpoint Determination (draft)

3.5 ANSI/ISA S37.1-1969, Electrical Transducer Nomenclature and Terminology (formerly ANSI MC6.1-1975)

3.6 ANSI/ISA S51.1 - 1979, Process Instrumentation Terminology

3.7 ISA Aerospace Industries Division, Measurement Uncertainty Handbook, revised 1980

3.8 ISA-MC96.1-1982, Temperature Measurement Thermocouples

3.9 ISO/TAG 4/WG 3: June 1992, Guide to the Expression of Uncertainty in Measurement

3.10 ANSI/ASME PTC6 Report - 1985, Guidance for Evaluation of Measurement Uncertainty in Performance Tests of Steam Turbines

3.11 ANSI/ASME PTC 19.1 - 1985, Part 1, Measurement Uncertainty

3.12 ANSI/ASME MFC-2M-1983, Measurement Uncertainty for Fluid Flow in Closed Conduits

3.13 ASME MFC-3M-1989, Measurement of Fluid Flow in Pipes Using Orifice, Nozzle and Venturi

3.14 ASME Application, Part II of Fluid Meters, Sixth Edition 1971, Interim Supplement 19.5 on Instruments and Apparatus

3.15 SAMA PMC 20.1-1973, Process Measurement & Control Terminology (for information only, standard withdrawn)

3.16 NUREG/CR-3659, A Mathematical Model for Assessing the Uncertainties of Instrumentation Measurements for Power and Flow of PWR Reactors, February 1985

3.17 Commonwealth Edison company Procedure CC-AA-309, Control of Design Analysis

3.18 ANSI/IEEE Std 344-1975, IEEE Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations

3.19 EPRI TR-103335, Guidelines for Instrument Calibration Extension/Reduction Programs, October 1998, Revision 1

3.20 EPRI AP-106752, Instrument Performance Analysis Software System, IPASS User's Guide, August 1996

3.21 ComEd Nuclear Operating Division Standard NES- EIC -20.01, Standard for Evaluation of M&TE Accuracy When Calibrating Instrument Components and Channels, rev. 0, January 23, 1996

3.22 ComEd Nuclear Operating Division Standard ER-AA-520, Instrument Performance Trending

3.23 ComEd Nuclear Operating Division Standard NES-G-14, Calculations

4.0 DEFINITIONS

Note: symbols in parenthesis represent the ComEd methodology symbols used in setpoint accuracy calculations.

4.1 **allowable value (AV):** the limiting value that the trip setpoint may have when tested periodically, beyond which appropriate action shall be taken.

The allowable value provides operability criteria for those setpoints or channels that have a limiting operating condition. This limiting condition is typically imposed by the Technical Specification, but may also result from regulatory requirements, vendor requirements, design basis criteria or other operational limits.

The allowable value applies to the "as-found" condition or "as-found" calibration values.

4.2 **allowance for spurious trip avoidance (AST):** an evaluation to ensure that sufficient margin exists between the steady state operating value and the trip setpoint. May include a statistical combination of instrument channel accuracy (normal environment) including drift, processes effects and the effect of the limiting operating transient.

4.3 **analytical limit (AL):** limit of a measured or calculated variable established by the safety analysis to ensure that a safety limit is not exceeded.

4.4 **bias (e):** an uncertainty component that consistently has the same algebraic sign and is expressed as an estimated limit of error.
Bias error terms may also be represented by:

1) Symmetrical bias errors: the estimated limit of error is known but not its sign. The limit of error is evaluated separately in both the positive and negative directions.

2) Deterministic errors that may not be sufficiently random or independent to be combined with other random errors using the square-root-sum-of-squares (SRSS) methodology.

4.5 **calibration block:** the basic unit of evaluation in this standard. A calibration block is that part of the instrument channel between the point(s) where input test signals are applied and the point where the module performance is monitored (e.g. signal output, bi-stable actuation, etc.).

A calibration block may be a single component or module, or an assembly of interconnected components that are calibrated as a single unit (commonly referred to as a "string calibration").

4.6 **calibration error (CAL):** an uncertainty affecting the accuracy of an instrument channel or component resulting from the calibration method and calibration components. Calibration components include the uncertainties and errors associated with use of M&TE (e.g. reference accuracy, reading error, environmental effects, etc.) and uncertainties associated with the calibration and maintenance of the M&TE (e.g. calibration standard error or STD).

4.7 **calibration standard error (STD):** an uncertainty affecting the accuracy of an instrument channel or component resulting from the standards used to calibrate or validate the M&TE accuracy.

4.8 **drift (D):** an undesired change in output over a period of time where change is unrelated to the input, environment, or load.

4.9 **error:** the algebraic difference between the indication and the ideal value of the measured signal. Refer to sections 5.1.1 and 5.1.2 for a discussion of measurement uncertainty and measurement error.

4.10 **humidity error (eH):** an uncertainty affecting the accuracy of an instrument channel or component resulting from variations in ambient humidity.

4.11 **insulation resistance error (eIR):** an uncertainty affecting the accuracy of an instrument channel or component resulting from leakage currents caused by the degradation of the insulating properties of instrument channel components.

4.12 **limiting safety system setting (LSSS):** limiting safety system settings for nuclear reactors are settings for automatic protective devices related to those variables having significant safety functions.

The LSSS values may have been defined by the station Technical Specifications to correspond to either the allowable value or the trip setpoint. The LSSS values used in setpoint error analysis must be consistent with each stations Technical Specifications.

4.13 **margin (m):** in setpoint determination, an allowance added to the instrument channel uncertainty. Margin moves the setpoint farther away from the analytical limit.

Margin may result from 2 conditions:

1) margin is a method for arbitrarily adding additional conservatism or confidence, often as a result of engineering judgment, and

2) margin may exist where the instrument channel uncertainty is less than the difference between the calculated setpoint and the analytical limit. This margin may be utilized as an additional conservatism.

4.14 **module:** any assembly of interconnected components that constitutes an identifiable device, instrument, or piece of equipment. A module can be removed as a unit and replaced with a spare. It has definable performance characteristics that permit it to be tested as a unit. A module can be a card, a drawout circuit breaker, or other subassembly of a larger device, provided it meets the requirements of this definition

4.15 **power supply error (eV):** an uncertainty affecting the accuracy of an instrument channel or component resulting from variations in the electrical power supply voltage, current or frequency.

4.16 **pressure error (eP):** an uncertainty affecting the accuracy of an instrument channel or component resulting from changes in either 1) process pressure or 2) ambient pressure.

4.17 **process error (ep):** an uncertainty affecting the accuracy of an instrument channel or component resulting from process effects, e.g. flow turbulence, temperature stratification, process fluid density changes, etc.. The process error may also include uncertainties resulting

from the metering device itself, e.g. nozzle fouling. This uncertainty may also be referred to as "process measurement error" in some ComEd calculations.

4.18 **radiation error (eR):** an uncertainty affecting the accuracy of an instrument channel or component resulting from exposure to ionizing radiation.

4.19 **random (σ):** a variable whose value at a particular future instant cannot be predicted exactly but can only be estimated by a probability distribution function.

As used in this standard, the term "random" means random and *approximately* normally distributed.

4.20 **reading error (RE):** an uncertainty affecting the accuracy of an instrument channel or component resulting from the ability to interpret an indicated value.

4.21 **reference accuracy (RA):** a number or quantity that defines a limit that errors will not exceed, when a device is used under specified operating conditions. Reference accuracy includes the combined effects of linearity, hysteresis, deadband, and repeatability.

Caution should be used when applying vendor supplied values for reference accuracy to ensure that all of the above components that contribute to reference accuracy are included.

4.22 **safety limit:** a limit on an important process variable that is necessary to reasonably protect the integrity of physical barriers that guard against the uncontrolled release of radioactivity.

4.23 **seismic error (eS):** a temporary or permanent uncertainty affecting the accuracy of an instrument channel or component caused by seismic activity or vibration.

4.24 **setting tolerance (ST):** the accuracy to which a module is calibrated or maintained by a station calibration procedure. As used in this standard, the setting tolerance is equivalent to the "calibration tolerance" specified in the station calibration procedure.

4.25 **static pressure error (eSP):** an uncertainty affecting the accuracy of dP sensors resulting from operation at a pressure different from that to which it was calibrated. Static pressure error may consist of zero error and span error components.

4.26 **temperature error (eT):** an uncertainty affecting the accuracy of an instrument channel or component resulting from the effects of ambient temperature changes. The temperature error can effect component accuracy, M&TE accuracy, or process error.

4.27 **trip setpoint(SP):** a predetermined value for actuation of the final setpoint device to initiate a protective action. The actual calibrated setpoint may be more conservative than the calculated setpoint obtained from the analysis of instrument channel setpoint error.

4.28 **uncertainty:** the amount to which an instrument channel's output is in doubt (or the allowance made therefore) due to possible errors, either random or systematic, that have not been corrected. The uncertainty is generally identified within a probability and confidence level. Refer to sections 5.1.1 and 5.1.2 for a discussion of measurement uncertainty and measurement error.

5.0 METHODOLOGY

5.1 BASIC CONCEPTS

5.1.1 Measurement Error

The objective of a measurement is to determine the value of the measurand (ref. 3.8). The following contributors are included in the measurement:

- the specification of the measurand,
- the method of measurement and
- the measurement procedure.

The result of a measurement is an approximation or estimate of the value of the measurand due to errors, effects and corrections to these three contributors. For this reason, a measurement must be accompanied by a statement of the uncertainty of that estimate.

The measurement process includes imperfections that result in an error in the measurement result. Errors may be of 2 types: random or systematic. Random error results from unpredictable variations and is evidenced by variations in repeated observations or measurements of the measurand. Random errors of a measurement result cannot be compensated by correction. They can be minimized or reduced by increasing the number of observations, increasing the accuracy of the measurement device or by incorporating a measurement procedure that reduces sources of error. Similarly, systematic error also cannot be eliminated. Systematic errors resulting from identified effects can be quantified and a correction or correction factor may be applied to the measurement result to compensate for this type of error

An error in the measurement results is not the same as measurement uncertainty, and should not be confused in the process of instrument channel setpoint error analysis or instrument loop accuracy.

5.1.2 Measurement Uncertainty

"The word 'uncertainty' means 'doubt', and thus in its broadest sense uncertainty of measurement means doubt about the exactness or accuracy of the result of a measurement" (reference 3.8). Typically, uncertainty is defined and quantified using a parameter associated with the result of the measurement, e.g. standard deviation, width or confidence interval, dispersion interval, etc.

The uncertainty of measurement is a combination of a number of components. Some of these components may be determined from the statistical evaluation of the distribution of a number of measurement results. These are characterized by a level of confidence in the uncertainty and a level of confidence in the distribution of the results. Some components may rely on assumed probability distributions based on experience or other information.

5.1.3 Methodology

Methodology defines a consistent means of:

- identifying sources of uncertainties and errors that may effect instrument channel accuracy,
- defining the mechanisms and processes used to evaluate the magnitude of these effects,
- defining the process for combining individual effects into a channel accuracy, and
- defining the equations used to determine setpoints and allowable values.

Given the uniqueness of many of the instrument channels and the special requirements of many instrument setpoints, situations that are not consistent with this methodology are expected. Where specific documentation, references or experience exists that dictates a deviation from this methodology, this information may be incorporated in the basis for channel accuracy and instrument setpoints.

Changes to this methodology require the review and approval of the NES Electrical/I&C Chief Engineer. Deviations from this methodology shall be documented in an associated engineering calculation as required by NEP-12-02, Preparation, Review, and Approval of Calculations.

5.1.4 Accuracy

Accuracy is the combination of:

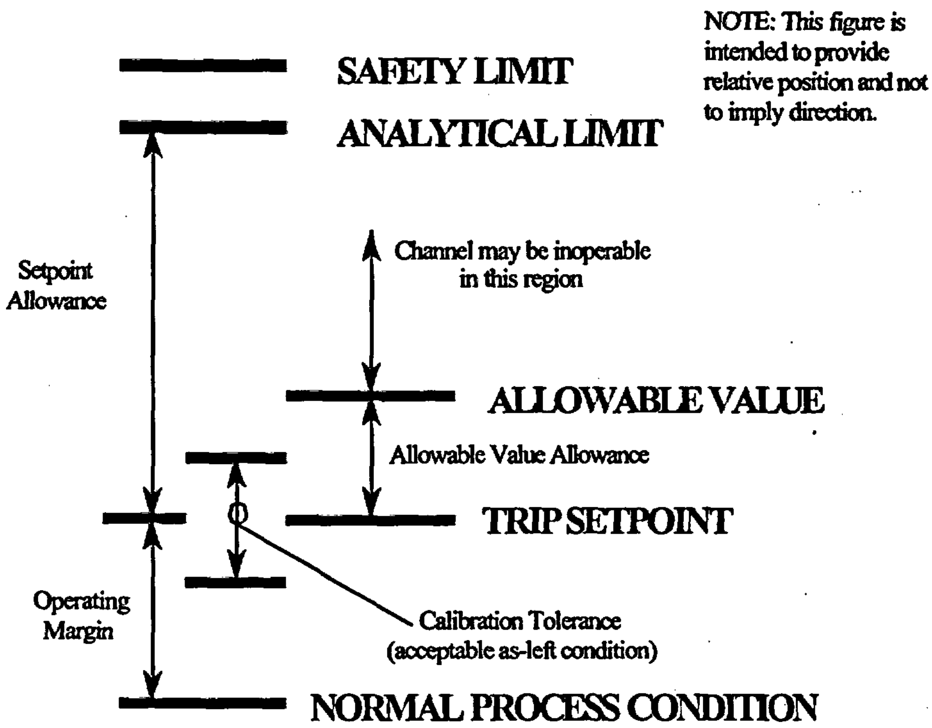
- known or expected process effects,
- known or expected instrument or instrument channel performance characteristics,
- known or expected measurement errors,
- known or expected measurement uncertainties, and
- allowances for conservatism (margin).

Determination of instrument loop accuracy, instrument setpoints and the associated allowable values must consider all of these areas. Appendix A provides a minimum list of the errors and uncertainties that must be included in this analysis.

5.2 ESTABLISHMENT OF SETPOINTS AND ALLOWABLE VALUES

This methodology should be used to provide sufficient allowance between the trip setpoint and an analytical limit, safety limit or other acceptance limit, to account for instrument channel accuracy.

The relationship between the analytical limit and the trip setpoint is shown in Figure 1. Figure 1 also indicates the relation ship between the safety limit, the analytical limit, the allowable value, the trip setpoint and the normal process condition. These relationships are described by the following allowances.



Safety Limit: A limit on an important process variable that is necessary to reasonably protect the integrity of the physical barriers that guard against the uncontrolled release of radioactivity.

Analytical Limit: The limit of a measured or calculated variable established by the safety analysis to ensure that a safety limit is not exceeded.

Trip Setpoint: The calculated trip value that will provide the necessary level of confidence that the analytical limit will not be exceeded.

Allowable Value: The criteria used for the determination of operability.

Figure 1, Setpoint Relationships

5.2.1 Setpoint Allowance: The setpoint allowance describes the relationship between the trip setpoint and the analytical limit. This allowance may be determined through the evaluation of the instrument channel accuracy, operating experience (including as-found/as-left analysis), equipment qualification tests, vendor design specifications, engineering analyses, laboratory tests, engineering drawings, etc.

The setpoint allowance shall account for all applicable design basis events (normal and abnormal) and the following process instrument uncertainties unless they were included in the determination of the analytical limit.

Instrument uncertainties included in the setpoint allowance:

1) Instrumentation calibration uncertainties; including:
   - calibration standards,
   - calibration M&TE, and
   - setting tolerances.
2) Calibration methods
3) Instrument uncertainties during normal operation; including:
   - reference accuracy,
   - power supply voltage and frequency changes,
   - ambient temperature changes,
   - humidity changes,
   - pressure changes,
   - inservice vibration allowances,
   - radiation exposure, and
   - A/D and D/A conversion.
4) Instrument drift
5) Uncertainties caused by design basis events
6) Process dependent effects
7) Calculation effects
8) Dynamic effects
9) Installation biases

It is often difficult to determine what errors and uncertainties have been included by the NSSS supplier or A/E in the determination of the original design basis analytical limit. This is especially true for the environmental conditions. It should not be assumed that analytical limits contained in ComEd documents and/or Tech Specs are correctly implemented as LSSS setpoints or calculated setpoints without evaluation of the original setpoint accuracy analysis or preparation of a new analysis using this standard.

5.2.2 Allowable Value Allowance: This allowance describes the relationship between the trip setpoint and the allowable value. The purpose of the allowable value is to identify a value that, if exceeded, may mean that the instrument, device or channel has not performed within the basis of the setpoint calculation. A channel whose as-found condition exceeds the

allowable value should be evaluated for operability, taking into account the setpoint calculation methodology.

At ComEd nuclear stations, non-reactor protection setpoints frequently have administrative limits, reportable tolerances or other station specific criteria to evaluate the as-found condition of a setpoint, calibration or operational test. Refer to ER-AA-520, Instrument Performance Trending, for additional information associated with these limits.

Instrument uncertainties included in the Allowable Value allowance:

1) Instrument calibration uncertainties
2) Instrument uncertainties during normal operation
3) Instrument drift

5.2.3 Operating Margin: This allowance describes the relationship between the normal process condition and the trip setpoint. It is considered good practice to evaluate this relationship in order to determine the effect of normal operating transients on the trip setpoint. The operating margin may consider instrument channel accuracy, transient analysis, "allowance for spurious trip allowance", operating experience (including as-found/as-left analysis), equipment qualification tests, vendor design specifications, engineering analysis, laboratory tests, engineering drawings, etc.

5.3 UNCERTAINTY ANALYSIS AND SETPOINT CALCULATION PROCESS

The process for determining instrument setpoints and allowable values is based on the analysis of the instrument loop accuracy and the identification of the acceptance criteria for each setpoint. This process is shown in figure 2.

5.3.1 Block Diagram the Instrument Channel and Identify Components, Modules and Calibration Blocks

The instrument channel to be analyzed should first be diagrammed to ensure that all errors and uncertainties affecting instrument channel accuracy are identified and correctly applied. The process for determining instrument channel accuracy is based on the propagation of errors and uncertainties through the instrument channel from the process to the final output, i.e. actuation or indication.

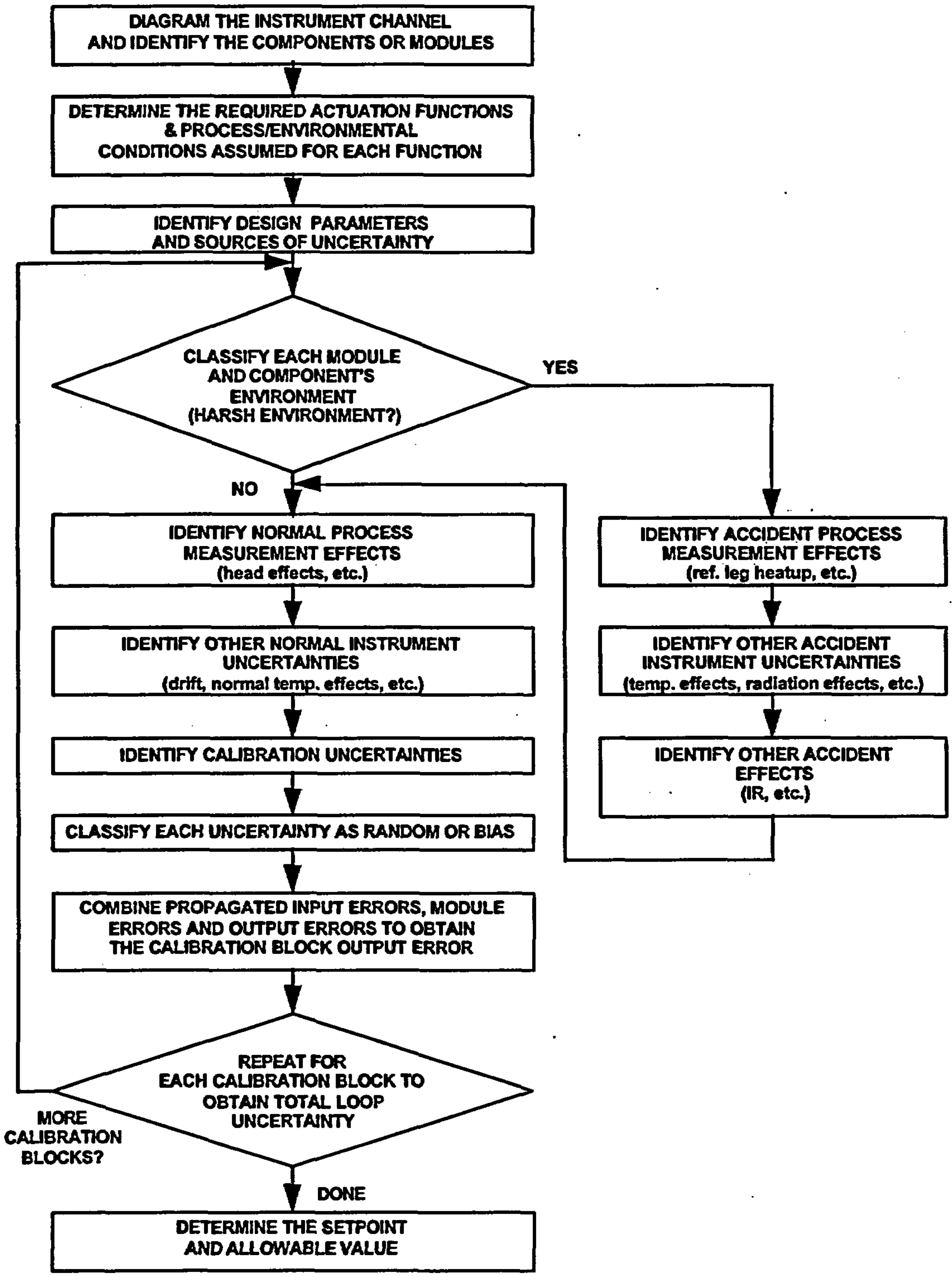


Figure 2, Setpoint Calculation Flowchart

This process includes:

- identifying individual components and modules contained within the instrument channel, and when appropriate identifying the calibration blocks within which the components or modules are calibrated,
- propagating input errors and uncertainties through the calibration block, and
- combining the propagated errors, the specific module errors and any output errors to determine a calibration block output uncertainty.

If necessary, this calibration block uncertainty becomes one of the input uncertainties to the next calibration block.

The definition of a calibration block is the basis for this methodology. A calibration block is identified by the calibration process associated with the instrument channel to be evaluated. A calibration block is contained between the point where a test input is applied and the point at which an output is observed. The calibration block output may be digital, i.e. a bistable output, or analog, as in a measured variable or an indicated variable.

As shown in figure 3, a calibration block has:

1) input errors and uncertainties, including process errors, calibration errors, uncertainties associated with the input from previous modules, etc..

2) calibration block errors and uncertainties, including:

   - environmental conditions that affect the modules or components within the calibration block,
   - reference accuracy of each internal module or component,
   - process conditions that affect an individual module or component, e.g. static pressure error, and
   - other uncertainties associated with the individual modules or components within the module

3) output errors and uncertainties, including calibration errors, setting tolerance, etc.

The total calibration block accuracy is a combination of:

- input errors/uncertainties propagated across the calibration block,
- module errors/uncertainties, some of which may have to be propagated across components within the calibration block, and
- output errors/uncertainties.

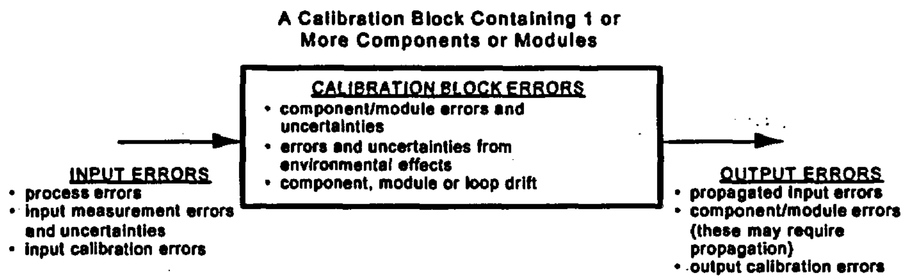


Figure 3, Input, Calibration Block and Output Errors and Uncertainties

See Appendices C and D for the equations used to combine individual errors and uncertainties when calculating total calibration block accuracy.

Some considerations when identifying a calibration block are:

1) A calibration block may contain 1 or more modules, or components based on the calibration methodology of the specific channel. Where a string calibration is performed as the final acceptance test, the entire string becomes the calibration block.

2) A calibration block can never contain just a resistor. Often a resistor is used for signal conversion. The interposing resistor may be part of the output errors of one calibration block, part of the input errors to the next calibration block or both. The calibration procedure must be carefully analyzed to ensure that the effect of these resistors are correctly incorporated into the channel or calibration block accuracy.

5.3.2 Determine The Required Actuation Functions and Process/Environmental Conditions For Each Function

Identify the purpose of the instrument channel and setpoint to be analyzed. Determine the conditions where the setpoint is required to function and the associated environment(s) when this function is required.

5.3.2.1 Design Basis

Determine the design basis of the setpoint and the associated instrument channels. The design basis information should include:

- the function of the instrument channel
- the purpose of the setpoint
- whether the existing setpoint represents an allowable value or limiting setpoint
- what analyses are affected by the setpoint
- what limiting criteria (acceptance criteria) and assumptions regarding the setpoint are included in these analyses

5.3.2.2 Environmental Conditions

Determine the environment in which each component/module is located and the environmental conditions in which they must perform their function. Figure 4 shows a typical instrument channel layout, the point within the channel affected by various types of errors and uncertainties, and the environment for each module.

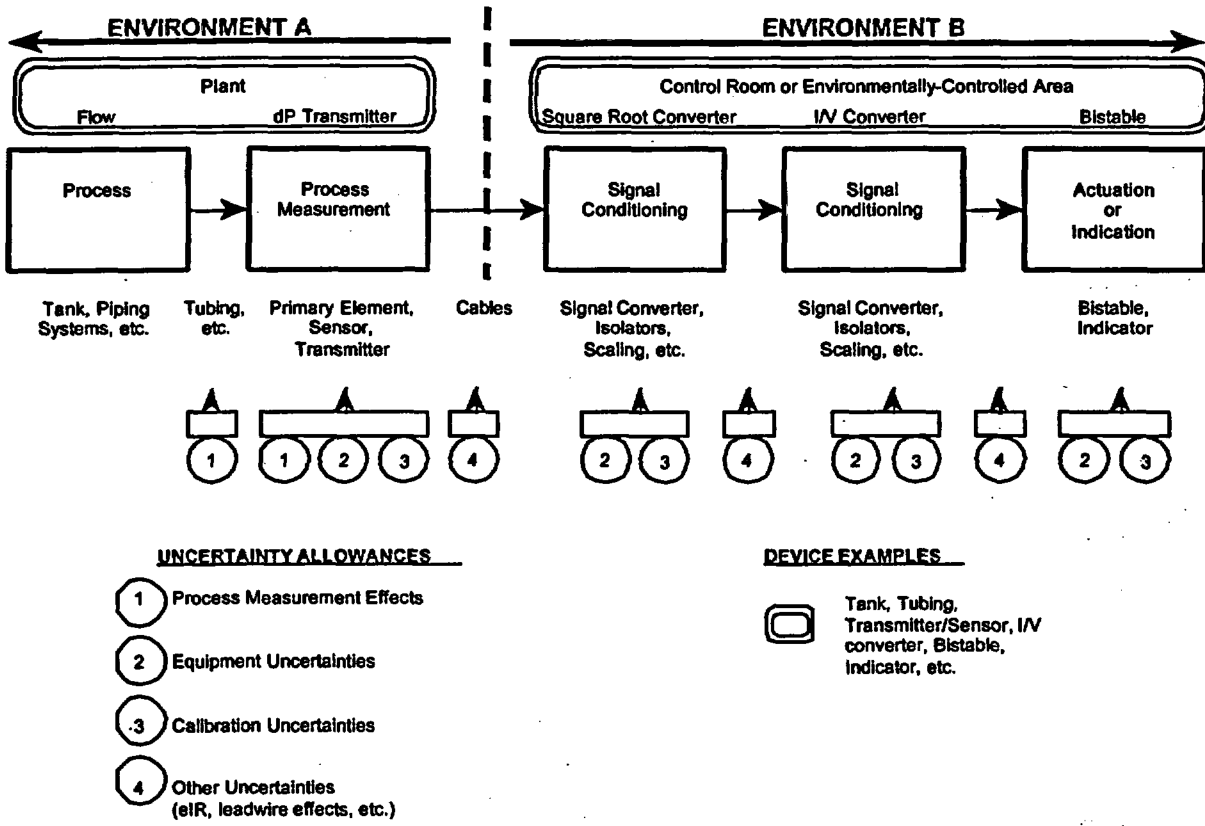


Figure 4, Typical Instrument Channel Layout

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[1] ISA-RP67.04-.02-2000, Methodologies for the Determination of Setpoints for Nuclear Safety-Related Instrumentation, Approved January 1, 2000.

5.3.3 Identify Design Parameters and Sources of Uncertainty

Once the design basis for the instrument setpoint and environment is determined, identify the potential sources of errors and uncertainties that may affect the instrument channel accuracy.

See Appendix A for a discussion of the minimum list of errors and uncertainties that must be included in accordance with this standard. This minimum list is not intended to limit the types and sources of error and uncertainty associated with an instrument setpoint. Each instrument channel, method of process measurement, calibration methodology, and environment may have unique errors and uncertainties.

5.3.4 Classify Each Modules Environment

This standard requires that the station specific EQ Zones contained in the UFSAR and the station specific environmental conditions associated for each zone are to be used in evaluating all environmental effects.

5.3.5 Identify Normal/Accident Process Measurement Effects, Instrument Uncertainties, Calibration Uncertainties and Other Uncertainties, and Classify Each Uncertainty as Random, Bias, etc.

See Appendix A and Reference 3.2 for applicable error effect equations and methods for determining values of uncertainty.

5.3.6 Combine Propagated Input Errors, Module Errors and Output Errors to Yield Total Calibration Block Output Error

See Appendix B for error propagation and Appendix C for equations for the combination of errors and uncertainties.

5.3.7 Obtain Total Channel Uncertainty

See appendix C for the methodology and equations used to combine individual errors and uncertainties.

5.3.8 Determine the Setpoint and Allowable Value

See appendix C for the methodology and equations used to determine an instrument setpoint and an associated allowable value.

5.3.9 Administrative Limits

Refer to ER-AA-520, Instrument Performance Trending, when administrative limits are required as part of the instrument loop accuracy determination.

APPENDIX A

SOURCES OF ERROR AND UNCERTAINTY

This appendix discusses the sources of error that may affect instrument loop accuracy. In all cases, sound engineering judgment should be applied to account for errors not explicitly described below. Significant errors, whether or not they are described in this appendix shall also be included in the computation of setpoint error, or instrument loop accuracy.

This appendix provides a minimum list of errors and uncertainties that shall be evaluated for each component and module when evaluating instrument channel accuracy in accordance with this standard.

1.0 PROCESS ERRORS

Process errors result from changes in the process or sensing channel from the nominal, or calibration conditions. They may also result from conditions that cannot be readily measured, e.g. turbulence or other system complexities To account for process errors in a setpoint error calculation, it is necessary to model the process, and the effects of sensing elements on the process. For example, intrusive flow sensing devices, such as venturis, directly effect the process that they measure. Process models should account for calibration conditions, normal operation, and accident conditions. For each of these conditions, the behavior of all applicable process variables, such as temperature, pressure, and density, must be understood well enough to predict the error.

Changes in the process may result in either random or non-random errors. Non-random process errors are those which can predictably be correlated to process conditions, such as thermal expansion effects. Random errors result from uncertainties that are not predictable as to their direction, but exist as a range or limit of error around the process value.

1.1 DENSITY EFFECTS

Measurements of fluid flow, pressure, and levels are effected by the process densities. Density changes in the process and in instrument sensing lines can result in measurement errors. An example of a process measurement that is affected by density changes is the measurement of fluid flow. Fluid flow is inversely proportional to the square root of fluid density. If a flow meter is calibrated for a specific fluid density, and the density changes, then a flow measurement error that is inversely proportional to the square root of the density change will result.

1.2 FLOW ERRORS

Flow measurements are based on nominal values for the dimensions of components such as nozzles, orifices, and venturis. These devices are subject to changes in dimension due to the erosion and/or corrosion effects of the material they contain. Changes in pipe diameter, or bore tolerance will cause flow measurement errors. and should be considered in the evaluation of instrument loop accuracy

1.3 TEMPERATURE ERRORS

Changes in the process media temperature from the nominal or calibration values will cause process measurement errors. Pressure and differential pressure measurements are particularly susceptible to temperature induced errors. Pressure and level measurements are made by sensing the hydrostatic head pressure of a fluid. The hydrostatic head pressure of a fluid is directly proportional to the product of the fluid's height and specific weight. Since specific weight is a temperature dependent parameter, temperature changes in the process fluid will cause process measurement errors. Temperature induced process errors will affect pressure, level, and flow measurements and should be considered in the evaluation of instrument loop accuracy.

1.4 THERMAL EXPANSION ERRORS

Changes in temperature cause dimensional changes in system structures, components and instrument sensing lines. Instrument calibration is often based on specific sensing line or component installed elevations. Component elevation changes due to temperature effects will cause process measurement errors and should be considered in the evaluation of instrument loop accuracy.

An example of a thermal expansion effect on a process measurement is reactor pressure vessel growth. As the reactor is heated and pressurized to operating conditions, dimensional increases occur. Differential pressure level sensing instruments are calibrated for specific values of process tap and component elevations. These elevations may change from calibration values as the reactor is brought up to operating conditions as a result of thermal expansion.

Thermal expansion errors should be accounted for in the evaluation of instrument loop accuracy.

1.5 PIPING CONFIGURATION

Intrusive devices, i.e. nozzles, orifices, venturis and valves, as well as pipe bends, changes in pipe diameter and material cause turbulence in flow media. Flow turbulence is a source of flow measurement error. Inspection of piping and isometric drawings can provide information on the proximity of flow sensors to fittings and valves that cause turbulence. It may be possible to bound flow measurement error due to turbulence based on the upstream or downstream separation between the flow sensor and source of turbulence. Refer to References 3.2, 3.10 and 3.13 for additional information.

2.0 REFERENCE ACCURACY (RA)

The Reference Accuracy of an instrument loop component is never zero. This would infer that there is no difference between the true value of a process and the measured value of a process. Error free measurements are physically impossible.

The error due to the Reference Accuracy of an instrument is usually given as a numerical expression, graph, or specification published by the instrument vendor.

Where independent test labs rather than the manufacturers have evaluated an instrument's performance characteristics, the test methods should be reviewed to ensure that the test results are consistent with their intended use.

The error due to instrument Reference Accuracy is classified as a normally distributed random variable.

3.0 OPERATIONAL ERRORS.

3.1 Drift (D)

Instrument drift is a change in instrument performance that occurs over a period of time that is unrelated to input, environment or load. Drift independently effects all components of an instrument loop. Ambient conditions such as temperature, radiation, and humidity do not affect the magnitude of an instrument's drift.

Specific instrument drift effect data is typically provided from:

- The instrument manufacturer
- The review of historical calibration data
- Documentation industry experience
- Environmental Test Reports

If specific values for this effect are not available from these sources, the following default values may be included when preparing the analysis for additional conservatism. The ComEd default drift effect values that will be used in these cases are:

Mechanical Components: ±1.0% of span per refueling cycle
Electronic Components: ±0.5% of span per refueling cycle

The intent of these ComEd default drift effect values is to establish consistent values for this type of error for inclusion into the calculations to achieve additional conservatism when this data is not available, applicable, or published. Selection of these default drift effect values is the result of engineering review and judgement of industry practices, typical Reference Accuracy for these device types, and industry experience. These default drift effect values shall not be used when instrument drift effect data is available from the sources listed above.

Manufacturer's published "drift specifications" that are explicitly dependent on operational conditions, i.e. temperature, should not be misinterpreted as Drift in the instrument analysis. In these instances, the use of the word drift is inconsistent with the definition in this standard. An example of this is, "the instrument's zero drift is 10 mv/ C." The net effect of drift on the components of an actuating loop may shift the trip point in the conservative direction, the non-conservative direction, or not at all. Drift is probabilistic in nature. Therefore, the magnitude and direction of its effects are impossible to predict precisely.

Drift is classified as a symmetric random error. This classification accurately models the uncertainty in the sign of the drift error and assumes that the maximum possible drift always occurs between successive instrument surveillances. However, if a instrument surveillance occurs either before or after the manufacturer's published drift interval, then the value for drift must be adjusted to account for the differing intervals (see Eq. A1 or A2).

Where the error caused by drift is assumed to be a linear function of time, equation A1 should be used. If the engineer preparing the calculation determines that the drift effect is not a linear function, i.e. "point drift", then the basis for the drift function shall be explained in the calculation.

The following equation should be used to calculate instrument drift (D):

$$D = (1 + LF/SI)SI \times IDE \qquad \text{(Eq. A1)}$$

where:

IDE = instrument drift effect that is specified by the instrument vendor, published by an independent test lab, or determined from plant historical data.

SI = instrument surveillance interval specified in the station technical specifications or other station document.

LF = test interval late factor. This is the amount of time (grace period) by which a required instrument surveillance is administratively allowed to exceed the licensed surveillance period. Surveillance intervals, grace periods and Late Factor are found in the plant technical specifications.

This method of drift error calculations should be used unless other data or vendor information is available. The drift term is considered a linear function of time unless other methods to evaluate drift are available.

Where multiple time periods of IDE and/or SI are to be evaluated, <u>and</u> it can be shown or reasonably argued that the drift error during each drift period is random and independent, then the SRSS of the individual drift periods between calibrations may be used.

$$D = [\,IDE\,]\,[(SI+LF)/VDP]^{1/2} \qquad \text{(Eq. A2)}$$

where:

VDP = vendor drift period that is specified by the instrument vendor or obtained from other testing (e.g. as-found/as-left analysis).

Example: SI+LF = 22 ½ months
VDP = 12 months
IDE = 1% span per 12 month period

$$D = [1\%][22\tfrac{1}{2} / 12]^{1/2} = \pm 1.37\%\ \text{span}$$

3.2 STATIC PRESSURE EFFECTS (eSP)

Static pressure effects are instrument errors due to a change in process pressure from the value present at the time of calibration. These effects should be considered for those devices with sensing elements that are in direct contact with the process. This effect typically applies to differential pressure sensors.

$$eSP = ISPE(\Delta SP) \qquad \text{(Eq. A3)}$$

where:

ISPE = the instrument static pressure effect specified by the vendor, independent test lab or determined from plant historical data.

ΔSP = the changes in static pressure conditions from calibration conditions.

3.3 PRESSURE EFFECTS (eP)

Pressure changes can cause density changes in process media. Pressure induced density changes in process media from nominal or calibration values are sources of process measurement error. Pressure changes due to environmental or accident effects can cause measurements errors in process parameters.

$$eP = IPE(\Delta P) \qquad \text{(Eq. A4)}$$

where:

IPE = instrument pressure effect is determined from vendor specifications, published independent test lab data or plant historical data.

ΔP = changes in pressure from calibration conditions.

3.4 POWER SUPPLY EFFECTS (eV)

Variations in the output of an instrument loop's power supply may cause errors in process measurement. Instrument errors due to fluctuations in the loop power supply may be estimated by:

$$eV = IPSE(\Delta V) \qquad \text{(Eq. A5)}$$

where:

IPSE = Instrument power supply effect is determined from vendor specifications or published independent test lab data.

ΔV = power supply stability as determined from plant data

4.0 ENVIRONMENTAL ERRORS

Changes in environmental conditions from those present at the time of calibration can cause measurement errors. Errors due to environmental fluctuations can occur during calibration,

during normal operation, or during an accident and should be included in the calculation of instrument loop accuracy.

Environmental errors are classified as non-random. The following three methods may be used to specify environmental error effects.

1) A numerical constant that bounds the error is specified for a specific range of environmental conditions. This constant is specified by the instrument manufacturer, or an independent test lab. An example of this type of error specification is:

1% of output span for ambient temperatures of 60 - 90°F.

2) An instrument's environmental error is calculated by evaluating a model that describes the instruments sensitivity to specific environmental fluctuations. Environmental error models may be available from instrument manufacturers and published in the instrument specifications, or from independent test labs. An example of this type of error specification is:

Temperature Error (eT) = 0.75% of the Upper Range Limit + 0.50% of the Calibrated Span

3) An instrument's environmental errors may be given as a graphical specification. Figure A1 shows a graphical representation of instrument error based on empirical or calculated data gathered by the instrument manufacturer, or by an independent test lab. A graphical error specification shows instrument error as a function of environmental changes.

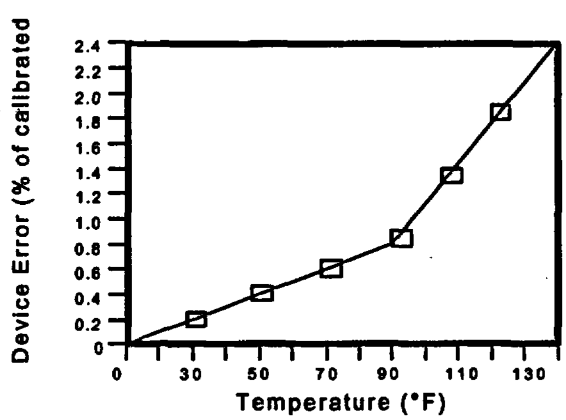


Figure A1, Graphical Specification of Device Error

4.1 TEMPERATURE EFFECTS (eT)

Temperature errors result from deviations in ambient temperature at the instrument location from the temperature at which the instrument was previously calibrated. Where a mathematical model (ITE) is available for temperature error, then the model should be evaluated for the anticipated temperature change.

$$eT = ITE(\Delta T) \quad \text{(Eq. A6)}$$

where:

ITE = the instrument temperature effect that models the measurement error as a function of the temperature changes (ΔT).

4.2 HUMIDITY EFFECTS (eH)

Humidity errors are due to changes in humidity at an instrument location from calibration or nominal values. If a model is available for humidity error, then the model should be evaluated for the anticipated humidity change.

$$eH = IHE(\Delta H) \quad \text{(Eq. A7)}$$

where:

IHE = the instrument humidity effect that models the measurement error as a function of humidity changes (ΔH).

4.3 RADIATION EFFECTS (eR)

Radiation errors are caused by instrument exposure to ionizing radiation. If a model is available for radiation error, then the model should be evaluated for the anticipated radiation dose.

$$eR = IRE(TID) \quad \text{(Eq. A8)}$$

where:

IRE = the instrument radiation effect that models the measurement error as a function of radiation dose, expressed as total integrated dose (TID).

4.4 SEISMIC EFFECTS (eS)

Seismic errors result from subjecting an instrument to high energy vibrations and accelerations. If a model is available for seismic error, then that model should be evaluated for the anticipated acceleration at the instrument location.

$$eS = ISE(ZPA) \quad \text{(Eq. A9)}$$

where:

ISE = the instrument seismic effect that models the measurement error as a function of Zero Period Acceleration (ZPA) anticipated at the instrument location.

Seismic error models must take into account the instrument response due to location, mounting, orientation, and flexibility of the instrument, etc. Data for required response spectra and the associated error due to seismic effects should be obtained from the plant UFSAR, seismic test reports, and seismic structure analysis reports. The published instrument error (and its associated ZPA due to seismic effects should be compared with the required response spectrum specified for the instrument location to ensure that they are consistent. IEEE Recommended Practice For Seismic Qualification of Class 1E Equipment For Nuclear Power Generating Stations (reference 3.18) defines Required Response Spectrum (RRS) as, "The response spectrum issued by the user or his agent as part of his specifications for qualifications or artificially created to cover future applications. The RRS constitutes a requirement to be met".

5.0 CALIBRATION ERRORS

Errors that occur in the adjustment and measurement of loop element signals due to measurement and test equipment (M&TE) are called calibration errors. Calibration errors are classified as random and include:

- M&TE reference accuracy,
- M&TE reading error,
- M&TE environmental errors,
- calibration standard reference accuracy (STD),
- calibration standard reading error, and
- setting tolerance (ST).

5.1 MEASUREMENT AND TEST EQUIPMENT (M&TE).

5.1.1 M&TE Error (RAMTE)

All calibration procedures require measurement and test equipment to monitor instrument adjustments using a specified set of conditions. Some calibration procedures require additional test components whose accuracy must be included in the determination of calibration error. M&TE error includes the reference accuracy of each device, the uncertainties resulting from the environment in which the M&TE was calibrated or used, and the uncertainty added by any component used in a calibration procedure. M&TE accuracy should be obtained from the manufacturer's published specifications unless the device has been calibrated or maintained to a different set of criteria. At ComEd, the calibration facility may be directed to maintain the M&TE to a accuracy different from the manufacturer's specification. This difference should be documented in the basis for the M&TE accuracy used in the instrument channel or setpoint accuracy calculation. When assumptions are required regarding which particular M&TE device may be utilized in a test or calibration procedure, the assumed accuracy of the test equipment data should be equal to that of the least accurate instrument in the group of possible candidates.

Measurement and test equipment used during calibration procedures may be sensitive to environmental fluctuations. M&TE errors should use the largest expected change between the instrument calibration conditions and the normal environment. These extremes typically are obtained from EQ documents, e.g. the station EQ zone maps. This provides a bounding or conservative estimate of M&TE environmental error. Restricting or assuming that the calibration environment deviates less than the associated EQ zone is not desirable since it places added requirements on the IM's to document the assumed environmental condition during each calibration.

5.1.2 Reading Error (REMTE)

Since it is unlikely that an analog gauge reading will always coincide with a graduation tick mark, the readability of the gauge scale is ½ of the smallest division. The uncertainty in this readability, or reading error (RE), is ± ¼ of the smallest graduation interval. For devices that have non-linear scales, the division used to determine the reading error is consistent with the desired reading.

For digital output devices, the reading error is considered to be the least significant digit (LSD) or least significant increment of the display.

5.1.3 Input M&TE Temperature Error (TEMTE)

M&TE temperature errors are determined from the vendor's expression for temperature effects (ITE) and the range of temperature fluctuations (ΔT). The temperature extremes at which the M&TE equipment was calibrated and the ambient temperature extremes in which the M&TE device is going to be used should be evaluated.

5.1.4 Calibration Standard Error (STD).

Calibration standards are used to perform periodic calibrations on M&TE. If the calibration standard is at least 4 times more accurate than the M&TE, then its error represents at most 6.25% of the M&TE error, and may be assumed to be negligible. If the calibration standard is not 4 times more accurate than the measurement and test equipment, then its error should be factored into the calculation of calibration error. Refer to NES-EIC-20.01, Standard for Evaluation of M&TE Accuracy When Calibrating Instrument Components and Channels, for additional guidance.

5.1.5 Surveillance Interval (SI).

The surveillance interval is the period between successive instrument surveillances or calibrations. Surveillance intervals are specified in the plant technical specifications, implemented in the plant calibration procedures, or identified by station instrument calibration scheduling programs.

Station Technical Specifications may allow a grace period beyond the specified calibration frequency. The surveillance frequency is typically limited to 125% of the required SI. The grace period should be included in the determination of instrument loop accuracy. The grace period should not be included in the calculation of the Allowable Value since it results in the potential for non-conservative evaluation of operability.

5.2 SETTING TOLERANCE (ST)

Setting tolerance is the uncertainty associated with the calibration procedure allowances used by technicians in the calibration process. Programs exist at each station to ensure that instrument channels and calibrated setpoints will not be left outside of a specified setting tolerance. As a result, it is expected that 100% of the population is left within the required setting tolerance. For pre-existing instrument channels that have established calibration procedures, the setting tolerance should be incorporated into the setpoint calculation as a 3σ error estimate. For new channels, the setting tolerance should be conservatively determined to justify a 3σ confidence value.

6.0 CALCULATIONAL ERRORS

6.1 NUMERICAL PRECISION AND ROUNDING

The precision of a number is determined by the significant digits in the number. Conclusions based on a calculation or measurement depend on the number of significant digits in the result of the calculation, or measurement. Calculated results can be no more precise than the calculation input data. To prevent the propagation of rounding and truncation errors in a calculation, round only the final result.

The final result should be rounded to the number of significant digits found in the least precise input data but no less than the number of significant digits utilized in presenting the calibration setpoint or the calibration endpoints for loops that do not have setpoints. If the output is read on a DVM that displays 3 digits after the decimal point, the calculations conclusions must be rounded to no less than 3 digits after the decimal point.

This standard recommends the following method for rounding. The left-most non-zero digit in a number is the most significant digit. The right-most non-zero digit is the least significant digit if there is no decimal point. If there is a decimal point, the right most digit is the least significant digit. The number of digits between the most significant and least significant digits are counted as the number of significant digits associated with a calculation, or measurement. The following numbers all have 4 significant digits: 1234, 1.234, 10.10, 0.0001010, 1.000 e-4.

Round the final results of calculations to a level of precision that is consistent with the data input to the calculation. The rules for rounding are:

1. If the next digit less than the desired degree of precision is greater than 5, round up the least significant digit.

   Example: $1.2347 \Rightarrow 1.235$

2. If the next digit less than the desired degree of precision is less than 5, do not change the least significant digit.

   Example: $7.8932 \Rightarrow 7.893$

3. If the next digit less than the desire degree of precision is equal to 5, increment the least significant digit only if it is an odd number.

   Examples: $3.4325 \Rightarrow 3.432$, $3.4335 \Rightarrow 3.434$

6.2 A-D AND D-A ERRORS

Analog-to-Digital or Digital-to-Analog conversions (A/D or D/A) errors occur whenever a continuous process is represented digitally with a fixed number of bits. The resolution of the A/D or D/A converter is a primary consideration when evaluating A/D or D/A errors. Resolution is given by:

$$\text{Resolution} = (1/2^n)(\text{signal span})$$

where 'n' is the number of bits in the A/D or D/A converter and signal span is the signal range present at the input of the A/D or D/A converter. There are several types of A/D or D/A converters, each of which has different sources of conversion error. Therefore, other A/D or D/A conversion errors must be determined on a case-by-case basis.

7.0 INSULATION RESISTANCE ERROR (eIR)

The eIR error shall be evaluated for all instrument components and instrument modules where the actuation function is expected to operate in an abnormal or harsh environment.

Sources of data for insulation resistance should include values typical for the instrument loop under consideration, such as maximum supply voltage, nominal supply voltage, maximum loop resistance, minimum loop resistance, nominal insulation resistance (which should include conductor-to-conductor and conductor-to-ground values), and splice and terminal block insulation resistance. It may be necessary to arrive at these values through performance of generic calculations typical of several types of instrument loops. For a further effects of process measurement errors due to accident related insulation resistance degradation see Reference 3.2.

8.0 Setpoint Margin (MAR)

Margin may be included in the determination of instrument loop accuracy when an additional level of confidence is desired. For example, a particular vendor's testing methodology is not considered sufficiently rigorous to justify a 2σ confidence value for one of the published performance criteria. This determination may be based on engineering judgment, evaluation of the vendor's test plan or station/industry experience with the component. For the component in this example, it is determined that no other information exists to identify an alternate confidence level. This standard recommends that the vendor data should be incorporated at the 2σ confidence level. Then an additional margin value is included in the instrument loop accuracy equation to provide additional conservatism.

NOTE: where as-found/as-left analysis or special test data is available, the component performance data should be utilized at the confidence level obtained from the statistical evaluation of the data.

For new instrument channels, an additional margin of 0.5% of the instrument measurement span, in instrument units, shall be included in order to account for unanticipated, or unknown loop component uncertainties. This margin may be deleted after sufficient calibration history exists to justify the instrument channel accuracy based on all other errors and uncertainties.

9.0 CLASSIFICATION OF ERROR TERMS

All errors and uncertainties shown in Table A1 shall be evaluated as part of the determination of instrument loop accuracy. Where an individual error or uncertainty is 0, negligible or not applicable, the calculation shall describe why this condition is appropriate. Table 1 indicates the default classification for each type of error or uncertainty. These classifications may be changed as a result of published vendor information, other monitoring programs (e.g. as-found/as-left drift analysis), or engineering judgment. The basis for any changes to the classification of an error term shall be fully documented in the associated instrument channel or setpoint accuracy calculation.

Table A1, Classification of Error Terms		
Error Type	Symbol	Error Classification
Process Errors	PE	
Density Error		non-random, bias
Process Error (non-instrument related, e.g. temperature stratification)		random (NOTE: temperature streaming uncertainty may also include an associated bias error)
Flow Element Error		random (when calculated in accordance with reference 3.10) except for errors resulting from fouling which are bias errors
Temperature Error	eT	non-random, bias
Thermal Expansion Error		non-random, bias
Configuration or Installation Error		random (e.g. installation tolerances) or bias (e.g. as measured installation deviation)
Reference Accuracy	RA	random
Operational Errors		
Drift Error	D	random
Static Pressure Error	eSP	non-random, bias
Pressure Error	eP	non-random, bias or symmetric
Power Supply Error	eV	non-random, bias or symmetric
Environmental Errors		
Temperature Error	eT	non-random, bias or symmetric
Humidity Error	eH	non-random, bias or symmetric
Radiation Error	eR	non-random, bias or symmetric
Seismic Error	eS	non-random, bias or symmetric

Table A1 (con't), Classification of Error Terms		
Error Type	Symbol	Error Classification
Calibration Errors		
M&TE Reference Accuracy	RAMTE	random
M&TE Reading Error	REMTE	random
M&TE Temperature Error	TEMTE	random
Calibration Standard Reference Accuracy	RASTD	random
Calibration Standard Reading Error	RESTD	random
Setting Tolerance	ST	random (3σ)
Calculational Errors		
Numerical Precision and Rounding		random
A-D and D-A Error		random
Other Errors		
Insulation Resistance	eIR	non-random, bias or symmetric
Margin	MAR	non-random, bias or symmetric

APPENDIX B

PROPAGATION OF ERROR AND UNCERTAINTIES

1.0 PROPAGATION OF UNCERTAINTIES THROUGH FUNCTIONAL MODULES

This purpose of this appendix is to provide the methodology and functional relations to propagate errors and uncertainties through a calibration block. This appendix provides common linear and non-linear propagation equations for both random and bias errors and uncertainties. The equations provided in this appendix may be used in engineering calculations without further derivation.

For module functions not identified in this appendix, the equivalent error function should be derived. See references 3.2 and 3.11 for further information.

2.0 SYMBOLS

Symbol	Type	Description
X, Y	input signals	Units must be consistent, e.g. % of span, mA, V, etc.
σ	random error	σ_X, σ_Y ... σ_n represent random errors associated with inputs X and Y. σ_{OUT} is the resulting composite random output error. Units must be consistent with the associated input signals, e.g. ±% full span, ±mA, ±V, etc. For linear functions (e.g. fixed linear gain amp), σ_{OUT} is a normally distributed, random error since the transfer function (gain) is linear. σ_{OUT} may be combined with other normally distributed error terms using the SRSS method. For non-linear functions (e.g. logarithmic amplification or square root extraction), σ_{OUT} assumes sufficiently small input errors so that σ_{OUT} is a nearly normal distribution. σ_{OUT} may then be combined with other normally distributed error terms using the SRSS method.
e	bias error	e_X, e_Y ...e_N represent bias errors associated with inputs X and Y and e_{OUT} represents the composite bias error. Units must be consistent with the associated input signals e.g. % full span, ±mA, ±V, etc.

Table B1, Uncertainty Symbols

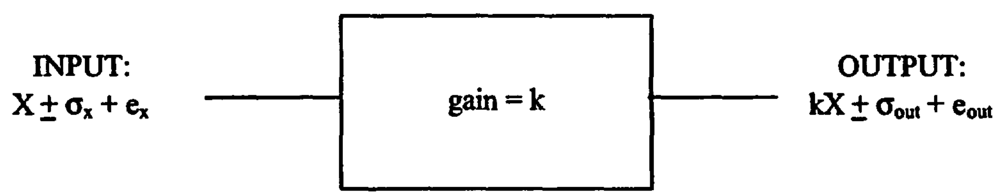
For simplification, the following examples only show the positive input and output bias error terms. Where the bias is symmetrical or assumed symmetrical (as in protection and reactor trip setpoints, and graded methodology level 1 applications), the negative output error would be identical in magnitude and opposite in sign.

Bias errors at the module output are combined by algebraically adding all of the positive biases and separately algebraically adding all of the negative biases. See appendix C for discussion of error combination.

3.0 FUNCTIONAL MODULES

3.1 LINEAR FIXED GAIN AMPLIFIER

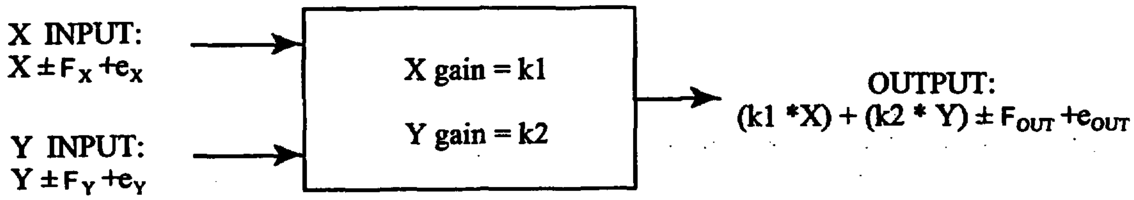
Note: this category also applies to modules that convert process units at the input into different output process units, e.g. a transmitter where the gain might equal mA/psi), or an isolator where the gain might be mA/mA, V/V or mA/V, etc.



where:

$$\sigma_{OUT} = k\sigma_X$$
$$e_{OUT} = ke_X$$

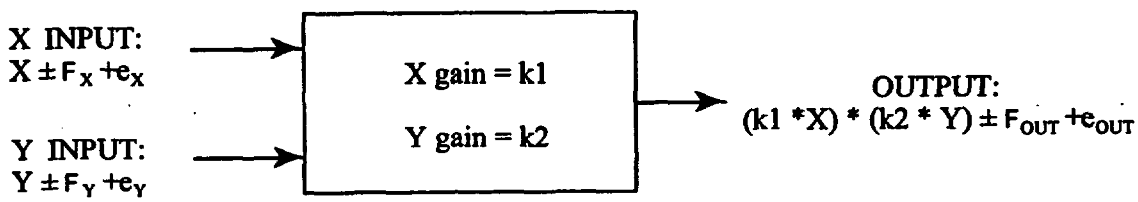
3.2 SUMMING AMPLIFIER



where:

$$\sigma_{OUT} = [(k1 * \sigma_X)^2 + (k2 * \sigma_Y)^2]^{1/2}$$
$$e_{OUT} = (k1 * e_X) + (k2 * e_Y)$$

3.3 MULTIPLIER

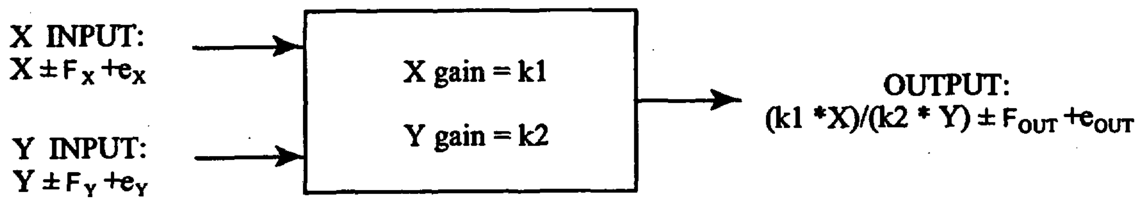


where:

$$\sigma_{OUT} \approx (k1 * k2)[(X * \sigma_Y)^2 + (Y * \sigma_X)^2]^{1/2}$$
$$e_{OUT} \approx (k1 * k2)[(X * e_Y) + (Y * e_X)]$$

σ_{OUT} is an approximation since it is assumed that the individual input errors are small and their cross product is negligible. See reference 3.2 for the complete equation.

3.4 DIVIDER

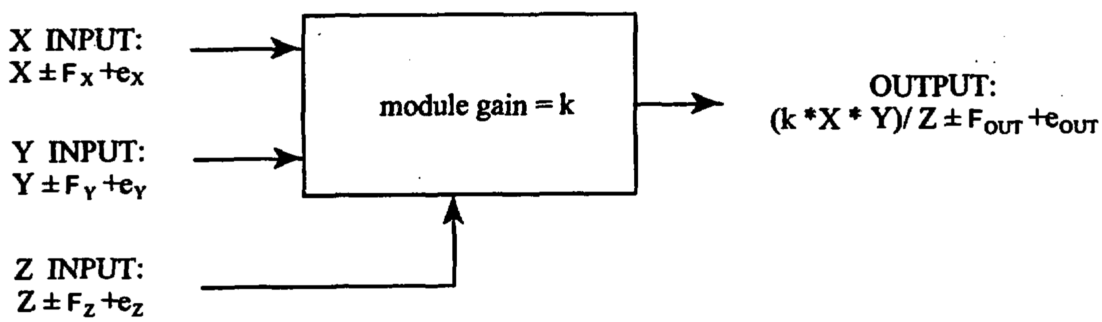


where:

$$\sigma_{OUT} \approx \frac{k1}{k2}\left[\frac{((Y \times \sigma_X)^2 + (X \times \sigma_Y)^2)^{1/2}}{Y^2}\right]$$

$$e_{OUT} \approx \frac{k1}{k2}\left[\frac{(Y \times e_X) - (X \times e_Y)}{Y^2}\right]$$

3.5 MULTIPLIER DIVIDER

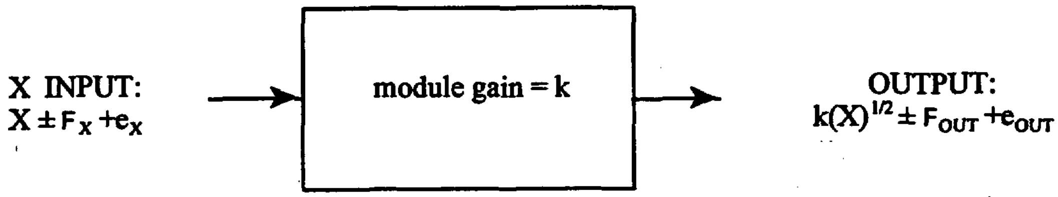


where:

$$\sigma_{OUT} \approx k\left[\left(\frac{Y}{Z} \times \sigma_X\right)^2 + \left(\frac{X}{Z} \times \sigma_Y\right)^2 + \left(\frac{XY}{Z^2} \times \sigma_Z\right)^2\right]^{1/2}$$

$$e_{OUT} \approx k\left[\left(\frac{Y}{Z} \times e_X\right) + \left(\frac{X}{Z} \times e_Y\right) - \left(\frac{XY}{Z^2} \times e_Z\right)\right]$$

3.6 SQUARE ROOT EXTRACTOR



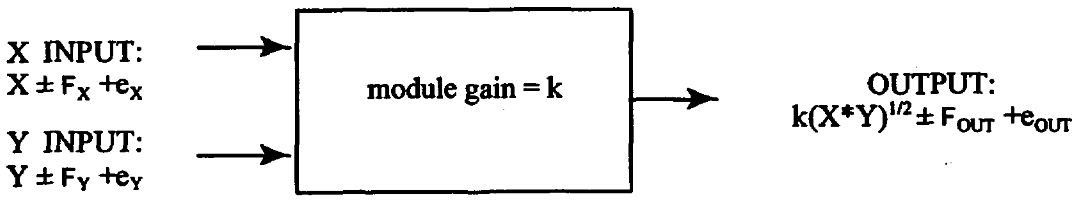
where:

$$\sigma_{OUT} = \frac{k\sigma_X}{2(X)^{1/2}}$$

$$e_{OUT} = k[(X + e_X)^{1/2} - (X)^{1/2}] \quad \text{for } \frac{e_X}{X} \geq 1$$

$$e_{OUT} \approx \frac{ke_X}{2(X)^{1/2}} \quad \text{for } \frac{e_X}{X} < 1$$

3.7 SQUARE ROOT EXTRACTOR WITH MULTIPLIER

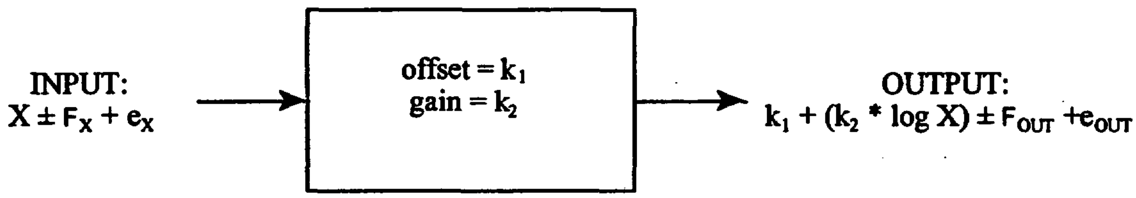


where:

$$\sigma_{OUT} \approx \frac{k[(Y \times \sigma_X)^2 + (X \times \sigma_Y)^2]^{1/2}}{2(XY)^{1/2}}$$

$$e_{OUT} \approx \frac{k[(Y \times e_X) + (X \times e_Y)]}{2(XY)^{1/2}}$$

3.8 LOGARITHMIC AMPLIFICATION



where:

$$\sigma_{OUT} \approx \left(\frac{k_2 \log e}{X}\right) \times \sigma_X$$

$$e_{OUT} \approx \left(\frac{k_2 \log e}{X}\right) \times e_X$$

4.0 MODULES WITH INPUT AND/OR OUTPUT SIGNAL OFFSETS

The functions provided in Appendix B, section 3 use normalized input and output signal values and do not explicitly indicate that either the input signal(s) or the output signal(s), or both, are offset from 0, e.g. 4-20 mA, 1-5 V. The above functions can be modified to include an offset where absolute signal values are desired. This is done by substituting $(x - x_I)$ for input X where the input offset is x_I. The output is modified in a similar manner with X_{OUT} replaced with $(x - x_0)$ and x_0 represents the output offset.

<u>Example (square root extractor with input and output offsets)</u>

INPUT: $X \pm \sigma_X + e_X \Rightarrow (x - x_I) \pm \sigma_X + e_X$

OUTPUT: $k(X)^{1/2} \pm \sigma_{OUT} + e_{OUT} \Rightarrow k(x - x_0)^{1/2} \pm \sigma_{OUT} + e_{OUT}$

where:

$$\sigma_{OUT} = \frac{k\sigma_X}{2(x - x_0)^{1/2}}$$

$$e_{OUT} = k((x - x_0) + e_X)^{1/2} - (x - x_0)^{1/2}$$

$$e_{OUT} \approx \frac{ke_X}{2(x - x_0)^{1/2}}$$

APPENDIX C

EQUATIONS FOR INSTRUMENT CHANNEL UNCERTAINTIES, SETPOINTS AND ALLOWABLE VALUES

1.0 UNCERTAINTY EQUATION

In order to provide a level of confidence that a setpoint actuation will occur prior to exceeding a performance or design basis criteria, the instrument loop accuracy must be determined. This level of confidence is dependent on determining the individual process and component errors and uncertainties, and then combining them in a consistent manner.

The combination of errors is based on statistical and algebraic methods. Errors and uncertainties are combined based on the type of error or uncertainty represented. These types are defined as:

- random, independent errors and uncertainties, which are combined using the square-root-sum-of square (SRSS) methodology.
- random, dependent or not sufficiently independent errors and uncertainties, which are combined by first algebraically adding them to form a pseudo-random composite uncertainty, then combining this uncertainty using SRSS with the other random uncertainties.
- dependent and/or non-randomly distributed errors and uncertainties, which are combined algebraically.

Accuracy, represented by the combination of errors and uncertainties, is calculated using the following equation.

$$Z = \pm[(A^2 + B^2 + C^2) + (D+E)^2]^{1/2} \pm (|F|) + (L) - (M) \qquad \text{(Eq. C1)}$$

Where:

Z = accuracy represented by the total uncertainty

A, B, C = random and independent terms. The terms are zero-centered, approximately normally distributed, and indicated by a ± sign.

D, E = random, dependent uncertainty terms that are independent of terms A, B and C

F = 1) non-normally (abnormally) distributed uncertainties, or
2) biases with unknown sign.

This term is used to indicate limits of error associated with uncertainties that are not normally distributed and do not have known direction. The magnitude of this term (absolute value) is assumed to contribute to the total uncertainty in a worst-case direction and is also indicated by a ± sign.

L, M = biases with known sign. These terms can impact an uncertainty in a specific direction and therefore, have a specific + or – contribution to the total uncertainty. L represents positive biases and M represents negative biases.

When the maximum and minimum total uncertainty is desired, equation C1 can be rewritten to combine all positive biases and all negative biases in separate terms.

$$Z^{+} = +[(A^2 + B^2 + C^2) + (D+E)^2]^{1/2} + G \quad \text{(Eq. C2)}$$

$$Z^{-} = -[(A^2 + B^2 + C^2) + (D+E)^2]^{1/2} - H \quad \text{(Eq. C3)}$$

Where:

Z, A, B, C, D, E, F, L and M are defined for equation C1, and

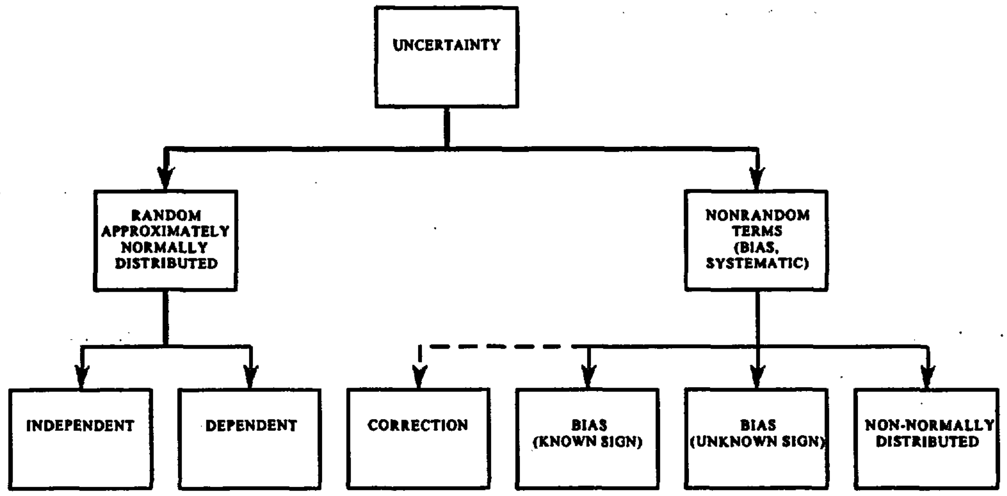
$G = (\Sigma|F^{+}|) + (\Sigma L)$, where F^{+} is the positive bias term sum (Eq. C4)

$H = (\Sigma|F^{-}|) + (\Sigma|M|)$, where F^{-} is the negative bias term sum (Eq. C5)

The categorization of errors and uncertainties is shown in Appendix C, Figure 1.

Random errors and uncertainties are provided using a value and a level of confidence. The combination of these errors and uncertainties MUST be evaluated at the same confidence level, e.g. 2σ, 1σ, etc.

NOTE: ComEd PWR protection setpoints are calculated using the Westinghouse methodology. See the applicable Westinghouse WCAP and the individual protection setpoint calculations for a discussion of this methodology.



ATTRIBUTES	VARIABLE MAGNITUDE, RANDOM SIGN		FIXED, KNOWN SIGN AND MAGNITUDE	VARIABLE OR FIXED MAGNITUDE AND KNOWN SIGN	VARIABLE OR FIXED MAGNITUDE AND KNOWN SIGN	VARIABLE MAGNITUDE RANDOM SIGN
OTHER NAMES	STATISTICAL, ACCIDENTAL, PRECISION	CORRELATED	OFFSET	SYSTEMATIC	NONE	NONE
COMBINATIONAL RESTRICTIONS	SRSS	SRSS AFTER LINEAR SUMMING	NOT USED TO CALCULATE CHANNEL UNCERTAINTY	COMBINE LIKE SIGNS LINEARILY	ABSOLUTE VALUE TO PRODUCE A CONSERVATIVE RESULT	
QUANTIFICATION	TWO SIGMA (95%) PROBABILITY LEVEL		CONSTANTS	ESTIMATED LIMITS OF ERROR		
EQUATION TERMS	+/- A, +/-B, +/-C	+/-D, +/-E	NONE	+L, -M	+/-F	

Figure C1, Uncertainty Model

2.0 UNCERTAINTY EQUATIONS USING COMED SYMBOLOGY

2.1 CALIBRATION ERROR

The equation for calibration error (CAL) is defined using ComEd symbology:

$$CAL = \pm[(RAMTE + TEMTE)^2 + REMTE^2 + STD^2]^{1/2} \quad \text{(Eq. C6)}$$

where: RAMTE = M&TE Reference Accuracy
TEMTE = M&TE Temperature Error
REMTE = M&TE Reading Error
STD = Calibration Standard Error and is determined from the following equation:

$$STD = \pm[(RASTD + TESTD)^2 + RESTD^2]^{1/2} \quad \text{(Eq. C7)}$$

RASTD = Calibration Standard Reference Accuracy
TESTD = Calibration Standard Temperature Error
RESTD = Calibration Standard Reading Error

Where both input M&TE and output M&TE are used in the calibration of a calibration block, Eq. C6 is rewritten as follows:

$$CAL = \pm[(RAMTE_{IN} + TEMTE_{IN})^2 + REMTE_{IN}^2 + STD_{IN}^2 + (RAMTE_{OUT} + TEMTE_{OUT})^2 + REMTE_{OUT}^2 + STD_{OUT}^2]^{1/2} \quad \text{(Eq. C8)}$$

2.2 TOTAL ERROR

The symbols shown in Appendix A, Table 1 can be substituted into equation C1 using the applicable default error classifications. Use of this equation should be consistent with the error classifications specific to each instrument loop. For example, if the vendor supplied drift error has been determined to be a bias error, an eD term would be added to the bias errors and the σ_D term would be removed.

$$Z = \pm[\sigma_{PE}^2 + \sigma_{RA}^2 + \sigma_D^2 + CAL^2 + ST^2 + \sigma_{IN}^2]^{1/2} \pm [eSP + eP + eV + eT + eH + eR + eS + eIR + MAR] \quad \text{(Eq. C9)}$$

where: all random errors are at the same confidence level and,

PE = Process Error
RA = Reference Accuracy

D = Drift
CAL = Calibration Error
ST = Setting Tolerance
IN = Random input Error(s)
eSP = Static Pressure Error
eP - = Pressure Error
eV - = Power Supply Error
eT - = Temperature Error
eH - = Humidity Error
eR - = Radiation Error
eS - = Seismic Error
eIR - = Error due to current leakage through insulation resistance
MAR = Margin (included only if applicable)

3.0 TRIP SETPOINT

The Trip Setpoint (SP) is calculated to provide a level of confidence that the setpoint function will occur prior an acceptance limit. For protection setpoints, this level of confidence is a 2σ value for random errors and the analytical limit is the associated acceptance limit.

Increasing Protection Setpoint

SP = AL – (Z+MAR) (Eq. C10)

Decreasing Protection Setpoint

SP = AL + (Z+MAR) (Eq. C11)

Other Increasing Setpoints

SP = acceptance limit – (Z+MAR) (Eq. C12)

Other Decreasing Setpoints

SP = acceptance limit + (Z+MAR) (Eq. C13)

where: SP = calculated trip setpoint
AL = analytical limit
Z = total uncertainty as defined in equation C9 or its equivalent
MAR = margin, if applicable for an additional level of conservatism acceptance limit: any other limit chosen to ensure that a condition is not exceeded. Examples are: plant protection limits , personnel safety limits, equipment protection limits, radiation dose limits, EOP setpoints, etc.

4.0 ALLOWABLE VALUE

The Allowable Value is calculated to provide acceptance criteria for evaluation of operability. It is a value, that if exceeded, may mean that the instrument loop, module or component is no longer performing within the assumptions of the setpoint calculation, the design basis or the Technical Specifications. The Allowable Value is typically used to evaluate the "as-found" trip setpoint with respect to a condition of operability. The Allowable Value is typically included in the station Technical Specifications.

The Allowable Value is calculated by combining ONLY those errors that effect the "as-found" setpoint value and then adding or subtracting the combined error from the trip setpoint.

Increasing Setpoint

AV = SP + applicable uncertainty (Eq. C14)

Decreasing Setpoint

AV = SP – applicable uncertainty (Eq. C15)

where: AV = Allowable Value
SP = Calculated Trip Setpoint
applicable uncertainty = a value calculated from the errors and uncertainties that have been determined to effect the trip setpoint

From all of the errors and uncertainties that have been determined to effect the trip setpoint, ONLY those that effect the as-found measurement are combined using equation C9 or its equivalent. For example, for an instrument channel where the as-found trip value is determined during a quarterly functional check, a test signal is applied to the instrument rack and the bistable is observed to change state. The total uncertainty consists of the input M&TE uncertainties, the instrument channel uncertainties, any environmental effects during

the functional check and the setting tolerance. None of the sensor errors effect the "as-found" setpoint value in this example, and would not be included in the applicable uncertainty for this setpoint when calculating an Allowable Value for the quarterly function check.

5.0 EXPANDED TOLERANCES

An Expanded Tolerance is a value calculated from available instrument uncertainties that is used to evaluate an instrument's performance and it's potential degradation. Refer to ER-AA-520 for calculation of Expanded Tolerances.

APPENDIX D

GRADED APPROACH TO DETERMINATION OF INSTRUMENT CHANNEL ACCURACY

1.0 INTRODUCTION

The ComEd setpoint methodology was developed and is defined by this standard to provide the basis, consistent with ANSI/ISA-67.04.01-2000, for the determination of instrument setpoints, allowable values and instrument loop accuracy. This ISA standard defines the requirements for establishing and maintaining setpoints for nuclear safety-related instrumentation. In addition, ISA- RP67.04.02-2000 provides guidance for implementing ANSI/ISA-67.04.01-2000 and imposes rigorous requirements for instrument uncertainty calculations and setpoint determination for safety-related instrument setpoints in nuclear power plants.

ISA- RP67.04.02-2000 recognizes that the historical focus of ANSI/ISA-67.04.01-2000 was the class of setpoints associated with the analytical limits as determined in the accident analysis. These setpoints have typically been interpreted as the reactor protection (RP) and emergency safety features (ESF) setpoints The RP and ESF setpoints are those critical to ensuring that the integrity of the multiple barriers to the release of fission products are maintained. The Recommended Practice also states that setpoints that are not part of the safety analysis and are not required to maintain the integrity of the fission product barriers may not require the same level of rigor or detail as described by the Recommended Practice. For these non-RP and non-ESF setpoints, a graduated or "graded" approach is appropriate for setpoints that:

- provide anticipatory inputs to the RP or ESF functions, but are not credited in the accident analysis or,
- support operation of, but not the initiation of, the ESF setpoints.

ISA draft Technical Report, ISA-dTR67.04.09, "Graded Approaches to Setpoint Determination", is being prepared to provide further guidance in establishing classification schemes for setpoints and recommending an approach to translate these classification schemes into a methodology for determination of instrument loop accuracies and setpoints. The technical report requires that a "graded methodology" provide a consistent hierarchy of both rigor and conservatism for classifying, determining and subsequently maintaining setpoints.

This appendix provides a classification scheme and the associated graded methodology for the determination of instrument loop accuracy at ComEd nuclear stations. The instrument loop accuracy may then be used to determine the associated instrument setpoints The ComEd "graded methodology" is summarized in Table D1.

2.0 CLASSIFICATION

The ComEd graded methodology classifies instrument setpoints into four levels. These correspond to a "level of confidence" that the setpoint will perform its function with respect to a limit or other limiting criteria. These levels range from Level 1, which provides the highest confidence, to Level 4, which may only document engineering judgment.

The following sections identify instrument channel functions and the minimum level of confidence used when determining instrument loop accuracy. Those individuals preparing and reviewing instrument loop accuracy calculations may choose to perform a particular instrument loop accuracy calculation using a higher level of confidence. This basis for this decision shall be fully documented in the instrument loop accuracy calculation.

It is not the intent of this standard to identify every instrument function encountered in a nuclear station. The following sections should provide sufficient guidance for selecting the appropriate level of confidence for those instrument functions not explicitly identified. Care should be taken to ensure that the function of the setpoint is clearly identified and that the instrument loop accuracy is determined consistent with the following levels.

2.1 LEVEL 1

This level is consistent with the definition of nuclear safety-related instrumentation in ANSI/ISA-67.04.01-2000. These instruments provide setpoints that:

1) Provide emergency reactor shutdown
2) Provide containment isolation
3) Provide reactor core cooling
4) Provide for containment or reactor heat removal
5) Prevent or mitigate a significant release of radioactive material to the environment or is otherwise essential to provide reasonable assurance that a nuclear power plant can be operated without undue risk to the health and safety of the public

For ComEd nuclear stations, this specifically includes all reactor protection system (RPS), emergency safety features (ESF), emergency core cooling system (ECCS), primary containment isolation system (PCIS) and secondary containment (SCIS) setpoints.

2.2 LEVEL 2

This level will include those setpoints that:

1) Ensure compliance with Technical Specification but are not level 1 setpoints.
2) Provide setpoints or limits associated with RG 1.97, category A variables.
3) Provide setpoints or limits associated with station emergency operating procedure (EOP) requirements.

The RG 1.97 category A variables are included in Level 2 since they provide the primary information required to permit the control room operator to take specific manually controlled actions for which no automatic control is provided and that are required for safety systems to accomplish their safety functions for design basis accident events.

Level 2 instrument loops are typically associated with those setpoints that provide the station operator with specific action values or limits used to verify plant status. This includes instrument loops that provide an indication of acceptable performance for structures, systems and components in the Technical Specifications.

Setpoints or limits contained in station EOPs that are RG 1.97 category A variables, or setpoints that provide specific action values are included in Level 2. Other EOP setpoints may be either Level 2 or 3 depending on their function.

2.3 LEVEL 3

This level will include those setpoints that:

1) Provide setpoints or limits associated with RG 1.97, category B, C or D variables.
2) Provide setpoints or limits associated with other regulatory requirements or operating commitments, e.g. OSHA, EPA, etc.
3) Provide setpoints or limits that are clearly associated with personnel safety or equipment protection.

The RG 1.97, category B, C and D variables are associated with contingency actions and may be included in EOPs or other written procedures.

Classification of EOP setpoints as a Level 3 setpoint shall be approved by the station EOP coordinator or other individual designated by the station operations department.

2.4 LEVEL 4

This level will include those setpoints that:

1) Provide setpoints or limits not identified with the requirements in levels 1, 2 or 3 above.
2) Require documentation of engineering judgment, industry or station experience, or other methods have been used to set or identify an operating limit.

Level 4 shall provide documentation of all non-ComEd methodologies used to establish instrument loop accuracies or instrument setpoints.

3.0 DETERMINATION OF INSTRUMENT LOOP ACCURACY

3.1 LEVELS OF CONFIDENCE

The level of confidence associated with the calculation enforces a gradation in rigor and conservatism to the instrument loop accuracy evaluation. Level 1, the highest level of conservatism, is typically associated with a 95% level of confidence that the setpoint will provide its intended function prior to limit or limiting condition. Levels 2, 3 and 4 provide decreasing levels of confidence by allowing various additions to the methodology used to calculate and combine errors and uncertainties. At Level 4, the instrument loop accuracy may not be associated with any clearly identified level of confidence other than experience.

The methodology associated with each level is shown in Table D1.

3.2 LEVEL 1

Calculation of instrument loop accuracy, instrument setpoints and allowable values in Level 1 shall use the equations in App. C. These equations use a 2σ level of confidence and require that determination of instrument loop accuracy <u>always</u> err on the side of conservatism.

Level 1 setpoints are consistent with ISA 67.04.01-2000 and ISA RP67.04.02-2000. in order to ensure that protective actions occur 95% of the time with a high degree of confidence before the analytical limits are reached.

3.3 LEVEL 2

Level 2 instrument loop accuracy is calculated using the equations in Appendix C with the following exceptions:

1) Random errors are evaluated at a 1σ level of confidence
2) Bias errors may be combined using SRSS in accordance with Reference 3.11
3) Where it can be determined that a setpoint function is only evaluated in a single direction, either increasing or decreasing, single side of interest confidence levels may be utilized (reference 3.2, section 8.1).

3.4 LEVEL 3

Level 3 instrument loop accuracy is calculated using the equations in Appendix C, the exceptions in Level 2 and the following additional exceptions:

1) Uncertainties applicable to the entire instrument channel are used wherever available, e.g. channel drift and channel temperature uncertainty vs. module /component drift and module/component temperature uncertainty.
2) Where all terms are expected to be approximately normally distributed and the number of terms is ≥4, the sum is assumed to be approximately distributed. Therefore, all terms can be combined using SRSS.
3) For bistables, the RA term does not require inclusion of the hysteresis/linearity components. Only the RA uncertainty OR the ST uncertainty, whichever is larger shall be used

3.5 LEVEL 4

Level 4 instrument loop accuracy may be calculated using the equations in Appendix C and include the exceptions in Level 2 and 3. For calculations associated with Level 4 instrument loops, the basis for determining the instrument loop accuracy shall be documented.

Table D1, Graded Methodology

LEVEL	TYPICAL APPLICATION	METHODOLOGY	APPLICABLE UNCERTAINTY METHODS
1	• Protection setpoints • ESF/RPS/ECCS • PCIS/SCIS	$2\sigma + \Sigma e_i$	• Consistent with ISA 67.04.01-2000 and ISA RP67.04.02-2000. • Ensures protective actions occur 95% of the time with a high degree of confidence before the analytical limits are reached. • Random and bias error combination: $Z = \pm[A^2 + B^2 + C^2 + (E + F)^2]^{1/2} \pm (\|F\|) + (L) - (M)$ Z = resultant uncertainty, combination of random and bias uncertainties A,B,C = random, independent terms D,E = random dependent terms (independent of A,B and C) F = abnormally distributed uncertainties and/or bias (unknown sign) L,M = biases with known sign
2	• EOP operator action setpoints • RG 1.97 Type A variables	$\sigma + \Sigma e_i$	• Bias errors combined using SRSS in accordance with ASME PTC 19.1: $e_i = \pm[F^2 + L^2 + M^2]^{1/2}$ where F, L and M are bias errors as shown above • Single side of interest confidence interval evaluation where the evaluated setpoint is in a single direction: $Z = 0.468\sigma + \Sigma e_i$

Table D1 (con't), Graded Methodology

LEVEL	TYPICAL APPLICATION	METHO-DOLOGY	APPLICABLE UNCERTAINTY METHODS
3	• RG 1.97 Type B, C & D variables	$\sigma + \Sigma e_i$	• Uncertainties applicable to the entire instrument channel are used wherever available, e.g. channel drift and channel temperature uncertainty vs. module/component drift and module/-component temperature uncertainty. • Single side of interest confidence interval evaluation where the evaluated setpoint is in a single direction: $Z = 0.468\sigma + \Sigma e_i$ • Where all terms are expected to be approximately normally distributed, the sum is assumed to be approximately distributed for $n \geq 4$: $Z = [\sigma_n^2 + e_n^2]^{1/2}$ • For bistables, the RA term does not require inclusion of the hysteresis/linearity components, therefore use the RA uncertainty OR the ST uncertainty, whichever is larger.
4	• Documentation of setpoint accuracy (e.g. non-safety, non-tech spec compliance) • Other regulatory related setpoints (consequences of non-compliance are deemed acceptable)	as appropriate	• Engineering Judgment shall be documented • Engineering evaluation/conclusions shall be documented • Vendor, ComEd, or other methodologies may be utilized where appropriate

APPENDIX E

REACTOR WATER LEVEL TO SENSOR dP CONVERSION

1.0 PURPOSE

Differential pressure transmitters are used to monitor reactor vessel water level in a BWR. Reactor vessel level is typically described by elevation from a reference level with units of "inches Reactor Water Level" or "in. RWL", while sensor dP is measured in units of pressure such as "inches water column" or "in.WC". For example; 380.87 in. WC may correspond to a range of –340 in. RWL to +60 in. RWL.

When converting between vessel level and sensor dP, changes in process conditions inside the reactor vessel and changes in environmental conditions must be accounted for. As shown in Figure E1, the sensing lines that connect the dP sensor and the reactor vessel are effected by at least 2 different environmental zones; the drywell and the reactor building. Each of these environmental zones has its own normal temperature deviations. During accident conditions, such as recirculation line break, each of these zones may experience significant temperature increases at the transmitter location or within the drywell.

This appendix will provide:

1) a conversion factor between "in. RWL" and the equivalent dP at the sensor as measured in "in.WC"
2) an equation to calculate changes in sensor dP that result from changes in the drywell and/or reactor building temperature.
3) a scaling conversion factor for changes to sensor dP that result from changes in process conditions.

2.0 CONVERSION OF "in. RWL" TO SENSOR dP IN "in.WC"

The differential pressure between the high and low inputs of a differential pressure transmitter is:

$$dP = P_H - P_L \qquad \text{(Eq. E1)}$$

where:

P_H = the sum of the hydrostatic head pressures at the high sensor input
P_L = the sum of the hydrostatic head pressures at the low sensor input

Hydrostatic pressure head is given by:

$$P = \rho g z \qquad \text{(Eq. E2)}$$

where:

P = pressure
ρ = density of the fluid (lbm/ft^3)
g = gravitational constant
z = height of the column of fluid

Using the definition of specific weight, $\gamma = \rho g$, the equation for dP is:

$$dP = \gamma(z_2 - z_1) \qquad \text{(Eq. E3)}$$

Using Figure E1, we can define a conversion constant (K) as the change in reactor water level (L) for a change in sensor dP.

$$K = \frac{\delta dP}{\delta L} \qquad \text{(Eq. E4)}$$

Referring to Figure E1 for the associated elevations, the dP resulting from a level, L, is:

$$dP = \gamma_2(E_C - E_{PH} - E_{NL} + E_{PL}) + \gamma_3(E_{PH} - E_{PL}) - \gamma_4(E_C - L) - \gamma_1(L - E_{NL}) \qquad \text{(Eq. E5)}$$

An incremental change in dP, given by $dP + \delta dP$, is a result of a corresponding incremental change in level, $L + \delta L$:

$$dP + \delta dP = \gamma_2(E_C - E_{PH} - E_{NL} + E_{PL}) + \gamma_3(E_{PH} - E_{PL}) - \gamma_4(E_C - (L + \delta L)) - \gamma_1((L + \delta L) - E_{NL}) \qquad \text{(Eq. E6)}$$

Solving for the change in dP by subtracting equation E5 from equation E6:

$$\delta dP = (dP + \delta dP) - (dP)$$

$$= [-\gamma_4(E_C - (L + \delta L)) - \gamma_1((L + \delta L) - E_{NL})] - [-\gamma_4(E_C - L) - \gamma_1(L - E_{NL})]$$

$$= \delta L(\gamma_4 - \gamma 1) \qquad \text{(Eq. E7)}$$

For the change in sensor dP corresponding to a 1 inch change in reactor vessel water level:

$\delta L =$ 1 in. RWL

From equation E4:

$$K = \frac{\delta dP}{\delta L} = (\gamma_4 - \gamma_1)\frac{\text{in. WC}}{\text{in. RWL}} \qquad \text{(Eq. E8)}$$

3.0 CHANGES IN SENSING LINE AND SENSOR ENVIRONMENT

Changes in sensor dP will result from changes in the drywell environment and/or changes in the reactor building environment due to changes in density of the sensing line fluid. For example:

- changes from calibrated environmental conditions to the maximum or minimum normal environmental conditions.
- changes from maximum normal environmental conditions to maximum accident conditions.

Using Figure E1, we can define the sensor dP for 2 different environments.

Environment 1

$$dP_{L1} = [\gamma_{2\text{-}1}(E_C - E_{PH}) + \gamma_{3\text{-}1}(E_{PH} - E_X)] - [\gamma_{1\text{-}1}(E_C - L1) + \gamma_{4\text{-}1}(L1 - E_{NL}) + \gamma_{2\text{-}1}(E_{NL} - E_{PL}) + \gamma_{3\text{-}1}(E_{PL} - E_X)$$

$$= \gamma_{2\text{-}1}(E_C - E_{PH} - E_{NL} + E_{PL}) + \gamma_{3\text{-}1}(E_{PH} - E_{PL}) - \gamma_{4\text{-}1}(E_C - L1) - \gamma_{1\text{-}1}(L1 - E_{NL})$$

(Eq. E9)

where:

$L1 =$ reactor vessel water level (in. RWL) at condition 1
$\gamma_{1\text{-}1} =$ spec. wgt. of saturated fluid in the reactor vessel at condition 1
$\gamma_{2\text{-}1} =$ spec. wgt. of fluid in that portion of the sensing lines in the drywell at drywell temperature 1
$\gamma_{3\text{-}1} =$ spec. wgt. of fluid in that portion of the sensing lines in the reactor building at reactor building temperature 1
$\gamma_{4\text{-}1} =$ spec. wgt. of saturated vapor in the reactor vessel at condition 1

Environment 2

$$dP_{L2} = \gamma_{2\text{-}2}(E_C - E_{PH} - E_{NL} + E_{PL}) + \gamma_{3\text{-}2}(E_{PH} - E_{PL}) - \gamma_{4\text{-}2}(E_C - L2) - \gamma_{1\text{-}2}(L2 - E_{NL})$$
(Eq. E10)

where:

$L2$ = reactor vessel water level (in. RWL) at condition 2
$\gamma_{1\text{-}2}$ = spec. wgt. of saturated fluid in the reactor vessel at condition 2
$\gamma_{2\text{-}2}$ = spec. wgt. of fluid in that portion of the sensing lines in the drywell at drywell temperature 2
$\gamma_{3\text{-}2}$ = spec. wgt. of fluid in that portion of the sensing lines in the reactor building at reactor building temperature 2
$\gamma_{4\text{-}2}$ = spec. wgt. of saturated vapor in the reactor vessel at condition 2

If we assume all changes between environment 1 and environment 2 are limited to changes in the drywell and reactor building environments:

$L1 = L2$
$\gamma_{1\text{-}1} = \gamma_{1\text{-}2}$
$\gamma_{4\text{-}1} = \gamma_{4\text{-}2}$

The change in sensor dP from condition 1 to condition 2 is:

$$\Delta dP = dP_{L2} - dP_{L1} = [(\gamma_{2\text{-}2} - \gamma_{2\text{-}1})(E_C - E_{PH} - E_{NL} + E_{PL})] + [(\gamma_{3\text{-}2} - \gamma_{3\text{-}1})(E_{PH} - E_{PL})]$$
(Eq. E11)

3.1 EXAMPLE

To calculate the process error due to a LOCA, we need to determine the change in sensor dP between maximum normal environmental conditions and the maximum accident environmental conditions in the drywell and reactor building. This is typically calculated at a specific reactor vessel level, e.g. one of the vessel level protection setpoints. In addition, in order to calculate a bounding change, the following assumptions apply:

1) Transient effects are ignored. It is assumed that the sensing lines are at thermal equilibrium with their environment.
2) Reactor vessel process conditions do not change, only the sensing line environments are effected by the LOCA. Obviously the reactor vessel saturation conditions will change if a scram occurs, but in this example we are looking only for the process error at the protection level setpoint.

From equation E11:

$$\Delta dP = [(\gamma_{2a} - \gamma_{2n})(E_C - E_{PH} - E_{NL} + E_{PL})] + [(\gamma_{3a} - \gamma_{3n})(E_{PH} - E_{PL})] \quad \text{(Eq. E12)}$$

where:

γ_{2n} = spec. wgt. of the fluid in that portion of the sensing lines in the drywell at the maximum normal environment.

γ_{2a} = spec. wgt. of the fluid in that portion of the sensing lines in the drywell at the maximum accident environment.

γ_{3n} = spec. wgt. of the fluid in that portion of the sensing lines in the reactor building at the maximum normal environment

γ_{2a} = spec. wgt. of the fluid in that portion of the sensing lines in the reactor building at the maximum accident environment.

Using equation E8 and equation E12, we can calculate the equivalent change in reactor vessel water level:

$$\Delta RWL = \frac{\Delta dP}{(\gamma_4 - \gamma_1)}$$

$$\Delta RWL = \frac{[(\gamma_{2a} - \gamma_{2n})(E_C - E_{PH} - E_{NL} + E_{PL})] + [(\gamma_{3a} - \gamma_{3n})(E_{PH} - E_{PL})]}{(\gamma_4 - \gamma_1)} \quad \text{(Eq. E13)}$$

4.0 REACTOR WATER LEVEL SCALING

Reactor vessel level is typically provided in inches above or below some reference, e.g. top of active fuel (TAF). In order to determine the correct dP transmitter scaling we use equation E5 to determine the dP at normal process conditions and normal drywell and reactor building environments. This dP must then be converted to the equivalent dP at calibration conditions. Transmitter calibration is typically performed at cold shut-down conditions where the reactor vessel vapor space contains air and it is assumed that the vessel fluid, drywell and reactor building are at the same temperature. From equation E8, we see that the conversion from sensor dP to in. RWL is a function of the process conditions and is not effected by the sensing line environmental conditions.

At normal process conditions:

$$\frac{dP_P}{dL_P} = \gamma_4 - \gamma_1 \qquad \text{(Eq. E14)}$$

At calibration conditions:

$$\frac{dP_C}{dL_C} = \gamma_{AIR} - \gamma_C F \qquad \text{(Eq. E15)}$$

For scaling dP values, we define a conversion factor that provides the equivalent change in reactor vessel level for a given sensor dP when we change from calibration conditions to the normal process conditions.

$$K_{S|dP=CONSTANT} = \frac{\text{vessel level at process conditions}}{\text{vessel level at calibration conditions}}$$

From equations E14 and E15, this is equivalent to $dP_C = dP_P$

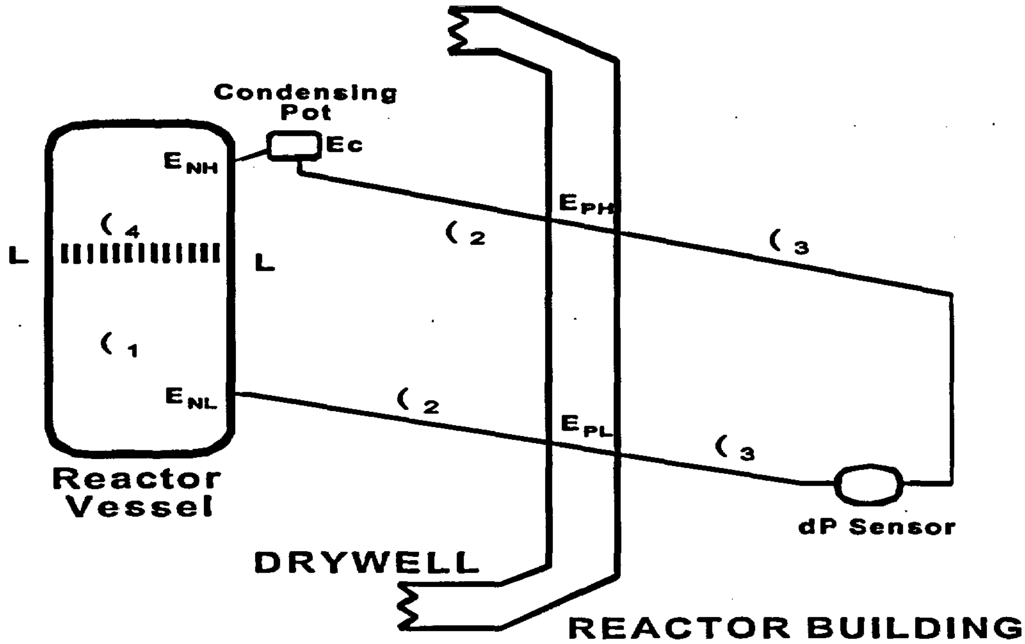
Therefore:

$$dL_C(\gamma_{AIR} - \gamma_C) = dL_P(\gamma_4 - \gamma_1) \qquad \text{(Eq. E16)}$$

$$K_S = \frac{dL_P}{dL_C} = \frac{\gamma_{AIR} - \gamma_C}{\gamma_4 - \gamma_1} \qquad \text{(Eq. E17)}$$

When using standard steam tables, it is convenient to rewrite equation E17 as a ratio of specific volumes. Neglecting the specific weight of air, conversion factor K_S is:

$$K_S = \frac{v_4 v_1}{v_C(v_4 - v_1)} \qquad \text{(Eq. E18)}$$



γ_1 - specific weight of the saturated fluid in the reactor vessel
γ_2 - specific weight of the fluid in the sensing lines located in the drywell
γ_3 - specific weight of the fluid in the sensing lines located in the reactor building
γ_4 - specific weight for the saturated vapor in the reactor vessel
E_{NL} - elevation of the lower nozzle
E_{NH} - elevation of the upper nozzle
E_C - elevation of the condensate pot
E_{PL} - elevation of the lower penetration
E_{PH} - elevation of the upper penetration
E_X - elevation of the sensor
L - Water Level (in. RWL)

Figure E1, Reactor Vessel Water Level and Sensor dP

APPENDIX F

TEMPERATURE EFFECTS ON LEVEL MEASUREMENT

1.0 INTRODUCTION

Differential pressure level measurement systems are typically calibrated for a specific set of operating conditions, i.e. processes pressure and reference leg temperature. If either of these conditions change, an error will be introduced between the actual level and the indicated level. This is due to changes in the dP at the sensor and results from changes in fluid density and not from changes in actual level. Since this error is of known magnitude and known direction (based on the difference between the calibrated condition and the new process and/or environmental condition), it is treated as a bias error.

This appendix provides simplified formulas for estimating the effects of:

- process pressure changes (assuming that the vessel is at saturation conditions),
- environmental changes (assuming that the reference leg fluid temperature is at equilibrium with the environment), and
- both process changes and reference leg temperature changes acting simultaneously to produce a worst case bias under specified conditions.

2.0 ERROR FRACTION

When evaluating the effects of process and environmental changes on level measurement accuracy, it is convenient to consider these effects as changes from the known (or calibrated) condition. Using this concept, the level error is a function of how much the indicated level differs from the actual level. The indicated level (IND LVL) corresponds to the transmitter scaling relationship where transmitter output is a function of the dP applied to the transmitter. The scaling relationship should be based on specific process conditions and specific environmental conditions. The actual level (ACT LVL) will then deviate from the indicated level (IND LVL) as a function of the deviation of the process and environmental conditions from the calibrated conditions. This difference between indicated level and actual level is defined as the "error fraction" (E)[2]:

$$E = \%\ \text{IND LVL} - \%\ \text{ACT LVL}$$

This appendix will use units of % level which is consistent with typical level measurement scales where indicated level ranges from 0% to 100% level. While units of level, and consequently E could be in other units, the derivations are simplified if % level is chosen.

[2] The term "error fraction" and the equation E = % IND LVL – % ACT LVL, is consistent with the steam generator level protection and EOP setpoint accuracy evaluation originally provided by Westinghouse and currently incorporated in ComEd setpoint accuracy calculations for Byron and Braidwood stations.

If E is calculated (regardless of the units of level measurement), the effects of temperature related errors on bistable or EOP setpoints can be evaluated. Table F1 can be used to determine if level bias error must be included in the instrument loop accuracy or may be ignored.

	sign of E is positive (IND LVL > ACT LVL)	sign of E is negative (ACT LVL > IND LVL)
Increasing setpoint	bias error will be conservative and may be ignored	bias error is non-conservative and must be included in the instrument loop accuracy
Decreasing setpoint	bias error is non-conservative and must be included in the instrument loop accuracy	bias error will be conservative and may be ignored

Table F1, Error Fraction Effect on Instrument Setpoints.

3.0 PROCESS FLUID DENSITY CHANGES

The following equations may be used to calculate indicated level and the error fraction resulting from process fluid density changes.

These equations assume:

1) saturated conditions inside the vessel The occurrence of subcooling in the downcomer region of PWR steam generators, which becomes significant above 70% RTP is typically included in instrument loop accuracy calculations, but is calculated through other mechanisms.

2) an actual steam generator level There is no actual level in the steam generator while generating steam. A transition zone exists between the saturated fluid and saturated vapor. The following equations calculate the actual level L as the collapsed level.

3) steady state process conditions Transient effects, such as rapid depressurization, are not included and would require a much more complicated analysis.

4) thermal equilibrium The reference leg fluid temperature is considered to be in equilibrium with the environment.

Typical condensing pot installations are located close to the vessel. This results in the H_L/H term in the following equations being sufficiently close to 1 for this term to be ignored.

3.1 FORMULAS

For an actual level L, the indicated level will be:

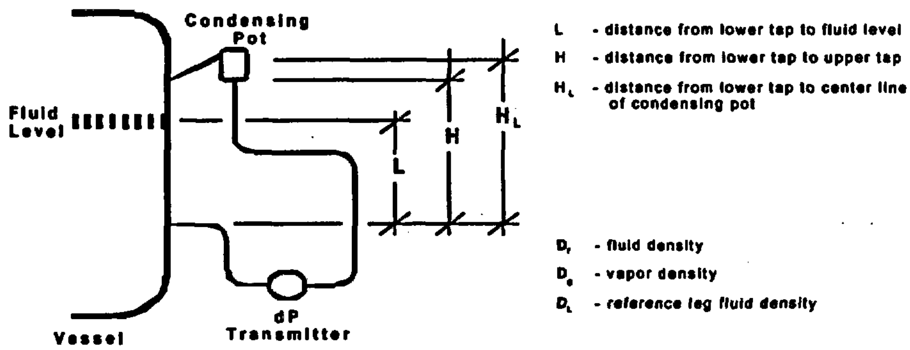
$$\% \text{ IND LVL} = \left(\frac{H_L}{H} \left(\frac{\rho_{L1} - \rho_{L2} - \rho_{g1} + \rho_{g2}}{\rho_{f1} - \rho_{g1}} \right) + \frac{L}{H} \left(\frac{\rho_{f2} - \rho_{g2}}{\rho_{f1} - \rho_{g1}} \right) \right) \times 100$$

where: all terms are defined in Figure F1, and
L, H and H_L are in consistent units of length (e.g. inches)

The error fraction for process fluid density changes is:

E = % IND LVL - % ACT LVL

$$\frac{E}{100} = \frac{H_L}{H} \left(\frac{\rho_{L1} - \rho_{L2} - \rho_{g1} + \rho_{g2}}{\rho_{f1} - \rho_{g1}} \right) + \frac{L}{H} \left(\frac{\rho_{f2} - \rho_{g2}}{\rho_{f1} - \rho_{g1}} - 1 \right)$$



T_1, P_1	-	temperature and pressure inside the vessel at calibrated conditions
ρ_{f1}, ρ_{g1}	-	density of saturated liquid and steam at calibration conditions T_1 and P_1
T_2, P_2	-	temperature and pressure inside the vessel at some new condition
ρ_{f2}, ρ_{g2}	-	density of saturated liquid and steam at the new conditions T_2 and P_2
$T_{REF\ LEG}$	-	temperature of the environment and reference leg fluid
ρ_{L1}	-	density of reference leg liquid at $T_{REF\ LEG}$ and P_1 (compressed liquid)
ρ_{L2}	-	density of reference leg liquid at $T_{REF\ LEG}$ and P_2 (compressed liquid)

Figure F1: Level Bias Error Due to Process Fluid Density Changes

3.2 DERIVATION

Calculate the transmitter 0% and 100% level for the dP at T_1 and P_1 conditions:

$$dP_{100\%\ lvl} = \rho_{L1}gH_L - (\rho_{f1}gH + \rho_{g1}g(H_L - H))$$
$$= gH_L(\rho_{L1} - \rho_{g1}) - gH(\rho_{f1} - \rho_{g1})$$

$$dP_{0\%\ lvl} = \rho_{L1}gH_L - \rho_{g1}gH_L$$
$$= gH_L(\rho_{L1} - \rho_{g1})$$

Calculate the transmitter dP at L% level for the dP at T_2 and P_2 conditions:

$$L\% = (L/H)\times 100\%\ lvl$$

$$\begin{aligned} dP_{L\%\,lvl} &= \rho_{L2}gH_L - (\rho_{f2}gL + \rho_{g2}g(H_L - L)) \\ &= \rho_{L2}gH_L - \rho_{f2}gL - \rho_{g2}gH_L + \rho_{g2}gL \\ &= gH_L(\rho_{L2} - \rho_{g2}) - gL(\rho_{f2} - \rho_{g2}) \end{aligned}$$

Calculate the indicated level at the known dP for L% level with respect to the calibrated transmitter dP:

$$\%\ IND\ LVL = \frac{dP_{L\%\,lvl} - dP_{0\%\,lvl}}{dP_{100\%\,lvl} - dP_{0\%\,lvl}}\times 100$$

$$= \left(\frac{[gH_L(\rho_{L2} - \rho_{g2}) - gL(\rho_{f2} - \rho_{g2})] - [gH_L(\rho_{L1} - \rho_{g1})]}{[gH_L(\rho_{L1} - \rho_{g1}) - gH(\rho_{f1} - \rho_{g1})] - [gH_L(\rho_{L1} - \rho_{g1})]}\right)\times 100$$

$$= \left(\frac{-H_L(\rho_{L1} - \rho_{L2} - \rho_{g1} + \rho_{g2}) - L(\rho_{f2} - \rho_{g2})}{-H(\rho_{f1} - \rho_{g1})}\right)\times 100$$

$$= \left(\frac{H_L}{H}\left(\frac{\rho_{L1} - \rho_{L2} - \rho_{g1} + \rho_{g2}}{\rho_{f1} - \rho_{g1}}\right) + \frac{L}{H}\left(\frac{\rho_{f2} - \rho_{g2}}{\rho_{f1} - \rho_{g1}}\right)\right)\times 100$$

The error fraction is:

$$E = \%IND\ LVL - \%ACT\ LVL$$

$$= \left(\frac{H_L}{H}\left(\frac{\rho_{L1} - \rho_{L2} - \rho_{g1} + \rho_{g2}}{\rho_{f1} - \rho_{g1}}\right) + \frac{L}{H}\left(\frac{\rho_{f2} - \rho_{g2}}{\rho_{f1} - \rho_{g1}}\right)\right)\times 100 - \left(\frac{L}{H}\right)\times 100$$

$$\frac{E}{100} = \frac{H_L}{H}\left(\frac{\rho_{L1} - \rho_{L2} - \rho_{g1} + \rho_{g2}}{\rho_{f1} - \rho_{g1}}\right) + \frac{L}{H}\left(\frac{\rho_{f2} - \rho_{g2}}{\rho_{f1} - \rho_{g1}} - 1\right)$$

4.0 REFERENCE LEG HEATUP

Changes in ambient temperature will effect the density of the fluid in the reference leg. The following equation may be used to calculate the error fraction for reference leg heatup.

These equations assume:

1) saturated conditions inside the vessel The occurrence of subcooling in the downcomer region of PWR steam generators, which becomes significant above 70% RTP is typically included in instrument loop accuracy calculations, but is calculated through other mechanisms.

2) an actual steam generator level There is no actual level in the steam generator while generating steam. A transition zone exists between the saturated fluid and saturated vapor. The following equations calculate the actual level L as the collapsed level.

3) steady state process conditions Transient effects, such as rapid depressurization, are not included and would require a much more complicated analysis.

4) thermal equilibrium The reference leg fluid temperature is considered to be in equilibrium with the environment.

Typical condensing pot installations are located close to the vessel. This results in the H_L/H term in the following equations being sufficiently close to 1 for this term to be ignored.

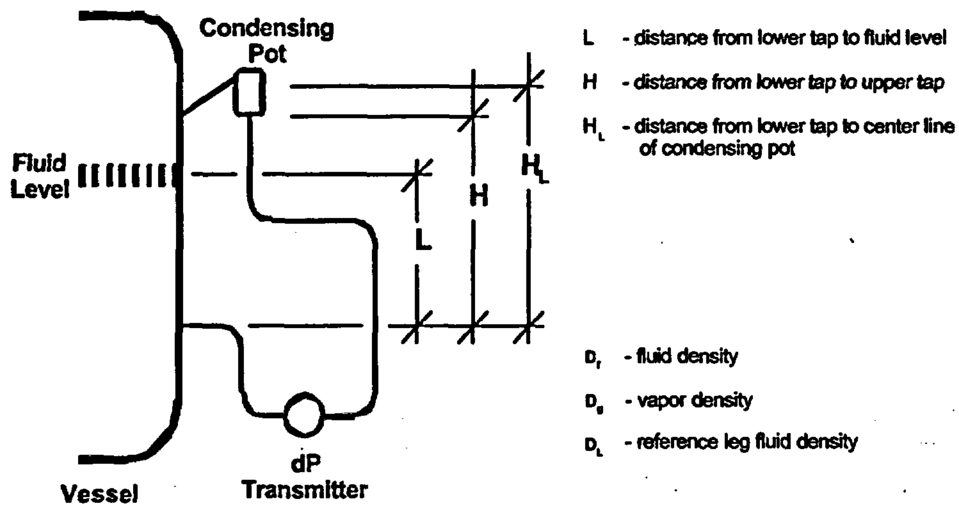
4.1 ERROR FRACTION

The error fraction for changes in reference leg temperature is:

E = % IND LVL - % ACT LVL

$$\frac{E}{100} = \frac{H_L}{H}\left(\frac{\rho_1 - \rho_2}{\rho_f - \rho_g}\right)$$

where: - all terms are defined in figure F2, and
- L, H and H_L are in consistent units of length (e.g. inches)



ρ_f, ρ_g - density of saturated liquid and vapor in the vessel

T_1 - environment and reference leg temperature at the calibrated condition

ρ_1 - density of liquid in the reference leg at calibration conditions

T_2 - environment and reference leg temperature at the new condition

ρ_2 - density of liquid in the reference leg at a new environmental temperature

Figure F2: Level Bias Error Due to Reference Leg Heatup

4.2 DERIVATION

Calculate the transmitter dP at 0%, 100% and L% level for the calibrated (T_1) conditions:

$$dP1_{100\%\,lvl} = \rho_1 gH_L - (\rho_f gH + \rho_g g(H_L - H))$$
$$= gH_L(\rho_1 - \rho_g) - gH(\rho_f - \rho_g)$$

$$dP1_{0\%\,lvl} = \rho_1 gH_L - \rho_g gH_L$$
$$= gH_L(\rho_1 - \rho_g)$$

Calculate the transmitter dP at 0% and 100% level for the T_2 conditions:

$$
\begin{aligned}
dP2_{100\%\ lvl} &= \rho_2 g H_L - (\rho_f g H + \rho_g g(H_L - H)) \\
&= gH_L(\rho_2 - \rho_g) - gH(\rho_f - \rho_g)
\end{aligned}
$$

$$
\begin{aligned}
dP2_{0\%\ lvl} &= \rho_2 g H_L - \rho_g g H_L \\
&= gH_L(\rho_2 - \rho_g)
\end{aligned}
$$

$$
\begin{aligned}
dP_L &= (L/100)(dP1_{100\%\ lvl} - dP1_{0\%\ lvl}) + dP1_{0\%\ lvl} \\
&= (L/100)(gH_L(\rho_1 - \rho_g) - gH(\rho_f - \rho_g) - gH_L(\rho_1 - \rho_g)) \\
&\quad + gH_L(\rho_1 - \rho_g) \\
&= gH_L(\rho_1 - \rho_g) - (LgH/100)(\rho_f - \rho_g)
\end{aligned}
$$

This derivation uses a different, but more realistic concept. Starting with the indicated level that we observe, the actual level is calculated by including the effect of changes in reference leg density. Since level vs. dP is a linear relationship, a ratio is used to determine the actual level. Figure F3 will help in visualizing the required ratio.

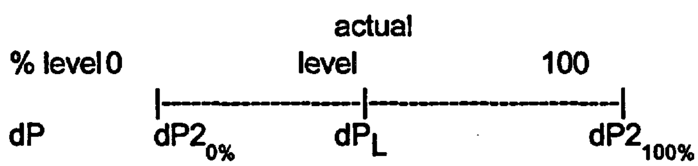


Figure F3, % Level vs. dP

$$\frac{ACT\ \ LVL - 0\%}{dP_L - dP2_{0\%}} = \frac{100\% - 0\%}{dP2_{100\%} - dP2_{0\%}}$$

$$ACT\ \ LVL = \frac{dP_L - dP2_{0\%}}{dP2_{100\%} - dP2_{0\%}} \times 100$$

The indicated level is equal to the calibrated dP, therefore:

$$dP_L = dP1_L$$

$$ACT\ LVL = \left(\frac{gH_L(\rho_1 - \rho_g) - \left(\frac{LgH}{100}\right)(\rho_f - \rho_g) - gH_L(\rho_2 - \rho_g)}{gH_L(\rho_2 - \rho_g) - gH(\rho_f - \rho_g) - gH_L(\rho_2 - \rho_g)} \right) \times 100$$

$$= \left(\frac{H_L(\rho_1 - \rho_g - \rho_2 + \rho_g) - \frac{LH}{100}(\rho_f - \rho_g)}{-H(\rho_f - \rho_g)} \right) \times 100$$

$$= \left(\frac{-H_L}{H}\left(\frac{\rho_1 - \rho_2}{\rho_f - \rho_g}\right) + \frac{L}{100} \right) \times 100$$

The error fraction is:

$$E = \%\ IND\ LVL - \%\ ACT\ LVL$$

$$= L - \left(\frac{-H_L}{H}\left(\frac{\rho_1 - \rho_2}{\rho_f - \rho_g}\right) + \frac{L}{100} \right) \times 100$$

$$= L + \left(\frac{H_L}{H}\left(\frac{\rho_1 - \rho_2}{\rho_f - \rho_g}\right) \right) \times 100 - L$$

$$\frac{E}{100} = \frac{H_L}{H}\left(\frac{\rho_1 - \rho_2}{\rho_f - \rho_g}\right)$$

5.0 SIMULTANEOUS EFFECTS OF REFERENCE LEG HEATUP AND PROCESS FLUID DENSITY CHANGES

When process changes and environmental changes interact, e.g. LOCA or steam breaks inside containment, or where a bounding error term is desired, the following equation can be used to calculate the error fraction.

These equations assume:

1) saturated conditions inside the vessel The occurrence of subcooling in the downcomer region of PWR steam generators, which becomes significant above 70% RTP is typically included in instrument loop accuracy calculations, but is calculated through other mechanisms.

2) an actual steam generator level There is no actual level in the steam generator while generating steam. A transition zone exists between the saturated fluid and saturated vapor. The following equations calculate the actual level L as the collapsed level.

3) steady state process conditions Transient effects, such as rapid depressurization, are not included and would require a much more complicated analysis.

4) thermal equilibrium The reference leg fluid temperature is considered to be in equilibrium with the environment.

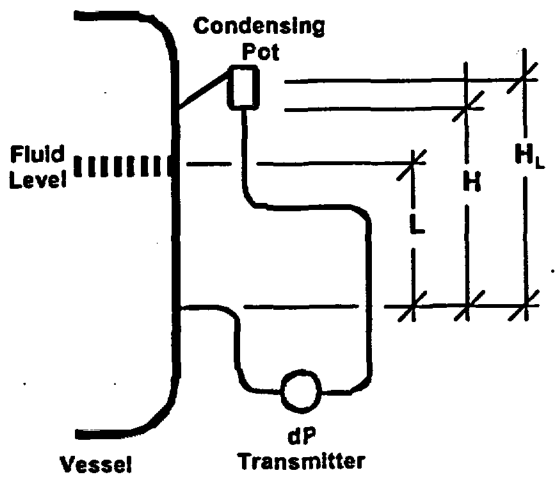
Typical condensing pot installations are located close to the vessel. This results in the H_L/H term in the following equations being sufficiently close to 1 for this term to be ignored.

5.1 ERROR FRACTION

$$E = \%\ \text{IND LVL} - \%\ \text{ACT LVL}$$

$$\frac{E}{100} = \frac{H_L}{H}\left(\frac{\rho_{L1} - \rho_{L2} - \rho_{g1} + \rho_{g2}}{\rho_{f1} - \rho_{g1}}\right) + \frac{L}{H}\left(\frac{\rho_{f2} - \rho_{g2}}{\rho_{f1} - \rho_{g1}} - 1\right)$$

where: - all terms are defined in figure F4, and
- L, H and H_L are in consistent units of length (e.g. inches)



T_1, P_1 - temperature and pressure inside the vessel at calibrated conditions
ρ_{f1}, ρ_{g1} - density of saturated liquid and steam at calibration conditions T_1 and P_1
T_2, P_2 - temperature and pressure inside the vessel at some new condition
ρ_{f2}, ρ_{g2} - density of saturated liquid and steam at the new conditions T_2 and P_2
$T_{REF\ LEG1}$ - temperature of environment and the liquid in the reference leg
ρ_{L1} - density of reference leg liquid at $T_{REF\ LEG1}$ and P_1 (compressed liquid)
$T_{REF\ LEG2}$ - temperature of environment and the liquid in the reference leg
ρ_{L2} - density of reference leg liquid at $T_{REF\ LEG2}$ and P_2 (compressed liquid)

Figure F4, Level Bias Error Due to Both Process Fluid Density Changes and Reference Leg Heatup

5.2 DERIVATION

Calculate the transmitter dP at 0% and 100% level for the calibrated conditions T_1, P_1 and $T_{REF\ LEG1}$:

$$dP1_{100\%\ lvl} = \rho_{L1} g H_L - (\rho_{f1} g H + \rho_{g1} g (H_L - H))$$
$$= g H_L (\rho_{L1} - \rho_{g1}) - g H (\rho_{f1} - \rho_{g1})$$

$$dP1_{0\%\ lvl} = \rho_{L1} g H_L - \rho_{g1} g H_L$$
$$= g H_L (\rho_{L1} - \rho_{g1})$$

Calculate the transmitter dP at L% level for the new conditions T_2, P_2 and $T_{REF\ LEG2}$:

$$
\begin{aligned}
dP2_{L\%\,lvl} &= \rho_{L2}gH_L - (\rho_{f2}gL + \rho_{g2}\,g(H_L - L)) \\
&= \rho_{L2}gH_L - \rho_{f2}gL - \rho_{g2}gH_L + \rho_{g2}gL \\
&= gH_L(\rho_{L2} - \rho_{g2}) - gL(\rho_{f2} - \rho_{g2})
\end{aligned}
$$

Calculate the indicated level (in % indicated level) for a dP = $dP2_{L\%\,lvl}$ at the calibrated conditions T_1, P_1, and $T_{REFLEG1}$.

$$\%\,INDLVL = \frac{dP_{L\%\,lvl} - dP_{0\%\,lvl}}{dP_{100\%\,lvl} - dP_{0\%\,lvl}} \times 100$$

$$= \frac{[gH_L(\rho_{L2} - \rho_{g2}) - gL(\rho_{f2} - \rho_{g2})] - [gH_L(\rho_{L1} - \rho_{g1})]}{[gH_L(\rho_{L1} - \rho_{g1}) - gH(\rho_{f1} - \rho_{g1})] - [gH_L(\rho_{L1} - \rho_{g1})]} \times 100$$

$$= \frac{H_L(\rho_{L2} - \rho_{g2} - \rho_{L1} + \rho_{g1}) - L(\rho_{f2} - \rho_{g2})}{-H(\rho_{f1} - \rho_{g1})} \times 100$$

$$= \left(\frac{H_L}{H}\left(\frac{\rho_{L1} - \rho_{L2} - \rho_{g1} + \rho_{g2}}{\rho_{f1} - \rho_{g1}}\right) + \frac{L}{H}\left(\frac{\rho_{f2} - \rho_{g2}}{\rho_{f1} - \rho_{g1}}\right)\right) \times 100$$

The error fraction is:

$$E = \%\,IND\ LVL - \%\,ACT\ LVL$$

$$= \left(\frac{H_L}{H}\left(\frac{\rho_{L1} - \rho_{L2} - \rho_{g1} + \rho_{g2}}{\rho_{f1} - \rho_{g1}}\right) + \frac{L}{H}\left(\frac{\rho_{f2} - \rho_{g2}}{\rho_{f1} - \rho_{g1}}\right)\right) \times 100 - \left(\frac{L}{H}\right) \times 100$$

$$\frac{E}{100} = \frac{H_L}{H}\left(\frac{\rho_{L1} - \rho_{L2} - \rho_{g1} + \rho_{g2}}{\rho_{f1} - \rho_{g1}}\right) + \frac{L}{H}\left(\frac{\rho_{f2} - \rho_{g2}}{\rho_{f1} - \rho_{g1}} - 1\right)$$

6.0 REFERENCE LEG BOILING

In addition to process and reference leg density changes, boiling could conceivable occur in the reference leg due to rapid depressurization. Boiling or other gases coming out of solution in the reference leg would result in a large level error for a short period of time.

For PWR plants, both pressurizer level and steam generator level could be effected by reference leg boiling. Analysis of chapter 15 events and containment analysis for ComEd PWR stations indicate that no reference leg boiling is expected that would effect a protection setpoint. For pressurizer level setpoints, the RCS pressure is not expected to decrease below 1400 psig during a transient which prevents reference leg boiling. The accidents that rely on steam generator low level setpoints are not expected to experience depressurization at a rate that would result in reference leg boiling.

NOTE: transients that could result in hydrogen coming out of solution in the pressurizer reference leg are not currently addressed in the setpoint analyses.

For BWR plants, the possibility of reference leg boiling and reactor vessel level errors due to dissolved gasses coming out of solution has been addressed. The RVLIS/Backfill modifications have been installed in accordance with Generic Letter 92-04, Resolution of the Issues Related to Reactor Vessel Water Level Instrumentation in BWRs Pursuant to 10CFR50.54(f). Setpoint accuracy calculations and reactor vessel level scaling calculations incorporate the effects of this modification on the associated reactor protection setpoints.

7.0 REFERENCES

7.1 CAE-92-189/CCE-92-201/CWE-92-214, Commonwealth Edison Company, Zion/Byron/Braidwood Stations, S/G Water Level PMA Term Inaccuracies, dated 6/18/92

7.2 CWE-79-26, Commonwealth Edison Company, Zion Station, NRC IE Bulletin 79-21, dated 8/29/79

7.3 NRC IE Bulletin 79-21, Temperature Effects on Level Measurements

7.4 "Delta-P Level Measurement Systems", Lang, Glenn E. And Cunnigham, James P., Instrumentation, Controls and Automation in the Power Industry, vol. 34, Proceeding of the 34th Power Instrument Symposium, June 1991

7.5 Generic Letter 92-04, Resolution of the Issues Related to Reactor Vessel Water Level Instrumentation in BWRs Pursuant to 10CFR50.54(f)

APPENDIX G

DELTA-P MEASUREMENTS EXPRESSED IN FLOW UNITS

1.0 INTRODUCTION

Propagation of errors and uncertainties through a non-linear device results in output errors and uncertainties that are a function of the input value. In the case of the typical flow vs. dP relationship, an approximation can be derived for the square root/square function. This appendix provides an equation that can be used to convert between errors in % dP and errors in % full scale.

Orifices, nozzles and venturies are typically provided with their flow uncertainty expressed as a % of full scale dP. This uncertainty is the same anywhere within the measured span. As an example, an orifice that has a full span of 100 in.WC and is specified to be accurate to ±1% full span, will have an uncertainty of ±1 inch of water anywhere in the measured span. Since dP is a function of flow squared, this cannot be said for errors expressed in terms of flow, % flow or % flow span. The flow error will depend on the corresponding value of flow.

2.0 DERIVATION

Since dP is proportional to flow squared:

$$(F_N)^2 = dP_N \qquad \text{(Eq. G1)}$$

where N = Nominal Flow

Taking the partial derivative and solving for ∂F_N:

$$2F_N \partial F_N = \partial dP_N$$
$$\partial F_N = (\partial dP_N)/(2F_N) \qquad \text{(Eq. G2)}$$

Similarly, the error at a point (not in %) is:

$$\frac{\partial F_N}{F_N} = \frac{\partial dP_N}{2(F_N)^2} = \frac{\partial dP_N}{2dP_N}$$

and from equation G1:

$$\frac{dP_N}{dP_{MAX}} = \frac{(F_N)^2}{(F_{MAX})^2} \qquad \text{(Eq. G3)}$$

where: MAX = maximum flow

The transmitter dP error is defined by:

$$\frac{\partial dP_N}{dP_{MAX}} = \%\text{ error in full scale dP } (\%\text{ FS dP}) \qquad \text{(Eq. G4)}$$

Therefore:

$$\frac{\partial F_N}{F_N} = \frac{\partial dP_N}{2dP_N} = \frac{dP_{MAX}\left(\frac{\%FS\ dP}{100}\right)}{2dP_{MAX}\left(\frac{F_N}{F_{MAX}}\right)^2}$$

$$= \frac{\%FS\ dP\left(\frac{F_{MAX}}{F_N}\right)^2}{(2)(100)} \qquad \text{(Eq. G5)}$$

The error in flow units is obtained by solving for ∂F_N:

$$\partial F_N = \frac{F_N(\%FS\ dP)\left(\frac{F_{MAX}}{F_N}\right)^2}{(2)(100)} \qquad \text{(Eq. G6)}$$

This can be rearranged to represent the error in % nominal flow:

$$\left(\frac{\partial F_N}{F_N}\right) \times 100 = \left(\frac{\%FS\ dP}{2}\right)\left(\frac{F_{MAX}}{F_N}\right)^2 \qquad \text{(Eq. G7)}$$

From equation G7, the error in % full span can be derived:

$$\left(\frac{\partial F_N}{F_{MAX}}\right) \times 100 = \frac{\left(F_N(\%FS\ dP)\left(\frac{F_{MAX}}{F_N}\right)^2\right) \times 100}{(F_{MAX})(2)(100)}$$

$$= \left(\frac{\%FS\ dP}{2}\right)\left(\frac{F_{MAX}}{F_N}\right) \qquad \text{(Eq. G8)}$$

Replacing equation G8 with variables equivalent to those typically used in accuracy analysis:

$$\text{Flow Error in \% Full Scale Flow} = \left(\frac{\text{dP Error in \% Full Scale dP}}{2}\right)\left(\frac{F_{MAX}}{F_N}\right)$$

(Eq. G9)

NOTE: full scale is equivalent to full span

Error in % nominal flow at any flow level can be obtained in the same manner from equation G7.

$$\text{Flow Error in \% Nominal Flow} = \left(\frac{\text{dP Error in \% Full Scale dP}}{2}\right)\left(\frac{F_{MAX}}{F_N}\right)^2$$

(Eq. G10)

3.0 APPLICABILITY

Equations G9 and G10 are used to convert between flow error and dP error. These equations are an approximation and assume that any sufficiently small portion of a curve can be replaced with a straight line. These equations show that the slope of a line segment at any point on a square root curve is: $F_{MAX} / 2F_N$. For a square root curve, this approximation provides a conservative estimate of error. Equation 9 is particularly useful when calculating instrument loop accuracy where all errors are converted to % of "full" span for consistency.

Caution should be used when using equations G9 and G10 to determine flow channel setpoints. It is important to differentiate between "full flow" and "full span". For example, full span is typically 110% to 120% of full flow to ensure that the transmitter output signal is not limited at full flow. Equation G9 is used when 100% span error is desired and the error term is to be expressed in % full span. Equation G10 is used when the equivalent error at any other flow value, e.g. 100% flow, is desired.

4.0 EXAMPLES

4.1 EXAMPLE 1: Full Flow vs. Full Span Error

The following flow loop parameters are assumed for this example.

Full Scale Flow	=	20% flow
Nominal flow	=	100% flow
dP span	=	0-500 in. WC
Error	=	±1% span
Transmitter scaling:		0-500 in WC is equivalent to 4-20 mA

NOTE: typical orifice and nozzle span errors are provided as an error in dP span which is constant over the entire dP span.

4.1.1 Find the error in % flow at 100% flow

From section 4.1:

$F_{MAX} = 120\%$
$F_N = 100\%$
error in % full scale dP = 1% dP span

Use equation G10 for nominal flow error determination.

$$\text{Error}_{\%\ \text{Nominal Flow}} = \left(\frac{\text{dP Error in \% Full Scale dP}}{2}\right)\left(\frac{F_{MAX}}{F_N}\right)^2$$

$$= \left(\frac{1\%}{2}\right)\left(\frac{120}{100}\right)^2$$

$$= \pm 0.72\% \text{ flow at } 100\% \text{ flow}$$

4.1.2 Find the error at full span (120% flow).

$F_{MAX} = 120\%$
$F_N = 100\%$
error in % full scale dP = ±1% dP span

Use equation G9 for full span error determination.

$$\text{Error}_{\%\ \text{Full Scale Flow}} = \left(\frac{\text{dP Error in \% Full Scale dP}}{2}\right)\left(\frac{F_{MAX}}{F_N}\right)$$

$$= \left(\frac{1\%}{2}\right)\left(\frac{120}{100}\right)$$

$$= \pm 0.6\% \text{ flow span}$$

4.2 EXAMPLE 2: Calculation of flow error using dP

The following flow loop parameters are assumed for this example.

Full span	=	120% flow
Nominal flow	=	100% flow
dP span	=	0-500 in. WC
Error	=	±1% span
Transmitter scaling:		0-500 in WC is equivalent to 4-20 mA

NOTE: typical orifice and nozzle span errors are provided as an error in dP span which is constant over the entire dP span.

4.2.1 Find the error in % flow at 100% flow

$$\text{Flow}^2 \propto \text{dP}$$

$$\frac{(\text{Flow}_{MAX}\%)^2}{\text{dP}_{MAX}} = \frac{(\text{Flow}_N\%)^2}{\text{dP}_N}$$

$$\frac{(120\%)^2}{500\,\text{in. WC}} = \frac{(100\%)^2}{\text{dP}_N}$$

$$\text{dP}_N = 347.22 \text{ in. WC}$$

The dP error is 1% of 500 in. WC = ±5 in. WC. Therefore, at full flow (equivalent to nominal or 100% flow) the dP should be 347.22±5 in. WC. Calculating the flow error:

Hi flow:

$$\frac{(\text{Flow}_{MAX}\%)^2}{\text{dP}_{MAX}} = \frac{(\text{Flow}_N\%)^2}{\text{dP}_N \pm 5\,\text{in. WC}}$$

$$\frac{(120\%)^2}{500\text{ in. WC}} = \frac{(\text{Flow}_N\%)^2}{352.22\text{ in. WC}}$$

$$\text{Flow}_{N+} = 100.72\ \%\ \text{flow}$$

Low flow:

$$\frac{(120\%)^2}{500\text{ in. WC}} = \frac{(\text{Flow}_N\%)^2}{342.22\text{ in. WC}}$$

$$\text{Flow}_{N-} = 99.28\ \%\ \text{flow}$$

Therefore the flow error is ±0.72% flow at full flow. This is consistent (to 2 decimal places) with the error calculated using the approximation formula in step 4.1.1.

4.2.2 Find the error in % full span at 100% flow

When using % full span to combine errors, the error at 100% flow must also be expressed in terms of % full span.

Full flow = (100% flow)(100% span / 120% flow)
= 83.33% of full span

From 4.2.1, the flow error is ±0.72% flow at full flow, which is equivalent to 100±0.72% flow. Converting this to % of span:

(100 + 0.72)(100% span / 120% flow) = 83.93% full span

(100 - 0.72)(100% span / 120% flow) = 82.73% full span

The deviation from full flow as a % of span is: 83.93% span - 83.33% span = 0.6% span and 83.33% span - 82.73% span = 0.6% span. Therefore, the nominal or 100% flow in terms of % full span is equivalent to 83.33±0.6% full span, which is consistent with step 4.1.2.

4.3 FLOW ERROR AT LOW FLOWS

As shown in step 4.2, the approximation and the actual flow errors are expected to be relatively close when the nominal flow is close to full flow. Since errors as a % of span increase as flow decreases, the approximation becomes increasingly conservative at lower flows. Therefore, at low flows or when the exact flow error is desired, the dP method should be used to calculate flow error.

4.4 EXAMPLE 3: Error at Low flows

The flow error associated with a low flow trip at 30% flow is required. Using the same values in steps 4.1 and 4.2:

Approximation:

$$\text{Error}_{\%\ \text{Nominal Flow}} = \left(\frac{\text{dP Error in \% Full Scale dP}}{2}\right)\left(\frac{F_{MAX}}{F_N}\right)^2$$

$$= \left(\frac{1\%}{2}\right)\left(\frac{120}{30}\right)^2$$

$$= \pm 8.0\% \text{ flow at } 30\% \text{ flow}$$

$$\text{Error}_{\%\ \text{Full Scale Flow}} = \left(\frac{\text{dP Error in \% Full Scale dP}}{2}\right)\left(\frac{F_{MAX}}{F_N}\right)$$

$$= \left(\frac{1\%}{2}\right)\left(\frac{120}{30}\right)$$

$$= \pm 2.0\% \text{ flow span}$$

Actual error:

$$\text{Flow}^2 \propto \text{dP}$$

$$\frac{(\text{Flow}_{MAX}\%)^2}{\text{dP}_{MAX}} = \frac{(\text{Flow}_N\%)^2}{\text{dP}_N}$$

$$\frac{(120\%)^2}{500 \text{ in. WC}} = \frac{(30\%)^2}{\text{dP}_N}$$

$$\text{dP}_N = 31.25 \text{ in. WC}$$

Using a 1% span error = ±5 in. WC:

$$\frac{(\text{Flow}_{MAX}\%)^2}{\text{dP}_{MAX}} = \frac{(\text{Flow}_N\%)^2}{\text{dP}_N}$$

Hi flow: $$\frac{(120\%)^2}{500 \text{ in. WC}} = \frac{(\text{Flow}_N\%)^2}{36.25 \text{ in. WC}}$$

$$\text{Flow}_{N+} = 32.31 \text{ \% flow}$$

Low flow: $$\frac{(120\%)^2}{500 \text{ in. WC}} = \frac{(Flow_N \%)^2}{26.25 \text{ in. WC}}$$

$$Flow_{N^-} = 27.50 \text{ \%. flow}$$

For a low flow trip setpoint, we use the error in the conservative, decreasing direction. Therefore 30.0% flow – 27.50% flow = 2.5% flow. This is considered a random error or ±2.50% flow when used in a loop accuracy calculation.

NOTE: when considering accuracy requirements, it is good engineering practice to ensure flow setpoints are never less than 25% span.

In example 3, the 30% flow setpoint is equivalent to 25% flow span. The equivalent error in % span is:

(30 + 2.50)(100% span / 120% flow) = 27.08% flow span

(30 – 2.50)(100% span / 120% flow) = 22.92% flow span

The conservative error for a decreasing setpoint is:

25% span – 22.92% span = ±2.08% flow span.

Step 4.4 shows that when errors are calculated as a "% of flow span", the approximate and actual error (±2.0% flow span vs. ±2.08% flow span) are relatively close even at the minimum recommended flow setpoint. The flow error as a "% flow" indicates that the approximation is conservative (±8% flow vs. ±2.5% flow). Care should be taken to ensure that the method chosen to determine flow error is sufficiently conservative with respect to the function of the flow setpoint.

CAUTION: When it is necessary to evaluate performance in terms of % flow (or gpm or mpph, etc), as in Technical Specification acceptance criteria or ISI test criteria, the use of the approximation method to calculate flow error may be excessively conservative with respect to the real accuracy of the measurement. Using the approximation to calculate flow error could result in overly conservative performance or test requirement. The result being a component, e.g. a pump, considered inoperable due to conservative acceptance criteria rather than excessively degraded performance.

APPENDIX H

CALCULATION OF EQUIVALENT POINTS ON NON-LINEAR SCALES

1.0 INTRODUCTION

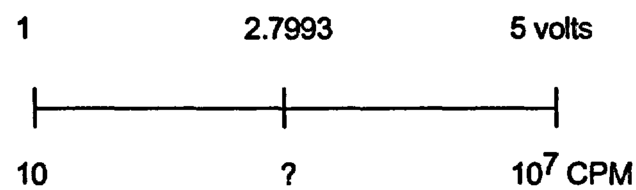
Conversion of linear information to equivalent non-linear data points can be performed using ratios. This technique can be used for all non-linear continuous functions; e.g. square root, logarithmic, etc.

For logarithmic scales, those of you who remember slide rules will quickly recognize the technique of ratioing distances. This method can be easily extended to any two scales that are equivalent. Typical instrument setpoint accuracy and instrument scaling examples include: mA to GPM, volts to source range counts, mA to DPM (decades per minute), etc. Equivalent scales are any two ranges that have a 1:1 analog relationship.

2.0 SCALE CONVERSION

The following discussion uses a logarithmic indicator scale as an example. The indicator has a 1 to 5 volt input and a 10 to 10^7 CPM scale.

First, the equivalent ranges are 1 to 5 volts and 10 to 10^7 CPM. The graphical representation below can often aid in visualizing this concept.



Next, determine the equivalent CPM to 2.7993 volts using the technique of ratios. From the above graphic, it is obvious the distances represented on the linear and logarithmic scales are identical. Most of us are familiar with analog ratios, where the ratio (2.7993 to 1)/ (5 to 1) will give us the voltage ratio. For the logarithmic ratio, one must recognize that the equivalent distances are logarithms. We use this fact to write an equation for the unknown CPM:

$$\left(\frac{2.7993 \text{ volts} - 1 \text{ volt}}{5 \text{ volts} - 1 \text{ volt}}\right) = \left(\frac{\log x - \log 10}{\log 10^7 - \log 10}\right)$$

$$\left(\frac{1.7993 \text{ volts}}{4 \text{ volts}}\right) = \left(\frac{\log x - 1}{7 - 1}\right)$$

$$\log x = 3.69895$$

$$x = 4999.77 \approx 5000 \text{ CPM}$$

An alternate method to solve for log x:

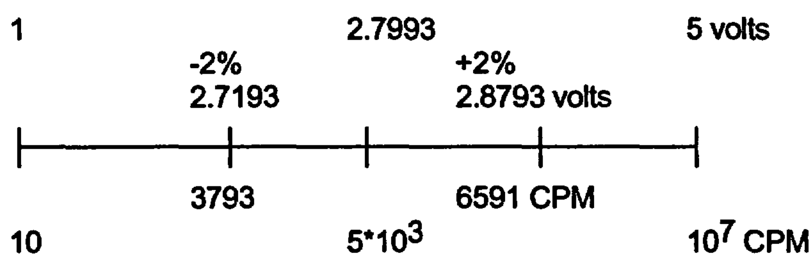
$$\log x = 3.69895$$
$$x = 10^{3.69895} = 10^{0.69895} \times 10^{3}$$
$$= 4.998 \times 10^{3} \approx 5000 \text{ CPM}$$

For this discussion, assume that the linear uncertainty is 2% of span. This is equivalent to:

2.7993 volts ± (2%(5 volts - 1 volt)) = 2.7993 ± 0.08 volts

Using the ratioing technique, it becomes a simple matter to find the equivalent CPM values for 2.8793 volts and 2.7919 volts. The ±2% tolerance equations are provided below, followed by the completed graphic.

$$\left(\frac{2.7993 \text{ volts} - 0.8 \text{ volts}}{5 \text{ volts} - 1 \text{ volt}}\right) = \left(\frac{\log x - \log 10}{\log 10^{7} - \log 10}\right)$$
$$\left(\frac{1.8793 \text{ volts}}{4 \text{ volts}}\right) = \left(\frac{\log x - 1}{7 - 1}\right)$$
$$\log x = 3.81895$$
$$x = 6590.98 \approx 6591 \text{ CPM}$$



Thus, for a linear input of 1 to 5 volts with an error of ±2% of span, the equivalent uncertainty range at 5000 CPM is 3793 to 6591 CPM. As with all non-linear relationships, it is important to note that the uncertainty range is dependent on the point on the non-linear scale around which the uncertainty is calculated. In other words the +1591, -1207 CPM uncertainty range is only valid at 5000 CPM.

3.0 EXAMPLES

The following examples demonstrate some of the typical problems that can quickly be solved using this technique. A graphical representation is used to visualize the problem. One advantage of quickly sketching the problem is that incorrect relationships can be easily identified.

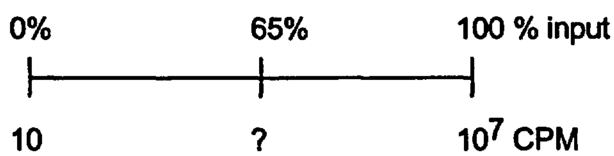
3.1 EXAMPLE 1

For an input range of 1 to 5 volts (0 to 100% span) and an output range of 10 to 10^7 CPM, find the setpoint in CPM at 65% input span. NOTE: Since 0 to 100% span is linear, there is no need to convert anything to volts.

$$\left(\frac{65\% - 0\%}{100\% - 0\%}\right) = \left(\frac{\log x - \log 10}{\log 10^7 - \log 10}\right)$$

$$(0.65(7-1)) + 1 = \log x$$

$$x = 79{,}432 \approx 7.9 \times 10^4 \text{ CPM}$$

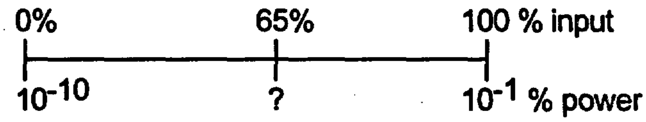


3.2 EXAMPLE 2

For an input range of 1 to 5 volts (0 - 100% span) and an output range of 10^{-10} to 10^{-1} % power, find the setpoint (in percent power) at 3.6 volts. This example is typical of nuclear instrumentation where the source and intermediate range need to be displayed in percent power.

First, calculate % power, so that we don't have to do any conversion in our ratio equation.

$$\left(\frac{3.6 - 1 \text{ volt}}{5 - 1 \text{ volt}}\right) \times 100\% \text{ span} \times \left(\frac{100\% \text{ power}}{100\% \text{ span}}\right) = 65\% \text{ power}$$



$$\left(\frac{65\% - 0\%}{100\% - 0\%}\right) = \left(\frac{\log x - \log 10^{-10}}{\log 10^{-1} - \log 10^{-10}}\right)$$

$$0.65 = \left(\frac{\log x + 10}{-1 + 10}\right)$$

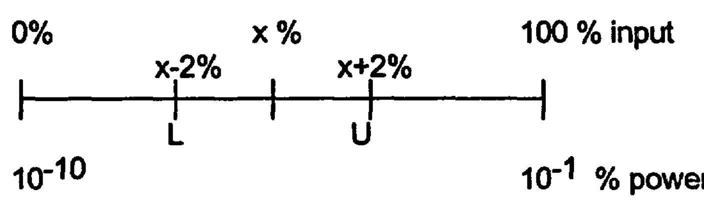
$$\log x = -4.15$$

$$x = 10^{-4.15} = 10^{0.85} \times 10^{-5}$$

$$= 7.08 \times 10^{-5}\% \text{ power}$$

3.3 EXAMPLE 3

Using the ranges in Example 2, find the ±2% of span tolerance for a setpoint of 7×10^{-5} % power, where 2% of span represents the input error. NOTE: Once again there is no need to convert to other input units.



First find the equivalent setpoint:

$$\left(\frac{\log(7 \times 10^{-5}) - \log 10^{-10}}{\log 10^{-1} - \log 10^{-10}}\right) = \left(\frac{x - 0\%}{100\% - 0\%}\right)$$

$$\left(\frac{-4.154902 + 10}{-1 + 10}\right) = \left(\frac{x - 0\%}{100\% - 0\%}\right)$$

$$x = 64.94553\% \text{ input span}$$

Use the following ratio to solve for the upper limit (U).

$$\left(\frac{(64.94553+2)-0\%}{100\%-0\%}\right)=\left(\frac{\log U-\log 10^{-10}}{\log 10^{-1}-\log 10^{-10}}\right)$$

$$0.6694533=\left(\frac{\log U+10}{9}\right)$$

$$U=10^{-3.974902}=1.06\times10^{-4}\%\ \text{power}$$

Solve for the lower limit (L).

$$U=10^{-3.974902}=1.06\times10^{-4}\%\ \text{power}$$

As expected, non-linear scales result in non-symmetrical upper and lower values for an equivalent symmetrical input error. When evaluating the accuracy of a single point (e.g. bistable setpoint or EOP required actuation point), you can use the limit associated with the direction of the process change. Thus an increasing setpoint would use U and a decreasing setpoint would use L for calculating accuracy.

When calculating accuracy for a point on an indicator scale, the accuracy values are used in 2 different ways. When calibrating the indicator the calibration limits can use the specific L and U values for each cardinal point. When providing accuracy values to a plant operator or other individual that is using the indicator to monitor a plant process condition, it is usually inconvenient to list asymmetric limits. In this case it is conservative to describe accuracy as ±U or ±L, whichever is larger.

In order to use the ratio technique for other non-linear functions, compare (ratio) the equivalent scalar distances of each range. Thus with square root/square relationships, such as flow (GPM, CFM, etc.) or percent of flow, the ratio is obtained by taking the square root or square of the corresponding linear value.

APPENDIX I

NEGLIGIBLE UNCERTAINTIES

1.0 INTRODUCTION

The errors and uncertainties listed in this appendix have historically been found to be negligible under normal operating conditions. If the individual preparing an instrument loop accuracy calculation determines that the specific conditions apply, then these errors and uncertainties do not have to be evaluated in the calculation.

2.0 NEGLIGIBLE UNCERTAINTIES

2.1 Radiation Effects

The effects of normal radiation are small and accounted for in the periodic calibration process. Outside of containment there is not a creditable increase in radiation during normal operation. The uncertainty introduced by radiation effects on components is considered to be negligible.

If an as-found/as-left analysis has been performed based on historical calibration data, then normal radiation effects are considered to be included in the drift analysis results.

2.2 Humidity Effects

The uncertainty introduced by humidity effects during normal conditions is not typically addressed in vendor literature. Therefore humidity effects are considered to be negligible unless the manufacturer specifically mentions humidity effects in the applicable technical manual. The effects of changes in humidity on the components is considered to be calibrated out on a periodic basis. A condensing environment is regarded as an abnormal event which will require maintenance to the equipment. Humidities below 10% are expected to occur very infrequently and are not considered.

If an as-found/as-left analysis has been performed based on historical calibration data, the humidity effect is assumed to be included in the drift analysis results.

2.3 Power Supply Effects

It is expected that regulated instrument power supplies have been designed to function within manufacturer's required voltage limits. The variations of voltage and frequency are expected to be small and the power supply voltage and frequency uncertainties are considered to be negligible with respect to other error terms.

If an as-found/as-left analysis has been performed based on historical calibration data, the power supply voltage and frequency effects are assumed to be included in the drift analysis results.

2.4 Calibration Standard Error (STD)

The calibration standards used by the station to maintain and calibrate station M&TE are expected to be maintained to manufacturer's specifications. These calibration standards are more accurate than the station M&TE by a ratio greater than 4:1. Therefore, the effects of the calibration standard error are considered to be negligible with respect to other error terms.

2.5 Seismic/Vibration Effects

The impact of Seismic Effects in the setpoint calculation should be consistent with the Licensing Design Basis of the specific station (e.g. assuming a design Seismic Event coincident with a Design Basis Accident).

For normal errors, seismic events less than or equal to an OBE are considered to cause no permanent shift in the input/output relationship of the device. For seismic events greater than an OBE, it should be verified that the affected instrumentation is recalibrated prior to any subsequent accident to negate any permanent shift which may be resulted from a post seismic shift.

Unlike Seismic effects, Vibration effects may not always be calibrated out or included in the statistical drift. Consideration must be made of the "normal operating" versus "calibration" conditions. If the relative vibration conditions of these two states is not the same, then the vibration effect must be considered. This effect is not calibrated out or included in the historical calibrations data.

If an as-found/as-left analysis has been performed based on historical calibration data, the vibration effect is considered to be included in the drift analysis results, if the normal operation conditions and the calibration conditions are similar.

2.6 Lead Wire Effects

Since the resistance of a wire is equal to the resistivity times the length divided by the cross sectional area, the very small differences in the length of wires between components does not contribute any significant resistance differences between wires. Therefore, the effect of lead wire resistance differences is considered negligible, except for RTDs and thermocouples.

If a system design requires that lead wire effects be considered as a component of uncertainty, that requirement must be included in the design basis. It is assumed that the general design standard is to eliminate lead wire effects as a concern in both equipment design and installation. Failure to do so is a design fault that should be corrected.

The lead wire effects for RTDs and thermocouples must be considered separately and must be evaluated for each specific application.

3.0 NEGLIGIBLE UNCERTAINTIES FOR RELAYS, TIMERS, LIMIT AND MECHANICAL DISPLACER-TYPE SWITCHES

3.1 Relays and Timers

Table I1, Negligible Errors and Uncertainties for Relays and Timers

Error Type	Symbol	Justification
Process Errors	PE	These particular devices are not in direct contact with the process and are not subject to these types of errors or uncertainties.
Density Error		
Process Error		
Flow Element Error		
Temperature Error	eT	
Thermal Expansion Error		
Configuration or Installation Error		
Operational Errors		
Drift Error	D	Unless specifically prescribed by the Vendor, drift is assumed to be accounted for in the published Reference Accuracy for the device.
Static Pressure Error	eSP	These particular devices are not in direct contact with the process and are not subject to these types of errors or uncertainties.
Pressure Error	eP	There are no Pressure Errors associated with the function of these devices as the ambient pressure at the device location remains constant at normal atmospheric pressure.
Power Supply Error	eV	There are no Power Supply Errors associated with the function of these particular devices.
Environmental Errors		Unless specifically prescribed by the Vendor, environmental errors are assumed to be accounted for in the published Reference Accuracy for the device. Additionally, as these types of devices are typically installed in controlled environments and expected to perform their functions under normal operating conditions, the effects of these errors is considered negligible.
Temperature Error	eT	
Humidity Error	eH	
Seismic Error	eS	
Radiation Error	eR	
Other Errors		
Insulation Resistance	eIR	There are no Insulation Resistance Errors associated with the function of these particular devices
Random Input Errors		These devices function as separate modules and have no random input errors.

3.2 Limit Switches

Table I2, Negligible Errors and Uncertainties for Limit Switches		
Error Type	**Symbol**	**Justification**
Process Errors	PE	These particular devices are not in direct contact with the process and are not subject to these types of errors or uncertainties.
Density Error		
Process Error		
Flow Element Error		
Temperature Error	eT	
Thermal Expansion Error		
Configuration or Installation Error		
Operational Errors		
Drift Error	D	Unless specifically prescribed by the Vendor, drift is not applicable for these type of devices.
Static Pressure Error	eSP	These particular devices are not in direct contact with the process and are not subject to these types of errors or uncertainties.
Pressure Error	eP	There are no Pressure Errors associated with the function of these devices as the ambient pressure at the device location remains constant at normal atmospheric pressure.
Power Supply Error	eV	There are no Power Supply Errors associated with the function of these particular devices.
Environmental Errors		Unless specifically prescribed by the Vendor, environmental errors are assumed to be accounted for in the published Reference Accuracy for the device.
Temperature Error	eT	
Humidity Error	eH	
Seismic Error	eS	
Radiation Error	eR	
Other Errors		
Insulation Resistance	eIR	There are no Insulation Resistance Errors associated with the function of these particular devices
Random Input Errors		These devices function as separate modules and have no random input errors.

3.3 Mechanical Displacer-Type Switches (Float Switches)

Table I3, Negligible Errors and Uncertainties for Mechanical Displacer-Type Switches		
Error Type	**Symbol**	**Justification**
Operational Errors		
Drift Error	D	Unless specifically prescribed by the Vendor, drift is not applicable for these type of devices.
Pressure Error	eP	There are no Pressure Errors associated with the function of these devices as the ambient pressure at the device location remains constant at normal atmospheric pressure.
Power Supply Error	eV	There are no Power Supply Errors associated with the function of these particular devices.
Environmental Errors		Unless specifically prescribed by the Vendor, environmental errors are assumed to be accounted for in the published Reference Accuracy for the device.
Temperature Error	eT	
Humidity Error	eH	
Seismic Error	eS	
Radiation Error	eR	
Other Errors		
Insulation Resistance	eIR	There are no Insulation Resistance Errors associated with the function of these particular devices
Random Input Errors		These devices function as separate modules and have no random input errors.

APPENDIX J

GUIDELINE FOR THE ANALYSIS AND USE OF AS-FOUND/AS-LEFT DATA

1.0 INTRODUCTION

The analysis of the data from calibration of installed instrumentation can provide the station with several pieces of information that will allow for better prediction of instrument behavior and will provide more "accurate" data for computation of loop uncertainties.

This attachment defines a process that will be used at ComEd to ensure consistency and compliance with regulatory position GL-91-04. This process will specifies certain requirements, but does not provide a step-by-step methodology. Each site should develop specific methodologies, utilizing these guidelines to support their specific needs.

There are several approaches to the analysis of data and it's subsequent use. ComEd has adopted a general methodology similar to that presented in EPRI TR-103335, *Guidelines for Instrument Calibration Extension/Reduction Programs, Revision 1.* Refer to this document for a complete understanding of the guidelines developed in this Appendix.

This Appendix is divided into the following sections:

Each of these sections contains a general discussion of the expected actions that will conform to TR-103335 and the guidelines to be followed for analysis at ComEd sites.

2.0 ANALYSIS METHODOLOGY

2.1 DATA COLLECTION AND POOLING

2.1.1 To evaluate the performance of an instrument or group of instruments the data that is collected should consist of a sufficient number of independent samples to allow for statistical analysis of the data that could indicate drift changes. The sample should also represent a good distribution of the instruments used. In most cases, this will be the whole population. For instruments that are used extensively in the plant, a sample can be used. When collecting data, the application of each instrument must be identified to avoid application specific errors that will cause pooling of data to be an incorrect decision. Because the evaluation includes the important element of time dependency determination, the data collected should have data

from different calibration intervals. The evaluation must include all of the times that the instrument has been calibrated, or checked for accuracy (i.e. surveillance testing without adjustment).

2.1.2 Selection of the Instruments to be Evaluated (Pooled) for a Given Drift Study

2.1.2.1. All instruments evaluated shall be from the same manufacturer and shall perform in an identical manner for the critical parameters that are to be analyzed. Determining which instruments meet this criterion is eschewed by the fact that many manufacturers' have different model numbers based on mounting, enclosure, etc. The differences typically have no effect on the method that the instrument uses to monitor the parameter of concern. In addition, the range of the instrument may vary without having any significant change in the measurement method. If multiple model numbers are used, the evaluations must include a discussion of the reason why the instruments are assumed identical, specifically in the critical areas of concern.

2.1.2.2. ComEd has specified that the minimum targeted number of valid data points that are required to make a drift study statistically significant shall be 30 data points. The sample value of 30 is generally accepted as a minimum valid sample size. An analysis using less than this number can be performed if justification is provided in the study results. To allow for the potential of an outlier, this number should be > 30 data points. If there are more than approximately 150 data points, there is no significant improvement in the statistical rigor of the analysis.

2.1.2.3. In order to obtain the necessary number of data points required to ensure that there is variance in the calibration interval for the make/model of concern, the calibration data from multiple instruments will be needed. The following criteria for the selection of which instruments and calibration data points shall be used:

a. All instruments that are directly associated with RPS/ESF/ECCS automatic trips and actuations shall include at least one channel's instruments.

b. To ensure that there is a historical perspective to the data evaluated, at least four calibration intervals of data shall be collected. The four intervals provide for historical data while ensuring that the more recent calibration data is used to detect current problems. If the instrument has not been installed for that period, then the available data will be used. There may be some problems in the evaluation of the instrument over a given calibration interval.

c. If more than 150 data points can be developed for a given analysis, then a sample of instruments can be used instead of the whole population. The selection of which instruments to include will be done on a random basis, provided Section 2.1.2.3.a

requirements are maintained. The method of selection will be prepared and included in the calculation.

2.1.3 Data Collection is the transfer of data from the calibration records to the final analysis tool. This very sensitive process will require independent verification and validation of data transferred.

2.1.3.1 A search of all preventive and corrective maintenance records shall be conducted on each instrument selected for inclusion in the study. This search shall identify every calibration and every corrective maintenance activity for the period of concern for the study. The search should go back at least four calibration intervals (i.e. at least five sets of calibration data). If there are less than eight instruments included in the study then additional historical data will need to be collected to achieve the minimum number of data points specified by Section 2.1.2.2.

The data collected should ensure that the results are not from overlapping calibration intervals.

2.1.3.2 The data from the calibrations will be entered into a spreadsheet or data base program using a format similar to Figure J1. For instruments that have multiple calibration points (transmitters, function generators, etc.) each calibration point will be entered in the spreadsheet using the percent of span as the column title. If there are discrepancies in the exact percent of span then calibration points that are within 5% of each other can be used together (e.g. 0% FS, 1% FS and 5% FS can be considered the same calibration point).

For switches, relays or other equipment where there is a single point that is calibrated the data can be entered in percent of instrument span or in process units.

Due to the diversity of software that can be used to compute this spreadsheet statistics, there may be some variation in format. The specific project or calculation shall identify the software used and justify that the data entry is in agreement with the intent of Section 4.0 of TR-103335.

Initial Data Analysis									
Date Mo.	Yr.	Data Status	Interval Months	Tag Number	Calibration Data (mA) 0%	25%	50%	75%	100%
5	93	As-Found	12	LT-459	4.00	8.00	11.94	15.96	20.01
		As-Left		LT-459	4.00	8.00	11.94	15.96	20.01
5	92	As-Found	14	LT-459	4.20	8.04	12.05	16.05	20.04
		As-Left		LT-459	4.00	8.00	11.98	15.98	20.00
3	91	As-Found	11	LT-459	4.09	8.04	12.02	16.05	20.04
		As-Left		LT-459	4.09	8.04	12.02	16.05	20.04
4	90	As-Found	10	LT-459	4.06	7.92	11.95	15.98	19.95
		As-Left		LT-459	4.06	7.92	11.95	15.98	19.95
6	89	As-Found	13	LT-459	4.00	8.00	12.02	16.07	20.02
		As-Left		LT-459	4.00	8.00	12.02	16.07	20.02
5	88	As-Found	12	LT-459	4.24	8.20	12.16	16.12	20.15
		As-Left		LT-459	4.00	7.97	11.98	15.98	20.00
5	87	As-Found		LT-459	NEW	NEW	NEW	NEW	NEW
		As-Left		LT-459	4.02	7.99	11.99	16.07	20.01

Figure J1, Example Spreadsheet Data Entry

The following information is particularly valuable for the analysis:

- The date of calibration is documented. The time interval since the previous calibration is calculated in months in the *Interval* column. Depending on the data, the time interval might be calculated in days, weeks, or months.

- The as-found and as-left data are entered into the spreadsheet exactly as recorded on the instrument data sheet. The values are in milliamperes (in this case) corresponding to a range of 0% to 100% of calibrated span.

- Note that all calibration data points have been recorded. In general, it is preferable to consider and evaluate all available data. By this approach, a better understanding of instrument drift can be obtained.

  For calibrations that check calibration points during ascending and descending calibration, the ascending and descending point will be kept separately for the initial evaluation.

2.1.3.3 All Data transfer will require 100% independent verification.

2.1.3.4. Due to legibility problems, even if it is obvious that the data recorded in original records is incorrect, verbatim transcription of the data is required. If the information cannot be determined from the original record (due to legibility problems) then the data point will be left blank. Record of this omission shall be included in the analysis.

2.1.3.5 In addition to the calibration point as-found and as-left values, the calibrated span of the instrument, date of the calibration and any significant calibration anomalies are to be recorded in the spreadsheet.

2.2 INITIAL ANALYSIS PROCESS

2.2.1 From the original data, certain manipulations may be required to get the data in a form that can be evaluated across various instruments.

2.2.1.1 If the instrument loop is not a linear loop and the data has not been converted, then the raw calibration data should be converted to Linear Equivalent Full Scale (LEFS) to ensure that drift information is not masked.

2.2.1.2 If the instrument has a known span, the data should be normally converted into percent of calibrated span by dividing the raw data by the span.

If the instrument does not have a known span, the data should be left in process units or converted to percent of the setpoint.

2.2.1.3 For each calibration interval where there is an as-left value from the older calibration and an as-found value from the younger calibration, a raw drift value should be determined by subtracting the as-left value from the as-found value. The calibration interval, in days, should also be determined.

2.2.2 Once the data is in the correct format, the number of data points, the average and the sample standard deviation should be determined for each column, (reference Section 4.0 of TR-103335).

Due to the diversity of software that can be used to compute this spreadsheet statistics, there may be some variation in format. The specific project or calculation should identify the software used and justify that the data entry is in agreement with this Standard.

2.3. OUTLIER AND POOLING VERIFICATION REQUIREMENTS

2.3.1 After the initial computation of the average and the sample standard deviation, identification of any potential outliers and the cause of these outliers will provide important information as to the behavior of the data that was evaluated.

2.3.1.1 Using a T-Test, A statistical check of the raw data against the average and the sample standard deviation shall be conducted.

Outlier Detection by the Critical values for T-Test

ASTM Standard E 178-80 provides several methods for determining the presence of outliers. The recommended method for detection of an outlier is by the T-Test. This test compares an individual measurement to the sample statistics and calculates a parameter, T, known as the extreme studentized deviate as follows:

$$T = \frac{|x_i - \bar{x}|}{s}$$

Where,

T - Calculated value of extreme studentized deviate that is compared to the critical value of T for the sample size

$\bar{x}$ - Sample mean

x_i - Individual data point

s - Sample standard deviation

If the calculated value of T exceeds the critical value for the sample size and desired significance level, then the evaluated data point is identified as an outlier. The critical values of T for the upper 1%, 2.5%, and 5% levels are shown in Table J1.

Outlier Analysis			
Sample Size	Upper 5 % Significance Level	Upper 2.5% Significance Level	Upper 1% Significant Level
10	2.18	2.29	2.41
20	2.56	2.71	2.88
30	2.75	2.91	3.10
40	2.87	3.04	3.24
50	2.96	3.13	3.34
75	3.10	3.28	3.50
100	3.21	3.38	3.60
125	3.28	3.46	3.68
~150	3.33	3.51	3.73

Table J1, Critical Values for T

Note that the critical value of T increases as the sample size increases. The significance of this is that as the sample size grows, it is more likely that the sample is truly representative of the population. In this case, it is less likely that an extreme observation is truly an outlier. Thus, the T-Test makes it progressively more difficult to identify a point as an outlier as the sample size grows larger. This intuitively makes sense. As the sample size approaches infinity, there should be no outliers since all the data truly is a part of the total population. For this reason, it is relatively easy to identify a larger than average data point as an outlier if the sample size is small; however, it is (and should be) harder to call a given data point an outlier if the sample size is large.

Table J1 provides outlier criteria up to a sample of 150 data points. Beyond this size, it should be even more difficult to declare an observation as an outlier. For greater than 150 data points, an outlier factor of 4 (or 4 standard deviations) is recommended in order to assure that outliers are not easily rejected from the sample.

The T-Test inherently assumes that the data is normally distributed. The significance levels in Table J1 represent the probability that a data point will be chance exceed the stated critical value. Referring to Table J1 for a sample size of 40, we would expect to have a calculated value of T greater than 2.87 about 5% of the time and a calculated value of T greater than 3.24 about 1% of the time. For safety-related calculations, testing outliers at the 2.5% significance level is required. Refer to ASTM Standard E 178-80 for further information regarding the interpretation of the T-Test.

Example, Instrument Draft Sample

Consider the 20 instrument drift data points shown in Table J2. The data appears to be within a ±2.5% range with the exception of a single large data point, 5.20%. Would the T-Test identify this point as an outlier?

Instrument Drift Sample Data	
0.47%	5.20%
-0.27%	0.21%
0.03%	-0.12%
-0.28%	0.42%
0.60%	0.69%
-0.30%	-0.78%
-0.82%	0.30%
-0.28%	-0.08%
0.27%	0.03%
0.00%	-0.45%

Table J2, Instrument Draft Sample Data

The T-Test method requires the calculation of the sample mean and standard deviation before the calculated value of T can be obtained. For the above data, the sample mean and standard deviation are:

Sample mean: 0.23%
Sample Standard deviation: 1.24%

Now, evaluate the 5.20% data point to determine if it might be an outlier. The calculation of T is as follows:

$$T = \frac{|5.20 - 0.23|}{1.24} = 4.01$$

As shown, the calculated value of T is 4.01. Compare this result to the critical values of T for this sample size is 2.56 at the 5% significant level and 2.88 at the 1% significant level (see Table J1). In either case, the calculated value of T exceeds the critical value of T and the 5.20% data point is identified as an outlier.

If the 5.205 data point is rejected from the sample, the sample statistics would be recomputed for the 19 remaining data points with the following results:

Sample mean: -0.03%
Sample standard deviation: 0.42%

Notice that the single outlying observation was the only reason for an apparent bias of 0.23%. The standard deviation was reduced by approximately 65% (from 1.24% to 0.42%) by elimination of this single extreme value.

2.3.1.2 For any raw drift value that exceeds the critical T-Test, an evaluation shall be performed to determine if the data point should be excluded from the final data set. In no case can more than 5% of the original data be removed. Removal of outliers from the data set should be minimized as the process is to predict actual instrument performance. Since the data is all that we have to depict that performance, whether we like it or not, we need to accept the data unless underlying information can be inferred. The outlier process can not be repeated after an outlier or outliers have been removed within the constraints of this section.

2.3.1.3 Identification of a potential outlier in Section 2.3.1.2 does not mean that the value will be automatically excluded. Examples of when outliers should be removed include:

a. Review of the calibration indicates that a data entry error was likely. This will normally be seen as a random value that is significantly outside the rest of the data with no explanation. This type of outlier is a rare event and should not be done routinely.

b. Review of the data indicates that a bad calibration was performed. This will normally be seen by multiple outliers from the same calibration and a reverse drift of similar magnitude in the next calibration. In these cases, both sets of raw data should be removed.

2.3.1.4 The pattern of outliers should also be evaluated to determine if there is a bad instrument or application that is contaminating the data set.

It is permissible for this evaluation to rerun the T-Test with a smaller critical T value to force outliers. If this is done, these outliers should not be removed from the final data set.

This process will provide a number of data points that were at the extremes of the data set. If these extremes were primarily in one instruments' data or in one application area then additional evaluations need to be performed to determine if this data can be used with the rest of the data.

2.3.1.5 Bad instruments or bad applications will be detectable from the outliers that are identified. The best indication will be that the outliers will be bunched in the instrument or instruments used for a specific application. Other potential causes that could be identified by this process are:

a. Variations in range or span
b. Variations in age of calibration or equipment.

2.3.1.6 If the result of the outlier analysis indicates the potential for an application, range, age, etc. type of problem, then an analysis of the selection at that particular instrument should be conducted. Inclusion of data from any instrument can be checked by comparing this mean and variance of the instrument data to the mean and variance to the remainder of the data as explained in TR-103335 Section B.9.

2.4 NORMALITY

2.4.1 For this analysis, the assumption of normality is an integral assumption. To ensure that the data is a normal distribution or that a normal distribution is a conservative assumption, a test for normality of the data will be performed for all as-found/as-left data analysis after any outliers have been removed.

2.4.2 There are several tests for the normality of a data set. (See Appendix C of TR-103335). ComEd requires at least one of the following numerical approaches be conducted before the qualitative evaluations are performed.

- Chi-Squared, χ^2, Goodness of Fit Test. This well known test is stated as a method for assessing normality in ISA-RP67.04, Recommended Practice, *Methodologies for the Determination of Setpoints for Nuclear Safety-Related Instrumentation.*
- WTest. This test is recommended by ANSI N15.15-1974, *Assessment of the Assumption of Normality (Employing Individual Observed Values),* for sample sizes less than 50.
- D-Prime Test. This test is recommended by ANSI N15.15-1974, *Assessment of the Assumption of Normality (Employing Individual Observed Values),* for moderate to large sample sizes.

2.4.3 If normality cannot be determined from a standard test then the data should be evaluated to determine if the assumption of normality is a conservative assumption. This can be done by one of the following techniques:

- Probability Plots. Probability plots (See Figure J2) provide a graphical presentation of the data that can reveal possible reasons for why the data is or is not normal. Use of a

probability plot and qualitative evaluation demonstrates how close the tails of the curve approach a diagonal.

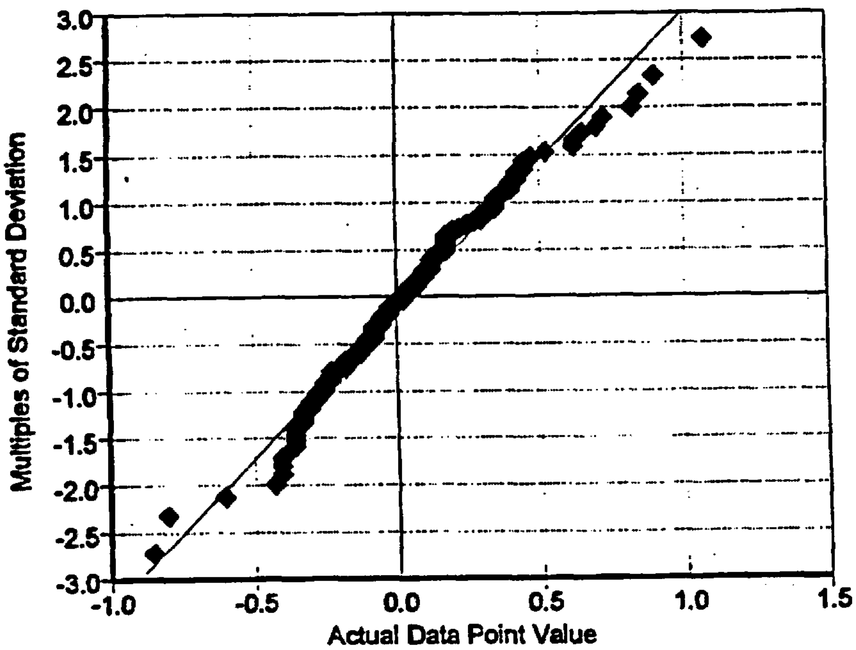


Figure J2, Typical Probability Plot for Approximately Normally Distributed Data

- Coverage Analysis. A coverage analysis (See figure J3) is used for cases in which the data fails a test for normality, but the assumption of normality can still be a conservative representation of the data.

This is performed by a visual evaluation of a histogram of the data with a normal curve for the data overlaid. In most cases instrument data will tend to have a high kurtosis (center peaked data). Since the area of concern for uncertainty analysis is in the tails of the normal curve beyond at least two standard deviations, a high kurtosis will not invalidate the conservative assumption of normality if there are not multiple data points outside the two standard deviation points.

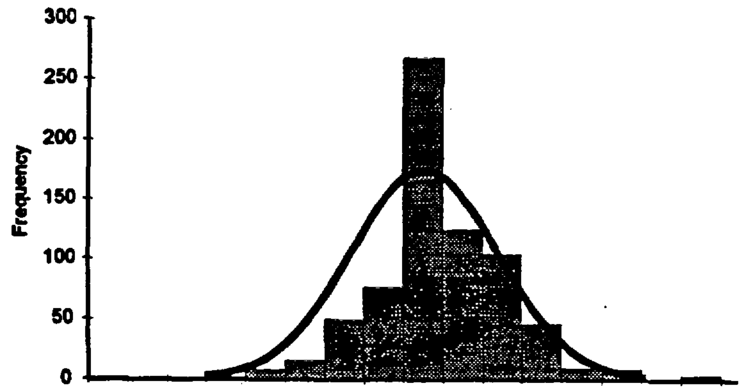


Figure J3, Coverage Analysis Histogram

2.4.4 If normality or a bounding condition of normality cannot be assumed for the data set, then depending on the distribution:

a. A distribution free tolerance value must be determined.
b. The size of the standard deviation will be expanded to bound the distribution.

As this is a seldom used case, this will not be discussed in this Standard. Refer to standard statistics texts for binomial and distribution free statistical method.

To determine the amount of increase needed from the tabular 95/95 value for the histogram evaluation, use the count in each bar of the histogram and ensure that greater than 95% of the data is captured. Increase the standard deviation as necessary to capture at least 95% of the data.

2.5 TIME DEPENDENCE

2.5.1 The way the resultant drift value from this as-found/as-left analysis is used is very sensitive to the determination of the time dependency.

This is particularly important for the extension of operating cycles via the NRC Generic Letter 91-04. This drift analysis requires that some decision be made on how the drift at thirty months can be determined from data that is taken over an eighteen month period.

2.5.2 The basic and most conservative assumption that drift is linear time dependant will be used for the initial evaluation of the computed drift. However, during the development of the EPRI TR-103335, significant data was collected that indicates that drift does not follow a linear time dependent pattern and challenges this basic assumption.

To determine the existence or lack of time dependency requires evaluation of the mean of the data over the calibration interval and the variation in uncertainty over the calibration interval. The evaluation of the mean of the data over the calibration interval will identify any bias component of the instrument drift that is time dependent. The evaluation of the variation in the data over the calibration interval will identify any change in the random component of drift that is time dependent.

The following methodology is to be used to determine time dependence. Evaluation of the drift mean and its changes over time will use any combination of the following tools.

a. Qualitative methods, which will include visual evaluation of the data on scatter plots, regression predication plots and bin mean plots.

b. Quantitative methods, which will include regression of the significant data and the regression of the means of the bins (if there is sufficient data).

Evaluation of drift variability and its changes over time will use any combination of the following tools:

a. Qualitative methods, which will include visual evaluation of the data on scatter plots, regression predication plots and bin standard deviation plots.

b. Quantitative methods, which will include regression of the Absolute Value of the significant data and the regression of the standard deviation of the bins (if there is sufficient data).

2.5.2.1 First, the data will be evaluated to determine if any of the data will generate significant leverage during regression. To do this the data collected shall be placed in interval bins. The interval bins that will normally be used are:

a. 0 to 45 days (covers most weekly and monthly calibrations)
b. 46 to 135 days (covers most quarterly calibrations)
c. 136 to 225 days (covers most semi-annual calibrations)
d. 226 to 445 days (covers most annual calibrations)
e. 446 to 650 days (covers most old refuel cycle calibrations)
f. 651 to 800 days (covers most extended refuel cycle calibrations)
g. 801 to 999 days
h. > 1000 days

2.5.2.2 For each internal bin, the average ($\bar{x}$), sample standard deviation (σ) and data count (η) shall be computed. In addition, the average calibration interval of the data points in each bin will be computed.

2.5.2.3 To determine the existence of time dependency, ideally the data needs to be "equally" distributed across the multiple bins. However, equal distribution in all bins would not normally occur. The minimum expected distribution that would allow this evaluation is:

a. A bin will be considered in the final analysis if it holds more than five data points and more than ten percent of the total data count. The minimum number of data points in a bin was selected to ensure that one calibration at a point would not adversely affect evaluation of a significant amount of data at other intervals. The choice of five data points is engineering judgement and may be changed for a specific case with appropriate documentation in the specific calculation.

b. For those bins that are to be considered the difference between bins will be less than twenty percent of the total data count. If there is a bin with significant data that does not meet this requirement, the evaluation should be done and the bin included if it can be shown to be from the same data set (a pooling test).

c. At least two bins including the bin with the most data must be left for evaluation to occur.

The following example demonstrates the process described above.

Example, Time Dependence Evaluation

For a given make and model of transmitter there were twelve EPNs that were looked at with historical calibrations for five calibration periods. Including corrective actions there were a total of 66 data points. The distribution of the data by bins was:

Bin	Data Count	% of Total Count
0 to 45 days	7	11
46 to 135 days	4	6
136 to 225 days	29	44
226 to 445 days	6	9
446 to 650 days	18	27
651 to 800 days	2	3

The 46 to 135 day and 46 to 135 day bins are thrown out due to less than five data points and the 226 to 445 day bin is thrown out do to having less than ten percent of the data. Of the remaining three bins the 446 to 650 day bin is within twenty percent of the other two bins so there will be three bins used for evaluation.

With a slight variation in the data:

Bin	Data Count	% of Total Count
0 to 45 days	7	11
46 to 135 days	4	6
136 to 225 days	29	44
226 to 445 days	3	5
446 to 650 days	21	32
651 to 800 days	2	3

Now the 0 to 45 day bin is greater than twenty percent from the next bin and thus only the 136 to 225 day and 446 to 650 day bins can be used for analysis.

With another slight variation:

Bin	Data Count	% of Total Count
0 to 45 days	7	11
46 to 135 days	3	5
136 to 225 days	33	50
226 to 445 days	6	9
446 to 650 days	15	23
651 to 800 days	2	3

The majority of the data is in the 136 to 225 day bin and that bin is greater than twenty percent from the next most populous bin. In this case the normal analysis cannot be used. Engineering evaluation of the other bins with greater than ten percent of the data should be done to determine if they can be grouped with the data from the large bin. This could be done by the pooling techniques listed above

2.5.2.4 Once the bins have been selected, data from selected bins and all bins between them will be entered into a regression analysis program.

The initial regression is for the data that populates all of the significant bins and the data that is between them. By eliminating the data that is in low populated bins and at the extremes of the calibration interval, leverage is minimized. This regression is to determine if the mean of the data changes over calibration interval.

A regression analysis will be performed using calibration interval as the independent variable and drift as the dependant variable. Output of the regression analysis shall be in a standard ANOVA table similar to that shown in Table J3.

DEP VAR: DOT2 N: 31 MULTIPLE R: 0.178 SQUARED MULTIPLE R: 0.032						
ADJUSTED SQUARED MULTIPLE R: .000 STANDARD ERROR OF ESTIMATE: 1.304						
VARIABLE	**COEFFICIENT**	**STD ERROR**	**STD COEF**	**TOLERANCE**	**T**	**P (2 TAIL)**
CONSTANT	0.848	0.740	0.000		1.146	0.266
PERIOD	-0.001	0.002	-0.178	1.000	-0.787	0.441
ANALYSIS OF VARIANCE						
SOURCE	**SUM-OF-SQUARES**	**DF**	**MEAN-SQUARE**	**F-RATIO**	**P**	
REGRESSION	1.054	1	1.054	0.620	0.441	
RESIDUAL	32.319	29	1.701			

Table J3, Sample ANOVA Table

If the value for R^2 is greater than 0.3, then the bias component of the drift should be considered to be linearly time dependent over the range of the calibration intervals included in the analysis. The constant and slope of the drift line will be used for bias values in uncertainty analysis for this instrument make and model. The appropriate tolerance interval for the 95/95 case should also be determined for this regression. [Note: This case will only occur rarely]

If the value of R^2 is less than 0.3 but greater than 0.1 then there still can be a time dependency. To continue the evaluation use terms from the ANOVA table generated by the regression program (partial printout below) or an equivalent ANOVA table.

Example, ANOVA Table Evaluation for Time Dependency

ANOVA				
	df	*SS*	*MS*	*F*
Regression	001	0.606767762	0.6067678	2.7507691
Residual	119	26.24915424	0.2205811	
Total	120	26.855922		
	Coefficients	*Standard Error*	*t Stat*	*P – value*
Intercept	0.1594012	0.087925043	1.812913	0.0723646
X Variable 1	-0.0003408	0.000205483	-1.6586443	0.0998413

Table J4, Time Dependence Evaluation ANOVA Table

From this table, the following values will give an indication of the potential for linear time dependency:

1. X Variable 1 *P-value,* if less than 0.05, would indicate a time dependency

2. ANOVA table F value, if it is greater than the F-table value for a 0.25% probability, the number of data points for the regression, and two degrees of freedom for the numerator, would indicate a time dependency.

2.5.2.5 After the initial regression test the same regression test is applied to the absolute value of the same data. This test detects the increasing variability with calibration interval but will not provide a correct mean. The same decision criteria as the first regression apply but the variable that is being evaluated is the random component of the drift. The slope of the regression will represent the variation in the standard deviation as calibration interval increases if a time dependency is determined. This variation will NOT provide a numerical value for the increase, but will indicate the trend.

2.5.2.6 If neither of the regression tests show an R^2 value greater than 0.3, then a review of the mean and standard deviation data for each bin of significance and an evaluation of qualitative plots will assist the engineer in determining time dependence.

2.5.2.7 If the R-Square value is less than 0.1, then the bias component of the drift should be considered to be time independent over the range of the calibration intervals included in the analysis. For those cases with no apparent time dependency, one additional check should be performed to identify any potential problems resulting from increasing uncertainty.

The evaluation of the mean and standard deviation of each bin of significance will provide visual trending of the mean and standard deviation with calibration interval.

For each bin that was evaluated, plot the mean and sample standard deviation against the average calibration interval for that bin. These plots will provide visual indication of the stability of the mean and sample standard deviation for the data available. Indications of increased magnitude of the mean and/or the standard deviation with increasing or decreasing calibration interval can be qualitatively assessed.

A linear extrapolation of the expected increase in sample standard deviation and mean to the next bin outside the analyzed interval can be determined through the regression of the plotted values for the mean and standard deviation. This will provide a value for the mean and sample standard deviation, in Units/Day, for projection into the next bin.

If there are more than three bins with significant data then a regression of the mean and standard deviation values that were plotted can be used for evaluation of the linear fit of the data.

2.5.2.8 Determination of time dependency will be in two parts. One for the bias section and one for the random section of the drift term. These decisions will be based on the following decision process:

a. Bias Component

If the bias is showing a time dependency it will be deviating from its calibration as-left value of near zero drift as the calibration interval is increased. This deviation will be repeatable in only one direction (positive or negative).

1) If the regression of the data has an R-Square value greater than 0.3 then it is assumed that the data is time dependent.

2) If the R-Square is less than 0.3 but greater than 0.1 then the X Variable 1 *P-value* and the F-Value tests should be completed. If either test indicates that the regression is significant then assume time dependency unless there is a reason to disregard the tests.

One result that would be a reason for disregarding the regression test is that the result could not represent the real instrument behavior. This has shown up in several cases where the regression line has a large intercept value and then trends toward or crosses the zero drift term. This implies that the maximum drift will occur at time zero which is not the expectation of the instrument calibration process.

3) If the R-Square value is less than 0.1 then there is an expectation that the bias is time independent. This will be checked against the qualitative visual information to make a final determination.

Review:

The scatter plot of all data – Include linear approximation line

The plot of the data that was regressed – Include linear approximation line

The plot of the means of each significant bin – Include linear approximation line

If the review of these plots indicates a clear trend toward an increasing value in the magnitude of the mean versus calibration interval, then engineering judgement should be used to conservatively treat the mean as a linearly time dependent bias.

4) The value of the bias will be either the linear extrapolated value of the time dependent regression for a time dependent bias component or the mean of the final data set for a time independent bias component.

5) If the value of bias is determined to be less than 0.1% FS, it will be considered negligible whether it is time independent or time dependent (computed to the maximum surveillance interval).

b. Random Component

The variation of the data about the mean is normally the larger uncertainty in drift evaluations and this value is the random component of drift. If the magnitude of this variation is a function of calibration interval then this variation can be said to be time dependent.

1) If the regression of the Absolute Value of the data has an R-Square value greater than 0.3 then it is assumed that the data is time dependent.

2) If the R-Square is less than 0.3 but greater than 0.1 then the X Variable 1 *P-value* and the F-Value tests should be completed. If either test indicates that the regression is significant then assume time dependency unless there is a reason to disregard the tests.

3) If the R-Square value is less than 0.1 then there is an expectation that the random uncertainty is time independent. This will be checked against the qualitative visual information to make a final determination.

Review:

The scatter plot of all data – Include linear approximation line

The plot of the Absolute Value of the data that was regressed – Include linear approximation line

The plot of the standard deviation of each significant bin – Include linear approximation line

If the review of these plots indicates a clear trend toward a linear variation in the standard deviation with calibration interval, then engineering judgement should be used to assume time dependency for the random component of the uncertainty.

4) The value of the random component of the drift will be either:

The linear extrapolated value of the standard deviation of the bins plot for a time dependent random uncertainty

or

The standard deviation of the data for a time independent random component

The interval for which this is valid is only the interval of the bins that were analyzed.

2.5.3 If two or more bins were not identified for analysis then the value of drift from this evaluation must determined from the data from the most populated bin. For this case the process utilized is:

2.5.3.1 Compute the mean and sample standard deviation for the most populated bin. In addition, compute the average calibration interval for the data in that bin.

2.5.3.2 The bias and random components of the drift are then determined by:

a. The bias component will be then mean of the data in the single bin. This bias will be considered time independent unless a qualitative evaluation of the data would visually indicate that it is time dependent.

Extrapolation of the bias value from this bin to other bins will be by assuming it is a constant value throughout the range of concern for a time independent bias.

b. The random component will be the 95/95 tolerance value of the data. This will be assumed to be time independent.

Extrapolation to the bin either side of the single bin will require the use of the 99/95 tolerance value for additional conservatism. For extrapolation to larger calibration interval the random value will be expanded using the A2 Equation method of Appendix A Section 3.1.

2.6 RESULTS

2.6.1 The results of these as-found/as-left analyses determine a value of derived drift for the instrument make/model This value will require the following minimum elements:

2.6.1.1 Bias – Will normally be either the mean of the final data set for time independent drift or the intercept (constant) and slope for linear time dependent drift. For time dependent drift, this cannot be from the regression of the absolute value data set but from the final data set. A mean that is less than 0.1% FS will be assumed to be zero. This is a standard value. Bias below this value has no significant effect on the loop uncertainty.

2.6.1.2 Time Dependent Drift Value – For drift that was classified as time dependent, the slope of the regression curve (Units/Day) is the dependent drift value. If this number was determined from the absolute value regression, it still should be specified.

2.6.1.3 Tolerance Value – This value will come from the regression study for time dependent drift. For time independent drift, it will be the sample standard deviation times a multiplier based on the sample size. The selection of the multiplier will be based on the required expectations. Some specific requirements are:

99/95 – For cases where only one bin has sufficient data for analysis use this tolerance if the intent is to still assume time independent drift.

95/95 – For RPS and ECCS automatic actuations. If any instruments of the make/model are used for this then the result must be this confidence and tolerance interval.

95/75 – For other safety related instrumentation. If no instruments of this make/model are used for automatic actuations but they are used in safety related indication and alarm circuits then the tolerance value can be reduced to 75%.

75/75 – If the make/model is only used for non-safety related activities.

2.6.1.4 Valid Interval – The bounds of the calibration interval that were included in the analysis. For the above example, the first case would be 0 to 650 days and the second case would be 136 to 650 days. As extrapolation of statistical evaluations are not normally done this provides the data over the range where it should be valid. Some evaluation of the data within the bounding bins may be necessary to ensure that all of the data is not bunched at one interval. If there is bunching of data, the valid interval should be adjusted to account for this effect.

2.6.1.5 Extrapolation Margin – If the data from the analysis is to be extrapolated to either of the adjacent bins from the Valid Interval, then an additional margin will be added to the results of the evaluation.

2.6.2 The analysis should clearly indicate the make/model that it was performed for, and any functions excluded.

2.7 USING THE RESULTS

2.7.1 The data reduction has generated a "drift" value, but that number includes several uncertainties in addition to the classical drift. If the determined drift value is used in uncertainty calculations, the following uncertainties can normally be eliminated. To replace these values state that they are included in the calculated drift value and set their individual values to zero.

2.7.1.1 Reference Accuracy – The reference accuracy of the instrument is included in the calibration data and can be removed from the uncertainty calculation.

2.7.1.2 M&TE – As long as the calibration process uses the same, or more accurate, test equipment then this uncertainty is included in the calibration data and can be removed from the uncertainty calculation.

2.7.1.3 Drift – The true drift is included in the determined drift and is included in the calibration data and can be removed from the uncertainty calculation.

2.7.1.4 Normal Environmental Effects – For the instruments that are included in the calibration, the effects of variations in radiation, humidity, temperature, vibration, etc. experienced during the calibration are included in the calibration data and can be removed from the uncertainty calculation. These terms cannot be removed from the uncertainty calculations if these components see different conditions or magnitudes of the parameter, such as vibration or temperature, while operating then during calibration.

2.7.1.5 Power Supply Effects – If the instruments are attached to the same power supply during calibration that is used during operation, then the affects are included in the calibration data and can be removed from the uncertainty calculation.

2.7.1.6 Setting Tolerance – If the setting tolerance is such that it is less than the determined drift then this tolerance will show up in that determined drift and can be removed from the uncertainty calculation.

If the ST is much larger than the determined drift it will not normally be used in the calibration process and will not be seen in the determined drift. In this case the ST can be combined with the determined drift using SRSS.

2.7.2 For cases were there are time dependent drifts, the time frame used for determining the drift should be the normal surveillance interval plus twenty-five percent.

Time dependent drift that is random is assumed to be normally distributed and can be combined using the Square Root Sum of the Squares method for intervals beyond the given interval for the drift as explained in Appendix A and C to this procedure.

2.7.3 Time independent drift can be assumed constant over the Valid Interval. It can also be assumed constant over the interval in the next bin if the Extrapolation Margin is applied.

2.8 CONTINUING EVALUATION

2.8.1 To maintain these evaluations current and to detect increasing drift, the process stipulated in CC-AA-520 "Instrument Performance Trending" shall be followed.