ATTACHMENT 13
Exelon Generation Company, LLC Instrument Setpoint Calculations

LIST OF CALCULATIONS INCLUDED

L-001345, Rev. 2, “Average Power Range Monitor (APRM), Rod Block Monitor (RBM), and Recirculation Flow Monitor (RFM) Bistable Loop Accuracy for Rod Block and Scram Functions”

L-001345, Minor Rev. 2 A
L-001345, Minor Rev. 2 B
L-001345, Minor Rev. 2 C
L-001345, Minor Rev. 2 D

Note: Minor Revision 2 D provides the changes related to the proposed power uprate. However, the preceding revisions are provided, since the minor revisions are not incorporated into the body of Revision 2.

Exhibit A
NEP-12-02LA
Revision 4

CALCULATION TITLE PAGE

PAGE NO: 1

ComEd

LaSalle

☒ Unit 1 ☒ Unit 2 ☐ Unit 0

Calculation No. L-001345

DESCRIPTION CODE: I04
DISCIPLINE CODE: I
SYSTEM CODE: C51
ELEVATION (C016) 768' 0"

TITLE: Average Power Range Monitor (APRM), Rod Block Monitor (RBM), and Recirculation Flow Monitor (RFM) Bistable Loop Accuracy for Rod Block and Scram Functions

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

REFERENCE NUMBERS (C011Panel)

Type	Number	Type	Number
AEDV	I&C Engineering		
CHRN			
PAL			
PROG			
PROJ	10620-008		
SSYS			
RNID			

COMPONENT EPN : (C014 Panel)

EPN	Compt Type
See Section 1.0	

DOCUMENT NUMBERS: (C012 Panel)

Doc Type	Sub Type	Document Number	Assoc. Calc.
PROG	STN	See Reference 3.5	☐ Yes ☒ No
DCD	DCP	9700500	☐ Yes ☒ No
DCD	DCP	9700502	☐ Yes ☒ No
CALC	ENG	NED-I-EIC-0255	☒ Yes ☐ No
			☐ Yes ☐ No

REMARKS: GE DRF C51-00206

REV. NO.	REVISING ORGANIZATION	APPROVED PRINT/SIGN	DATE
0	General Electric	Larry Chi (GE)	12-22-97
1	Sargent & Lundy	W. A. Barasa	3-19-99
2	Sargent & Lundy	W.A. Barasa WABarasa	7-9-99

REVISION SUMMARIES

REV: 0 ☐ Partial (Only Revised Pages Included) ☒ Complete (All Calculation Pages Included)

REVISION SUMMARY:

Initial Issue.

Electronic Calculation Data Files:
(Program Name, Version, File name ext/size/date/hour: min)
WordPerfect 6.1, L-001345.6R0/1,281,278/12-22-97/11:55 pm
Word 6.0, L1345FIG.DOC/29,696/12-19-97/2:23 pm

PREPARED BY: W. Kent Green (GE) Print ____ Sign 12-22-97 Date

REVIEWED BY: Daniel L. Gould (GE) Print ____ Sign 12-22-97 Date

Type of Review ☒ Detailed ☐ Alternate ☐ Test
Supplemental Review Required ☐ Yes (NEP-12-05 documentation attached) ☐ No
Supervisor: ____

DO ANY ASSUMPTIONS IN THIS CALCULATION REQUIRE LATER VERIFICATION ☐ YES ☒ NO
Tracked by: ____

REV: 1 ☒ Partial (Only Revised Pages Included) ☐ Complete (All Calculation Pages Included)

REVISION SUMMARY: Revised to widen calibration tolerances for modules σ3A, σ3B, σ6A, σ6B in support of DCPs 9700500 & 9700502. Added limitations to the allowed upscale and comparator trip setpoint calibration tolerances for the recirculation flow monitor. Also corrected minor typos. Revised the following pages: 43, 44, 76, 77, 78, 144, 145, 151, 152, 166, 167, 172, 173, 178, 179, 188, 190, 191.
also revised pages 1 and 2.

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

PREPARED BY: D.J. Cujko Print D. J. Cujko Sign 3-19-99 Date

REVIEWED BY: P.J. Ripp Print P. J. Ripp Sign 3-19-99 Date

Type of Review ☒ Detailed ☐ Alternate ☐ Test
Supplemental Review Required ☐ Yes (NEP-12-05 documentation attached) ☒ No
Supervisor: ____

DO ANY ASSUMPTIONS IN THIS CALCULATION REQUIRE LATER VERIFICATION ☐ YES ☒ NO
Tracked by: ____

Exhibit A
NEP-12-02LA
Revision 4

COMMONWEALTH EDISON COMPANY
CALCULATION REVISION PAGE

CALCULATION NO. L-001345 PAGE NO.: 2.1 of 191

REVISION SUMMARIES

REV: 2 ☒ Partial (Only Revised Pages Included) ☐ Complete (All Calculation Pages Included)

REVISION SUMMARY: Revised pages 1, 2.1, 3, 6, 7, 10, ~~11~~ D.J.C 14, 17, 18, 44, 110, 111, 113, 114, 149, 150, 153, 154, 155, 156, 160, 161, 168, 169, 171, 184, 187, 188, and 191. Calculated new setpoints and allowable values for APRM flow biased simulated power scram and rod blocks (flow biased and clamp) based on revised analytical limits resulting from power uprate.

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

PREPARED BY: J.R. Basak Thomas J Behring for J. R. Basak DATE: 7/9/99
Print/Sign

REVIEWED BY: D. J. Cujko D.J. Cujko NAB DATE: 7/9/99
Print/Sign

Type of Review ☒ Detailed ☐ Alternate ☐ Test
Supplemental Review Required ☐ YES (NEP-12-05 documentation attached) ☒ NO
Supervisor: N A Barosa

DO ANY ASSUMPTIONS IN THIS CALCULATION REQUIRE LATER VERIFICATION ☐ YES ☒ NO
Tracked by: ______

REV:

REVISION SUMMARY:

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

PREPARED BY: ______ DATE: ______
Print/Sign

REVIEWED BY: ______ DATE: ______
Print/Sign

Type of Review ☐ Detailed ☐ Alternate ☐ Test
Supplemental Review Required ☐ YES (NEP-12-05 documentation attached) ☐ NO
Supervisor: ______

DO ANY ASSUMPTIONS IN THIS CALCULATION REQUIRE LATER VERIFICATION ☐ YES ☐ NO
Tracked by: ______

Exhibit D
NEP-12-02
Revision ~~5~~ 6
qKB

COMMONWEALTH EDISON COMPANY
CALCULATION TABLE OF CONTENTS

CALCULATION NO. L-001345	REV. NO. 2	PAGE NO. 3 OF 191

Exhibit D
NEP-12-02
Revision 5

CALCULATION NO. L-001345	REV. NO. 0	PAGE NO. 4 OF 191
DESCRIPTION	PAGE NO.	SUB-PAGE NO.
D. GE Drawing 248A9544, Rev. 1, "Rod Block Monitor (Page) '69" Specification.	D1 - D10	
E. NEDC-31336P-A, "General Electric Instrumentation Setpoint Methodology," September 1996, (GE Proprietary Information), Sections 2.2.5 and 4.5.	E1 - E22	
F. ComEd Letter DG 97-001088, "Reclassification of the drift error term in the ComEd Setpoint Accuracy Methodology," dated 25 August, 1997.	F1 - F3	
G. Rosemount Nuclear Data Sheet, "Model 1152 Alphaline Pressure Transmitter for Nuclear Service," MAN 4235A00, 1995.	G1 - G5	
H. GE Drawing 225A6445, Rev. 0, "Flow Unit (Page)" Design and Performance Specification.	H1 - H5	
I. Letter to File, KG971022.DOC, Documents Telecons with LaSalle NMS Engineer Gene Pfister.	I1 - I2	
J. E-Mail from Julie Leong to Clark F. Canham and W. Kent Green dated 10/14/97, Subject: LaSalle Recirc Flow Drift and Flow Element Accuracy.	J1 - J2	
K. NEDO-31558-A dated March 1993, "Position on NRC Regulatory Guide 1.97, Revision 3, Requirements for Post-Accident Neutron Monitoring System."	K1 - K15	
L. GE letter, A097-011, Allowance for Process Computer Core Power Measurement Analytical Uncertainty in LaSalle, from Jose L. Casillas, dated December 12, 1997.	L1 - L3	
M. GE letter, A097-015 Rev. 1, Flow Biased Simulated Thermal Power Scram and APRM Rod Block in LaSalle, from Jose L. Casillas, dated December 22, 1997 with its Enclosure (4).	M1 - M4	
N. GE Drawing 328X105TD, Rev. 3, "Power Range Monitoring Cabinet," Parts List.	N1 - N3	
O. GE Drawing PL791E507TD, Rev. 10, "Power Range Monitoring Cabinet," Parts List.	O1 - O5	
P. GE Drawing PL791E392BB, Rev. 14, "Flow Unit," Parts List.	P1 - P8	
Q. E-Mail from Andrew N. Poulos to Jose L. Casillas, Daniel L. Gould, and Larry Chi dated December 10, 1997, Subject: LaSalle Flow Bias.	Q1 - Q3	

1.0 PURPOSE AND OBJECTIVE

The purpose of this calculation is to determine with a high degree of certainty whether or not there exists positive margin between the Analytical Limits and the calibration and Tech Spec setpoints, and between the Tech Spec LCO values and the calibration and Tech Spec setpoints, for the various trips of the Power Range Neutron Monitoring System (PRNMS). For the purposes of this calculation the PRNMS consists of the Average Power Range Monitors (APRM), the Rod Block Monitors (RBM), and the Recirculation Flow Monitor (RFM). The evaluated trips from these three subsystems can cause a scram via the Reactor Protection System (RPS) or a rod withdrawal block via the Reactor Manual Control System (RMCS). Following is a list of the evaluated trips:

<u>Trips that cause a scram</u>

APRM Neutron Flux - High (Fixed)
APRM Neutron Flux - High (Fixed)(Setdown)
APRM Simulated Thermal Power - Upscale (Flow Biased)
  Two Recirculation Loop Operation
APRM Flow Biased Trip Clamp
  Two Recirculation Loop Operation
APRM Simulated Thermal Power - Upscale (Flow Biased)
  Single Recirculation Loop Operation
APRM Flow Biased Trip Clamp
  Single Recirculation Loop Operation

<u>Trips that cause a rod block</u>

APRM Neutron Flux - High (Fixed)
APRM Neutron Flux - Downscale
APRM Flow Biased Upscale Trip

RBM Upscale
RBM Downscale

RFM Upscale
RFM Comparator

The equipment covered by this calculation is listed below:

FT-1B33-N014A
FT-1B33-N014B
FT-1B33-N014C
FT-1B33-N014D
FT-1B33-N024A
FT-1B33-N024B
FT-1B33-N024C
FT-1B33-N024D

FT-2B33-N014A
FT-2B33-N014B
FT-2B33-N024A
FT-2B33-N024B

FT-2B33-N014C
FT-2B33-N014D
FT-2B33-N024C
FT-2B33-N024D

FY-1B33-K608A
FY-1B33-K608B
FY-1B33-K608C
FY-1B33-K608D
FY-1B33-K606A
FY-1B33-K606B
FY-1B33-K606C
FY-1B33-K606D

FY-2B33-K608A
FY-2B33-K608B
FY-2B33-K608C
FY-2B33-K608D
FY-2B33-K606A
FY-2B33-K606B
FY-2B33-K606C
FY-2B33-K606D

FY-1B33-K607A
FY-1B33-K607B
FY-1B33-K607C
FY-1B33-K607D
FY-2B33-K607A
FY-2B33-K607B
FY-2B33-K607C
FY-2B33-K607D

RY-1C51-K605GM
RY-1C51-K605GP
RY-1C51-K605GS
RY-1C51-K605GN
RY-1C51-K605GR
RY-1C51-K605GT

RY-2C51-K605GM
RY-2C51-K605GP
RY-2C51-K605GS
RY-2C51-K605GN
RY-2C51-K605GR
RY-2C51-K605GT

RY-1C51-K605GU
RY-2C51-K605GU
RY-1C51-K605GV
RY-2C51-K605GV

Since the components of the PRNMS are not relied upon for any accident mitigation or post accident control function (Reference 3.21) this calculation takes into account only the normal environmental conditions.

The Standard Technical Specifications (Reference 3.24, Table 3.3.1.1-1) are only applicable to this calculation for the Neutron Flux High - Setdown and Fixed Neutron Flux - High Scram trips. The values given for the flow biased trips are differnt than the current LaSalle values (i.e., LaSalle, a BWR/5, has different slope and offset values). The rod block functions of the RBM and Recirculation Flow Monitor are not covered in the Standard Technical Specifications of Reference 3.24.

In addition, this calculation will determine the required nominal trip setpoints and allowable values for the APRM flow biased simulated thermal power scram and rod block functions (flow biased and clamped) for the revised analytical limits resulting from the uprating of thermal power discussed in Reference 3.33.

2.0 METHODOLOGY AND ACCEPTANCE CRITERIA

The methodology used for this calculation is that presented in References 3.2 and 3.3. A setpoint will be considered acceptable if the calculation shows that a positive margin exists. If a positive margin does not exist a new setpoint will be calculated according to the criteria of Reference 3.3. Revision 2 of this calculation is in accordance with Reference 3.34.

For all trips, the calculation will begin with the existing Tech Spec Nominal Trip Setpoint (NTSP). The 'Total Error' (TE) for each setpoint will be determined twice, once to support an Analytical Limit (AL) evaluation and once to support an Allowable Value (AV) evaluation. Then, by adding or subtracting the appropriate error terms, the AL and AV margins to the Tech Spec setpoint will be demononstrated to be positive. Positive margin for the procedual setpoints is also documented.

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 (1σ)

b. Drift Time Period Extension

Section 3.3.1 of Reference 3.2, Exhibit A, gives the following equation for calculating the effective drift based on a given surveillance interval (SI) and a known drift uncertainty term (IDE):

eD = (1 + LF/SI)*SI*IDE

where LF is the late factor. In this equation IDE is some variable per unit time. This effectively says that eD is adjusted for time differences linearly by the ratio of (1 + LF/SI)*SI to the time interval portion of IDE.

Reference 3.8 allows drift to be treated as a random variable. Therefore, as is done in Reference 3.13, when it is necessary to adjust the drift data for a time period that is longer than the time period associated with the given drift data, the adjustment will be performed by using the square root of the ratio of the two time periods.

$$RD = \{[(1 + LF/SI)*SI]/IDE_T\}^{0.5}*IDE_V$$

where IDE_T is the per unit time portion (denominator) of IDE, and IDE_V is the drift value portion (numerator) of IDE. Note that drift values will not be reduced when the surveillance interval is less than the given instrument drift time period.

c. Error propagation through Square Root Modules

The Recirculation Flow Monitors each contain two square root modules that convert the 4 to 20 ma signals from the flow transmitters to a 0 to 10 Vdc output. From these values the transfer equation is determined to be

$$V = 2.5\sqrt{I-4} \qquad \text{Equation 1}$$

where V is the output in Vdc and I is the input current from the transmitter in milliamps. Since this is a non-linear function the error transfer from input to output depends on the operating point. The transfer of the error at any point can be determined by taking the derivative of this transfer function (Reference 3.3). The result is

$$dV = \frac{1.25}{\sqrt{I-4}}dI \qquad \text{Equation 2}$$

where dV is the output error caused by an input error of dI at a value of I current. Since there may be times where the operating point may be known as a function of the output voltage rather than input current an equation for this condition can be developed by solving the first equation for I and substituting in the second equation. The result is

$$dV = \frac{3.125dI}{V} \qquad \text{Equation 3}$$

These last two equations will be used as necessary in determining the effect of the flow transmitters' errors on the flow loop accuracy.

The procedures actually measure the input current by running it through a one ohm resistor and measuring the voltage across the resistor. Therefore, the measured value is actually millivolts. However, since the resistor is one ohm the numerical value of the millivolt signal is exactly the same as the current in milliamps. Therefore, the voltage readings in millivolts can be used directly for the terms I and dI in equations 1 through 3.

d. Static Pressure Span Effect

References 3.5.s and 3.5.t state that a 1% of span correction has been included in the calibration to compensate for the static pressure span effect. However, Reference 3.14 states that there is a plus/minus correction uncertainty associated with this compensation. Therefore, this uncertainty will be included as a random error term in this calculation. Although the vendor gives this error term as a percent of reading, it will be considered as percent calibrated span which simplifies the calculation and is conservative.

2.2 Flow Biased Trip Slope Adjustment

The procedures of Reference 3.5 allow a certain tolerance when setting the flow biased trips in both the APRMs and RBMs. This has the effect of permitting a slope other than the specified value in the Flow to Power conversion circuit. Because of this the specified slope will be modified using the methodology of Reference 3.3 to a value that will allow for the setting tolerances.

Both the APRM and RBM procedures check the flow biased trip setpoints at two different values. The maximum error in the slope would then be determined by taking the most positive error at one point and the most negative error at the other point (procedural tolerances are in Vdc). This can then be converted to a percent power change by dividing by the volts per percent power, and then converted to a fraction by dividing by the flow difference between the two measurement points. The resulting error fraction can then be added to the specified slope to give a new value for use in the calculation. This slope will be the worst case slope (maximum) allowable by the procedures. The equation for this new slope is:

$$\text{Slope}_{NEW} = \text{Slope}_{SP} + [(T^{+} + T^{-})/0.08]/\Delta\text{Flow}$$

This will be used for both APRM and RBM flow biased error calculations. For the APRMs, the tolerance (T^+,T^-) is ± 0.04 Vdc and the calibration flow (Δflow) is 80% flow, (Section 10.4). For the RBMs, the tolerance (T^+,T^-) is ± 0.04 Vdc and the calibration flow (Δflow) is 100% flow (Section 10.5).

2.3 The numbers displayed in this calculation have not been rounded to six decimal places. As such, the internal spreadsheet is carrying additional digits. This may cause the sixth decimal place to vary from normal rounding convention. Rounding was removed to make the electronic file more stable. The variations of the last digits do not affect the final calculation results and therefore are considered acceptable.

3.0 REFERENCES

3.1 ANSI/ISA-S67.04-1988, "Setpoints for Nuclear Safety Related Instrumentation."

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

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

3.4 NED-I-EIC-0255, Rev. 0, dated 04-14-94, "Measurement and Test Equipment (M&TE) Accuracy Calculation For Use With Commonwealth Edison Company Boiling Water Reactors." Chron 208597

3.5 LaSalle Station Procedures

a. LIS-NR-103AA, Rev. 2, "Unit 1 Average Power Range Monitor Channels A, C, and E Rod Block and Scram Semiannual Calibration for Normal Plane Conditions."

b. LIS-NR-103AB, Rev. 2, "Unit 1 Average Power Range Monitor Channels A, C, and E Rod Block and Scram Semiannual Calibration During Single Loop Operation."

c. LIS-NR-103BA, Rev. 3, "Unit 1 Average Power Range Monitor Channels B, D, and F Rod Block and Scram Semiannual Calibration for Normal Plane Conditions."

d. LIS-NR-103BB, Rev. 3, "Unit 1 Average Power Range Monitor Channels B, D, and F Rod Block and Scram Semiannual Calibration During Single Loop Operation."

e. LIS-NR-105, Rev. 12, "Unit 1 Rod Block Monitor Calibration."

f. LIS-NR-107, Rev. 6, "Unit 1 APRM/RBM Flow Converter to Total Core Flow Adjustment."

g. LIS-NR-109, Rev. 7, "Unit 1 APRM Gain Adjustment."

h. LIS-NR-111, Rev. 7, "Unit 1 LPRM Flux Amplifier Gain Adjustment."

i. LIS-NR-113, Rev. 6, "Unit 1 Rod Block Monitor Calibration for Single Reactor Recirculation Loop Operation."

j. LIS-NR-203AA, Rev. 0, "Unit 2 Average Power Range Monitor Channels A, C, and E Rod Block and Scram Semiannual

Calibration for Normal Plant Conditions."

k. LIS-NR-203AB, Rev. 0, "Unit 2 Average Power Range Monitor Channels A, C, and E Rod Block and Scram Semiannual Calibration During Single Loop Operation."

l. LIS-NR-203BA, Rev. 0, "Unit 2 Average Power Range Monitor Channels B, D, and F Rod Block and Scram Semiannual Calibration for Normal Plant Conditions."

m. LIS-NR-203BB, Rev. 0, "Unit 2 Average Power Range Monitor Channels B, D, and F Rod Block and Scram Semiannual Calibration During Single Loop Operation."

n. LIS-NR-205, Rev. 12, "Unit 2 Rod Block Monitor Calibration."

o. LIS-NR-207, Rev. 6, "Unit 2 APRM/RBM Flow Converter to Total Core Flow Adjustment."

p. LIS-NR-209, Rev. 7, "Unit 2 APRM Gain Adjustment."

q. LIS-NR-211, Rev. 7, "Unit 2 LPRM Flux Amplifier Gain Adjustment."

r. LIS-NR-213, Rev. 6, "Unit 2 Rod Block Monitor Calibration for Single Reactor Recirculation Loop Operation."

s. LIS-RR-101, Rev. 11, "Unit 1 Recirculation Flow Converter Calibration."

t. LIS-RR-201, Rev. 10, "Unit 2 Recirculation Flow Converter Calibration."

3.6 LaSalle Station UFSAR, Rev. 11, dated April 8, 1996

3.7 LaSalle Station Technical Specification Unit 1, Amendment No. 117, dated January, 29, 1997 and Technical Specification Unit 2, Amendment No. 102, dated January 29,

3.8 ComEd Letter DG 97-001088, "Reclassification of the drift error term in the ComEd Setpoint Accuracy Methodology," dated 25 August, 1997.

3.9 GE Drawing 22A2843, Rev. 7, "Neutron Monitoring System" Design Specification.

3.10 GE Drawing 22A2843AF, Rev 7, "Neutron Monitoring System" Design Specification Data Sheet.

3.11 GE Drawing 235A1386, Rev. 1, "Design and Performance Specification APRM (Page)."

3.12 GE Drawing 248A9544, Rev. 1, "Rod Block Monitor (Page) '69" Specification.

3.13 NEDC-31336P-A, "General Electric Instrumentation Setpoint Methodology," September 1996, (GE Proprietary Information), Sections 2.2.5 and 4.5.

3.14 Rosemount Nuclear Data Sheet, "Model 1152 Alphaline Pressure Transmitter for Nuclear Service," MAN 4235A00, 1995.

3.15 Core Operating Limits Report, Appendix A, LaSalle Unit 1 Cycle 8 dated March 1996, and Appendix B, LaSalle Unit 2 Cycle 7 (no date).

3.16 Letter to File, KG971022.DOC, Documents Telecons with LaSalle NMS Engineer Gene Pfister.

3.17 E-Mail from Julie Leong to Clark F. Canham and W. Kent Green dated 10/14/97, Subject: LaSalle Recirc Flow Drift & Flow Element Accuracy.

3.18 GE Drawing 225A6445, Rev. 0, "Flow Unit (Page)" Design and Performance Specification.

3.19 ABB Combustion Engineering Document 00000-ICE-3231, Rev. 2, "Flow Unit Requirements Specification."

3.20 NDIT No. LS-0643, Upgrade 0, Transmittal of information concerning ambient temperature and seismic errors.

3.21 NEDO-31558-A dated March 1993, "Position on NRC Regulatory Guide 1.97, Revision 3, Requirements for Post-Accident Neutron Monitoring System."

3.22 NDIT No. LS-0588, Upgrade 0, Transmits documents describing ComEd methodology for performing setpoint calculations, MT&E accuracies, and ComEd calibration procedures.

3.23 NDIT No. LS-0598, Upgrade 1, Transmits ComEd procedures LIS-RR-101, Rev. 11 and LIS-RR-201, Rev. 10; NEP-12-02, Rev. 5; LaSalle County Station UFSAR, Rev. 11, Chapter 3.11, Environmental Design of Mechanical and Electrical Equipment; Letter DG 97-001088, dated August 25, 1997, regarding, "Reclassification of the drift error term in the ComEd Setpoint Accuracy."

3.24 NUREG 1434, Rev. 0, "Standard Technical Specifications, General Electric Plants, BWR/6" dated September 1992.

3.25 NDIT No. LS-0604, Upgrade 0, Transmittal of ABB "Flow Unit Requirements Specification 00000-ICE-3231, Rev. 2."

3.26 GE letter, A097-011, Allowance for Process Computer Core Power Measurement Analytical Uncertainty in LaSalle, from Jose L. Casillas, dated December 12, 1997.

3.27 NDIT No. LS-0684, Upgrade 1, "Analytical Limits for use as Inputs in APRM Setpoint Calculations."

3.28 GE letter, A097-015 Rev. 1, Flow Biased Simulated Thermal Power Scram and APRM Rod Block in LaSalle, from Jose L. Casillas, dated December 22, 1997 with its Enclosure (4).

3.29 GE Drawing 328X105TD, Rev. 3, "Power Range Monitoring Cabinet," Parts List.

3.30 GE Drawing PL791E507TD, Rev. 10, "Power Range Monitoring Cabinet," Parts List.

3.31 GE Drawing PL791E392BB, Rev. 14, "Flow Unit," Parts List.

3.32 E-Mail from Andrew N. Poulos to Jose L. Casillas, Daniel L. Gould, and Larry Chi dated December 10, 1997, Subject: LaSalle Flow Bias.

3.33 SEAG 99-000517, "Power Uprate Safety Analysis Report for LaSalle County Station Units 1 and 2", GE Nuclear Energy, NEDC-32701P, Revision 1, DRF A13-00384-16, July 1999.

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

4.0 DESIGN INPUTS

4.1 Accuracy for Flow Transmitters

The procedures of Reference 3.5.s and 3.5.t indicate that there are five different calibrated spans for the 16 flow transmitters covered by this calculation. Since some of the uncertainty terms depend on the calibrated span and/or the transmitters upper range, the lowest value of the calibrated span will be used for all flow loops since this will produce conservative results.

4.2 Environmental Conditions at Flow Transmitters

The ComEd EWCS (Electronic Work Control System) indicates that the EQ Zone for the Flow Transmitters is LH4A. Table 3.11-6 of Reference 3.6 indicates that the short term peak temperature in this area resulting from an HELB event is 145°F with a total integrated gamma dose of 1×10^7 rads. However, the Flow Transmitters are only being evaluated for normal operating conditions so these bounding conditions are not applicable.

Table 3.11-15 of Reference 3.6 gives the service conditions environment for this zone. This indicates that under normal conditions temperatures could reach a maximum of 118°F, although this is predicted to occur for only about 9 days out of the remaining plant life (about 13,000 days). Therefore, 118°F will be used as the maximum temperature at the flow transmitter.

4.3 Temperature, radiation, humidity, and power supply errors are considered to be included in the manufactures accuracy terms when they are not identified separately.

4.4 Instrument reference accuracy was obtained from the published manufacturer's accuracy specifications.

4.5 Calibration tolerances were obtained from the associated LIS calibration procedures listed in Reference 3.5.

4.6 Per Reference 3.20 "A minimum ambient temperature of 60°F should be used to calculate temperature effect and Measurement & Test Equipment (M&TE) error."

4.7 Per Reference 3.20 "For normal errors, seismic events less than or equal to an Operating Basis Earthquake (OBE) are considered to cause no permanent shift in the input/output relationship of the devices. For seismic events greater than an OBE, affected instrumentation will be recalibrated as necessary prior to any subsequent accident (i.e., prior to restart), negating any permanent shift which may have resulted from a post seismic shift. Therefore, the seismic error for normal operating conditions is considered to be negligible." Since the Power Range Neutron Monitoring System is not for mitigation of an accident this statement is applicable for all seismic error terms.

4.8 The RBM contains a variable gain function whose purpose is to adjust the reading of the local average monitored by the RBM to equal the overall core average as monitored by a reference APRM. The range of gain variation in the RBM is 1 to 9 (Reference 3.12) in order to accommodate the range of local averages from center core to core edge. For this calculation the gain of the RBM will be considered equal to the nominal APRM gain since the RBM output is adjusted to equal an APRM output. This will produce conservative results when rod movement involves control rods centrally located in the core and non-conservative results when rods near the outside of the core are involved. However, this is considered acceptable for this application since the outside control rods have a lower rod worth making their movement less effective than movement of the inside rods.

4.9 The Comparator Trip in the RFM compares the outputs from two RFMs by subtracting one of the signals from the other and then comparing the absolute value of the result with a fixed reference. Because of this subtraction process any portions of each RFM's error terms which are generated by the same input will be canceled. Since all four RFMs receive their input from the same two flow elements (one for the A loop and one for the B loop), the error induced by each flow element into each RFM will be exactly the same. Therefore, this error term does not need to be carried through the RFM when determining the error associated with the Comparator Trip function.

4.10 Since the square root converter is not a linear module error terms appearing at the input must be converted to equivalent output values by one of the equations of Section 2.1.c. Also, these equations indicate that the conversion factor is a function of the operating point. Therefore, an operating point must be chosen at which the conversion will take place. For this calculation the operating point is considered to be 6 Vdc (OP_{SR}) at the output of the square root converters which is equal to approximately 75% Flow. Choosing this value is a compromise in that the error term is then conservative at flows greater than 75% but non-conservative at flows less than 75%. This is considered acceptable since in general plant operating margins become larger at low power, low flow conditions (Reference 3.28).

4.11 Reference 3.13 indicates that the bias portion of LPRM detector non-linearity (SNL_B), which is part of Primary Element Accuracy (PEA) term, depends on the operating point. Figure 4.5-4 show that at low power levels the bias would actually help the trip to occur sooner than necessary. For the downscale trips the value of the bias is approaching zero. Therefore, in this calculation a value of zero will be used for error determinations involving the APRM and RBM Downscale, APRM Setdown Rod Block, and APRM Setdown Scram trips.

4.12 Flow Element Accuracy

Reference 3.17 provides an accuracy value for the elbow type flow elements used at LaSalle. For the purposes of this calculation this value will be considered to be the error in the measurable parameter (ΔP) over the applicable flow range.

4.13 Errors pertaining to core power measurement as determined by the plant process computer have already been considered by various analyses as is indicated in Reference 3.26. Therefore, the core power measurement uncertainty does not need to be included in the setpoint calculations.

4.14 Analytical Limits and Allowable Values Inputs

From References 3.27 and 3.33, Analytical Limit inputs are provided for all non-flow biased setpoints and the APRM Flow Biased Trip functions (flow biased and clamp). Reference 3.15 provides the Allowable Values for the RBM Upscale Trips. The Analytical Limits for the RBM flow-biased setpoints are calculated in Section 13. The information provided by References 3.15, 3.27, and 3.33 is summarized below:

Bistable	AL	AV	Reference
APRM Flow Biased Trips			
Flow Biased Trip Clamp, Two Recirc Loop Operation (TLO)	115.5%, 119.5%	-	3.27
Flow Biased Trip Clamp, Single Recirc Loop Operation (SLO)	113.8%		3.33
Flow Biased STP Scram -TLO	0.62W+70.9%		3.33
Flow Biased STP Scram -SLO	0.55W+58.33%		3.33
Flow Biased STP Rod Block -TLO	0.62W+59.47%		3.33
Flow Biased STP Rod Block -SLO	0.55W+46.9%		3.33

Bistable	AL	AV	Reference
APRM Fixed Trips			
Neutron Flux - High (Fixed) (Scram)	122.4%, 124.2%	-	3.27, 3.33
Neutron Flux - High (Fixed) (Setdown) (Scram)	25%	-	3.27
Neutron Flux - High (Fixed) (Setdown) (Rod Block)	19%	-	3.27
Neutron Flux Downscale (Rod Block)	0%	-	3.27
Rod Block Monitor Trips			
RBM Upscale (Rod Block), Two Recirc Loop Operation	-	0.66W + 48%	3.15 and Section 10.5
RBM Upscale (Rod Block), Single Recirc Loop Operation	-	0.66W + 42.7%	3.15 and Section 10.5
RBM Downscale (Rod Block)	0%	-	3.27
Recirc Flow Monitor Trips			
RFM Upscale (Rod Block)	116%	-	3.27
RFM Comparator (Rod Block)	19%	-	3.27

5.0 ASSUMPTIONS

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

5.2 It is assumed that the M&TE listed in Section 9.0 is calibrated to the required manufacturer's specifications and within the manufacturer's required environmental conditions. Temperature related errors are based on the difference between the manufacturer's specified calibration temperature and the worst case temperature at which the device is used.

It is also assumed that the calibration standard accuracy error of the M&TE is negligible with respect to the other error terms unless noted otherwise within this calculation.

5.3 Deleted

5.4 When no setting tolerances are given in the procedures for measurements using digital instruments, it will be assumed that the setting tolerance is equal to the reference accuracy of the test instrument.

5.5 Deleted

5.6 Deleted

5.7 Since the ABB designed flow unit has not yet been installed, it will be assumed that this flow unit will be mounted in the same general area as is the present flow unit. Therefore, the environmental parameters for the current flow unit will be assumed to be applicable to the new ABB flow unit.

5.8 Reference 3.18 gives only a "Stability" value for the specifications of the trip circuits in the GE manufactured Recirculation Flow Monitor. Therefore, it will be assumed that this uncertainty encompasses both accuracy and drift and the value given will be divided equally (algebraically) between accuracy and drift. This makes their values equivalent to those for the APRM Fixed Trips which are of similar design. It will also be assumed that the drift time period given for the analog drift term applies here.

5.9 Since there have been no procedures generated for calibrating the ABB designed flow unit it will be assumed that, when developed, they will be similar to those used to calibrate the GE designed flow unit. Therefore, the MTE and ST terms derived for the GE flow unit will be assumed applicable to the calibration of the ABB flow unit.

5.10 Reference 3.19 does not give a value for drift for the ABB RFM trip circuits. Therefore, it will be assumed that drift is included in the accuracy term.

5.11 Based on the information contained in References 3.4 and 3.16 it will be assumed that LaSalle is using a Wallace and Tiernan Model 65-120 instrument when the procedures of References 3.5.s and 3.5.t call for a Pneumatic Calibrator.

6.0 INSTRUMENT CHANNEL CONFIGURATION

The Power Range Neutron Monitoring System (PRNMS) can be divided into three primary blocks; the Recirculation Flow Monitors (RFM) of which there are four, the Average Power Range Monitors (APRM) of which there are six, and the Rod Block Monitors (RBM) of which there are two. Each of these three blocks will be discussed separately. Block diagrams of the complete PRNMS and one for each of the three subsystems follows the discussion.

Recirculation Flow Monitor

Each RFM receives the current output from two differential pressure transmitters that are monitoring the flow in the two reactor recirculation drive loops. These signals are applied to the input of square root converters that change the current input to a voltage output that is proportional to the flow in each loop. The outputs of the square root converters are then summed, the resulting output representing the total flow in the two recirculation loops. The total flow signal is then applied to an Upscale Trip, one input of a Comparator Trip, and to the associated APRMs and RBMs. The other input to the Comparator Trip comes from another RFM, the comparison being a means of determining possible problems in the flow monitoring equipment.

Average Power Range Monitor

An APRM is made up of several individual monitoring channels of Local Power Range Monitors (LPRM) plus the electronic circuitry required to average the outputs of these LPRM channels, and the trip circuits required to indicate high or low average power.

Each LPRM card receives a current signal from an incore neutron detector and converts this signal to a voltage output which in turn is applied to an input of the APRM averaging circuitry. The averaging circuitry takes the inputs from as many as 22 LPRMs and, as the name implies, provides an output that is the average of the inputs. This output is then calibrated to represent average core thermal power.

The output of the averaging circuitry is applied to the several upscale or downscale trip circuits. Some of the trip circuits use a field adjustable voltage as a reference. These are referred to throughout this calculation as the fixed trip circuits. Other trip circuits use as a reference a signal which varies as a function of the recirculation flow. These trips are referred to as flow biased trips. This variable reference is generated within the APRM by a circuit (Flow Controlled Trip Reference Unit) that receives the output from one of the RFMs and converts this to a signal proportional to the input but with a slope less than one. The uncertainties for the Flow Controlled Trip Reference Unit is included in the APRM uncertainties.

The outputs from the trip circuits go either to the Reactor Protection System where they can cause a scram, or to the Reactor Manual Control System where a rod withdrawal block may be initiated.

Rod Block Monitor

The Rod Block Monitor is similar to the APRM in that it receives the signals from multiple LPRMs, averages them, and provides outputs to trip circuits. However, instead of averaging LPRMs from throughout the core, the RBM looks only at those LPRMs immediately surrounding a control rod that has been selected for movement. Once the average has been performed the RBM adjusts the output such that it is equal to or greater than the output of a reference APRM.

The output of the averaging circuit then goes to some flow biased upscale trip circuits and a fixed downscale trip. The flow biased reference in the RBM is generated exactly as it is in the APRM.

The outputs of the trip circuits in the RBM all go to the Reactor Manual Control System where they will initiate a rod block.

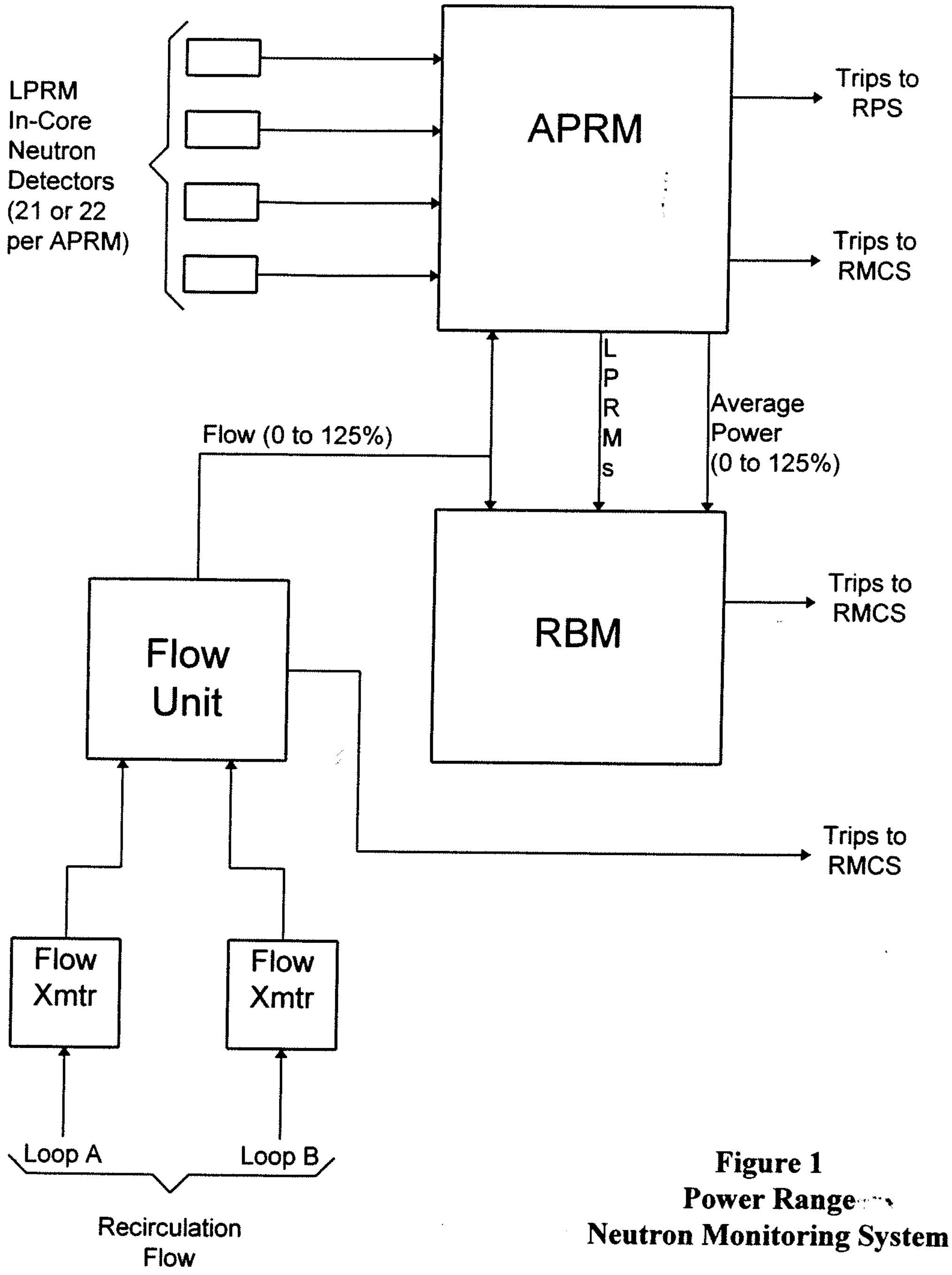

Figure 1
Power Range
Neutron Monitoring System

CALCULATION NO. L-001345		PAGE 24 of 191

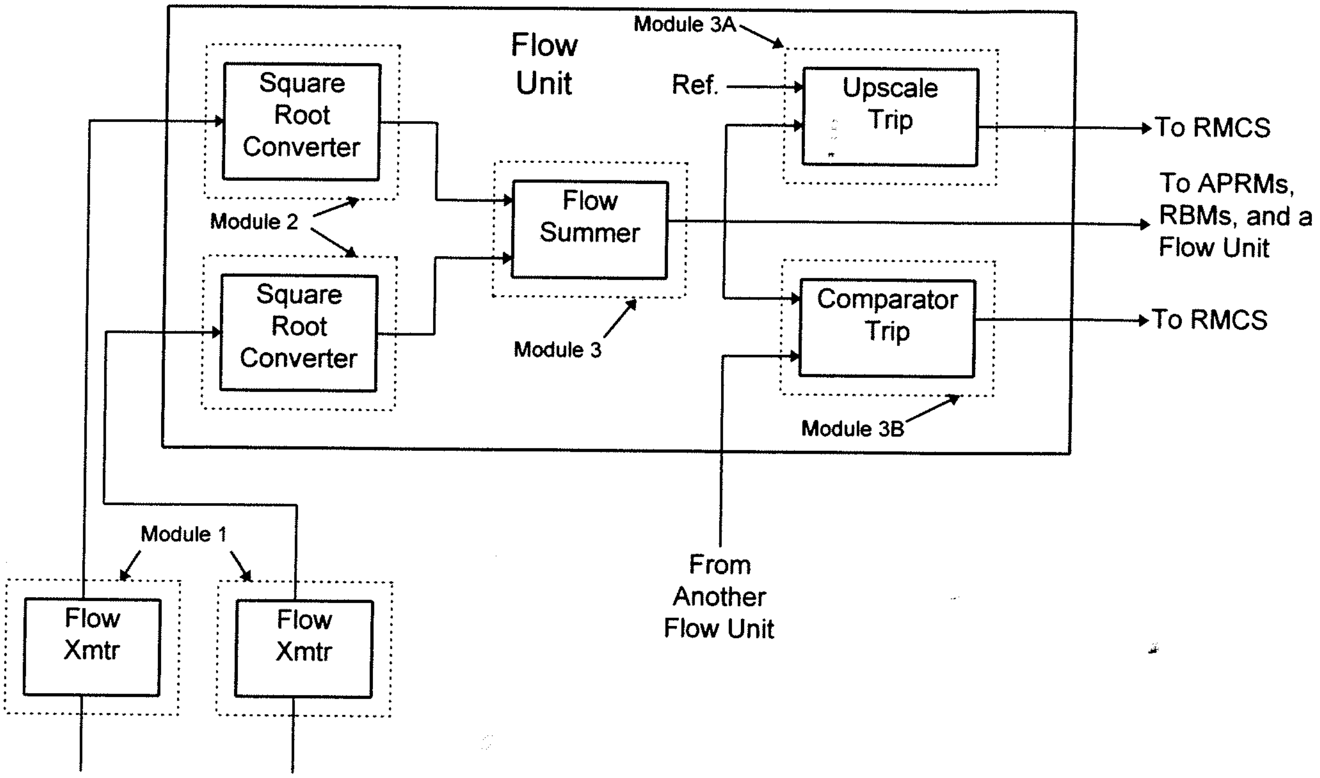

Figure 2
Recirculation Flow Monitor

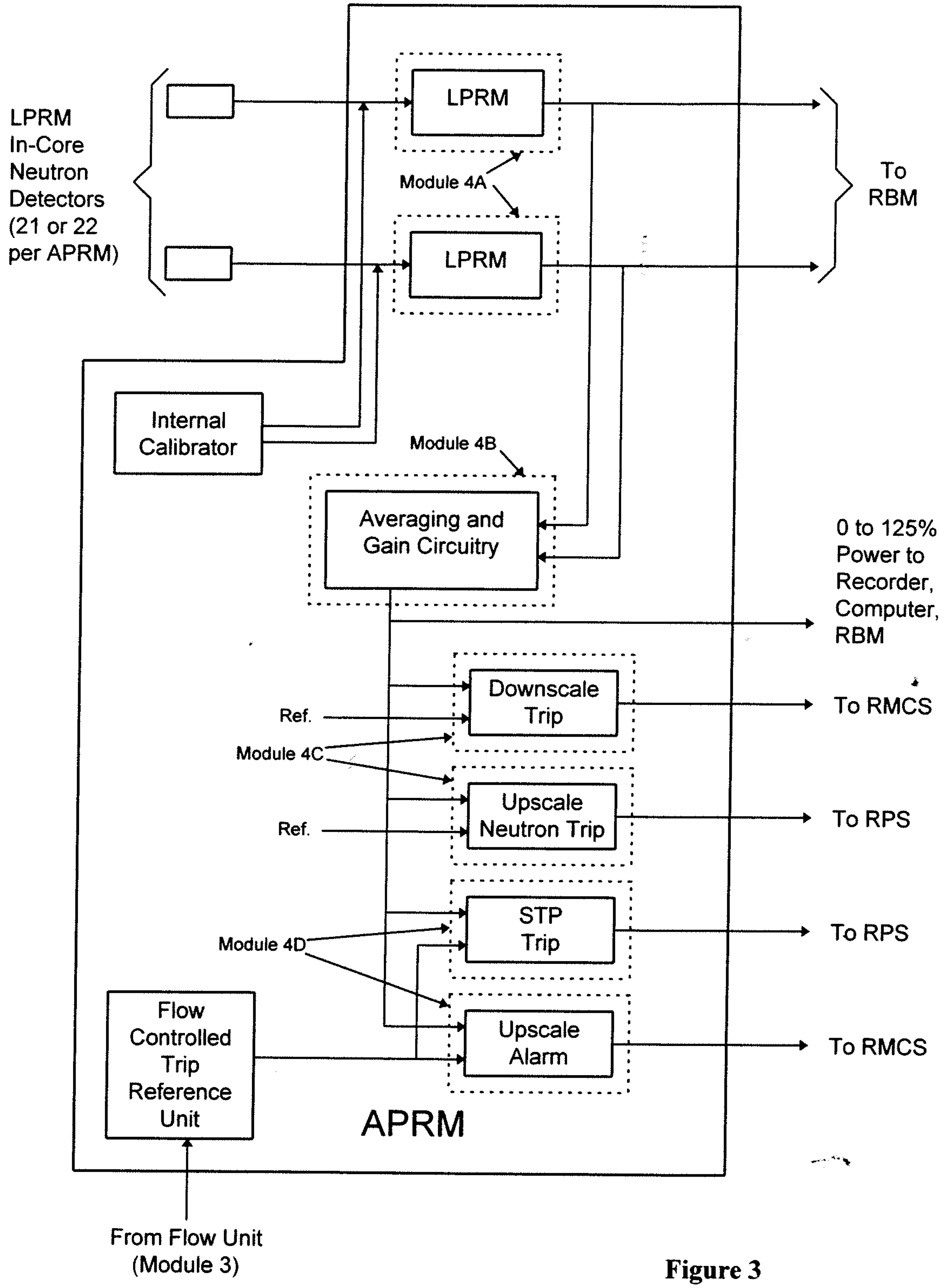

Figure 3
Average Power Range Monitor

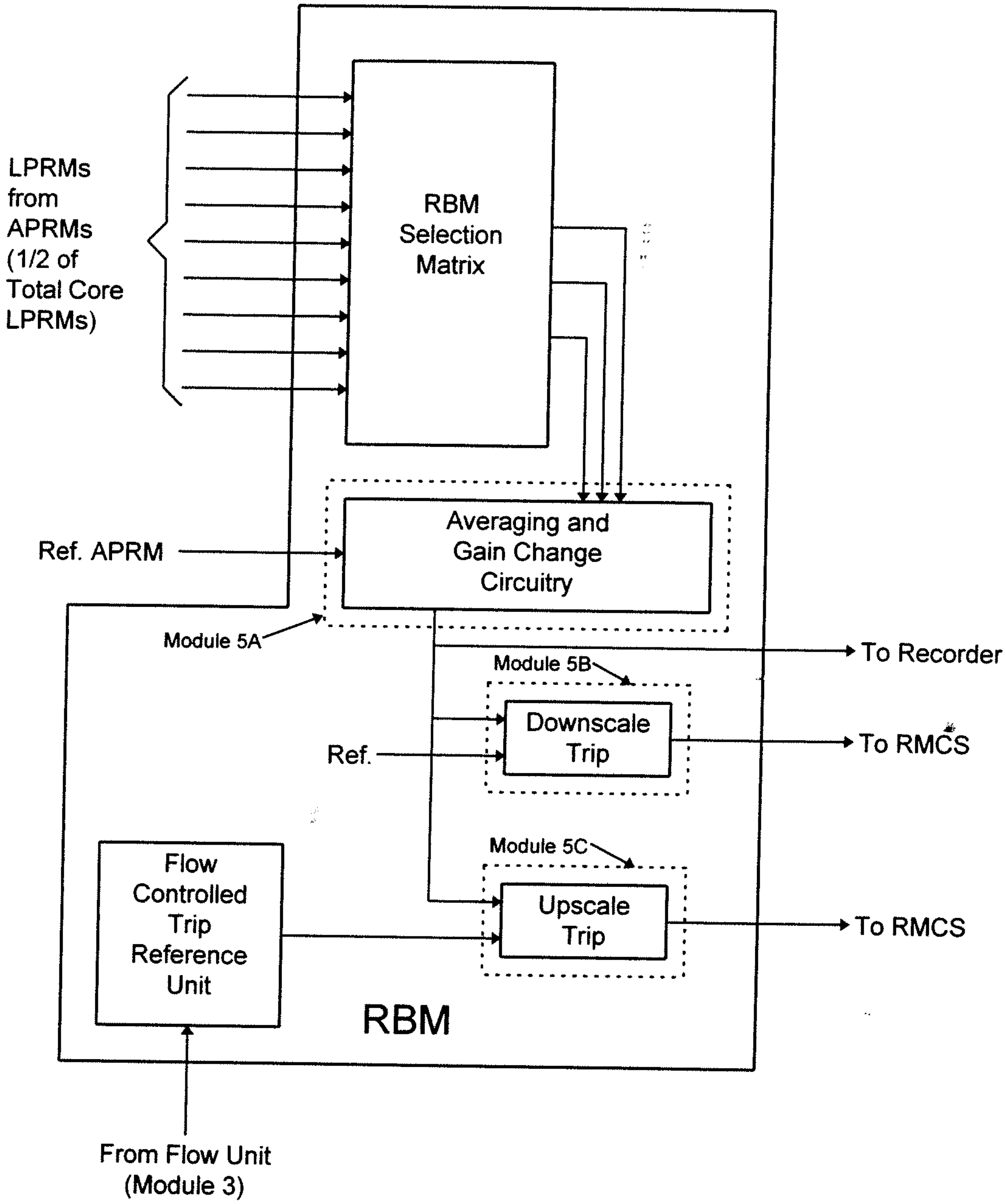

Figure 4
Rod Block Monitor

7.0 PROCESS PARAMETERS

The process being measured by the LPRM detectors is reactor core neutron activity, normally referred to as neutron flux. The detectors are positioned three-dimensionally throughout the reactor core and are in contact with reactor water.

The following are the applicable process parameters (References 3.9 and 3.10):

Neutron Flux:		
Operating:	1.2×10^{12} to 2.8×10^{14} nv	(nv = unit of neutron density)
Peak:	3.4×10^{14} nv at 120% Rated Power	
Gamma Flux:		
Operating:	4.2×10^{8} to 1.2×10^{9} R/hr at 100% Rated Power	
Pressure:	1025 psig nominal at 100% Rated Power 1375 psig maximum emergency	
Temperature	546°F nominal 583°F emergency conditions	

The Power Range Neutron Monitoring System interfaces with some differential pressure transmitters from the Reactor Recirculation System that are being used to measure recirculation drive flow. The sensing portion of these transmitters is exposed to approximately the same process pressure as are the neutron detectors. The temperature of the fluid has, however, dropped to reactor building ambient temperature by the time it reached the location of the transmitters. Based on References 3.5.s and 3.5.t, 100% Flow in these flow loops is equal to 55,000 GPM.

8.0 LOOP ELEMENT DATA

8.1 Module 1	Rosemount Differential Pressure Transmitter Model 1152DP5E220280PB (From EWCS)
Equipment Numbers (From Procedures)	FT-1B33-N014A FT-1B33-N024A FT-1B33-N014B FT-1B33-N024B FT-1B33-N014C FT-1B33-N024C FT-1B33-N014D FT-1B33-N024D FT-2B33-N014A FT-2B33-N024A FT-2B33-N014B FT-2B33-N024B FT-2B33-N014C FT-2B33-N024C FT-2B33-N014D FT-2B33-N024D

8.1.1 Transmitter Specifications (Range 5) (Reference 3.14)

Upper Range:	750 in H_2O
Accuracy:	±0.25%SP
Temperature Effect:	±(0.5%UR + 0.5%SP) per 100°F
Drift:	±0.2%UR/30 months
Power Supply Effect:	±0.005%SP/volt
Static Pressure Zero Effect:	±0.25%UR/2000 psi
Static Pressure Span Effect: (Correction Uncertainty)	±0.25% Reading/1000 psi
Seismic Effect:	±0.25%UR to 3g
Radiation Effect:	±8%UR for TID = 5×10^6 rads at a dose rate of 0.4×10^6 rad/hr

8.1.2 Environmental Parameters at Transmitter Location (Zone LH4A from EWCS)

The maximum temperature for EQ Zone LH4A is 118°F (See Section 4.3). The minimum temperature is 60°F (Assumption 5.3)

From Table 3.11-15 of Reference 3.6, the expected relative humidity is 35%, the pressure is -0.4" W.G., and the integrated gamma dose is 2×10^6 rads.

8.2 Module 2	GE Square Root Converter Model 136B3051AAG003 (Reference 3.31)
Equipment Numbers (From Section 3.5)	FY-1B33-K608A FY-1B33-K606A FY-1B33-K608B FY-1B33-K606B FY-1B33-K608C FY-1B33-K606C FY-1B33-K608D FY-1B33-K606D

FY-2B33-K608A	FY-2B33-K606A
FY-2B33-K608B	FY-2B33-K606B
FY-2B33-K608C	FY-2B33-K606C
FY-2B33-K608D	FY-2B33-K606D

8.2.1 Square Root Converter Specifications

Per Reference 3.18 the reference accuracy for the square root converter is included in an overall RFM accuracy which will be applied at the output of the Flow Summer (Module 3).

8.2.2 Environmental Parameters at Square Root Converter Location (Zone LC1A from EWCS)(Reference 3.6, Table 3.11-24)

Temperature (°F)	72 - 74
Relative Humidity (%)	35 - 45
Radiation	1×10^3 rads gamma (integrated)

8.3 Module 3

GE Flow Summer Model 136B3088AAG001 (Reference 3.31)

Equipment Numbers (From Section 3.5)	FY-1B33-K607A	FY-2B33-K607A
	FY-1B33-K607B	FY-2B33-K607B
	FY-1B33-K607C	FY-2B33-K607C
	FY-1B33-K607D	FY-2B33-K607D

8.3.1 Flow Summer Specifications

Per Reference 3.18 the following specifications apply to the flow unit in total including the square root converters (Module 2).

Accuracy:	±2% FS
Drift:	±1.25% FS per 700 hrs.
Trip Stability:	2% FS

Per Assumption 5.8 stability is divided equally between accuracy and drift. Therefore,

Trip Accuracy:	1% FS
Trip Drift:	1% FS per 700 hrs.

8.3.2 Environmental Parameters at Flow Summer Location (Zone LC1A from EWCS) (Reference 3.6, Table 3.11-24)

Temperature (°F)	72 - 74
Relative Humidity (%)	35 - 45
Radiation	1×10^3 rads gamma (integrated)

8.4 Module 4	Average Power Range Monitor (APRM) Model 145C3096BBG001 & G002 (Reference 3.30)
Equipment Numbers (From Section 3.5)	RY-1C51-K605GM RY-1C51-K605GN RY-1C51-K605GP RY-1C51-K605GR RY-1C51-K605GS RY-1C51-K605GT RY-2C51-K605GM RY-2C51-K605GN RY-2C51-K605GP RY-2C51-K605GR RY-2C51-K605GS RY-2C51-K605GT

8.4.1 APRM Specifications

<u>LPRM Specifications</u> (Reference 3.9)

Accuracy:	±0.8% FS
Drift:	±0.8% FS/700 Hrs.

<u>Averaging Circuitry Specifications</u> (Reference 3.11)

Accuracy:	±0.8% FS
Drift:	±0.5% FS/700 Hrs.
Gain:	2.5 ± 40%

<u>Trip Circuits</u> (Non-Flow Biased) (Reference 3.11)

Accuracy:	±1% FS
Drift:	±1% FS/700 Hrs.

<u>Trip Circuits</u> (Flow Biased) (Reference 3.11)

Accuracy:	
(50 to 100% Flow)	±1% FS
(0 to 50% Flow)	±2% FS
Drift:	±1% FS/700 Hrs. (Reference 3.9)

8.4.2 Environmental Parameters at APRM Location (Zone LC1A from EWCS) (Reference 3.6, Table 3.11-24)

Temperature (°F)	72 - 74
Relative Humidity (%)	35 - 45
Radiation	1×10^3 rads gamma (integrated)

8.5 Module 5	Rod Block Monitor (RBM) Model 145C3105BBG001 & G002 (Reference 3.30)
Equipment Numbers (Reference 3.16)	RY-1C51-K605GU RY-1C51-K605GV RY-2C51-K605GU RY-2C51-K605GV

8.5.1 RBM Specifications (Reference 3.12)

Averaging and Gain Adjust Circuitry

Accuracy:	±0.8% FS
Drift:	±0.3% FS per 4 hrs.
Gain Range:	1 to 9
Accuracy of Null:	±1% of Point

Trip Circuits (Non-Flow Biased)

Same as APRM (Uses same Quad Trip Cards)

Trip Circuits (Flow Biased)

Same as APRM (Uses same Quad Trip and Flow Biased Trip Unit Cards)

8.5.2 Environmental Parameters at RBM Location (Zone LC1A from EWCS) (Reference 3.6, Table 3.11-24)

Temperature (°F)	72 - 74
Relative Humidity (%)	35 - 45
Radiation	1×10^3 rads gamma (integrated)

8.6 Module 6	ABB Recirculation Flow Monitor Model (Reference 3.25)
Equipment Numbers	Not Known

8.6.1 Flow Unit Specifications (Reference 3.19)

Accuracy: (Total Flow Voltage Output)	±1% CS
Temperature Effect: (Total Flow Voltage Output)	±0.5% CS
Drift: (Total Flow Voltage Output)	±0.5% CS per 30 months
Comparator Trip Accuracy: (±2% minus 1% total flow error)	±1% CS
Upscale Trip Accuracy: (±2% minus 1% total flow error)	±1% CS
Transmitter Power Supply Drift:	±2% per 30 months

8.6.2 Environmental Parameters at Flow Unit Location (Zone LC1A from EWCS) (Reference 3.6, Table 3.11-24) [It is assumed that this flow unit will be mounted in the same general area as is the present flow unit]

Temperature (°F)	72 - 74
Relative Humidity (%)	35 - 45
Radiation	1×10^3 rads gamma (integrated)

9.0 CALIBRATION INSTRUMENT DATA

Most of the calibration procedures listed in Section 3.5 specify the specific instrument to be used. However, References 3.5.f, h, o, and q require only that the DMM used should have an accuracy of at least ± 0.01 Vdc. If this is considered a two sigma value the one sigma requirement, which makes it compatible with the DMM data from Reference 3.4, would be 0.01/2 or ±0.005 Vdc. This value will be considered the MTE uncertainty term in the portions of the calculation involving the above four specified procedures.

The specified or acceptable DMMs are listed below with the evaluations of Reference 3.4 shown in Section 9.1

Calibration Instrument	MTE Error [1σ]	Evaluation Parameters
MTE for all DMM Calibrations		
Fluke 45 Med(30 Vdc Rng)	±0.002462 Vdc	@10Vdc, 64.4→82.4°F
Fluke 8050A(20 Vdc Rng)	±0.002693 Vdc	@10Vdc, 64.4→82.4°F
Fluke 8060A(20 Vdc Rng)	±0.003640 Vdc	@10Vdc, 64.4→82.4°F
Fluke 8300A(10 Vdc Rng)	±0.001005 Vdc	@10Vdc, 68→86°F
Fluke 8500A(10 Vdc Rng)	±0.000180 Vdc	@10Vdc, 64.4→82.4°F
Fluke 8505A(10 Vdc Rng)	±0.000140 Vdc	@10Vdc, 64.4→82.4°F
Fluke 8600A(200 mVdc Rng)	±0.017205 mV	@20 mVdc, 59→95°F
Fluke 8600A(200 mVdc Rng)	±0.022809 mV	@20 mVdc, 104°F
Fluke 8600A(200 mVdc Rng)	±0.034961 mV	@20 mVdc, 122°F
Fluke 8600A(20 Vdc Rng)	±0.001803 Vdc	@10Vdc, 59→95°F
Fluke 8800A(20 Vdc Rng)	±0.000658 Vdc	@10Vdc, 64.4→82.4°F
Fluke 8810A(20 Vdc Rng)	±0.000658 Vdc	@10Vdc, 64.4→82.4°F
Fluke 8840A Slo(20 Vdc Rng)	±0.000461 Vdc	@10Vdc, 64.4→82.4°F
Fluke 8840A Med(20 Vdc Rng)	±0.000559 Vdc	@10Vdc, 64.4→82.4°F
Fluke 8840A Fst(20 Vdc Rng)	±0.002059 Vdc	@10Vdc, 64.4→82.4°F

9.1 DMM Measurement Error Evaluations

From Reference 3.5 DMMs are used to measure the voltage of various signals during calibration of the analog and trip functions. Therefore, each DMM which is either specified or acceptable for use in these applications will be evaluated on the appropriate Vdc scale and at the maximum voltage to be read.

FLUKE 45 MEDIUM READING RATE RANGE: 30 Vdc

Manufacturer's Specifications

Reference Accuracy[†] (RA) = ±(0.025%(RDG) + 2(digits)) [2σ]
Resolution (RES) = 0.001 V
Temperature Effect[*] (TE) = ±(0.1(Accuracy Spec.)/°C)(ΔT) [2σ]

[†] 1 Year Accuracy Specification
[*] From 0 °C to 18 °C and 28 °C to 50 °C

Temperature Differential (ΔT)

64.4 → 82.4 °F (18 → 28 °C) Temperature Effect Not Applicable
104 °F = 40.0 °C ⇒ ΔT = (40.0 - 28.0)°C = 12.0 °C
122 °F = 50.0 °C ⇒ ΔT = (50.0 - 28.0)°C = 22.0 °C

Total Measurement Error (MTE)

$$MTE = \pm[(RA/2 + TE/2)^2 + RES^2]^{\frac{1}{2}} \quad [1\sigma]$$

Maximum Zone Temp.	MTE at RDG = 10 V	MTE at RDG = 30 V
64.4 → 82.4 °F	± 0.002462 V	± 0.004854 V
104 °F	± 0.005050 V	± 0.010498 V
122 °F	± 0.007269 V	± 0.015233 V

FLUKE 8050A **RANGE: 20 Vdc**

Manufacturer's Specifications

Reference Accuracy[†] (RA) = ±(0.03%(RDG) + 2(digits)) [2σ]
Resolution (RES) = 0.001 V
Temperature Effect[*] (TE) = ±(0.1(Accuracy Spec.)/°C)(ΔT) [2σ]

[†] 1 Year Accuracy Specification
[*] From 0 °C to 18 °C and 28 °C to 50 °C

Temperature Differential (ΔT)

64.4 → 82.4 °F (18 → 28 °C) Temperature Effect Not Applicable
104 °F = 40.0 °C ⇒ ΔT = (40.0 - 28.0)°C = 12.0 °C
122 °F = 50.0 °C ⇒ ΔT = (50.0 - 28.0)°C = 22.0 °C

Total Measurement Error (MTE)

$$MTE = \pm[(RA/2 + TE/2)^2 + RES^2]^{½} \quad [1\sigma]$$

Maximum Zone Temp.		MTE at RDG = 10 V	MTE at RDG = 20 V
64.4 → 82.4	°F	± 0.002693 V	± 0.004123 V
104	°F	± 0.005590 V	± 0.008857 V
122	°F	± 0.008062 V	± 0.012839 V

FLUKE 8060A **RANGE: 20 Vdc**

Manufacturer's Specifications

Reference Accuracy[†] (RA) = ±(0.05%(RDG) + 2(digits)) [2σ]
Resolution (RES) = 0.001 V
Temperature Effect[*] (TE) = ±(0.1(Accuracy Spec.)/°C)(ΔT) [2σ]

[†] 1 Year Accuracy Specification
[*] From 0 °C to 18 °C and 28 °C to 50 °C

Temperature Differential (ΔT)

64.4 → 82.4 °F (18 → 28 °C) Temperature Effect Not Applicable
104 °F = 40.0 °C ⇒ ΔT = (40.0 - 28.0)°C = 12.0 °C
122 °F = 50.0 °C ⇒ ΔT = (50.0 - 28.0)°C = 22.0 °C

Total Measurement Error (MTE)

$$MTE = \pm[(RA/2 + TE/2)^2 + RES^2]^{½} \quad [1\sigma]$$

Maximum Zone Temp.		MTE at RDG = 10 V	MTE at RDG = 20 V
64.4 → 82.4	°F	± 0.003640 V	± 0.006083 V
104	°F	± 0.007765 V	± 0.013238 V
122	°F	± 0.011245 V	± 0.019226 V

FLUKE 8300A **RANGE: 10 Vdc**

Manufacturer's Specifications

Ref. Accuracy† (RA) = $\pm(0.015\%(\text{RDG}) + 0.005\%(\text{RNG}))$ [2σ]
Resolution (RES) = 0.0001 V
Temp. Effect* (TE) = $\pm((0.0007\%(\text{RDG}) + 0.0003\%(\text{RNG}))/°\text{C})(\Delta T)$ [2σ]

† 1 Year Accuracy Specification
* From 0 °C to 20 °C and 30 °C to 50 °C

Temperature Differential (ΔT)

68 → 86 °F (20 → 30 °C) Temperature Effect Not Applicable
104 °F = 40.0 °C ⇒ $\Delta T = (40.0 - 30.0)°\text{C} = 10.0\ °\text{C}$
122 °F = 50.0 °C ⇒ $\Delta T = (50.0 - 30.0)°\text{C} = 20.0\ °\text{C}$

Total Measurement Error (MTE)

$$\text{MTE} = \pm[(\text{RA}/2 + \text{TE}/2)^2 + \text{RES}^2]^{½} \quad [1\sigma]$$

Maximum Zone Temp.	MTE at RDG = 2 V	MTE at RDG = 10 V
68 → 86 °F	± 0.000412 V	± 0.001005 V
104 °F	± 0.000628 V	± 0.001503 V
122 °F	± 0.000846 V	± 0.002003 V

FLUKE 8500A **5½ DIGIT RESOLUTION** **RANGE: 10 Vdc**

Manufacturer's Specifications

Ref. Accuracy† (RA) = $\pm(0.002\%(\text{RDG}) + 1(\text{digit}))$ [2σ]
Resolution (RES) = 0.0001 V
Temp. Effect* (TE) = $\pm((0.0002\%(\text{RDG}) + 0.5(\text{digit}))/°\text{C})(\Delta T)$ [2σ]

† 1 Year Accuracy Specification
* From 0 °C to 18 °C and 28 °C to 50 °C

Temperature Differential (ΔT)

64.4 → 82.4 °F (18 → 28 °C) Temperature Effect Not Applicable
104 °F = 40.0 °C ⇒ $\Delta T = (40.0 - 28.0)°\text{C} = 12.0\ °\text{C}$
122 °F = 50.0 °C ⇒ $\Delta T = (50.0 - 28.0)°\text{C} = 22.0\ °\text{C}$

Total Measurement Error (MTE)

$$\text{MTE} = \pm[(\text{RA}/2 + \text{TE}/2)^2 + \text{RES}^2]^{½} \quad [1\sigma]$$

Maximum Zone Temp.	MTE at RDG = 2 V	MTE at RDG = 10 V
64.4 → 82.4 °F	± 0.000122 V	± 0.000180 V
104 °F	± 0.000406 V	± 0.000579 V
122 °F	± 0.000671 V	± 0.000925 V

COMMONWEALTH EDISON COMPANY

CALCULATION NO. L-001345		PAGE 37 of 191

FLUKE 8600A **RANGE: 200 mVdc**

Manufacturer's Specifications

Ref. Accuracy† (RA) = ±(0.04%(RDG) + 0.01%(RNG)) [2σ]
Resolution (RES) = 0.01 mV
Temp. Effect* (TE) = ±((0.003%(RDG) + 0.001%(RNG))/°C)(ΔT) [2σ]

† 6 Month Accuracy Specification
* From 0 °C to 15 °C and 35 °C to 50 °C

Temperature Differential (ΔT)

59 → 95 °F (15 → 35 °C) Temperature Effect Not Applicable
104 °F = 40.0 °C ⇒ ΔT = (40.0 - 35.0)°C = 5.0 °C
122 °F = 50.0 °C ⇒ ΔT = (50.0 - 35.0)°C = 15.0 °C

Total Measurement Error (MTE)

$$MTE = \pm[(RA/2 + TE/2)^2 + RES^2]^{1/2} \quad [1\sigma]$$

Maximum Zone Temp.		MTE at RDG = 20 mV	MTE at RDG = 50 mV
59 → 95	°F	± 0.017205 mV	± 0.022361 mV
104	°F	± 0.022809 mV	± 0.030439 mV
122	°F	± 0.034961 mV	± 0.047319 mV

FLUKE 8600A **RANGE: 20 Vdc**

Manufacturer's Specifications

Ref. Accuracy† (RA) = ±(0.02%(RDG) + 0.005%(RNG)) [2σ]
Resolution (RES) = 0.001 V
Temp. Effect* (TE) = ±((0.001%(RDG) + 0.0005%(RNG))/°C)(ΔT) [2σ]

† 6 Month Accuracy Specification
* From 0 °C to 15 °C and 35 °C to 50 °C

Temperature Differential (ΔT)

59 → 95 °F (15 → 35 °C) Temperature Effect Not Applicable
104 °F = 40.0 °C ⇒ ΔT = (40.0 - 35.0)°C = 5.0 °C
122 °F = 50.0 °C ⇒ ΔT = (50.0 - 35.0)°C = 15.0 °C

Total Measurement Error (MTE)

$$MTE = \pm[(RA/2 + TE/2)^2 + RES^2]^{1/2} \quad [1\sigma]$$

Maximum Zone Temp.		MTE at RDG = 10 V	MTE at RDG = 20 V
59 → 95	°F	± 0.001803 V	± 0.002693 V
104	°F	± 0.002236 V	± 0.003400 V
122	°F	± 0.003162 V	± 0.004854 V

REVISION NO.	0			

FLUKE 8800A **RANGE:** **20 Vdc**

Manufacturer's Specifications

Ref. Accuracy[†] (RA) = $\pm(0.01\%(\text{RDG}) + 0.0015\%(\text{RNG}))$ [2σ]
Resolution (RES) = 0.0001 V
Temp. Effect[*] (TE) = $\pm((0.0007\%(\text{RDG}) + 0.0002\%(\text{RNG}))/°\text{C})(\Delta T)$ [2σ]

† 90 Day Accuracy Specification
* From 0 °C to 18 °C and 28 °C to 50 °C

Temperature Differential (ΔT)

64.4 → 82.4 °F (18 → 28 °C) Temperature Effect Not Applicable
104 °F = 40.0 °C ⇒ $\Delta T = (40.0 - 28.0)°\text{C} = 12.0\ °\text{C}$
122 °F = 50.0 °C ⇒ $\Delta T = (50.0 - 28.0)°\text{C} = 22.0\ °\text{C}$

Total Measurement Error (MTE)

$$\text{MTE} = \pm[(\text{RA}/2 + \text{TE}/2)^2 + \text{RES}^2]^{½} \quad [1\sigma]$$

Maximum Zone Temp.	MTE at RDG = 10 V	MTE at RDG = 20 V
64.4 → 82.4 °F	± 0.000658 V	± 0.001154 V
104 °F	± 0.001314 V	± 0.002232 V
122 °F	± 0.001863 V	± 0.003132 V

FLUKE 8810A **RANGE:** **20 Vdc**

Manufacturer's Specifications

Reference Accuracy[†] (RA) = $\pm(0.01\%(\text{RDG}) + 3(\text{digits}))$ [2σ]
Resolution (RES) = 0.0001 V
Temperature Effect[*] (TE) = $\pm((0.0007\%(\text{RDG}) + 1(\text{digit}))/°\text{C})(\Delta T)$ [2σ]

† 90 Day Accuracy Specification
* From 0 °C to 18 °C and 28 °C to 50 °C

Temperature Differential (ΔT)

64.4 → 82.4 °F (18 → 28 °C) Temperature Effect Not Applicable
104 °F = 40.0 °C ⇒ $\Delta T = (40.0 - 28.0)°\text{C} = 12.0\ °\text{C}$
122 °F = 50.0 °C ⇒ $\Delta T = (50.0 - 28.0)°\text{C} = 22.0\ °\text{C}$

Total Measurement Error (MTE)

$$\text{MTE} = \pm[(\text{RA}/2 + \text{TE}/2)^2 + \text{RES}^2]^{½} \quad [1\sigma]$$

Maximum Zone Temp.	MTE at RDG = 10 V	MTE at RDG = 20 V
64.4 → 82.4 °F	± 0.000658 V	± 0.001154 V
104 °F	± 0.001673 V	± 0.002592 V
122 °F	± 0.002522 V	± 0.003791 V

FLUKE 8840A SLOW READING RATE RANGE: 20 Vdc

Manufacturer's Specifications

Ref. Accuracy† (RA) = ±(0.006%(RDG) + 3(digits)) [2σ]
Resolution (RES) = 0.0001 V
Temp. Effect* (TE) = ±((0.0006%(RDG) + 0.3(digits))/°C)(ΔT) [2σ]

† 1 Year Accuracy Specification
* From 0 °C to 18 °C and 28 °C to 50 °C

Temperature Differential (ΔT)

64.4 → 82.4 °F (18 → 28 °C) Temperature Effect Not Applicable
104 °F = 40.0 °C ⇒ ΔT = (40.0 - 28.0)°C = 12.0 °C
122 °F = 50.0 °C ⇒ ΔT = (50.0 - 28.0)°C = 22.0 °C

Total Measurement Error (MTE)

$$MTE = \pm[(RA/2 + TE/2)^2 + RES^2]^{1/2} \quad [1\sigma]$$

Maximum Zone Temp.		MTE at RDG = 10 V	MTE at RDG = 20 V
64.4 → 82.4	°F	± 0.000461 V	± 0.000757 V
104	°F	± 0.000995 V	± 0.001653 V
122	°F	± 0.001443 V	± 0.002402 V

FLUKE 8840A MEDIUM READING RATE RANGE: 20 Vdc

Manufacturer's Specifications

Ref. Accuracy† (RA) = ±(0.006%(RDG) + 5(digits)) [2σ]
Resolution (RES) = 0.0001 V
Temp. Effect* (TE) = ±((0.0006%(RDG) + 0.3(digits))/°C)(ΔT) [2σ]

† 1 Year Accuracy Specification
* From 0 °C to 18 °C and 28 °C to 50 °C

Temperature Differential (ΔT)

64.4 → 82.4 °F (18 → 28 °C) Temperature Effect Not Applicable
104 °F = 40.0 °C ⇒ ΔT = (40.0 - 28.0)°C = 12.0 °C
122 °F = 50.0 °C ⇒ ΔT = (50.0 - 28.0)°C = 22.0 °C

Total Measurement Error (MTE)

$$MTE = \pm[(RA/2 + TE/2)^2 + RES^2]^{1/2} \quad [1\sigma]$$

Maximum Zone Temp.		MTE at RDG = 10 V	MTE at RDG = 20 V
64.4 → 82.4	°F	± 0.000559 V	± 0.000856 V
104	°F	± 0.001095 V	± 0.001753 V
122	°F	± 0.001543 V	± 0.002502 V

FLUKE 8840A **FAST READING RATE** **RANGE: 20 Vdc**

Manufacturer's Specifications

Ref. Accuracy[†] (RA) = ±(0.006%(RDG) + 3(digits)) [2σ]
Resolution (RES) = 0.001 V
Temp. Effect[*] (TE) = ±((0.0006%(RDG) + 0.3(digits))/°C)(ΔT) [2σ]

† 1 Year Accuracy Specification
* From 0 °C to 18 °C and 28 °C to 50 °C

Temperature Differential (ΔT)

64.4 → 82.4 °F (18 → 28 °C) Temperature Effect Not Applicable
104 °F = 40.0 °C ⇒ ΔT = (40.0 - 28.0)°C = 12.0 °C
122 °F = 50.0 °C ⇒ ΔT = (50.0 - 28.0)°C = 22.0 °C

Total Measurement Error (MTE)

$$MTE = \pm[(RA/2 + TE/2)^2 + RES^2]^{1/2} \quad [1\sigma]$$

Maximum Zone Temp.	MTE at RDG = 10 V	MTE at RDG = 20 V
64.4 → 82.4 °F	± 0.002059 V	± 0.002326 V
104 °F	± 0.004084 V	± 0.004727 V
122 °F	± 0.005846 V	± 0.006794 V

9.2 Pressure Measurement Error Evaluation

References 3.5.s and 3.5.t specify the use of a "Pneumatic Calibrator, 0-850" W.C. (Accuracy: ±2.0" W.C., minimum)." Discussions with site personnel (Reference 3.16) revealed that the instrument used at LaSalle is from Wallace & Tiernan and has a minor scale division of 1" W.C. Of the two possible instruments listed in Reference 3.4 only Model 65-120 meets the accuracy requirement of the procedure at the environmental conditions where it will be used, and then only if the procedural accuracy is considered to be a one sigma value. Also, Reference 3.4 does not indicate that this instrument is used at LaSalle, only at Quad Cities.

WALLACE & TIERNAN MODEL 65-120 -100 "WC to 850 "WC

Manufacturer's Specifications

Reference Accuracy (RA) = $\pm(2)(0.1\%(\text{RNG}))$ [2σ]
Minor Division (MD) = 1.0 "WC
Temperature Effect* (TE) = $\pm(0.1\%(\text{RNG})/10\ ^\circ\text{C})(\Delta T)$ [2σ]
* Referred to 25 °C

Calibrated Accuracy - RA Rounded Up To Nearest Minor Division

RA = $\pm(2)(0.1\%(\text{RNG}))$ = ± 1.9 "WC
Calibrated Accuracy (CA) = ± 2.0 "WC

Temperature Differential (ΔT)

77 °F = 25.0 °C ⇒ ΔT = (25.0 - 25.0) °C = 0.0 °C
104 °F = 40.0 °C ⇒ ΔT = (40.0 - 25.0) °C = 15.0 °C
120 °F = 48.9 °C ⇒ ΔT = (48.9 - 25.0) °C = 23.9 °C

Total Measurement Error (MTE)

$$\text{MTE} = \pm[(\text{CA}/2 + \text{TE}/2)^2 + (\text{MD}/4)^2]^{1/2} \quad [1\sigma]$$

Maximum Zone Temperature	MTE
77 °F	± 1.030776 "WC
104 °F	± 1.730652 "WC
120 °F	± 2.149835 "WC

10.0 CALIBRATION PROCEDURE DATA

The loop calibration procedures (Reference 3.5) provide the following information. Information on Nominal Trip Setpoint and Allowable Value (Tech Spec LCO) come from the Technical Specifications (Reference 3.7) or, for the RBM, the Core Operating Limits Reports (Reference 3.15).

10.1 Flow Transmitter Calibration

The calibrated span for all flow transmitters represents 0 to 55,000 GPM (Section 7.0).

For FT-1B33-N014A/B/C/D and FT-1B33-N024C/D

Test Inputs:	0 to 387.1" W.C.
Input Tolerance:	None Given
Desired Output:	4 to 20 mVdc
Output Tolerance:	±0.080 mV

For FT-1B33-N024A/B

Test Inputs:	25.5 to 272.9" W.C.
Input Tolerance:	None Given
Desired Output:	4 to 20 mVdc
Output Tolerance:	±0.080 mV

For FT-2B33-N014A/B

Test Inputs:	0 to 390.4" W.C.
Input Tolerance:	None Given
Desired Output:	4 to 20 mVdc
Output Tolerance:	±0.080 mV

For FT-2B33-N014C/D and FT-2B33-N024A/B

Test Inputs:	0 to 410.7" W.C.
Input Tolerance:	None Given

Desired Output: 4 to 20 mVdc

Output Tolerance: ±0.080 mV

For FT-2B33-N024C/D

Test Inputs: 0 to 448.7" W.C.

Input Tolerance: None Given

Desired Output: 4 to 20 mVdc

Output Tolerance: ±0.080 mV

10.2 Square Root Converter Calibration

Test Inputs: 4 to 20 mVdc

Input Tolerance: ±0.050 mV

Desired Output: 0 to 10 Vdc

Output Tolerance: ±0.025 V

10.3 Flow Summer Calibration

<u>Analog Circuitry</u>

Test Inputs: 7.660 Vdc
1.000 Vdc

Input Tolerance: ±0.010 V

Desired Output: 8.000 Vdc
1.044 Vdc

Output Tolerance: ±0.010 V

Correlation to Computer Calculated Flow: +0.0, -0.05 Vdc

<u>Upscale Trip</u>

Instrument Setpoint: 8.630 Vdc (increasing)

Allowable Range: 8.530 to 8.730 Vdc (±0.10 Vdc)*

Nominal Trip Setpoint: ≤108% Flow (8.640 Vdc)

Tech Spec LCO: ≤111% Flow (8.88 Vdc)

Analytic Limit: ≤116% Flow (Reference 3.27)

Comparator Trip

Test Input: 8.000 Vdc (100% Flow)

Input Tolerance: ±0.010 V

Instrument Setpoint: 8.790 Vdc (increasing)
Allowable Range: 8.710 to 8.870 Vdc (±0.080 Vdc)*

Instrument Setpoint: 7.210 Vdc (decreasing)
Allowable Range: 7.130 to 7.290 Vdc (±0.080 Vdc)*

Nominal Trip Setpoint: ≤10% Flow Deviation (±0.8 Vdc)

Tech Spec LCO: ≤11% Flow Deviation (±0.88 Vdc)

Analytic Limit: ≤19% Flow (Reference 3.27)

*Note: The setting tolerance for theupscale (±0.1 Vdc) and comparator trip (±0.08 Vdc) are proposed values that will be analyzed by this calculation. The calibration procedure may incorporate tolerances less than or equal to the proposed values.

10.4 APRM Calibration - Note: The following reflects current information that will change as a result of this calculation and the implementation of power uprate (Reference 3.33).

AGAF Adjustment

AGAF Setpoint: 1.00
Allowable Range: 0.98 to 1.02 (±0.02)

Neutron Flux High (Rod Block) - Setdown

Instrument Setpoint: 0.920 Vdc (11.5%)
Allowable Range: 0.880 to 0.960 Vdc (±0.040 Vdc)
Nominal Trip Setpoint: ≤12%
Tech Spec LCO: ≤14% (1.120 Vdc)
Analytic Limit: ≤19% (Reference 3.27)

Neutron Flux High (Scram) - Setdown

Instrument Setpoint: 1.160 Vdc (14.5%)
Allowable Range: 1.120 to 1.200 Vdc (±0.040 Vdc)

Nominal Trip Setpoint: ≤15%

Tech Spec LCO: ≤20% (1.600 Vdc)

Analytic Limit: 25% (Reference 3.27)

Neutron Flux High (Scram)

Instrument Setpoint: 9.400 Vdc (117.5%)

Allowable Range: 9.360 to 9.440 Vdc (±0.040 Vdc)

Nominal Trip Setpoint: ≤118%

Tech Spec LCO: ≤120% (9.600 Vdc)

Analytic Limit: 124.2% (Reference 3.27)

Flow Biased Simulated Thermal Power - Upscale (Scram) Two Recirculation Loop Operation

Instrument Setpoint: 8.390 Vdc (104.9%)
(80% Flow)
Allowable Range: 8.350 to 8.430 Vdc (±0.040 Vdc)

Nominal Trip Setpoint: ≤0.58W + 59%

Tech Spec LCO: ≤0.58W + 62%

Analytic Limit: To be calculated in Section 13.

Flow Biased Simulated Thermal Power - Upscale (Scram) Single Recirculation Loop Operation

Instrument Setpoint: 8.010 Vdc (100.1%)
(80% Flow)
Allowable Range: 7.970 to 8.050 Vdc (±0.040 Vdc)

Nominal Trip Setpoint: ≤0.58W + 54.3%

Tech Spec LCO: ≤0.58W + 57.3%

Analytic Limit: To be calculated in Section 13.

Flow Biased Simulated Thermal Power - Upscale Clamp (Scram) Two Recirculation Loop Operation

Instrument Setpoint: 9.040 Vdc (113%)

Allowable Range: 9.000 to 9.080 Vdc (±0.040 Vdc)

Nominal Trip Setpoint: ≤113.5%

Tech Spec LCO: ≤115.5% (9.240 Vdc)

Analytic Limit: To be calculated in Section 13.

Flow Biased Simulated Thermal Power - Upscale Clamp (Scram) Single Recirculation Loop Operation

Instrument Setpoint: 9.040 Vdc (113%)

Allowable Range: 9.000 to 9.080 Vdc (±0.040 Vdc)

Nominal Trip Setpoint: ≤113.5%

Tech Spec LCO: ≤115.5% (9.240 Vdc)

Analytic Limit: To be calculated in Section 13.

Flow Biased Simulated Thermal Power - Upscale (Rod Block) Two Recirculation Loop Operation

Instrument Setpoint: (80% Flow) 7.430 Vdc (92.9%)
Allowable Range: 7.390 to 7.470 Vdc (±0.040 Vdc)

Nominal Trip Setpoint: ≤0.58W + 47%

Tech Spec LCO: ≤0.58W + 50%

Analytic Limit: To be calculated in Section 13.

Flow Biased Simulated Thermal Power - Upscale (Rod Block) Single Recirculation Loop Operation

Instrument Setpoint: (80% Flow) 7.050 Vdc (88.1%)
Allowable Range: 7.010 to 7.090 Vdc (±0.040 Vdc)

Nominal Trip Setpoint: ≤0.58W + 42.3%

Tech Spec LCO: ≤0.58W + 45.3%

Analytic Limit: To be calculated in Section 13.

Neutron Flux Downscale (Rod Block)

Instrument Setpoint: 0.440 Vdc (5.5%)

Allowable Range: 0.400 to 0.480 Vdc (±0.040 Vdc)

Nominal Trip Setpoint: ≥5%

Tech Spec LCO: ≥3% (0.240 Vdc)

Analytic Limit: 0% (Reference 3.27)

10.5 RBM Calibration

RBM Upscale (Two Recirculation Loop Operation)

Instrument Setpoint: (100% Flow) 8.84 Vdc (110.5%)
Allowable Range: 8.80 to 8.88 Vdc (±0.040 Vdc)

Nominal Trip Setpoint: (Reference 3.15) ≤0.66W + 45% (111%)
Tech Spec LCO: (Reference 3.15) ≤0.66W + 48% (114%)
Analytic Limit: To be calculated in Section 13.

RBM Upscale (Single Recirculation Loop Operation)

Instrument Setpoint: (100% Flow) 8.09 Vdc (101.7%)
Allowable Range: 8.05 to 8.13 Vdc (±0.040 Vdc)

Nominal Trip Setpoint: (Reference 3.15) ≤0.66W + 39.7% (105.7%)
Tech Spec LCO: (Reference 3.15) ≤0.66W + 42.7% (108.7%)
Analytic Limit: To be calculated in Section 13.

RBM Downscale

Instrument Setpoint: 0.404 Vdc

Allowable Range: 0.400 to 0.408 Vdc (±0.004 Vdc)

Nominal Trip Setpoint: ≥5% (0.400)

Tech Spec LCO: ≥3% (0.240)

Analytic Limit: 0% (Reference 3.27)

11.0 MODULE ERRORS

11.1 Module 1 (Flow Transmitter)

Classification of Module

Since Module 1 is a flow transmitter, its input and output are both analog signals. Therefore, Module 1 is classified as an analog module.

11.1.1 Module 1 Random Error ($\sigma 1$)

This section addresses random uncertainties that have the potential to be expressed in the output of Module 1.

11.1.1.1 Reference Accuracy (RA1)

Per Section 8.1.1 the reference accuracy for the flow transmitters is

RA1 = 0.25% CS (calibrated span)

Per Assumption 5.1, this is assumed to be a 2 sigma value. This is then converted to a 1 sigma value by dividing by 2.

$RA1_{(1\sigma)} = \pm RA1/2$ % CS

$RA1_{(1\sigma)} = \pm 0.25/2$ % CS

$RA1_{(1\sigma)} = \pm 0.125\%$ CS

11.1.1.2 Drift (RD1)

Per Reference 3.8 drift is considered a random variable for this calculation. Section 8.1.1 gives a value of ±0.2%UR (upper range) per 30 months for vendor drift (RD_{FT}). In order to keep all error terms as a function of calibrated span, UR can be converted to CS by multiplying UR by CS/CS resulting in UR equaling (UR/CS)*CS. Using this gives

$RD1 = \pm RD_{FT}\%*(UR/CS)*CS$

$RD1 = \pm 0.2*(750/247.4)\%$ CS

$RD1 = \pm 0.606306\%$ CS

Per Assumption 5.1, this is assumed to be a 2 sigma value. This is then converted to a 1 sigma value by dividing by 2.

$$RD1_{(1\sigma)} = \pm RD1/2 \text{ \% CS}$$

$$RD1_{(1\sigma)} = \pm 0.606306/2 \text{ \% CS}$$

$$RD1_{(1\sigma)} = \pm 0.303153\text{\% CS}$$

Table 4.3.6-1 of Reference 3.7 indicates a surveillance interval of 13 weeks (Quarterly) for this instrument loop. However, as stated in Section 2.1.b the drift error term will not be reduced even though the surveillance interval is shorter than the period for which the vendor drift value applies.

11.1.1.3 Calibration Uncertainty (CAL1)

The uncertainties associated with calibrating the flow transmitters are composed of the uncertainties in setting the input signal and the uncertainties in reading the output signal. References 3.5.s and 3.5.t do not give a particular instrument to be used for setting the input during calibration. Rather, they simply indicate a "Pneumatic Calibrator, 0-850" W.C. (accuracy: ±2.0" W.C., minimum)" is required. Per Assumption 5.11 LaSalle is assumed to be using a Wallace and Tiernan Model 65-120 instrument for this input monitoring function. For the maximum temperature applicable to this location the accuracy given by Reference 3.4 for this instrument is 2.149835" W.C. This is the value that will be used in this calculation. The reading error term ($REMTE1_{FT}$) is included in total MTE error term given in Reference 3.4. Therefore, a value of 0 will be used for $REMTE1_{FT}$ for this calculation.

The instrument specified by the procedures for measurement of the flow transmitter output is a Fluke 8600A DMM. For the voltage range of interest for this calculation the reference accuracy, from Reference 3.4, is 0.034961 mVdc. ($RAMTE2_{FT}$). Since this is a digital instrument, there is no reading error associated with its use ($REMTE2_{FT} = 0$).

The voltage at the flow transmitter output is measured across a precision one ohm resistor which Reference 3.16 indicates is accurate to 0.005%. This means that the maximum voltage error induced by the resistor is 0.00005×20 mV or 0.001 mV. Since vendor accuracies are considered two sigma values, it must be divided by 2 to be compared with the DMM accuracy value ($RAMTE2_{FT}$). The one sigma error is then 0.0005 mVdc. This is a factor of more than 30 less than the DMM error term so it can be ignored in the calculation.

From Reference 3.3,

$$MTE1 = [(RAMTE1/n)^2 + REMTE1^2]^{0.5}$$

where n is the number of standard deviations applicable to the error term. Reference 3.4 gives a value of 1 for n for both the input and output test instruments.

For this calculation

$$MTE1_{FT} = \pm[(RAMTE1_{FT}/n)^2 + REMTE1_{FT}{}^2]^{0.5} \text{ "WC}$$

$$MTE1_{FT} = \pm[(2.149835/1)^2 + 0^2]^{0.5} \text{ "WC}$$

$$MTE1_{FT} = \pm 2.149835 \text{ "WC}$$

In order to make this term compatible with the other error terms it must be converted to %CS by dividing by the span and multiplying by 100.

$$MTE1_{FT(CS)} = \pm(MTE1_{FT}/CS_{FT})*100 \text{ \% CS}$$

$$MTE1_{FT(CS)} = \pm(2.149835/247.4)*100 \text{ \% CS}$$

$$MTE1_{FT(CS)} = \pm 0.868971\text{\% CS}$$

The output error $MTE2_{FT}$ is determined in the same way as was the input error.

$$MTE2_{FT} = \pm[(RAMTE2_{FT}/n)^2 + REMTE2_{FT}{}^2]^{0.5} \text{ mVdc}$$

$$MTE2_{FT} = \pm[(0.034961/1)^2 + 0^2]^{0.5} \text{ mVdc}$$

$$MTE2_{FT} = \pm 0.034961 \text{ mVdc}$$

This also must be converted to % CS by dividing by the output span ($CS_{FT(OUT)}$) and multiplying by 100.

$$MTE2_{FT(CS)} = \pm(MTE2_{FT}/CS_{FT(OUT)})*100 \text{ \% CS}$$

$$MTE2_{FT(CS)} = \pm(0.034961/16)*100 \text{ \% CS}$$

$$MTE2_{FT(CS)} = \pm 0.218506\text{\% CS}$$

From Section 5.2 the error attributed to the calibration standards is considered negligible. Therefore, the only terms which contribute to CAL1 are MTE1 and MTE2. For this calculation

$$CAL1_{FT} = \pm[(MTE1_{FT(CS)})^2 + (MTE2_{FT(CS)})^2]^{0.5} \text{ \% CS}$$

$$CAL1_{FT} = \pm[0.868971^2 + 0.218506^2]^{0.5}$$

$$CAL1_{FT} = \pm0.896022\text{\% CS}$$

11.1.1.4 Setting Tolerance (ST1)

The setting tolerance for the flow transmitters is the combination of the input and output setting tolerances. From References 3.5.s and 3.5.t the setting tolerance for the flow transmitters' output ($ST_{FT(OUT)}$) is 0.08 mVdc. No setting tolerance is given in the procedures for the input instrument. Therefore, the input setting tolerance ($ST_{FT(IN)}$) used for this calculation will be one half of one minor division which, from References 3.4 and 3.16, would be 0.5" WC.

Both of these setting tolerance terms will now be converted to % CS by dividing by the appropriate span and multiplying by 100.

$$ST_{FT(IN)(CS)} = \pm(ST_{FT(IN)}/CS_{FT})*100 \text{ \% CS}$$

$$ST_{FT(IN)(CS)} = \pm(0.5/247.4)*100 \text{ \% CS}$$

$$ST_{FT(IN)(CS)} = \pm0.202102\text{\% CS}$$

$$ST_{FT(OUT)(CS)} = \pm(ST_{FT(OUT)}/CS_{FT(OUT)})*100 \text{ \% CS}$$

$$ST_{FT(OUT)(CS)} = \pm(0.08/16)*100 \text{ \% CS}$$

$$ST_{FT(OUT)(CS)} = \pm0.5\text{\% CS}$$

The total setting tolerance for the flow transmitters is the combination of these two terms by SRSS. Also, from Section 2.1.a these are considered 3 sigma values and must, therefore, be divided by 3 to make them compatible with the other 1 sigma error terms. The total setting tolerance $ST1_{(1\sigma)}$ is then

$$ST1_{(1\sigma)} = \pm[(ST_{FT(IN)(CS)}/3)^2 + (ST_{FT(OUT)(CS)}/3)^2]^{0.5} \text{ \% CS}$$

$$ST1_{(1\sigma)} = \pm[(0.202102/3)^2 + (0.5/3)^2]^{0.5} \text{ \% CS}$$

$$ST1_{(1\sigma)} = \pm0.179767\text{\% CS}$$

11.1.1.5 Static Pressure Span Effect (Correction Uncertainty) ($SPSE_{FT}$)

References 3.5.s and 3.5.t state that a 1% of span correction has been included in the calibration to compensate for the static pressure span effect. However, Reference 3.14 states that there is a plus/minus correction uncertainty associated with this compensation. Therefore, this uncertainty will be included as a random error term in this calculation. Although the vendor gives this error term as a percent of reading, it will be considered as percent calibrated span which simplifies the calculation and is conservative.

$$SPSE_{FT} = \pm 0.25\%\ CS/1000\ psi$$

Since the normal operating pressure is very near 1000 psi (1025 psi from Section 7.0) this value will be used as is.

This must now be divided by 2 since the manufacturer's data is considered a 2 sigma value.

$$SPSE_{FT(1\sigma)} = \pm SPSE_{FT}/2\ \%\ CS$$

$$SPSE_{FT(1\sigma)} = \pm 0.25/2\ \%\ CS$$

$$SPSE_{FT(1\sigma)} = \pm 0.125\%\ CS$$

11.1.1.6 Static Pressure Zero Effect ($SPZE_{FT}$)

For this device the vendor lists a Static Pressure Zero Effect of ±0.25% UR/2000 psi. This must be multiplied by the actual static pressure ($STAPR_{FT}$) to find the effect for this application. At this time it will also be converted to % CS using the discussion from Section 11.1.2.2 below in order to make it compatible with the other error terms. In addition the result must be divided by 2 in order to make it a 1 sigma value. The result is:

$$SPZE_{FT(1\sigma)} = \pm(SPZE_{FT}/2)(STAPR_{FT}/2000)(UR_{FT}/CS_{FT})\ \%\ CS$$

$$SPZE_{FT(1\sigma)} = \pm(0.25/2)(1025/2000)(750/247.4)\ \%\ CS$$

$$SPZE_{FT(1\sigma)} = \pm 0.194207\%\ CS$$

11.1.1.7 Input Uncertainty (σinput1)

Since module 1 is the first module, there is no input from a previous module. However, per Reference 3.17, there is a 5% error associated with the elbow type flow element. If this is considered a two sigma value, the one sigma value would be 5/2 or 2.5%. This term will be considered the input error. Therefore,

$$\sigma input1 = \pm 2.5\% \text{ CS}$$

Per Section 4.9 this is considered 0 for the Comparator Trip error analysis.

$$\sigma input1_C = 0$$

11.1.1.8 Determination of Module Random Error ($\sigma 1$)

Using the methodology of Reference 3.3,

$$\sigma 1 = \pm[(RA1_{(1\sigma)})^2 + (RD1_{(1\sigma)})^2 + (CAL1_{FT})^2 + (ST1_{(1\sigma)})^2 + (SPSE_{FT(1\sigma)})^2 + (SPZE_{FT(1\sigma)})^2 + (\sigma input1)^2]^{0.5} \% \text{ CS}$$

$$\sigma 1 = \pm[(0.125)^2 + (0.303153)^2 + (0.896022)^2 + (0.179767)^2 +(0.125)^2 + (0.194207)^2 + 2.5^2]^{0.5} \% \text{ CS}$$

$$\sigma 1 = \pm 2.691847\% \text{ CS}$$

For the Comparator Trip:

$$\sigma 1_C = \pm[(RA1_{(1\sigma)})^2 + (RD1_{(1\sigma)})^2 + (CAL1_{FT})^2 + (ST1_{(1\sigma)})^2 + (SPSE_{FT(1\sigma)})^2 + (SPZE_{FT(1\sigma)})^2 + (\sigma input1_C)^2]^{0.5} \% \text{ CS}$$

$$\sigma 1_C = \pm[(0.125)^2 + (0.303153)^2 + (0.896022)^2 + (0.179767)^2 +(0.125)^2 + (0.194207)^2 + 0^2]^{0.5} \% \text{ CS}$$

$$\sigma 1_C = \pm 0.998018\% \text{ CS}$$

11.1.2 Module 1 Non-Random Errors ($\Sigma e1$)

11.1.2.1 Humidity Errors (e1H)

Since Reference 3.14 does not identify a humidity error term a value of zero will be used per Section 4.3.

$$e1H = 0\%\ CS$$

11.1.2.2 Temperature Error (e1T)

From Section 8.1.1 the temperature effect (VTE_{FT}) error of the flow transmitters is a function of both the calibrated span (CS) and the upper range (UR) per 100°F temperature change. From Section 4.2 the maximum temperature at the transmitter during normal operation is expected to be 118°F ($MAXTEMP_{FT}$). From Section 4.6 the minimum calibration temperature for the flow transmitters is considered to be 60°F ($CALTEMP_{FT}$). Using the vendor's equation VTE_{FT} is then

$$VTE_{FT} = \pm(0.5\%UR + 0.5\%CS) \text{ per } 100°F$$

In order to keep all error terms as a function of calibrated span, UR can be converted to CS by multiplying UR by CS/CS resulting in UR equaling (UR/CS)*CS. Using this in the above equation gives

$$VTE_{FT} = \pm[0.5\%(UR_{FT}/CS_{FT}) + 0.5]*[(MAXTEMP_{FT}-CALTEMP_{FT})/100]\%CS_{FT}$$

For this calculation VTE_{FT} equals e1T. Therefore,

$$e1T = \pm[0.5\%(UR_{FT}/CS_{FT}) + 0.5]*[(MAXTEMP_{FT}-CALTEMP_{FT})/100]\%\ CS_{FT}$$

$$e1T = \pm[0.5(750/247.4) + 0.5]*[(118-60)/100]\%\ CS$$

$$e1T = \pm1.169143\%\ CS$$

11.1.2.3 Radiation Error (e1R)

Section 8.1.1 gives a radiation effect that is applicable to and following accident conditions. Since this calculation does not apply to accident conditions, and since the transmitters are being calibrated at an interval during which the TID is insignificant (maintenance personnel calibrate the transmitters in place) the radiation error for this calculation is insignificant and does not provide any radiation induced error specifications. Therefore, per Assumption 5.2 these errors are assumed to be included within the vendor's accuracy terms.

e1R = 0% CS

11.1.2.4 Seismic Error (e1S)

Per Section 4.7 seismic error for this module is considered negligible.

e1S = 0% CS

11.1.2.5 Static Pressure Effect (e1SP)

From References 3.5.s and 3.5.t, these instruments have been compensated for static pressure effect during calibration. Therefore, static pressure effects are considered to be negligible.

e1SP = 0% CS

11.1.2.6 Pressure Error (e1P)

From Section 8.1.2, these instruments are exposed to an environment whose pressure varies only slightly from ambient conditions (1 atmosphere). Therefore, pressure effects are considered to be negligible.

e1P = 0% CS

11.1.2.7 Process Errors(e1p)

References 3.5.f and 3.5.o provide instructions on calibrating the total flow as measured by this instrumentation to the total flow as is calculated by the process computer. Therefore, any process error is compensated for by this calibration.

e1p = 0% CS

11.1.2.8 Power Supply Effects (e1V)

From Section 8.1.1, the power supply effect (PSE_{FT}) given by the vendor is 0.005% CS per volt. References 3.5.s and 3.5.t allow a range (ΔV_{FT}) of 0.5 Vdc for the transmitter power supply, and Reference 3.19 gives this same value (0.02×24 Vdc) as a possible drift amount. This range will be considered the amount by which the power supply can vary.

Therefore,

$$e1V = \pm PSE_{FT} * \Delta V_{FT} \ \% \ CS$$

$$e1V = \pm 0.005 * 0.5 \ \% \ CS$$

$$e1V = \pm 0.0025\% \ CS$$

11.1.2.9 Non-Random Input Error (einput1)

Since this is the first module, the only input is from the flow element. Non-Random error from this device is considered to be zero.

$$einput1 = 0\% \ CS$$

11.1.2.10 Non-Random Error ($\Sigma e1$)

From Reference 3.3 the non-random error is the algebraic sum of all the above terms.

$$\Sigma e1 = \pm(e1H + e1T + e1R + e1S + e1SP + e1P + e1p + e1V + einput1)\% \ CS$$

$$\Sigma e1 = \pm(0 + 1.169143 + 0 + 0 + 0 + 0 + 0 + 0.0025 + 0)\% \ CS$$

$$\Sigma e1 = \pm 1.171643\% \ CS$$

11.2 Module 2 (Square Root Converter)

Classification of Module

Since Module 2 is a square root converter, its input and output are both analog signals. Therefore, Module 2 is classified as an analog module.

11.2.1 Module 2 Random Error ($\sigma 2$)

This section addresses random uncertainties that have the potential to be expressed in the output of Module 2.

11.2.1.1 Reference Accuracy (RA2)

Per Section 8.2.1 the reference accuracy for the square root converter is included in an overall RFM accuracy which will be applied at the output of the Flow Summer (Module 3). Therefore, the reference accuracy (RA2) for this module will be considered

$$RA2 = 0\% \ CS$$

Per Assumption 5.1, this is assumed to be a 2 sigma value. This is then converted to a 1 sigma value by dividing by 2.

$$RA2_{(1\sigma)} = \pm RA2/2 \ \% \ CS$$

$$RA2_{(1\sigma)} = \pm 0/2 \ \% \ CS$$

$$RA2_{(1\sigma)} = \pm 0\% \ CS$$

11.2.1.2 Drift (RD2)

Per Section 8.2.1 the reference drift for the square root converter is included in an overall RFM accuracy which will be applied at the output of the Flow Summer (Module 3). Therefore, the reference drift (RD2) for this module will be considered

$$RD2 = 0\% \ CS$$

Per Assumption 5.1, this is assumed to be a 2 sigma value. This is then converted to a 1 sigma value by dividing by 2.

$$RD2_{(1\sigma)} = RD2/2 \ \% \ CS$$

$$RD2_{(1\sigma)} = 0/2 \ \% \ CS$$

$RD2_{(1\sigma)} = \pm 0\%$ CS

11.2.1.3 Calibration Uncertainty (CAL2)

The uncertainties associated with calibrating the square root converters are composed of the uncertainties in setting the input signal and the uncertainties in reading the output signal. References 3.5.s and 3.5.t specify that Fluke 8600A DMMs be used for measurement of the input and output signals. In addition the input voltage is developed by running a current through a precision one ohm resistor. However, as was determined in Section 11.1.1.3 the uncertainty contributed by the precision resistor itself is much smaller than the uncertainty contributed by the DMM and, therefore, can be ignored.

For the voltage range of interest for the DMM measuring the input voltage the reference accuracy, from Reference 3.4, is 0.017205 mVdc ($RAMTE1_{SR}$). Since this is a digital instrument, there is no reading error associated with its use ($REMTE1_{SR} = 0$).

For the voltage range of interest for the DMM measuring the output voltage the reference accuracy, from Reference 3.4, is 0.001803 Vdc ($RAMTE2_{SR}$). Since this is a digital instrument, there is no reading error associated with its use ($REMTE2_{SR} = 0$).

From Reference 3.3,

$$MTE1 = [(RAMTE1/n)^2 + REMTE1^2]^{0.5}$$

where n is the number of standard deviations applicable to the error term. Reference 3.4 gives a value of 1 for n for both the input and output test instruments.

For this calculation

$$MTE1_{SR} = \pm[(RAMTE1_{SR}/n)^2 + REMTE1_{SR}{}^2]^{0.5} \text{ mVdc}$$

$$MTE1_{SR} = \pm[(0.017205/1)^2 + 0^2]^{0.5} \text{ mVdc}$$

$$MTE1_{SR} = \pm 0.017205 \text{ mVdc}$$

Since the square root converter is not a linear module this value must be converted to an equivalent output value ($MTE1_{SR(OUT)}$) by one of the equations of Section 2.1.c. Also, these equations indicate that the conversion factor is a function of the operating point. Therefore, an operating point must be chosen at which the conversion will take place. For this calculation the operating point is considered to be 6 Vdc (OP_{SR}) at the output of the square root converters which is equal to approximately 75% Flow. Choosing this value is a compromise in that the error term is then conservative at flows greater than 75% but non-conservative at flows less than 75%.

Using Equation 3 from Section 2.1.c the conversion is

$$MTE1_{SR(OUT)} = (3.125*MTE1_{SR})/(OP_{SR})\ Vdc$$

$$MTE1_{SR(OUT)} = (3.125*0.017205)/6\ Vdc$$

$$MTE1_{SR(OUT)} = \pm 0.008961\ Vdc$$

In order to make this term compatible with the other error terms it must be converted to %CS by dividing by the span and multiplying by 100.

$$MTE1_{SR(CS)} = \pm(MTE1_{SR(OUT)}/CS_{SR(OUT)})*100\ \%\ CS$$

$$MTE1_{SR(CS)} = \pm(0.008961/10)*100\ \%\ CS$$

$$MTE1_{SR(CS)} = \pm 0.08961\%\ CS$$

The output error $MTE2_{SR}$ is determined in the same way as was the input error.

$$MTE2_{SR} = \pm[(RAMTE2_{SR}/n)^2 + REMTE2_{SR}{}^2]^{0.5}\ Vdc$$

$$MTE2_{SR} = \pm[(0.001803/1)^2 + 0^2]^{0.5}\ Vdc$$

$$MTE2_{SR} = \pm 0.001803\ Vdc$$

This also must be converted to % CS by dividing by the output span ($CS_{FT(OUT)}$) and multiplying by 100.

$$MTE2_{SR(CS)} = \pm(MTE2_{SR}/CS_{SR(OUT)})*100\ \%\ CS$$

$$MTE2_{SR(CS)} = \pm(0.001803/10)*100\ \%\ CS$$

$$MTE2_{SR(CS)} = \pm 0.01803\%\ CS$$

From Section 5.2 the errors attributed to the calibration standards are considered negligible. Therefore, the only terms which contribute to CAL2 are MTE1 and MTE2. For this calculation

$$CAL2_{SR} = \pm[(MTE1_{SR(CS)})^2 + (MTE2_{SR(CS)})^2]^{0.5} \text{ \% CS}$$

$$CAL2_{SR} = \pm[0.08961^2 + 0.01803^2]^{0.5} \text{ \% CS}$$

$$CAL2_{SR} = \pm 0.091406\text{\% CS}$$

11.2.1.4 Setting Tolerance (ST2)

The setting tolerance for the square root converters is the combination of the input and output setting tolerances. From References 3.5.s and 3.5.t the setting tolerance for the square root converter's input ($ST_{SR(IN)}$) is 0.05 mVdc. The setting tolerance for the square root converter's output ($ST_{SR(OUT)}$) is given as 0.025 Vdc.

The input setting tolerance must now be converted to an equivalent output value as was done in Section 11.2.1.3. The same operating point will also be used. Using Equation 3 from Section 2.1.c, the input setting tolerance converted to the output ($ST_{SR(IN)(OUT)}$) is

$$ST_{SR(IN)(OUT)} = (3.125*ST_{SR(IN)})/OP_{SR} \text{ Vdc}$$

$$ST_{SR(IN)(OUT)} = (3.125*0.05)/6 \text{ Vdc}$$

$$ST_{SR(IN)(OUT)} = 0.026042 \text{ Vdc}$$

Both of these setting tolerance terms will now be converted to % CS by dividing by the square root converter output span and multiplying by 100.

$$ST_{SR(IN)(CS)} = \pm(ST_{SR(IN)(OUT)}/CS_{SR(OUT)})*100 \text{ \% CS}$$

$$ST_{SR(IN)(CS)} = \pm(0.026042/10)*100 \text{ \% CS}$$

$$ST_{SR(IN)(CS)} = \pm 0.26042\text{\% CS}$$

$$ST_{SR(OUT)(CS)} = \pm(ST_{SR(OUT)}/CS_{SR(OUT)})*100 \text{ \% CS}$$

$$ST_{SR(OUT)(CS)} = \pm(0.025/10)*100 \text{ \% CS}$$

$$ST_{SR(OUT)(CS)} = \pm 0.25\text{\% CS}$$

The total setting tolerance for the square root converter is the combination of these two terms by SRSS. Also, from Section 2.1.a these are considered 3 sigma values and must, therefore, be divided by 3 to make them compatible with the other 1 sigma error terms. The total setting tolerance $ST2_{(1\sigma)}$ is then

$$ST2_{(1\sigma)} = \pm[(ST_{SR(IN)(CS)}/3)^2 + (ST_{SR(OUT)(CS)}/3)^2]^{0.5} \text{ \% CS}$$

$$ST2_{(1\sigma)} = \pm[(0.26042/3)^2 + (0.25/3)^2]^{0.5} \text{ \% CS}$$

$$ST2_{(1\sigma)} = \pm 0.120332\text{\% CS}$$

11.2.1.5 Input Uncertainty (σinput2)

In addition to its own error terms, Module 2 also operates on the error terms from Module 1. Therefore, the random error term (σ1) from the flow transmitter must be transferred through the square root converter from input to output using the equations from Section 2.1.c. The resultant term will be σinput2 for this module. However, before this can be done σ1 must be converted to a millivolt signal. This can be done by dividing σ1 by 100 and multiplying by the input span $CS_{FT(OUT)}$.

$$\sigma 1_{MV} = \pm(\sigma 1/100)*CS_{FT(OUT)} \text{ mVdc}$$

$$\sigma 1_{MV} = \pm(2.691847/100)*16 \text{ mVdc}$$

$$\sigma 1_{MV} = \pm 0.430696 \text{ mVdc}$$

Transferring this through the square root converter using Equation 3 of Section 2.1.c gives

$$\sigma input2_V = \pm(3.125*\sigma 1_{MV})/OP_{SR} \text{ Vdc}$$

$$\sigma input2_V = \pm(3.125*0.430696)/6 \text{ Vdc}$$

$$\sigma input2_V = \pm 0.224321 \text{ Vdc}$$

Next this is changed into % CS by dividing by the output span and multiplying by 100.

$$\sigma input2 = \pm(\sigma input2_V/CS_{SR(OUT)})*100 \text{ \% CS}$$

$$\sigma input2 = \pm(0.224321/10)*100 \text{ \% CS}$$

$$\sigma input2 = \pm 2.24321\text{\% CS}$$

For the Comparator Trip Loop the above nine equations become:

$$\sigma 1_{MVC} = \pm(\sigma 1_C/100)*CS_{FT(OUT)} \text{ mVdc}$$

$$\sigma 1_{MVC} = \pm(0.998018/100)*16 \text{ mVdc}$$

$\sigma 1_{MVC} = \pm 0.159683$ mVdc

Transferring this through the square root converter using Equation 3 of Section 2.1.c gives

$\sigma input2_{VC} = \pm(3.125 * \sigma 1_{MVC})/OP_{SR}$ Vdc

$\sigma input2_{VC} = \pm(3.125 * 0.159683)/6$ Vdc

$\sigma input2_{VC} = \pm 0.083168$ Vdc

Next this is changed into % CS by dividing by the output span and multiplying by 100.

$\sigma input2_{C} = \pm(\sigma input2_{VC}/CS_{SR(OUT)}) * 100$ % CS

$\sigma input2_{C} = \pm(0.083168/10) * 100$ % CS

$\sigma input2_{C} = \pm 0.83168\%$ CS

11.2.1.6 Determination of Module Random Error ($\sigma 2$)

Using the methodology of Reference 3.3,

$$\sigma 2 = \pm[(RA2_{(1\sigma)})^2 + (RD2_{(1\sigma)})^2 + (CAL2_{SR})^2 + (ST2_{(1\sigma)})^2 + (\sigma input2)^2]^{0.5} \text{ \% CS}$$

$$\sigma 2 = \pm[(0)^2 + (0)^2 + (0.091406)^2 + (0.120332)^2 + (2.24321)^2]^{0.5} \text{ \% CS}$$

$$\sigma 2 = \pm 2.248294\% \text{ CS}$$

For the Comparator Trip this becomes:

$$\sigma 2_C = \pm[(RA2_{(1\sigma)})^2 + (RD2_{(1\sigma)})^2 + (CAL2_{SR})^2 + (ST2_{(1\sigma)})^2 + (\sigma input2_c)^2]^{0.5} \text{ \% CS}$$

$$\sigma 2_C = \pm[(0)^2 + (0)^2 + (0.091406)^2 + (0.120332)^2 + (0.83168)^2]^{0.5} \text{ \% CS}$$

$$\sigma 2_C = \pm 0.845297\% \text{ CS}$$

11.2.2 Module 2 Non-Random Errors ($\Sigma e2$)

As is indicated in Section 8.2 the specifications for the square root converters are included in an overall recirculation flow monitor specification which will be applied at the output of the flow summer, Module 3. Therefore, all the non-random error terms will be considered to be 0 except for einput2 which is the non-random error from Module 1 ($\Sigma e1$).

11.2.2.1 Humidity Errors (e2H)

Per Section 11.2.2 this error is considered to be zero.

e2H = 0% CS

11.2.2.2 Temperature Error (e2T)

Per Section 11.2.2 this error is considered to be zero.

e2T = 0% CS

11.2.2.3 Radiation Error (e2R)

Per Section 11.2.2 this error is considered to be zero.

e2R = 0% CS

11.2.2.4 Seismic Error (e2S)

Per Section 11.2.2 this error is considered to be zero.

e2S = 0% CS

11.2.2.5 Static Pressure Effect (e2SP)

Per Section 11.2.2 this error is considered to be zero.

e2SP = 0% CS

11.2.2.6 Pressure Error (e2P)

Per Section 11.2.2 this error is considered to be zero.

e2P = 0% CS

11.2.2.7 Process Errors(e2p)

Per Section 11.2.2 this error is considered to be zero.

$e2p = 0\%\ CS$

11.2.2.8 Power Supply Effects (e2V)

Per Section 11.2.2 this error is considered to be zero.

$e2V = 0\%\ CS$

11.2.2.9 Non-Random Input Error (einput2)

In addition to its own error terms, Module 2 also operates on the error terms from Module 1. Therefore, the non-random error term (Σe1) from the flow transmitter must be transferred through the square root converter from input to output using the equations from Section 2.1.c. The resultant term will be einput2 for this module. However, before this can be done Σe1 must be converted to a millivolt signal. This can be done by dividing Σe1 by 100 and multiplying by the input span $CS_{FT(OUT)}$.

$$\Sigma e1_{MV} = \pm(\Sigma e1/100)*CS_{FT(OUT)}\ mVdc$$

$$\Sigma e1_{MV} = \pm(1.171643/100)*16\ mVdc$$

$$\Sigma e1_{MV} = \pm 0.187463\ mVdc$$

Transferring this through the square root converter using Equation 3 of Section 2.1.c gives

$$einput2_V = \pm(3.125*\Sigma e1_{MV})/OP_{SR}\ Vdc$$

$$einput2_V = \pm(3.125*0.187463)/6\ Vdc$$

$$einput2_V = \pm 0.097637\ Vdc$$

Next this is changed into % CS by dividing by the output span and multiplying by 100.

$$einput2 = \pm(einput2_V/CS_{SR(OUT)})*100\ \%\ CS$$

$$einput2 = \pm(0.097637/10)*100\ \%\ CS$$

$$einput2 = \pm 0.97637\%\ CS$$

11.2.2.10 Non-Random Error (Σe2)

From Reference 3.3 the non-random error is the algebraic sum of all the above terms.

$$\Sigma e2 = \pm(e2H + e2T + e2R + e2S + e2SP + e2P + e2p + e2V + einput2)\%\ CS$$

$$\Sigma e2 = \pm(0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0.97637)\%\ CS$$

$$\Sigma e2 = \pm 0.97637\%\ CS$$

11.3 Module 3 (Flow Summer)

Classification of Module

Module 3 is an analog summer. As such its input and output are both analog signals. Therefore, Module 3 is classified as an analog module.

11.3.1 Module 3 Random Error ($\sigma 3$)

This section addresses random uncertainties that have the potential to be expressed in the output of Module 3.

11.3.1.1 Reference Accuracy (RA3)

Per Section 8.3.1 the reference accuracy applied to this module is the overall RFM accuracy which will be applied at the output of this module, the Flow Summer. Per Reference 3.18 the reference accuracy for this unit is ±2%. Since the vendor does not state percent of what, this value will be considered percent of calibrated span. This is conservative and makes it compatible with the other error terms.

$$RA3 = 2\%\ CS$$

Per Assumption 5.1, this is assumed to be a 2 sigma value. This is then converted to a 1 sigma value by dividing by 2.

$$RA3_{(1\sigma)} = \pm RA3/2\ \%\ CS$$

$$RA3_{(1\sigma)} = \pm 2/2\ \%\ CS$$

$$RA3_{(1\sigma)} = \pm 1\%\ CS$$

11.3.1.2 Drift (RD3)

Per Section 8.3.1 the reference drift applied to this module is the overall RFM drift which will be applied at the output of this module. Per Reference 3.18 the reference drift for this unit is ±1.25% per 700 Hrs. Since the vendor does not state percent of what, this value will be considered percent of calibrated span. This is conservative and makes it compatible with the other error terms.

Reference 3.7, Table 4.3.1.1-1, Note (e) indicates that the RFM is adjusted weekly to a calibrated flow signal. Therefore, this drift term does not need to be extended to a longer period.

$RD3 = 1.25\%\ CS$

Per Assumption 5.1, this is assumed to be a 2 sigma value. This is then converted to a 1 sigma value by dividing by 2.

$RD3_{(1\sigma)} = RD3/2\ \%\ CS$

$RD3_{(1\sigma)} = 1.25/2\ \%\ CS$

$RD3_{(1\sigma)} = \pm 0.625\%\ CS$

11.3.1.3 Calibration Uncertainty (CAL3)

The uncertainties associated with calibrating the flow summer are composed of the uncertainties in setting the input signal and the uncertainties in reading the output signal. References 3.5.s and 3.5.t specify that Fluke 8600A DMMs be used for measurement of the input and output signals.

Both input and output signals of the flow summer are 0 to 10 Vdc signals. Therefore, the MTE error terms will be the same for both of them. For the voltage range of interest for the DMMs measuring the input and output voltages the reference accuracy, from Reference 3.4, is 0.001803 Vdc ($RAMTE1_{SUM}$, $RAMTE2_{SUM}$). Since this is a digital instrument, there is no reading error associated with its use ($REMTE1_{SUM}$ and $REMTE2_{SUM} = 0$).

From Reference 3.3,

$MTE1 = [(RAMTE1/n)^2 + REMTE1^2]^{0.5}$

where n is the number of standard deviations applicable to the error term. Reference 3.4 gives a value of 1 for n for both the input and output test instruments.

For this calculation

$MTE1_{SUM} = \pm[(RAMTE1_{SUM}/n)^2 + REMTE1_{SUM}{}^2]^{0.5}\ Vdc$

$MTE1_{SUM} = \pm[(0.001803/1)^2 + 0^2]^{0.5}\ Vdc$

$MTE1_{SUM} = \pm 0.001803\ Vdc$

In order to make this term compatible with the other error terms it must be converted to %CS by dividing by the span ($CS_{SR(OUT)}$ will be used since the input span of the summer is the same as the output span of the square root converter) and multiplying by 100.

$$MTE1_{SUM(CS)} = \pm(MTE1_{SUM}/CS_{SR(OUT)})*100 \ \% \ CS$$

$$MTE1_{SUM(CS)} = \pm(0.001803/10)*100 \ \% \ CS$$

$$MTE1_{SUM(CS)} = \pm 0.01803\% \ CS$$

Since the input and output use the same instrument and have the same range the output MTE term ($MTE2_{SUM(CS)}$) is equal to the input term or

$$MTE2_{SUM(CS)} = MTE1_{SUM(CS)}$$

From Section 5.2 the errors attributed to the calibration standards are considered negligible. Therefore, the only terms which contribute to CAL3 are MTE1 and MTE2. For this calculation

$$CAL3_{SUM} = \pm[(MTE1_{SUM(CS)})^2 + (MTE2_{SUM(CS)})^2]^{0.5} \ \% \ CS$$

$$CAL3_{SUM} = \pm[0.01803^2 + 0.01803^2]^{0.5} \ \% \ CS$$

$$CAL3_{SUM} = \pm 0.025498\% \ CS$$

11.3.1.4 Setting Tolerance (ST3)

The setting tolerance for the flow summer is the combination of the input and output setting tolerances. From References 3.5.s and 3.5.t the setting tolerance for the flow summer's input ($ST_{SUM(IN)}$) is 0.01 Vdc. The setting tolerance for the flow summer's output ($ST_{SUM(OUT)}$) is given as 0.01 Vdc.

Since both input and output have the same span, both of these setting tolerance terms will now be converted to % CS by dividing by the flow summer output span ($CS_{SUM(OUT)}$) and multiplying by 100.

$$ST_{SUM(IN)(CS)} = \pm(ST_{SUM(IN)}/CS_{SUM(OUT)})*100 \ \% \ CS$$

$$ST_{SUM(IN)(CS)} = \pm(0.01/10)*100 \ \% \ CS$$

$$ST_{SUM(IN)(CS)} = \pm 0.1\% \ CS$$

$$ST_{SUM(OUT)(CS)} = \pm(ST_{SUM(OUT)}/CS_{SUM(OUT)})*100 \ \% \ CS$$

$$ST_{SUM(OUT)(CS)} = \pm(0.01/10)*100 \ \% \ CS$$

$$ST_{SUM(OUT)(CS)} = \pm 0.1\% \text{ CS}$$

The total setting tolerance for the flow summer is the combination of these two terms by SRSS. Also, from Section 2.1.a these are considered 3 sigma values and must, therefore, be divided by 3 to make them compatible with the other 1 sigma error terms. The total setting tolerance $ST3_{(1\sigma)}$ is then

$$ST3_{(1\sigma)} = \pm[(ST_{SUM(IN)(CS)}/3)^2 + (ST_{SUM(OUT)(CS)}/3)^2]^{0.5} \% \text{ CS}$$

$$ST3_{(1\sigma)} = \pm[(0.1/3)^2 + (0.1/3)^2]^{0.5} \% \text{ CS}$$

$$ST3_{(1\sigma)} = \pm 0.04714\% \text{ CS}$$

11.3.1.5 Input Uncertainty (σinput3)

In addition to its own error terms, Module 3 also operates on the error terms from Module 2. Therefore, the random error terms $\sigma 2$ and $\sigma 2_C$ from the square root converter must be transferred through the flow summer from input to output factoring in the gain of the summing circuit. The resultant terms will be σinput3 and σinput3$_C$ for this module.

From References 3.5.s and 3.5.t the gain of the summer (G_{SUM}) is equal to 1.044386. Since the flow summer is adding the outputs of two square root converters, and since the output spans of the square root converters and the flow summer are the same, the effective gain from each input of the flow summer to its output is $G_{SUM}/2$. Therefore, the transfer of each input error through the summer is

$$\sigma 2_3 = \pm\sigma 2 * (G_{SUM}/2) \% \text{ CS}$$

$$\sigma 2_3 = \pm 2.248294 * (1.044386/2) \% \text{ CS}$$

$$\sigma 2_3 = \pm 1.174043\% \text{ CS}$$

For the Comparator Trip this is:

$$\sigma 2_{3C} = \pm\sigma 2_C * (G_{SUM}/2) \% \text{ CS}$$

$$\sigma 2_{3C} = \pm 0.845297 * (1.044386/2) \% \text{ CS}$$

$$\sigma 2_{3C} = \pm 0.441408\% \text{ CS}$$

For both inputs the resulting errors (σinput3 and σinput3$_C$) at the output of the summer would be

$$\sigma input3 = \pm[(\sigma 2_3)^2 + (\sigma 2_3)^2]^{0.5} \text{ \% CS}$$

$$\sigma input3 = \pm[(1.174043)^2 + (1.174043)^2]^{0.5} \text{ \% CS}$$

$$\sigma input3 = \pm 1.660348\text{\% CS}$$

For the Comparator Trip:

$$\sigma input3_C = \pm[(\sigma 2_{3C})^2 + (\sigma 2_{3C})^2]^{0.5} \text{ \% CS}$$

$$\sigma input3_C = \pm[(0.441408)^2 + (0.441408)^2]^{0.5} \text{ \% CS}$$

$$\sigma input3_C = \pm 0.624245\text{\% CS}$$

11.3.1.6 Determination of Module Random Error ($\sigma 3$ and $\sigma 3_C$)

Using the methodology of Reference 3.3, and converting to % Flow by multiplying by 125/100:

$$\sigma 3 = \pm(125/100)*[(RA3_{(1\sigma)})^2 + (RD3_{(1\sigma)})^2 + (CAL3_{SUM})^2 + (ST3_{(1\sigma)})^2 + (\sigma input3)^2]^{0.5} \text{ \% Flow}$$

$$\sigma 3 = \pm(125/100)*[(1)^2 + (0.625)^2 + (0.025498)^2 + (0.04714)^2 + (1.660348)^2]^{0.5} \text{ \% Flow}$$

$$\sigma 3 = \pm 2.546521\text{\% Flow}$$

For the Comparator Trip:

$$\sigma 3_C = \pm(125/100)*[(RA3_{(1\sigma)})^2 + (RD3_{(1\sigma)})^2 + (CAL3_{SUM})^2 + (ST3_{(1\sigma)})^2 + (\sigma input3_C)^2]^{0.5} \text{ \% Flow}$$

$$\sigma 3_C = \pm(125/100)*[(1)^2 + (0.625)^2 + (0.025498)^2 + (0.04714)^2 + (0.624245)^2]^{0.5} \text{ \% Flow}$$

$$\sigma 3_C = \pm 1.669197\text{\% Flow}$$

Per Reference 3.3 the Allowable Value calculation uses all error terms except those pertaining to the process. Therefore, since $\sigma 3_C$ is the same as $\sigma 3$ except for the removal of the process terms, $\sigma 3_C$ will also be used for the Allowable Value calculation.

11.3.2 Module 3 Non-Random Errors ($\Sigma e3$)

Per Section 8.3.1 the errors applied to this module are the overall RFM error terms.

11.3.2.1 Humidity Errors (e3H)

Since Reference 3.18 does not identify a humidity error term a value of zero will be used per Section 4.3.

e3H = 0% CS

11.3.2.2 Temperature Error (e3T)

Since Reference 3.18 does not identify a temperature error term a value of zero will be used per Section 4.3.

e3T = 0% CS

11.3.2.3 Radiation Error (e3R)

Since Reference 3.18 does not identify a radiation error term a value of zero will be used per Section 4.3.

e3R = 0% CS

11.3.2.4 Seismic Error (e3S)

Per Section 4.7 seismic error for this module is considered negligible.

e3S = 0% CS

11.3.2.5 Static Pressure Effect (e3SP)

This module is an all electronic device that is not exposed to any pressure other than atmospheric. Therefore, there is no static pressure effect.

e3SP = 0% CS

11.3.2.6 Pressure Error (e3P)

This module is an all electronic device that is not exposed to any pressure other than atmospheric. Therefore, there is no pressure effect.

e3P = 0% CS

11.3.2.7 Process Errors(e3p)

This module is intermediate in the loop and, as such, is not exposed to any process parameters. Therefore, there are no process errors.

$$e3p = 0\%\ CS$$

11.3.2.8 Power Supply Effects (e3V)

Since Reference 3.18 does not identify a power supply effect error term a value of zero will be used per Section 4.3.

$$e3V = 0\%\ CS$$

11.3.2.9 Non-Random Input Error (einput3)

In addition to its own error terms, Module 3 also operates on the error terms from Module 2. Therefore, the non-random error term ($\Sigma e2$) from the square root converter must be transferred through the flow summer from input to output factoring in the gain of the summing circuit. The resultant term will be einput3 for this module.

Using the discussion from Section 11.3.1.5 the input of a single square root converter is transferred through the flow summer as follows:

$$\Sigma e2_3 = \pm\Sigma e2 * (G_{SUM}/2)\ \%\ CS$$

$$\Sigma e2_3 = \pm 0.97637 * (1.044386/2)\ \%\ CS$$

$$\Sigma e2_3 = \pm 0.509854\%\ CS$$

Since this is a non-random error the sum for both inputs at the output of the summer (einput3) would be the algebraic sum of the inputs.

$$einput3 = \pm(\Sigma e2_3 + \Sigma e2_3)\ \%\ CS$$

$$einput3 = \pm(0.509854 + 0.509854)\ \%\ CS$$

$$einput3 = \pm 1.019708\%\ CS$$

11.3.2.10 Non-Random Error ($\Sigma e3$)

From Reference 3.3 the non-random error is the algebraic sum of all the above terms. In addition, this term can be converted to % Flow by multiplying by 125/100. The result is;

$$\Sigma e3 = \pm(125/100)*(e3H + e3T + e3R + e3S + e3SP + e3P + e3p + e3V + einput3)\%\ \text{Flow}$$

$$\Sigma e3 = \pm(125/100)*(0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 1.019708)\%\ \text{Flow}$$

$$\Sigma e3 = \pm 1.274635\%\ \text{Flow}$$

11.3.3 Module 3A and 3B (RFM Trip Circuits)

Classification of Module

Module 3A receives an analog input from the Flow Summer (Module 3) and provides a bistable output, the state of which depends on the relative magnitudes of the input signal and the reference value. Therefore, Module 3A is a bistable module.

There are actually two separate trip circuits in each flow unit. The Hi Flow trip looks at the output of the Flow Summer and compares its magnitude to a fixed reference value (Module 3A above). The Comparator Trip Circuit looks at the output of the Flow Summer and compares it to the output of a Flow Summer from another RFM (Module 3B) and provides a bistable output, the state of which depends on the relative magnitudes of the two input signals. Therefore, Module 3B is a bistable module. The Comparator Trip will have to combine the error terms from two Flow Summers.

11.3.3.1 Module 3A and 3B Random Error (σ3A and σ3B)

This section addresses random uncertainties that have the potential to be expressed in the outputs of Modules 3A and 3B.

11.3.3.1.1 Reference Accuracy (RA3A)

Per Assumption 5.8 the reference accuracy for this module is included in the Module 3 accuracy term:

$$RA3A = 1\%\ CS$$

Per Assumption 5.1, this is assumed to be a 2 sigma value. This is then converted to a 1 sigma value by dividing by 2. In the same step this will be converted to % Flow by multiplying by 125/100.

$$RA3A_{(1\sigma)} = \pm(RA3A/2)*(125/100)\ \%\ Flow$$

$$RA3A_{(1\sigma)} = \pm(1/2)*(125/100)\ \%\ Flow$$

$$RA3A_{(1\sigma)} = \pm 0.625\%\ Flow$$

11.3.3.1.2 Drift (RD3A)

Per Assumption 5.8 the reference drift for this module is included in the Module 3 drift term:

RD3A = 1% CS/700 HRS

Table 4.3.6-1 of Reference 3.7 gives the surveillance interval (RD3ATSI) for these trip functions as 13 weeks (quarterly). In addition, a 25% late factor will added to the required value. Per Reference 3.8 drift is considered a random function and can be extended to a longer period by the square root of the ratio of the time periods per Section 2.2.5 of Reference 3.13.

Per Assumption 5.1, the drift value is assumed to be a 2 sigma value. This is then converted to a 1 sigma value by dividing by 2, and then to % Flow by multiplying by 125/100. RD3ATSI is converted to hours by multiplying by 168. The one sigma drift is then:

$$RD3A_{(1\sigma)} = \pm(RD3A/2)*(125/100)*[(1.25*RD3ATSI*168)/RD3AT]^{0.5} \text{ \% Flow}$$

$$RD3A_{(1\sigma)} = \pm(1/2)*(125/100)*[(1.25*13*168)/700]^{0.5} \text{ \% Flow}$$

$$RD3A_{(1\sigma)} = \pm 1.234276\text{\% Flow}$$

11.3.3.1.3 Calibration Uncertainty (CAL3A)

The uncertainties associated with calibrating the trip circuits are composed entirely of the uncertainties associated with the DMM used to set the input trip voltage. References 3.5.s and 3.5.t specify that A Fluke 8600A DMM be used for this measurement. From Section 9.1 the error associated with this instrument is 0.001803 Vdc ($RAMTE1_{3A}$). Since this is a digital instrument $REMTE1_{3A}$ is equal to zero.

From Reference 3.3,

$$MTE1 = [(RAMTE1/n)^2 + REMTE1^2]^{0.5}$$

where n is the number of standard deviations applicable to the error term. The values of the error terms from Reference 9.1 are already expressed in one sigma terms. Therefore, the value of n is 1.

$$MTE1_{3A} = \pm[(RAMTE1_{3A}/1)^2 + REMTE1_{3A}{}^2]^{0.5} \text{ Vdc}$$

$$MTE1_{3A} = \pm[(0.001803/1)^2 + 0^2]^{0.5} \text{ Vdc}$$

$$MTE1_{3A} = \pm 0.001803 \text{ Vdc}$$

This can be converted to % Flow by dividing by the voltage span ($SPAN_{SUM}$) and multiplying by the full scale flow (125).

$$MTE1_{3A(PF)} = \pm[(MTE1_{3A}/SPAN_{SUM})*125] \text{ \% Flow}$$

$$MTE1_{3A(PF)} = \pm[(0.001803/10)*125] \text{ \% Flow}$$

$$MTE1_{3A(PF)} = \pm 0.022538\text{\% Flow}$$

From Section 5.2 the errors attributed to the calibration standards are considered negligible. Therefore, the only term which contributes to CAL3A is the MTE1 term. Therefore, for this section

$$CAL3A = \pm MTE1_{3A(PF)} = \pm 0.022538\text{\% Flow}$$

11.3.3.1.4 Setting Tolerance (ST3A)

From Design Input 10.3, the setting tolerance to be evaluated for the upscale and comparator trip functions is ±0.1 Vdc and ±0.08 Vdc, respectively. This can be converted to % Flow by dividing by the voltage span ($SPAN_{SUM}$) and multiplying by the full scale flow (125).

From Section 2.1.a the given setting tolerances are considered 3 sigma values. Therefore, ST3A must be divided by 3 to make it compatible with the other 1 sigma error terms. Combining this operation with the conversion to percent flow gives

$$ST3A_{(1\sigma)} = \pm[(ST3A/SPAN_{SUM})*125]/3 \text{ \% Flow}$$

<u>Upscale Trip:</u>

$$ST3A_{A(1\sigma)} = \pm[(0.1/10)*125]/3 \text{ \% Flow}$$
$$ST3A_{A(1\sigma)} = \pm 0.416667\text{\% Flow}$$

<u>Comparator Trip:</u>

$$ST3A_{B(1\sigma)} = \pm[(0.08/10)*125]/3 \text{ \% Flow}$$
$$ST3A_{B(1\sigma)} = \pm 0.333333\text{\% Flow}$$

11.3.3.1.5 Input Uncertainty (σinput3A, σinput3B)

In addition to its own error terms, the error terms from Module 3 must also be considered. Since the trip circuits perform no function on the input signal σinput3A becomes equal to the random input terms $\sigma3$ for the Hi Flow trip. However, the Comparator Trip is also looking at the output of another RFM so both inputs also have a $\sigma3_C$ term impressed on them. Therefore, the uncertainty term σinput3B for the Comparator Trip will combine two $\sigma3_C$ terms by SRSS.

$$\sigma\text{input3A} = \pm\sigma3 = \pm2.546521\%\ \text{Flow}$$

And

$$\sigma\text{input3B} = \pm(\sigma3_C^{\,2} + \sigma3_C^{\,2})^{0.5}\ \%\ \text{Flow}$$

$$\sigma\text{input3B} = \pm(1.669197^2 + 1.669197^2)^{0.5}\ \%\ \text{Flow}$$

$$\sigma\text{input3B} = \pm2.360601\%\ \text{Flow}$$

A new term ($\sigma\text{input3A}_{AV}$) will be introduced at this time to account for errors associated only with the Allowable Value calculation. Per Reference 3.3 the Allowable Value determination involves all the error terms except those pertaining to the process. Therefore, $\sigma\text{input3A}_{AV}$ will equal $\sigma3_C$ since the difference between $\sigma3_C$ and $\sigma3$ is the absence of the flow element error.

$$\sigma\text{input3A}_{AV} = \sigma3_C = 1.669197\%\ \text{Flow}$$

11.3.3.1.6 Determination of Module Random Error ($\sigma3A$, $\sigma3B$)

Using the methodology of Reference 3.3,

$$\sigma3A = \pm[(RA3A_{(1\sigma)})^2 + (RD3A_{(1\sigma)})^2 + (CAL3A)^2 + (ST3A_{A(1\sigma)})^2 + (\sigma\text{input3A})^2]^{0.5}\ \%\ \text{Flow}$$

$$\sigma3A = \pm[(0.625)^2 + (1.234276)^2 + (0.022538)^2 + (0.416667)^2 + (2.546521)^2]^{0.5}\ \%\ \text{Flow}$$

$$\sigma3A = \pm2.92796\%\ \text{Flow}$$

And

$$\sigma3B = \pm[(RA3A_{(1\sigma)})^2 + (RD3A_{(1\sigma)})^2 + (CAL3A)^2 + (ST3A_{B(1\sigma)})^2 + (\sigma\text{input3B})^2]^{0.5}\ \%\ \text{Flow}$$

$$\sigma3B = \pm(0.625^2 + 1.234276^2 + 0.022538^2 + 0.333333^2 + 2.360601^2)^{0.5}\ \%\ \text{Flow}$$

$$\sigma3B = \pm2.756468\%\ \text{Flow}$$

CALCULATION NO. L-001345		PAGE 78 of 191

And

$$\sigma 3A_{AV} = \pm[(RA3A_{(1\sigma)})^2 + (RD3A_{(1\sigma)})^2 + (CAL3A)^2 + (ST3A_{A(1\sigma)})^2 + (\sigma input3A_{AV})^2]^{0.5} \text{ \% Flow}$$

$$\sigma 3A_{AV} = \pm[(0.625)^2 + (1.234276)^2 + (0.022538)^2 + (0.416667)^2 + (1.669197)^2]^{0.5} \text{ \% Flow}$$

$$\sigma 3A_{AV} = \pm 2.207804\% \text{ Flow}$$

11.3.3.2 Module 3A Non-Random Errors (Σe3A)

11.3.3.2.1 Humidity Errors (e3AH)

Since Reference 3.18 does not identify a humidity error term a value of zero will be used per Section 4.3.

e3AH = 0% Flow

11.3.3.2.2 Temperature Error (e3AT)

Since Reference 3.18 does not identify a temperature error term a value of zero will be used per Section 4.3.

e3AT = 0% Flow

11.3.3.2.3 Radiation Error (e3AR)

Since Reference 3.18 does not identify a radiation error term a value of zero will be used per Section 4.3.

e3AR = 0% Flow

11.3.3.2.4 Seismic Error (e3AS)

Per Section 4.7 seismic error for this module is considered negligible.

e3AS = 0% Flow

11.3.3.2.5 Static Pressure Effect (e3ASP)

This module is an all electronic device that is not exposed to any pressure other than atmospheric. Therefore, there is no static pressure effect.

e3ASP = 0% Flow

11.3.3.2.6 Pressure Error (e3AP)

This module is an all electronic device that is not exposed to any pressure other than atmospheric. Therefore, there is no pressure effect.

e3AP = 0% Flow

11.3.3.2.7 Process Errors(e3Ap)

This module is intermediate in the loop and, as such, is not exposed to any process parameters. Therefore, there are no process errors.

e3Ap = 0% Flow

11.3.3.2.8 Power Supply Effects (e3AV)

Since Reference 3.18 does not identify a power supply effect error term a value of zero will be used per Section 4.3.

e3AV = 0% Flow

11.3.3.2.9 Non-Random Input Error (einput3A, einput3B)

In addition to its own error terms, the error terms from Module 3 must also be considered. Since the trip circuits perform no function on the input signal einput3A becomes equal to the non-random input term Σe3 for the Hi Flow trip. However, the Comparator Trip is also looking at the output of another RFM so the reference input also has a Σe3 term impressed on it. Since these are not random terms, it is expected that their magnitudes would be the same from each Module 3. However, the methodology of Reference 3.3 does not allow the cancellation of non-random terms. Therefore, the total error at the comparator will be the algebraic sum of two Σe3 terms.

$$einput3A = \pm\Sigma e3 = \pm 1.274635\%\ Flow$$

And

$$einput3B = \pm(\Sigma e3 + \Sigma e3)\ \%\ Flow$$

$$einput3B = \pm(1.274635 + 1.274635)$$

$$einput3B = \pm 2.54927\%\ Flow$$

11.3.3.2.10 Non-Random Error ($\Sigma e3A$, $\Sigma e3B$)

From Reference 3.3 the non-random error is the algebraic sum of all the above terms.

$$\Sigma e3A = \pm(e3AH + e3AT + e3AR + e3AS + e3ASP + e3AP + e3Ap + e3AV + einput3A)\%\ Flow$$

$$\Sigma e3A = \pm(0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 1.274635)\%\ Flow$$

$$\Sigma e3A = \pm 1.274635\%\ Flow$$

And

$$\Sigma e3B = \pm(e3AH + e3AT + e3AR + e3AS + e3ASP + e3AP + e3Ap + e3AV + einput3B)\%\ Flow$$

$$\Sigma e3B = \pm(0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 2.54927)\ \%\ Flow$$

$$\Sigma e3B = \pm 2.54927\%\ Flow$$

11.4 Module 4 (APRM)

The APRM will be divided into four parts for this calculation; LPRM, APRM Averaging Circuitry, Trip Circuits (Fixed), and Trip Circuits (Flow Biased). These will be designated Module 4A, 4B, 4C, and 4D respectively. This separation is performed because the vendor lists the specifications for these items separately in References 3.9 and 3.11, and because the calibration procedures of Reference 3.5 effectively make this separation.

11.4.1 Module 4A (LPRM)

Classification of Module

Module 4A receives a current from an incore fission chamber and provides an analog voltage output that is proportional to the input current. Therefore, Module 4A is an analog module.

11.4.1.1 Module 4A Random Error ($\sigma 4A$)

This section addresses random uncertainties that have the potential to be expressed in the output of Module 4.

11.4.1.1.1 Reference Accuracy (RA4A)

Per Section 8.4.1 the reference accuracy for this module is 0.8% CS. However, the reference also states that this is referred to a full scale value of 125% Power. Therefore, this value will be considered to be 0.8 × 125 or 1% Power.

$$RA4A = 1\%\ Power$$

Per Assumption 5.1, this is assumed to be a 2 sigma value. This is then converted to a 1 sigma value by dividing by 2.

$$RA4A_{(1\sigma)} = \pm RA4A/2\ \%\ Power$$

$$RA4A_{(1\sigma)} = \pm 1/2\ \%\ Power$$

$$RA4A_{(1\sigma)} = \pm 0.5\%\ Power$$

11.4.1.1.2 Drift (RD4A)

Per Section 8.4.1 the reference drift for this module is 0.8% CS per 700 hours. However, the reference also states that this is referred to a full scale value of 125% Power. Therefore, this value will be considered to be 0.8 × 125 or 1% Power.

RD4A = 1% Power/700 HRS

Table 4.3.1.1-1 of Reference 3.7 states that "The LPRMs shall be calibrated at least once per 1000 effective full power hours (EFPH)." However, Table 4.3.1.1-1 of Reference 3.7 states that the APRM Gain Adjustment Factor (GAF) shall be calibrated weekly. This effectively calibrates out the LPRM drift term each week. Since this time period plus the 25% late factor is shorter than vendor specified drift time period, the vendor drift value will be used as is (Section 2.1.b). Therefore, the value used for the Surveillance Interval (RD4ATSI) will be 700 hours, thereby making the drift extension term equal to 1. Also, per Assumption 5.1, RD4A is assumed to be a 2 sigma value. This will be converted to a 1 sigma value by dividing by 2.

$$RD4A_{(1\sigma)} = \pm(RD4A/2)*(RD4ATSI/RD4AT)^{0.5} \text{ \% Power}$$

$$RD4A_{(1\sigma)} = \pm(1/2)*(700/700)^{0.5} \text{ \% Power}$$

$$RD4A_{(1\sigma)} = \pm 0.5\text{\% Power}$$

11.4.1.1.3 Calibration Uncertainty (CAL4A)

The uncertainties associated with calibrating the LPRM Card are composed of the uncertainties in setting the input signal and the uncertainties in reading the output signal. Per References 3.5.h, and 3.5.q the DMM used should have an accuracy of at least ± 0.01 Vdc. If this is considered a two sigma value per Assumption 5.1, the one sigma requirement, which makes it compatible with the DMM data from Reference 3.4, would be 0.01/2 or ±0.005 Vdc. Since both uses of the DMM in measurements applicable to this calculation are to measure 10 Vdc, the span (RV4ACURS) is the same for both measurements. Converting this error term to % CS gives

$$RAMTE1_{4A(DMM)} = \pm(RA4A_{DMM}/RV4ACURS)*100 \text{ \% CS}$$

$$RAMTE1_{4A(DMM)} = \pm(0.005/10)*100 \text{ \% CS}$$

$$RAMTE1_{4A(DMM)} = \pm 0.05\text{\% CS}$$

This value will also be used for $RAMTE2_{4A(DMM)}$ since the output span is also 10 Vdc.

The first use of the DMM is to set the reference voltage for the built-in input current source. Once the reference voltage is set the accuracy of the current source is ±1.0%

(Reference 3.9). Since the procedures use the current source to make the LPRM read full scale, this error term will be considered ±1% CS.

Since the DMM is a digital instrument the reading error terms at both the input and output ($REMTE1_{4A(DMM)}$, $REMTE2_{4A(DMM)}$) are equal to 0% CS.

The input current source is also digital since the current is set by digital decade switches. Therefore, $REMTE1_{4A(CURS)}$ is also 0% CS.

From Reference 3.3,

$$MTE1 = [(RAMTE1/n)^2 + REMTE1^2]^{0.5}$$

where n is the number of standard deviations applicable to the error term. The DMM has been converted to a one sigma term in the text above; therefore, n is equal to 1 for this term. The current source, however, is a vendor specified error term and is, therefore, considered to be a two sigma term. MTE1 for this calculation is, therefore,

$$MTE1_{4A} = \pm[(RAMTE1_{4A(DMM)}/n)^2 + (RAMTE1_{4A(CURS)}/n)^2 \; REMTE1_{4A(DMM)}{}^2 + REMTE1_{4A(CURS)}{}^2]^{0.5} \; \% \; CS$$

$$MTE1_{4A} = \pm[(0.05/1)^2 + (1/2)^2 + 0^2 + 0^2]^{0.5} \; \% \; CS$$

$$MTE1_{4A} = \pm 0.502494\% \; CS$$

The output calibration uses only the DMM and its error terms have been discussed above. Therefore, the total output MTE error term is

$$MTE2_{4A} = \pm[(RAMTE2_{4A(DMM)})^2 + (REMTE2_{4A(DMM)})^2]^{0.5} \; \% \; CS$$

$$MTE2_{4A} = \pm[(0.05)^2 + 0^2]^{0.5} \; \% \; CS$$

$$MTE2_{4A} = \pm 0.05\% \; CS$$

From Section 5.2 the errors attributed to the calibration standards are considered negligible. Therefore, the only terms which contribute to CAL4A are the MTE1 and MTE2 terms. For this calculation

$$CAL4A = \pm[(MTE1_{4A})^2 + (MTE2_{4A})^2]^{0.5} \; \% \; CS$$

$$CAL4A = \pm[0.502494^2 + 0.05^2]^{0.5} \; \% \; CS$$

$$CAL4A = \pm 0.504975\% \text{ CS}$$

11.4.1.1.4 Setting Tolerance (ST4A)

The setting tolerance for the LPRM is the combination of the input and output setting tolerances. However, References 3.5.h and 3.5.q give no setting tolerances for the three measurements used to calibrate the LPRM gain. From Assumption 5.4 the setting tolerance will, therefore, be assumed equal to the reference accuracy of the applicable test instrument.

For this particular application then the setting tolerances are:

$$ST4A_{DMM} = \pm RAMTE1_{4A(DMM)} = \pm RAMTE2_{4A(DMM)} = \pm 0.05\% \text{ CS}$$

$$ST4A_{CURS} = \pm RAMTE1_{4A(CURS)} = \pm 1\% \text{ CS}$$

The total setting tolerance for the LPRM is the combination of two input terms ($ST4A_{DMM}$ and $ST4A_{CURS}$) and one output term ($ST4A_{DMM}$) by SRSS. From Section 2.1.a the given setting tolerances are considered 3 sigma values. However, $ST4A_{DMM}$ is already the result of dividing the original procedural value by 2. Therefore, it must now be multiplied by 2/3 to make it a one sigma value for setting tolerance. $ST4A_{CURS}$ is still as it was given by the vendor and, therefore, must be divided by 3 to make it compatible with the other 1 sigma error terms. The total setting tolerance $ST4A_{(1\sigma)}$ is then

$$ST4A_{(1\sigma)} = \pm\{[(ST4A_{DMM})*(2/3)]^2 + (ST4A_{CURS}/3)^2 + [(ST4A_{DMM})*(2/3)]^2\}^{0.5} \% \text{ CS}$$

$$ST4A_{(1\sigma)} = \pm\{[(0.05)*(2/3)]^2 + (1/3)^2 + [(0.05)*(2/3)]^2\}^{0.5} \% \text{ CS}$$

$$ST4A_{(1\sigma)} = \pm 0.33665\% \text{ CS}$$

11.4.1.1.5 Input Uncertainty (σinput4A)

In addition to its own error terms, Module 4A also operates on the error terms from an incore fission detector. From Section 4.5 of Reference 3.13 the primary element accuracy (PEA) for the incore fission detector is a combination of sensor sensitivity and sensor non-linearity uncertainties. The sensitivity of the detectors decreases with neutron fluence. The average sensitivity loss, and its two sigma variation, for all GE LPRM detectors has been determined to be:

Sensor Sensitivity Loss (SSL_B) = 0.33% (bias term)
(100% Power)

Sensor Sensitivity Loss (SSL_R) = ±0.20% (random term)
(100% Power)

The detector non-linearity and its two sigma variation (in the power range) have been determined to be:

Sensor Non-linearity (SNL_B) = 0.49% (bias term)
(100% Power)

Sensor Non-linearity (SNL_R) = ±1% (random term)
(0 to 120% Power)

The total sensor uncertainty can be obtained by adding the bias terms ($PEA_{4A(B)}$) and combining the random terms by SRSS ($PEA_{4A(R)}$). The result is:

$$PEA_{4A(B)} = SSL_B + SNL_B \text{ \% Power}$$

$$PEA_{4A(B)} = 0.33 + 0.49 \text{ \% Power}$$

$$PEA_{4A(B)} = 0.82 \text{ \% Power}$$

From Section 4.11, for the three low power trips, SNL_B will be set to zero leaving only SSL_B as the bias term for PEA.

$$PEA_{4A(LPB)} = SSL_B = 0.33\% \text{ Power}$$

Combining the random terms gives:

$$PEA_{4A(R)} = \pm[(SSL_R)^2 + (SNL_R)^2]^{0.5} \text{ \% Power}$$

$$PEA_{4A(R)} = \pm[(0.2)^2 + (1)^2]^{0.5} \text{ \% Power}$$

$$PEA_{4A(R)} = \pm 1.019804\% \text{ Power}$$

For the low power trips the random terms of PEA are the same as for the high power trips. Therefore,

$$PEA_{4A(LPR)} = PEA_{4A(R)} = 1.019804\% \text{ Power}$$

For this calculation the random uncertainty terms ($PEA_{4A(R)}$ and $PEA_{4A(LPR)}$) are equal to σinput4A and σinput4A_{LP} respectively. The bias uncertainty terms ($PEA_{4A(B)}$ and $PEA4_{4A(LPB)}$) are equal to einput4A and einput4A_{LP} respectively. The bias terms will be covered in Section 11.4.1.2.9.

$$\sigma\text{input4A} = \pm PEA_{4A(R)} = \pm 1.019804\%\ \text{Power}$$

And

$$\sigma\text{input4A}_{LP} = \pm PEA_{4A(LPR)} = \pm 1.019804\%\ \text{Power}$$

Per Reference 3.3 the process errors are not included in the determination of Allowable Value. Therefore,

$$\sigma\text{input4A}_{AV} = 0\%\ \text{Power}$$

11.4.1.1.6 Determination of Module Random Error (σ4A and $\sigma 4A_{LP}$)

Using the methodology of Reference 3.3,

$$\sigma 4A = \pm[(RA4A_{(1\sigma)})^2 + (RD4A_{(1\sigma)})^2 + (CAL4A)^2 + (ST4A_{(1\sigma)})^2 + (\sigma\text{input4A})^2]^{0.5}\ \%\ CS$$

However, since RA4A, RD4A, and σinput4A are in terms of percent power while the other terms are percent calibrated span, these terms will be removed from the equation and carried through to the APRM Averaging Circuitry separately. Therefore, for this section the equation for σ4A is:

$$\sigma 4A = \pm[(CAL4A)^2 + (ST4A_{(1\sigma)})^2]^{0.5}\ \%\ CS$$

$$\sigma 4A = \pm[(0.504975)^2 + (0.33665)^2]^{0.5}\ \%\ CS$$

$$\sigma 4A = \pm 0.606904\%\ CS$$

And

$$\sigma 4A_{PP} = \pm[(RA4A_{(1\sigma)})^2 + (RD4A_{(1\sigma)})^2]^{0.5}\%\ \text{Power}$$

$$\sigma 4A_{PP} = \pm[(0.5)^2 + (0.5)^2]^{0.5}\ \%\ \text{Power}$$

$$\sigma 4A_{PP} = \pm 0.707107\%\ \text{Power}$$

11.4.1.2 Module 4A Non-Random Errors ($\Sigma e4A$)

11.4.1.2.1 Humidity Errors (e4AH)

Since Reference 3.9 does not identify a humidity error term a value of zero will be used per Section 4.3.

e4AH = 0% CS

11.4.1.2.2 Temperature Error (e4AT)

Since Reference 3.9 does not identify a temperature error term a value of zero will be used per Section 4.3.

e4AT = 0% CS

11.4.1.2.3 Radiation Error (e4AR)

Since Reference 3.9 does not identify a radiation error term a value of zero will be used per Section 4.3.

e4AR = 0% CS

11.4.1.2.4 Seismic Error (e4AS)

Per Section 4.7 seismic error for this module is considered negligible.

e4AS = 0% CS

11.4.1.2.5 Static Pressure Effect (e4ASP)

This module is an all electronic device that is not exposed to any pressure other than atmospheric. Therefore, there is no static pressure effect.

e4ASP = 0% CS

11.4.1.2.6 Pressure Error (e4AP)

This module is an all electronic device that is not exposed to any pressure other than atmospheric. Therefore, there is no pressure effect.

e4AP = 0% CS

11.4.1.2.7 Process Errors(e4Ap)

This module is intermediate in the loop and, as such, is not exposed to any process parameters. Therefore, there are no process errors.

$$e4Ap = 0\%\ CS$$

11.4.1.2.8 Power Supply Effects (e4AV)

Since Reference 3.9 does not identify a power supply effect error term a value of zero will be used per Section 4.3.

$$e4AV = 0\%\ CS$$

11.4.1.2.9 Non-Random Input Error (einput4A)

In addition to its own error terms, Module 4A also operates on the error terms from an incore fission detector. This was discussed in Section 11.4.1.1.5. The value of einput4A was determined to be:

$$einput4A = (PEA_{4A(B)}) = 0.82\%\ Power$$

And

$$einput4A_{LP} = PEA_{4A(LPB)} = 0.33\%\ Power$$

Per Reference 3.3 the process errors are not included in the determination of Allowable Value. Therefore,

$$einput4A_{AV} = 0\%\ Power$$

11.4.1.2.10 Non-Random Error (Σe4A)

From Reference 3.3 the non-random error is the algebraic sum of all the above terms.

$$\Sigma e4A = \pm(e4AH + e4AT + e4AR + e4AS + e4ASP + e4AP + e4Ap + e4AV + einput4A)\%\ CS$$

However, since einput4A, $einput4A_{AV}$, and $einput4A_{LP}$ are in terms of percent power while the other terms are percent calibrated span, these terms will be removed from the equation and carried through to the APRM Averaging Circuitry separately. Therefore, for this section the equation for Σe4A is:

$$\Sigma e4A = \pm(e4AH + e4AT + e4AR + e4AS + e4ASP + e4AP + e4Ap + e4AV)\%\ CS$$

$$\Sigma e4A = \pm(0 + 0 + 0 + 0 + 0 + 0 + 0 + 0)\%\ CS$$

$$\Sigma e4A = \pm 0\%\ CS$$

11.4.2 Module 4B (APRM Averaging Circuitry)

Classification of Module

Module 4B receives analog inputs from multiple LPRM cards. These signals are averaged and then operated on by an adjustable gain factor resulting in an analog output that is some multiple of the average of the input signals. Therefore, Module 4B is an analog module.

11.4.2.1 Module 4B Random Error ($\sigma 4B$)

This section addresses random uncertainties that have the potential to be expressed in the output of Module 4B.

11.4.2.1.1 Reference Accuracy (RA4B)

Per Section 8.4.1 the reference accuracy for this module is:

RA4B = 0.8% CS

Per Assumption 5.1, this is assumed to be a 2 sigma value. This is then converted to a 1 sigma value by dividing by 2.

$RA4B_{(1\sigma)} = \pm RA4B/2$ % CS

$RA4B_{(1\sigma)} = \pm 0.8/2$ % CS

$RA4B_{(1\sigma)} = \pm 0.4$% CS

11.4.2.1.2 Drift (RD4B)

Per Section 8.4.1 the reference drift for this module is:

RD4B = 0.5% CS/700 Hrs

Table 4.3.1.1-1 of Reference 3.7 states that the APRM Gain Adjustment Factor (GAF) shall be calibrated weekly. Since this time period is shorter than vendor specified drift time period, the vendor drift value will be used as is. Also, per Assumption 5.1, RD4B is assumed to be a 2 sigma value. This will be converted to a 1 sigma value by dividing by 2.

$RD4B_{(1\sigma)} = \pm(RD4B/2)$ % CS

$RD4B_{(1\sigma)} = \pm(0.5/2)$ % CS

$RD4B_{(1\sigma)} = \pm 0.25$% CS

11.4.2.1.3 Calibration Uncertainty (CAL4B)

The uncertainties associated with calibrating the APRM gain are composed entirely of the uncertainties associated with the process computer. The process computer determines the core thermal power by heat balance. This can be considered the input to the calibration. The process computer also reads the APRM output and compares the two. The result of the comparison is the APRM Gain Adjustment Factor term (AGAF). Therefore, for this calculation $RAMTE1_{4B}$ is the accuracy with which the process computer determines core thermal power, and $RAMTE2_{4B}$ is the accuracy with which the process computer reads the APRM output signal. Per Assumption 5.5, both of these terms are considered zero. In addition, since the output of the process computer is a digital printout, $REMTE1_{4B}$ and $REMTE2_{4B}$ are zero.

From Reference 3.3,

$$MTE1 = [(RAMTE1/n)^2 + REMTE1^2]^{0.5}$$

where n is the number of standard deviations applicable to the error term. If the reference accuracy terms for the process computer are considered two sigma values, MTE1 for this calculation is:

$$MTE1_{4B} = \pm[(RAMTE1_{4B}/2)^2 + REMTE1_{4B}{}^2]^{0.5} \text{ \% CS}$$

$$MTE1_{4B} = \pm[(0/2)^2 + 0^2]^{0.5} \text{ \% CS}$$

$$MTE1_{4B} = \pm 0\text{\% CS}$$

Likewise, $MTE2_{4B}$ is:

$$MTE2_{4B} = \pm[(RAMTE2_{4B}/2)^2 + (REMTE2_{4B})^2]^{0.5} \text{ \% CS}$$

$$MTE2_{4A} = \pm[(0/2)^2 + 0^2]^{0.5} \text{ \% CS}$$

$$MTE2_{4A} = \pm 0\text{\% CS}$$

From Section 5.2 the errors attributed to the calibration standards are considered negligible. Therefore, the only terms which contribute to CAL4B are the MTE1 and MTE2 terms. For this calculation

$$CAL4B = \pm[(MTE1_{4B})^2 + (MTE2_{4B})^2]^{0.5} \text{ \% CS}$$

$$CAL4B = \pm[0^2 + 0^2]^{0.5} \text{ \% CS}$$

$$CAL4B = \pm 0\% \text{ CS}$$

11.4.2.1.4 Setting Tolerance (ST4B)

The setting tolerance for the APRM gain calibration is the allowance in the AGAF setting. From References 3.5.g and 3.5.p this allowance (ST4B) is ±0.02 from the ideal value of 1.00. Since the AGAF calibration is usually performed when the reactor is operating near 100% power this translates into an setting tolerance ($ST4B_{\%}$)of ±2% Power. Since full scale output of the APRM is 125% this term can be converted to percent calibrated span by multiplying by 100/125.

From Section 2.1.a the given setting tolerances are considered 3 sigma values. Therefore, $ST4B_{\%}$ must be divided by 3 to make it compatible with the other 1 sigma error terms. Combining this operation with the conversion to percent calibrated span gives

$$ST4B_{(1\sigma)} = \pm ST4B_{\%} * (100/125)/3 \ \% \text{ CS}$$

$$ST4B_{(1\sigma)} = \pm 2 * (100/125)/3 \ \% \text{ CS}$$

$$ST4B_{(1\sigma)} = \pm 0.533333\% \text{ CS}$$

11.4.2.1.5 Process Measurement Accuracy (PMA)

Section 4.5 of Reference 3.13 contains an error term called PMA which is applicable to the APRMs. PMA is a combination of APRM tracking error and the uncertainty due to neutron noise. This reference states that for the MSIV closure transient event, which is one of the more severe events, the APRM tracking error (TRAC) is 1.11% and the uncertainty due to neutron noise (NN) is typically 2.0% for fixed upscale trips. However, for trips primarily involved with slow transients (flow biased trips including STP, APRM Downscale, APRM Setdown Rod Block, and APRM Setdown Scram) the neutron noise will help the signal actuate the trip. Therefore, a value of zero will be used for neutron noise for these trips. The tracking error is the uncertainty of the maximum deviation of APRM readings with LPRM failures or bypasses during a power transient. For the low power trips the tracking accuracy is negligible. The neutron noise is the global neutron flux noise in the reactor core with a typical dominant frequency of approximately 0.3 to 0.5 Hertz and a typical maximum peak-to-peak amplitude of approximately 5 to 10 percent. Since both error terms are independent and random they can be combined by SRSS.

$PMA = \pm(TRAC^2 + NN^2)^{0.5}$ % Power

$PMA = \pm(1.11^2 + 2^2)^{0.5}$ % Power

$PMA = \pm 2.287378\%$ Power

And

$PMA_{FB} = 1.11\%$ Power

For the low power trips:

$PMA_{LP} = 0\%$ Power

These are considered to be a 2 sigma values and must be divided by 2 in order to make them compatible with the other error terms.

$PMA_{1\sigma} = \pm PMA/2$ % Power

$PMA_{1\sigma} = \pm 2.287378/2$ % Power

$PMA_{1\sigma} = \pm 1.143689\%$ Power

And

$PMA_{FB(1\sigma)} = \pm PMA_{FB}/2$ % Power

$PMA_{FB(1\sigma)} = \pm 1.11/2$ % Power

$PMA_{FB(1\sigma)} = \pm 0.555\%$ Power

Per Reference 3.3 the process errors are not included in the determination of Allowable Value. Therefore,

$PMA_{AV} = 0\%$ Power

11.4.2.1.6 Input Uncertainty (σinput4B)

In addition to its own error terms, Module 4B also operates on the error terms from Module 4A. Therefore, the random error terms $\sigma 4A$, $\sigma 4A_{PP}$, σinput4A, $\sigma input4A_{AV}$, and $\sigma input4A_{LP}$ from the LPRMs must be transferred through the Averaging Circuitry. The resultant terms will be σinput4B, $\sigma input4B_{AV}$, and $\sigma input4B_{LP}$ for this module.

Since $\sigma 4A$ is in % CS and $\sigma 4A_{PP}$, $\sigma input4A$, $\sigma input4A_{AV}$, and $\sigma input4A_{LP}$ are in % power the terms must be treated differently when being transferred through the Averaging Circuitry.

If N LPRMs are being averaged the gain associated with each LPRM through the averaging circuit is 1/N. This applies to $\sigma 4A$, $\sigma 4A_{PP}$, $\sigma input4A$, $\sigma input4A_{AV}$, and $\sigma input4A_{LP}$. Following the averaging function there is a gain function (G_{APRM}) that is used for the AGAF adjustment. Since $\sigma 4A_{PP}$, $\sigma input4A$, $\sigma input4A_{AV}$, and $\sigma input4A_{LP}$ are in % power and the output is also in % power the gain function has no effect. However, $\sigma 4A$ is in % CS and the gain function has the effect of changing the calibrated span. Therefore, $\sigma 4A$ must be multiplied by G_{APRM}. Based on this discussion then $\sigma 4A$ is propagated through the Averaging Circuitry by the factor G_{APRM}/N while $\sigma input4A$ is only operated on by 1/N. If the random error terms from N LPRMs are combined by SRSS the result is:

$$\sigma input4B_{CS} = \pm\{N[\sigma 4A*(G_{APRM}/N)]^2\}^{0.5} = \pm(\sigma 4A*G_{APRM})/N^{0.5} \text{ \% CS}$$

and

$$\sigma input4B_{PP} = \pm[N(\sigma input4A/N)^2 + N(\sigma 4A_{PP}/N)^2]^{0.5} \text{ \% Power}$$

$$\sigma input4B_{PP} = \pm[(\sigma input4A)^2 + (\sigma 4A_{PP})^2]^{0.5}/N^{0.5} \text{ \% Power}$$

From Table 3.3.1-1 of Reference 3.7 the minimum number of LPRMs which must be in the average in order for an APRM to be considered operable is 14. Using this value in the above equations gives:

$$\sigma input4B_{CS} = \pm(\sigma 4A*G_{APRM})/N^{0.5} \text{ \% CS}$$

$$\sigma input4B_{CS} = \pm(0.606904*2.5)/14^{0.5} \text{ \% CS}$$

$$\sigma input4B_{CS} = \pm 0.405505\text{\% CS}$$

And

$$\sigma input4B_{PP} = \pm[(\sigma input4A)^2 + (\sigma 4A_{PP})^2]^{0.5}/N^{0.5} \text{ \% Power}$$

$$\sigma input4B_{PP} = \pm[(1.019804)^2 + (0.707107)^2]/14^{0.5} \text{ \% Power}$$

$$\sigma input4B_{PP} = \pm 0.331663 \text{ \% Power}$$

And

$$\sigma input4B_{PP(LP)} = \pm[(\sigma input4A_{LP})^2 + (\sigma 4A_{PP})^2]^{0.5}/N^{0.5} \text{ \% Power}$$

$$\sigma input4B_{PP(LP)} = \pm[(1.019804)^2 + (0.707107)^2]^{0.5}/14^{0.5} \text{ \% Power}$$

$$\sigma input4B_{PP(LP)} = \pm 0.331663 \text{ \% Power}$$

And

$$\sigma input4B_{AV} = \pm[(\sigma input4A_{AV})^2 + (\sigma 4A_{PP})^2]^{0.5}/N^{0.5} \text{ \% Power}$$

$$\sigma input4B_{AV} = \pm[(0)^2 + (0.707107)^2]^{0.5}/14^{0.5} \text{ \% Power}$$

$$\sigma input4B_{AV} = \pm 0.188982\text{\% Power}$$

11.4.2.1.7 Determination of Module Random Error ($\sigma 4B$)

Using the methodology of Reference 3.3,

$$\sigma 4B = \pm[(RA4B_{(1\sigma)})^2 + (RD4B_{(1\sigma)})^2 + (CAL4B)^2 + (ST4B_{(1\sigma)})^2 + (PMA_{1\sigma})^2 + (\sigma input4B)^2]^{0.5} \text{ \% CS}$$

However, since $\sigma input4B_{PP}$, $\sigma input4B_{PP(LP)}$, $PMA_{1\sigma}$, $PMA_{FB(1\sigma)}$, PMA_{LP}, and PMA_{AV} are in terms of percent power while the other terms are percent calibrated span, these terms will be removed from the equation until the combination of the first four terms, plus $\sigma input4B_{CS}$, has been performed and the result converted to percent power by multiplying by 125/100. Then this result will be combined with $\sigma input4B_{PP}$, $\sigma input4B_{PP(LP)}$, and $PMA_{1\sigma}$ using SRSS. Therefore, for this section the equation for $\sigma 4BI$ is:

$$\sigma 4BI = \pm[(RA4B_{(1\sigma)})^2 + (RD4B_{(1\sigma)})^2 + (CAL4B)^2 + (ST4B_{(1\sigma)})^2 + (\sigma input4B_{CS})^2]^{0.5} \text{ \% CS}$$

$$\sigma 4BI = \pm[(0.4)^2 + (0.25)^2 + (0)^2 + (0.533333)^2 + (0.405505)^2]^{0.5} \text{ \% CS}$$

$$\sigma 4BI = \pm 0.819377\text{\% CS}$$

Converting this to percent power gives:

$$\sigma 4BI_{PP} = \pm\sigma 4BI*(125/100) \text{ \% Power}$$

$$\sigma 4BI_{PP} = \pm 0.819377*(125/100) \text{ \% Power}$$

$$\sigma 4BI_{PP} = \pm 1.024221\text{\% Power}$$

Now this can be combined with σinput4B and + $PMA_{1\sigma}$ using SRSS to obtain σ4B. $\sigma 4B_{FB}$ will be created for use with the flow biased trips, $\sigma 4B_{AV}$ will be created for use with the Allowable Value calculation, and $\sigma 4B_{LP}$ will be created for use with the low power trips.

$$\sigma 4B = \pm[(\sigma 4BI_{PP})^2 + (\sigma input4B_{PP})^2 + (PMA_{1\sigma})^2]^{0.5} \text{ \% Power}$$

$$\sigma 4B = \pm[(1.024221)^2 + (0.331663)^2 + (1.143689)^2]^{0.5} \text{ \% Power}$$

$$\sigma 4B = \pm 1.570686\text{\% Power}$$

And

$$\sigma 4B_{FB} = \pm[(\sigma 4BI_{PP})^2 + (\sigma input4B_{PP})^2 + (PMA_{FB(1\sigma)})^2]^{0.5} \text{ \% Power}$$

$$\sigma 4B_{FB} = \pm[(1.024221)^2 + (0.331663)^2 + (0.555)^2]^{0.5} \text{ \% Power}$$

$$\sigma 4B_{FB} = \pm 1.21122\text{\% Power}$$

And

$$\sigma 4B_{LP} = \pm[(\sigma 4BI_{PP})^2 + (\sigma input4B_{PP(LP)})^2 + (PMA_{LP})^2]^{0.5} \text{ \% Power}$$

$$\sigma 4B_{LP} = \pm[(1.024221)^2 + (0.331663)^2 + (0)^2]^{0.5} \text{ \% Power}$$

$$\sigma 4B_{LP} = \pm 1.076582\text{\% Power}$$

And

$$\sigma 4B_{AV} = \pm[(\sigma 4BI_{PP})^2 + (\sigma input4B_{AV})^2 + (PMA_{AV})^2]^{0.5} \text{ \% Power}$$

$$\sigma 4B_{AV} = \pm[(1.024221)^2 + (0.188982)^2 + (0)^2]^{0.5} \text{ \% Power}$$

$$\sigma 4B_{AV} = \pm 1.041510\text{\% Power}$$

11.4.2.2 Module 4B Non-Random Errors (Σe4B)

11.4.2.2.1 Humidity Errors (e4BH)

Since Reference 3.11 does not identify a humidity error term a value of zero will be used per Section 4.3.

e4BH = 0% CS

11.4.2.2.2 Temperature Error (e4BT)

Since Reference 3.11 does not identify a temperature error term a value of zero will be used per Section 4.3.

e4BT = 0% CS

11.4.2.2.3 Radiation Error (e4BR)

Since Reference 3.11 does not identify a radiation error term a value of zero will be used per Section 4.3.

e4BR = 0% CS

11.4.2.2.4 Seismic Error (e4BS)

Per Section 4.7 seismic error for this module is considered negligible.

e4BS = 0% CS

11.4.2.2.5 Static Pressure Effect (e4BSP)

This module is an all electronic device that is not exposed to any pressure other than atmospheric. Therefore, there is no static pressure effect.

e4BSP = 0% CS

11.4.2.2.6 Pressure Error (e4BP)

This module is an all electronic device that is not exposed to any pressure other than atmospheric. Therefore, there is no pressure effect.

e4BP = 0% CS

11.4.2.2.7 Process Errors(e4Bp)

This module is intermediate in the loop and, as such, is not exposed to any process parameters. Therefore, there are no process errors other than that previously discussed in Section 11.4.2.1.5.

$$e4Bp = 0\%\ CS$$

11.4.2.2.8 Power Supply Effects (e4BV)

Since Reference 3.11 does not identify a power supply effect error term a value of zero will be used per Section 4.3.

$$e4BV = 0\%\ CS$$

11.4.2.2.9 Non-Random Input Error (einput4B)

In addition to its own error terms, Module 4B also operates on the error terms from the LPRMs. The non-random error from the LPRMs was kept in two terms since one is in % CS ($\Sigma e4A$) and the other in % Power (einput4A). As was done for the random terms the % CS term must be operated on by the APRM gain (G_{APRM}) whereas the % Power term is not affected by the gain. For N LPRMs being averaged the result is:

$$einput4B_{CS} = G_{APRM}*N*(1/N)*(\Sigma e4A) = G_{APRM}*\Sigma e4A\ \%\ CS$$

$$einput4B_{CS} = 2.5*0\ \%\ CS$$

$$einput4B_{CS} = 0\%\ CS$$

And

$$einput4B_{PP} = N*(1/N)*(einput4A) = einput4A\ \%\ Power$$

$$einput4B_{PP} = 0.82\%\ Power$$

And

$$einput4B_{PP(LP)} = N*(1/N)*(einput4A_{LP}) = einput4A_{LP}\ \%\ Power$$

$$einput4B_{PP(LP)} = 0.33\%\ Power$$

And

$$einput4B_{AV} = N*(1/N)*(einput4A_{AV}) = einput4A_{AV}\ \%\ Power$$

$$einput4B_{AV} = 0\%\ Power$$

These four terms will be carried forward to the next section where they will be combined after the % CS terms are converted to % Power.

11.4.2.2.10 Non-Random Error ($\Sigma e4B$)

From Reference 3.3 the non-random error is the algebraic sum of all the above terms.

$$\Sigma e4B_{CS} = \pm(e4BH + e4BT + e4BR + e4BS + e4BSP + e4BP + e4Bp + e4BV + einput4B_{CS})\%\ CS$$

$$\Sigma e4B_{CS} = \pm(0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0)\%\ CS$$

$$\Sigma e4B_{CS} = \pm 0\%\ CS$$

This will now be converted to % Power and added to $einput4B_{PP}$ to obtain the total $\Sigma e4B$.

$$\Sigma e4B = \pm\Sigma e4B_{CS} * (125/100) + einput4B_{PP}\ \%\ Power$$

$$\Sigma e4B = \pm 0 * (125/100) + 0.82\ \%\ Power$$

$$\Sigma e4B = \pm 0.82\%\ Power$$

And

$$\Sigma e4B_{LP} = \pm\Sigma e4B_{CS} * (125/100) + einput4B_{PP(LP)}\ \%\ Power$$

$$\Sigma e4B_{LP} = \pm 0 * (125/100) + 0.33\ \%\ Power$$

$$\Sigma e4B_{LP} = \pm 0.33\%\ Power$$

And

$$\Sigma e4B_{AV} = \pm\Sigma e4B_{CS} * (125/100) + einput4B_{AV}\ \%\ Power$$

$$\Sigma e4B_{AV} = \pm 0 * (125/100) + 0\ \%\ Power$$

$$\Sigma e4B_{AV} = \pm 0\%\ Power$$

11.4.3 Module 4C (Trip Circuits - Fixed)

Classification of Module

Module 4C receives an analog input from the Averaging Circuitry and provides a bistable output, the state of which depends on the relative magnitudes of the input signal and the reference value. Therefore, Module 4C is a bistable module.

11.4.3.1 Module 4C Random Error ($\sigma 4C$)

This section addresses random uncertainties that have the potential to be expressed in the output of Module 4C.

11.4.3.1.1 Reference Accuracy (RA4C)

Per Section 8.4.1 the reference accuracy for this module is:

RA4C = 1% CS

Per Assumption 5.1, this is assumed to be a 2 sigma value. This is then converted to a 1 sigma value by dividing by 2. In the same step this will be converted to % Power by multiplying by 125/100.

$$RA4C_{(1\sigma)} = \pm(RA4C/2)*(125/100) \text{ \% Power}$$

$$RA4C_{(1\sigma)} = \pm(1/2)*(125/100) \text{ \% Power}$$

$$RA4C_{(1\sigma)} = \pm 0.625\text{\% Power}$$

11.4.3.1.2 Drift (RD4C)

Per Section 8.4.1 the reference drift for this module is:

RD4C = 1% CS/700 HRS

Tables 4.3.1.1-1 and 4.3.6-1 of Reference 3.7 give the surveillance interval (RD4CTSI) for all trip functions as 26 weeks (semi-annually). In addition, a 25% late factor will added to the required value. Per Reference 3.8 drift is considered a random function and can be extended to a longer period by the square root of the ratio of the time periods per Section 2.2.5 of Reference 3.13.

Per Assumption 5.1, the drift value is assumed to be a 2 sigma value. This is then converted to a 1 sigma value by dividing by 2, and then to % Power by multiplying by

125/100. RD4CTSI is converted to hours by multiplying by 168. The one sigma drift is then:

$$RD4C_{(1\sigma)} = \pm(RD4C/2)*(125/100)*[(1.25*RD4CTSI*168)/RD4CT]^{0.5} \text{ \% Power}$$

$$RD4C_{(1\sigma)} = \pm(1/2)*(125/100)*[(1.25*26*168)/700]^{0.5} \text{ \% Power}$$

$$RD4C_{(1\sigma)} = \pm 1.74553\text{\% Power}$$

11.4.3.1.3 Calibration Uncertainty (CAL4C)

The uncertainties associated with calibrating the trip circuits are composed entirely of the uncertainties associated with the DMM used to set the input trip voltage. Per the applicable procedures of Reference 3.5 a Fluke Model 8500A is specified for this function. From Section 9.1 the error associated with this instrument is 0.00018 Vdc ($RAMTE1_{4C}$). Since this is a digital instrument $REMTE1_{4C}$ is equal to zero.

From Reference 3.3,

$$MTE1 = [(RAMTE1/n)^2 + REMTE1^2]^{0.5}$$

where n is the number of standard deviations applicable to the error term. The values of the error terms from Reference 9.1 are already expressed in one sigma terms. Therefore, the value of n is 1.

$$MTE1_{4C} = \pm[(RAMTE1_{4C}/1)^2 + REMTE1_{4C}{}^2]^{0.5} \text{ Vdc}$$

$$MTE1_{4C} = \pm[(0.00018/1)^2 + 0^2]^{0.5} \text{ Vdc}$$

$$MTE1_{4C} = \pm 0.00018 \text{ Vdc}$$

This can be converted to % Power by dividing by the voltage span (SPAN4CIN) and multiplying by the full scale power (125).

$$MTE1_{4C(PP)} = \pm[(MTE1_{4C}/SPAN4CIN)*125] \text{ \% Power}$$

$$MTE1_{4C(PP)} = \pm[(0.00018/10)*125] \text{ \% Power}$$

$$MTE1_{4C(PP)} = \pm 0.00225\text{\% Power}$$

From Section 5.2 the errors attributed to the calibration standards are considered negligible. Therefore, the only term which contributes to CAL4C is the MTE1 term.

Therefore, for this section

$$CAL4C = \pm MTE1_{4C(PP)} = \pm 0.00225\% \text{ Power}$$

11.4.3.1.4 Setting Tolerance (ST4C)

The setting tolerance listed in the applicable procedures of Reference 3.5 for this function is 0.04 Vdc. This can be converted to % Power by dividing by the voltage span (SPAN4CIN) and multiplying by the full scale power (125).

From Section 2.1.a the given setting tolerances are considered 3 sigma values. Therefore, ST4C must be divided by 3 to make it compatible with the other 1 sigma error terms. Combining this operation with the conversion to percent power gives

$$ST4C_{(1\sigma)} = \pm[(ST4C/SPAN4CIN)*125]/3 \% \text{ Power}$$

$$ST4C_{(1\sigma)} = \pm[(0.04/10)*125]/3 \% \text{ Power}$$

$$ST4C_{(1\sigma)} = \pm 0.166667\% \text{ Power}$$

11.4.3.1.5 Input Uncertainty ($\sigma input4C$ and $\sigma input4C_{LP}$)

In addition to its own error terms, the error terms from Module 4B must also be considered. Since the trip circuits perform no function on the input signal $\sigma input4C$ and $\sigma input4C_{LP}$ become equal to the random input terms $\sigma 4B$ and $\sigma 4B_{LP}$ respectively.

$$\sigma input4C = \pm \sigma 4B = \pm 1.570686\% \text{ Power}$$

And

$$\sigma input4C_{LP} = \pm \sigma 4B_{LP} = \pm 1.076582\% \text{ Power}$$

And

$$\sigma input4C_{AV} = \pm \sigma 4B_{AV} = \pm 1.04151\% \text{ Power}$$

11.4.3.1.6 Determination of Module Random Error ($\sigma 4C$, $\sigma 4C_{AV}$, and $\sigma 4C_{LP}$)

Using the methodology of Reference 3.3,

$$\sigma 4C = \pm[(RA4C_{(1\sigma)})^2 + (RD4C_{(1\sigma)})^2 + (CAL4C)^2 + (ST4C_{(1\sigma)})^2 + (\sigma input4C)^2]^{0.5} \% \text{ Power}$$

$$\sigma 4C = \pm[(0.625)^2 + (1.74553)^2 + (0.00225)^2 + (0.166667)^2 + (1.570686)^2]^{0.5} \text{ \% Power}$$

$$\sigma 4C = \pm 2.435639\text{\% Power}$$

And

$$\sigma 4C_{LP} = \pm[(RA4C_{(1\sigma)})^2 + (RD4C_{(1\sigma)})^2 + (CAL4C)^2 + (ST4C_{(1\sigma)})^2 + (\sigma input4C_{LP})^2]^{0.5} \text{ \% Power}$$

$$\sigma 4C_{LP} = \pm[(0.625)^2 + (1.74553)^2 + (0.00225)^2 + (0.166667)^2 + (1.076582)^2]^{0.5} \text{ \% Power}$$

$$\sigma 4C_{LP} = \pm 2.150421\text{\% Power}$$

And

$$\sigma 4C_{AV} = \pm[(RA4C_{(1\sigma)})^2 + (RD4C_{(1\sigma)})^2 + (CAL4C)^2 + (ST4C_{(1\sigma)})^2 + (\sigma input4C_{AV})^2]^{0.5} \text{ \% Power}$$

$$\sigma 4C_{AV} = \pm[(0.625)^2 + (1.74553)^2 + (0.00225)^2 + (0.166667)^2 + (1.04151)^2]^{0.5} \text{ \% Power}$$

$$\sigma 4C_{AV} = \pm 2.133079\text{\% Power}$$

11.4.3.2 Module 4C Non-Random Errors ($\Sigma e4C$, $\Sigma e4C_{AV}$, and $\Sigma e4C_{LP}$)

11.4.3.2.1 Humidity Errors (e4CH)

Since Reference 3.11 does not identify a humidity error term a value of zero will be used per Section 4.3.

e4CH = 0% CS

11.4.3.2.2 Temperature Error (e4CT)

Since Reference 3.11 does not identify a temperature error term a value of zero will be used per Section 4.3.

e4CT = 0% CS

11.4.3.2.3 Radiation Error (e4CR)

Since Reference 3.11 does not identify a radiation error term a value of zero will be used per Section 4.3.

e4CR = 0% CS

11.4.3.2.4 Seismic Error (e4CS)

Per Section 4.7 seismic error for this module is considered negligible.

e4CS = 0% CS

11.4.3.2.5 Static Pressure Effect (e4CSP)

This module is an all electronic device that is not exposed to any pressure other than atmospheric. Therefore, there is no static pressure effect.

e4CSP = 0% CS

11.4.3.2.6 Pressure Error (e4CP)

This module is an all electronic device that is not exposed to any pressure other than atmospheric. Therefore, there is no pressure effect.

e4CP = 0% CS

11.4.3.2.7 Process Errors(e4Cp)

This module is intermediate in the loop and, as such, is not exposed to any process parameters. Therefore, there are no process errors.

e4Cp = 0% CS

11.4.3.2.8 Power Supply Effects (e4CV)

Since Reference 3.11 does not identify a power supply effect error term a value of zero will be used per Section 4.3.

e4CV = 0% CS

11.4.3.2.9 Non-Random Input Error (einput4C and einput4C_{LP})

In addition to its own error terms, the error terms from Module 4B must also be considered. Since the trip circuits perform no function on the input signal, einput4C and einput4C_{LP} become equal to the non-random input terms Σe4B and Σe4B_{LP} respectively.

$\text{einput4C} = \pm\Sigma \text{e4B} = \pm 0.82\%$ Power

And

$\text{einput4C}_{LP} = \pm\Sigma \text{e4B}_{LP} = \pm 0.33\%$ % Power

And

$\text{einput4C}_{AV} = \pm\Sigma \text{e4B}_{AV} = \pm 0\%$ Power

11.4.3.2.10 Non-Random Error (Σe4C)

From Reference 3.3 the non-random error is the algebraic sum of all the above terms. The % CS terms will also be converted to % Power by multiplying by 125/100.

$\Sigma \text{e4C} = \pm(125/100)*(\text{e4CH} + \text{e4CT} + \text{e4CR} + \text{e4CS} + \text{e4CSP} + \text{e4CP} + \text{e4Cp} + \text{e4CV}) + \text{einput4C}\%$ Power

$\Sigma \text{e4C} = \pm(125/100)*(0 + 0 + 0 + 0 + 0 + 0 + 0 + 0) + 0.82$ % Power

$\Sigma \text{e4C} = \pm 0.82\%$ Power

And

$\Sigma e4C_{LP} = \pm(125/100)*(e4CH + e4CT + e4CR + e4CS + e4CSP + e4CP + e4Cp + e4CV) + einput4C_{LP}$ % Power

$\Sigma e4C_{LP} = \pm(125/100)*(0 + 0 + 0 + 0 + 0 + 0 + 0 + 0) + 0.33$ % Power

$\Sigma e4C_{LP} = \pm 0.33$% Power

And

$\Sigma e4C_{AV} = \pm(125/100)*(e4CH + e4CT + e4CR + e4CS + e4CSP + e4CP + e4Cp + e4CV) + einput4C_{AV}$ % Power

$\Sigma e4C_{AV} = \pm(125/100)*(0 + 0 + 0 + 0 + 0 + 0 + 0 + 0) + 0$ % Power

$\Sigma e4C_{AV} = \pm 0$% Power

11.4.4 Module 4D (Trip Circuit - Flow Biased)

Classification of Module

Module 4D receives an analog input from the Averaging Circuitry and the Flow Summer (Module 3), and provides a bistable output, the state of which depends on the relative magnitudes of the input signal from the Averaging Circuitry and the reference value, which is a function of the Flow Summer signal. Therefore, Module 4D is a bistable module.

11.4.4.1 Module 4D Random Error ($\sigma 4D$)

This section addresses random uncertainties that have the potential to be expressed in the output of Module 4D.

11.4.4.1.1 Reference Accuracy (RA4D)

Per Section 8.4.1 the reference accuracy for this module is:

RA4D = 1% CS

Per Assumption 5.1, this is assumed to be a 2 sigma value. This is then converted to a 1 sigma value by dividing by 2. In the same step this will be converted to % Power by multiplying by 125/100.

$$RA4D_{(1\sigma)} = \pm(RA4D/2)*(125/100) \text{ \% Power}$$

$$RA4D_{(1\sigma)} = \pm(1/2)*(125/100) \text{ \% Power}$$

$$RA4D_{(1\sigma)} = \pm 0.625\% \text{ Power}$$

11.4.4.1.2 Drift (RD4D)

Per Section 8.4.1 the reference drift for this module is:

RD4D = 1% CS/700 HRS

Table 4.3.1.1-1 and 4.3.6-1 of Reference 3.7 give the surveillance interval (RD4DTSI) for all trip functions as 26 weeks (semi-annually). In addition, a 25% late factor will added to the required value. Per Reference 3.8 drift is considered a random function and can be extended to a longer period by the square root of the ratio of the time periods per Section 2.2.5 of Reference 3.13.

Per Assumption 5.1, the drift value is assumed to be a 2 sigma value. This is then converted to a 1 sigma value by dividing by 2, and then to % Power by multiplying by 125/100. RD4DTSI is converted to hours by multiplying by 168. The one sigma drift is then:

$$RD4D_{(1\sigma)} = \pm(RD4D/2)*(125/100)*[(1.25*RD4DTSI*168)/RD4DT]^{0.5} \text{ \% Power}$$

$$RD4D_{(1\sigma)} = \pm(1/2)*(125/100)*[(1.25*26*168)/700]^{0.5} \text{ \% Power}$$

$$RD4D_{(1\sigma)} = \pm 1.74553\text{\% Power}$$

11.4.4.1.3 Calibration Uncertainty (CAL4D)

The uncertainties associated with calibrating the trip circuits are composed entirely of the uncertainties associated with the DMM used to set the input trip voltage. Per the applicable procedures of Reference 3.5 a Fluke Model 8500A is specified for this function. From Section 9.1 the error associated with this instrument is 0.00018 Vdc ($RAMTE1_{4D}$). Since this is a digital instrument $REMTE1_{4D}$ is equal to zero.

From Reference 3.3,

$$MTE1 = [(RAMTE1/n)^2 + REMTE1^2]^{0.5}$$

where n is the number of standard deviations applicable to the error term. The values of the error terms from Reference 9.1 are already expressed in one sigma terms. Therefore, the value of n is 1.

$$MTE1_{4D} = \pm[(RAMTE1_{4D}/1)^2 + REMTE1_{4D}^2]^{0.5} \text{ Vdc}$$

$$MTE1_{4D} = \pm[(0.00018/1)^2 + 0^2]^{0.5} \text{ Vdc}$$

$$MTE1_{4D} = \pm 0.00018 \text{ Vdc}$$

This can be converted to % Power by dividing by the voltage span (SPAN4CIN - Both Fixed and Flow Biased trips have the same input span) and multiplying by the full scale power (125).

$$MTE1_{4D(PP)} = \pm[(MTE1_{4D}/SPAN4CIN)*125] \text{ \% Power}$$

$$MTE1_{4D(PP)} = \pm[(0.00018/10)*125] \text{ \% Power}$$

$$MTE1_{4D(PP)} = \pm 0.00225\text{\% Power}$$

From Section 5.2 the errors attributed to the calibration standards are considered negligible. Therefore, the only term which contributes to CAL4D is the MTE1 term. Therefore, for this section

$$CAL4D = \pm MTE1_{4D(PP)} = \pm 0.00225\% \text{ Power}$$

11.4.4.1.4 Setting Tolerance (ST4D)

The setting tolerance listed in the applicable procedures for this function is 0.04 Vdc. This can be converted to % Power by dividing by the voltage span (SPAN4CIN) and multiplying by the full scale power (125). From Section 2.1.a the given setting tolerances are considered 3 sigma values. Therefore, ST4D must be divided by 3 to make it compatible with the other 1 sigma error terms. Combining this operation with the conversion to percent power gives

$$ST4D_{(1\sigma)} = \pm[(ST4D/SPAN4CIN)*125]/3 \text{ \% Power}$$

$$ST4D_{(1\sigma)} = \pm[(0.04/10)*125]/3 \text{ \%} = \pm 0.166667\% \text{ Power}$$

11.4.4.1.5 Input Uncertainty (σinput4D)

The Module 4D input error (σinput4D) is the SRSS combination of random input terms from Module 4B ($\sigma 4B_{FB}$) and Module 3 (σ3). However, σ3 must be converted from % Flow to % Power using the flow biased trip slope adjustment from Section 2.2 which accounts for setting uncertainties.

11.4.4.1.5.1 Two Loop Operation (TLO) - From Design Input 4.14, the TLO flow biased slope (FCS_{SP}) is 0.62 which is adjusted as

$$FCS = FCS_{SP} + [(0.04+0.04)/0.08]/80$$
$$= 0.62 + [(0.04+0.04)/0.08]/80 \qquad = 0.6325$$

The module 4D input uncertainty for TLO is determined as

$$\sigma input4D = \pm[\sigma 4B_{FB}{}^{2} + (FCS * \sigma 3)^{2}]^{0.5}$$
$$\sigma input4D = \pm[1.21122^{2} + (0.6325 * 2.546521)^{2}]^{0.5}$$

$$\sigma input4D = \pm 2.015273\% \text{ Power}$$

And the module 4D AV uncertainty for TLO is determined as

$$\sigma input4D_{AV} = \pm[\sigma 4B_{AV}{}^{2} + (FCS * \sigma 3_{C})^{2}]^{0.5}$$
$$\sigma input4D_{AV} = \pm[(1.041510)^{2} + (0.6325 * 1.669197)^{2}]^{0.5}$$

$$\sigma input4D_{AV} = \pm 1.483033\% \text{ Power}$$

11.4.4.1.5.2 Single Loop Operation (SLO) - From Design Input 4.14, the SLO flow biased slope (FCS_{SPSLO}) is 0.55 which is adjusted as

$$FCS_{SLO} = FCS_{SPSLO} + [(0.04+0.04)/0.08]/80$$
$$= 0.55 + [(0.04+0.04)/0.08]/80 = 0.5625$$

The module 4D input uncertainty for SLO is determined as

$$\sigma input4D_{SLO} = \pm[\sigma 4B_{FB}{}^2 + (FCS_{SLO} * \sigma 3)^2]^{0.5}$$
$$\sigma input4D_{SLO} = \pm\{1.21122^2 + [(0.5625)*(2.546521)]^2\}^{0.5}$$

$$\sigma input4D_{SLO} = \pm 1.875867\% \text{ Power}$$

And the module 4D AV uncertainty for SLO is determined as

$$\sigma input4D_{AVSLO} = \pm[\sigma 4B_{AV}{}^2 + (FCS_{SLO} * \sigma 3_C)^2]^{0.5}$$
$$\sigma input4D_{AVSLO} = \pm[(1.041510)^2 + (0.5625 * 1.669197)^2]^{0.5}$$

$$\sigma input4D_{AVSLO} = \pm 1.402255\% \text{ Power}$$

11.4.4.1.6 Determination of Module Random Error

11.4.4.1.6.1 Two Loop Operation - Total module 4D random error is

$$\sigma 4D = \pm[RA4D_{(1\sigma)}{}^2 + RD4D_{(1\sigma)}{}^2 + CAL4D^2 + ST4D_{(1\sigma)}{}^2 + \sigma input4D^2]^{0.5}$$
$$\sigma 4D = \pm[0.625^2 + 1.74553^2 + 0.00225^2 + 0.166667^2 + 2.015273^2]^{0.5}$$

$$\sigma 4D = \pm 2.743466\% \text{ Power}$$

And the module 4D AV random error is

$$\sigma 4D_{AV} = \pm[RA4D_{(1\sigma)}{}^2 + RD4D_{(1\sigma)}{}^2 + CAL4D^2 + ST4D_{(1\sigma)}{}^2 + \sigma input4D_{AV}{}^2]^{0.5}$$
$$\sigma 4D_{AV} = \pm[0.625^2 + 1.74553^2 + 0.00225^2 + 0.166667^2 + 1.483033^2]^{0.5}$$

$$\sigma 4D_{AV} = \pm 2.380057\% \text{ Power}$$

11.4.4.1.6.2 Single Loop Operation - Total module 4D random error is

$$\sigma 4D_{SLO} = \pm[RA4D_{(1\sigma)}{}^2 + RD4D_{(1\sigma)}{}^2 + CAL4D^2 + ST4D_{(1\sigma)}{}^2 + \sigma input4D_{SLO}{}^2]^{0.5}$$
$$\sigma 4D_{SLO} = \pm[0.625^2 + 1.74553^2 + 0.00225^2 + 0.166667^2 + 1.875867^2]^{0.5}$$

$$\sigma 4D_{SLO} = \pm 2.642756\% \text{ Power}$$

And the module 4D AV random error is

$$\sigma 4D_{AVSLO} = \pm[RA4D_{(1\sigma)}{}^2 + RD4D_{(1\sigma)}{}^2 + CAL4D^2 + ST4D_{(1\sigma)}{}^2 + \sigma input4D_{AVSLO}{}^2]^{0.5}$$
$$\sigma 4D_{AVSLO} = \pm[0.625^2 + 1.74553^2 + 0.00225^2 + 0.166667^2 + 1.402255^2]^{0.5}$$

$$\sigma 4D_{AVSLO} = \pm 2.330580\% \text{ Power}$$

11.4.4.2 Module 4D Non-Random Errors ($\Sigma e4D$)

11.4.4.2.1 Humidity Errors (e4DH)

Since Reference 3.11 does not identify a humidity error term a value of zero will be used per Section 4.3.

e4DH = 0% CS

11.4.4.2.2 Temperature Error (e4DT)

Since Reference 3.11 does not identify a temperature error term a value of zero will be used per Section 4.3.

e4DT = 0% CS

11.4.4.2.3 Radiation Error (e4DR)

Since Reference 3.11 does not identify a radiation error term a value of zero will be used per Section 4.3.

e4DR = 0% CS

11.4.4.2.4 Seismic Error (e4DS)

Per Section 4.7 seismic error for this module is considered negligible.

e4DS = 0% CS

11.4.4.2.5 Static Pressure Effect (e4DSP)

This module is an all electronic device that is not exposed to any pressure other than atmospheric. Therefore, there is no static pressure effect.

e4DSP = 0% CS

11.4.4.2.6 Pressure Error (e4DP)

This module is an all electronic device that is not exposed to any pressure other than atmospheric. Therefore, there is no pressure effect.

e4DP = 0% CS

11.4.4.2.7 Process Errors(e4Dp)

This module is intermediate in the loop and, as such, is not exposed to any process parameters. Therefore, there are no process errors.

$$e4Dp = 0\%\ CS$$

11.4.4.2.8 Power Supply Effects (e4DV)

Since Reference 3.11 does not identify a power supply effect error term a value of zero will be used per Section 4.3.

$$e4DV = 0\%\ CS$$

11.4.4.2.9 Non-Random Input Error (einput4D)

The module 4D input error (einput4D) is equal to the combination by algebraic addition of the non-random input terms from Module 4B (Σe4B) and Module 3 (Σe3). However, Σe3 must be converted from % Flow to % Power using the same flow biased trip slope adjustments determined in Section 11.4.4.1.5.

11.4.4.2.9.1 Two Loop Operation (TLO) - Using the FCS determined in Section 11.4.4.1.5.1, the module 4D input error for TLO is determined as

$$einput4D = \pm[\Sigma e4B + (FCS * \Sigma e3)]$$
$$einput4D = \pm[0.82 + (0.632500 * 1.274635)]$$

$$einput4D = \pm 1.626207\%\ Power$$

And the module 4D AV error for TLO is determined as

$$einput4D_{AV} = \pm[\Sigma e4B_{AV} + (FCS * \Sigma e3)]$$
$$einput4D_{AV} = \pm[0 + (0.632500*1.274635)]$$

$$einput4D_{AV} = \pm 0.806207\%\ Power$$

11.4.4.2.9.2 Single Loop Operation (SLO) - Using the FCS determined in Section 11.4.4.1.5.2, the module 4D input error for SLO is determined as

$$einput4D_{SLO} = \pm[\Sigma e4B + (FCS * \Sigma e3)]$$
$$einput4D_{SLO} = \pm[0.82 + (0.562500 * 1.274635)]$$

$$einput4D_{SLO} = \pm 1.536982\%\ Power$$

And the module 4D AV error for SLO is determined as

$$einput4D_{AVSLO} = \pm[\Sigma e4B_{AV} + (FCS * \Sigma e3)]$$
$$einput4D_{AVSLO} = \pm[0 + (0.562500 * 1.274635)]$$

$$einput4D_{AVSLO} = \pm 0.716982\% \text{ Power}$$

11.4.4.2.10 Module 4D Non-Random Error ($\Sigma e4D$)

11.4.4.2.10.1 Two Loop Operation (TLO) - the module 4D total random error for TLO is

$$\Sigma e4D = \pm(125/100) * (e4DH + e4DT + e4DR + e4DS + e4DSP + e4DP + e4Dp + e4DV) + einput4D$$
$$\Sigma e4D = \pm(125/100) * (0 + 0 + 0 + 0 + 0 + 0 + 0 + 0) + 1.626207$$

$$\Sigma e4D = \pm 1.626207 \text{ \% Power}$$

And the module 4D AV error for TLO is determined as

$$\Sigma e4D_{AV} = \pm(125/100) * (e4DH + e4DT + e4DR + e4DS + e4DSP + e4DP + e4Dp + e4DV) + einput4D_{AV}$$
$$\Sigma e4D_{AV} = \pm(125/100) * (0+0+0+0+0+0+0+0) + 0.806207$$

$$\Sigma e4D_{AV} = \pm 0.806207 \text{ \% Power}$$

11.4.4.2.10.2 Single Loop Operation (SLO) - the module 4D total random error for SLO is

$$\Sigma e4D_{SLO} = \pm(125/100) * (e4DH + e4DT + e4DR + e4DS + e4DSP + e4DP + e4Dp + e4DV) + einput4D_{SLO}$$
$$\Sigma e4D_{SLO} = \pm(125/100) * (0 + 0 + 0 + 0 + 0 + 0 + 0 + 0) + 1.536982$$

$$\Sigma e4D_{SLO} = \pm 1.536982 \text{ \% Power}$$

And the module 4D AV error for SLO is determined as

$$\Sigma e4D_{AVSLO} = \pm(125/100) * (e4DH + e4DT + e4DR + e4DS + e4DSP + e4DP + e4Dp + e4DV) + einput4D_{AVSLO}$$
$$\Sigma e4D_{AVSLO} = \pm(125/100) * (0+0+0+0+0+0+0+0) + 0.716982$$

$$\Sigma e4D_{AVSLO} = \pm 0.716982 \text{ \% Power}$$

11.5 Module 5 (RBM)

The RBM will be divided into three parts for this calculation; RBM Averaging and Gain Change Circuitry, Trip Circuits (Fixed), and Trip Circuits (Flow Biased). These will be designated Module 5A, 5B, and 5C respectively. This separation is performed for convenience and because the calibration procedures of Reference 3.5 effectively make this separation.

11.5.1 Module 5A (RBM Averaging and Gain Change Circuitry)

Classification of Module

Module 5A receives analog inputs from multiple LPRM cards. These signals are averaged and then operated on by the Gain Change Circuitry resulting in an analog output that is some multiple of the average of the input signals. Therefore, Module 5A is an analog module.

11.5.1.1 Module 5A Random Error (σ5A)

This section addresses random uncertainties that have the potential to be expressed in the output of Module 5A.

11.5.1.1.1 Reference Accuracy (RA5A)

Per Section 8.5.1 the reference accuracy for this module is:

RA5A = 0.8% CS

The vendor also lists another accuracy term called "Accuracy of Null". This is the accuracy with which the RBM can adjust its gain so that its output is equal to the output of the reference APRM. The value for this term is:

$RA5A_{NULL}$ = ±1% of Point

Since the maximum power at which the RBM is used is essentially 100% Power, this nulling error represents a maximum of 1% Power which can be converted to % CS by multiplying by 100/125. The nulling error and the reference accuracy can be combined using SRSS.

Per Assumption 5.1, these are assumed to be 2 sigma values. They are then converted to 1 sigma values by dividing by 2.

$$RA5A_{(1\sigma)} = \pm\{(RA5A/2)^2 + [(100/125)*(RA5A_{NULL}/2)]^2\}^{0.5} \text{ CS}$$

$RA5A_{(1\sigma)} = \pm\{(0.8/2)^2 + [(100/125)*(1/2)]^2\}^{0.5}$ % CS

$RA5A_{(1\sigma)} = \pm 0.565685\%$ CS

11.5.1.1.2 Drift (RD5A)

Per Section 8.5.1 the reference drift for this module is:

RD5A = 0.3% CS/4 Hrs

The RBM automatically performs a gain adjustment each time a control rod is selected. This control rod selection process occurs much more frequently than the drift interval. Therefore, per Section 2.1.b the vendor drift data can be used as is. Per Assumption 5.1, RD5A is assumed to be a 2 sigma value. This will be converted to a 1 sigma value by dividing by 2.

$RD5A_{(1\sigma)} = \pm(RD5A/2)$ % CS

$RD5A_{(1\sigma)} = \pm(0.3/2)$ % CS

$RD5A_{(1\sigma)} = \pm 0.15\%$ CS

11.5.1.1.3 Calibration Uncertainty (CAL5A)

The uncertainties associated with calibrating the RBM Averaging and Gain Change Circuitry are composed entirely of the uncertainties associated with the DMM used to measure the zero offset of the amplifier on the Driver Card. Per the applicable procedures of Reference 3.5 a Fluke Model 8500A is specified for this function. From Section 9.1 the error associated with this instrument is 0.00018 Vdc ($RAMTE1_{5A}$). Since this is a digital instrument $REMTE1_{5A}$ is equal to zero.

From Reference 3.3,

$MTE1 = [(RAMTE1/n)^2 + REMTE1^2]^{0.5}$

where n is the number of standard deviations applicable to the error term. The values of the error terms from Reference 9.1 are already expressed in one sigma terms. Therefore, the value of n is 1.

$MTE1_{5A} = \pm[(RAMTE1_{5A}/1)^2 + REMTE1_{5A}{}^2]^{0.5}$ Vdc

$MTE1_{4C} = \pm[(0.00018/1)^2 + 0^2]^{0.5}$ Vdc

$MTE1_{4C} = \pm0.00018$ Vdc

From Section 5.2 the errors attributed to the calibration standards are considered negligible. Therefore, the only term which contributes to CAL5A is MTE1. In order to convert CAL5A to % CS, $MTE1_{5A}$ will be divided by the RBM span ($SPAN_{RBM}$) and multiplied by 100. For this calculation

$CAL5A = \pm(MTE1_{5A}/SPAN_{RBM})*100$ % CS

$CAL5A = \pm(0.00018/10)*100$ % CS

$CAL5A = \pm0.0018\%$ CS

11.5.1.1.4 Setting Tolerance (ST5A)

The setting tolerance for the RBM Averaging and Gain Change Circuitry calibration is the allowance in setting the zero offset of the amplifier on the Driver Card. From the applicable procedures in Reference 3.5 this allowance (ST5A) is ±0.025 Vdc. This can be converted to % CS by dividing by the RBM span ($SPAN_{RBM}$) and multiplying by 100.

From Section 2.1.a the given setting tolerances are considered 3 sigma values. Therefore, ST5A must be divided by 3 to make it compatible with the other 1 sigma error terms. Combining this operation with the conversion to percent calibrated span gives

$ST5A_{(1\sigma)} = \pm[(ST5A/SPAN_{RBM})*100]/3$ % CS

$ST5A_{(1\sigma)} = \pm[(0.025/10)*100]/3$ % CS

$ST5A_{(1\sigma)} = \pm0.083333\%$ CS

11.5.1.1.5 Process Measurement Accuracy (PMA_{RBM})

Section 4.5 of Reference 3.13 contains an error term called PMA of which part is applicable to the RBMs. Although primarily applicable to large and rapid transient events, the tracking portion of this error is considered applicable to the RBM. Therefore,

$PMA_{RBM} = \pm1.11\%$ Power

This is considered to be a 2 sigma value and must be divided by 2 in order to make it compatible with the other error terms.

$PMA_{RBM(1\sigma)} = \pm PMA_{RBM}/2$ % Power

$PMA_{RBM(1\sigma)} = \pm 1.11/2$ % Power

$PMA_{RBM(1\sigma)} = \pm 0.555\%$ Power

Per Reference 3.3 process terms are not to be included in the Allowable Value determination. Therefore,

$PMA_{RBM(AV)} = 0\%$ Power

11.5.1.1.6 Input Uncertainty (σinput5A)

In addition to its own error terms, Module 5A also operates on the error terms from Module 4A. Therefore, the random error terms $\sigma 4A$, $\sigma 4A_{PP}$, $\sigma input4A_{AV}$, and σinput4A from the LPRMs must be transferred through the Averaging and Gain Change Circuitry. The resultant term will be σinput5A for this module.

Since $\sigma 4A$ is in % CS and $\sigma 4A_{PP}$, $\sigma input4A_{AV}$, and σinput4A are in % power they term must be treated differently when being transferred through the Averaging and Gain Change Circuitry.

If N LPRMs are being averaged the gain associated with each LPRM through the averaging circuit is 1/N. This applies to both $\sigma 4A$ and σinput4A. Following the averaging function there is a gain function (G_{RBM}) that adjusts the RBM output to read the same as the reference APRM (Section 4.8). Since $\sigma 4A_{PP}$, $\sigma input4A_{AV}$, and σinput4A are in % power and the output is also in % power the gain function has no effect. However, $\sigma 4A$ is in % CS and the gain function has the effect of changing the calibrated span. Therefore, $\sigma 4A$ must be multiplied by G_{RBM}. Based on this discussion then $\sigma 4A$ is propagated through the Averaging and Gain Change Circuitry by the factor G_{RBM}/N_{RBM} while $\sigma 4A_{PP}$, $\sigma input4A_{AV}$, and σinput4A are only operated on by $1/N_{RBM}$. If the random error terms from N LPRMs are combined by SRSS the result is:

$$\sigma input5A_{CS} = \pm\{N_{RBM}*[\sigma 4A*(G_{RBM}/N_{RBM})]^2\}^{0.5}$$
$$= \pm(\sigma 4A*G_{RBM})/(N_{RBM})^{0.5} \text{ \% CS}$$

and

$$\sigma input5A_{PP} = \pm\{N_{RBM}*[(\sigma input4A/N_{RBM})^2 + (\sigma 4A_{PP}/N_{RBM})^2]\}^{0.5}$$
$$\sigma input5A_{PP} = \pm[(\sigma input4A)^2 + (\sigma 4A_{PP})^2]^{0.5}/(N_{RBM})^{0.5} \text{ \% Power}$$

From Section 4.5.6 of Reference 3.10 the minimum number of

LPRMs which must be in the average in order for an RBM to be considered operable is 2. Using this value in the above equations gives:

$$\sigma input5A_{CS} = \pm(\sigma 4A*G_{RBM})/(N_{RBM})^{0.5}\ \%\ CS$$

$$\sigma input5A_{CS} = \pm(0.606904*2.5)/2^{0.5}\ \%\ CS$$

$$\sigma input5A_{CS} = \pm 1.072865\%\ CS$$

And

$$\sigma input5A_{PP} = \pm[(\sigma input4A)^2 + (\sigma 4A_{PP})^2]^{0.5}/(N_{RBM})^{0.5}\ \%\ Power$$

$$\sigma input5A_{PP} = \pm[(1.019804)^2+(0.707107)^2]^{0.5}/2^{0.5}\ \%\ Power$$

$$\sigma input5A_{PP} = \pm 0.877496\ \%\ Power$$

And

$$\sigma input5A_{AV} = \pm[(\sigma input4A_{AV})^2 + (\sigma 4A_{PP})^2]^{0.5}/(N_{RBM})^{0.5}\ \%\ Power$$

$$\sigma input5A_{AV} = \pm[(0)^2 + (0.707107)^2]^{0.5}/2^{0.5}$$

$$\sigma input5A_{AV} = \pm 0.500000\%\ Power$$

Since the output of the Averaging and Gain Change Circuitry is the output of the RBM, it is desirable to have the terms in % Power. $\sigma input5A_{cs}$ can be converted to % Power by multiplying by the output span (125%) and dividing by 100%. The result is:

$$\sigma input5A_{CS(PP)} = \pm\sigma input5A_{CS}(125/100)\ \%\ Power$$

$$\sigma input5A_{CS(PP)} = \pm 1.072865*(125/100)\ \%\ Power$$

$$\sigma input5A_{CS(PP)} = \pm 1.341081\%\ Power$$

Now that all uncertainty terms are in % Power they may be combined by SRSS.

$$\sigma input5A = \pm[(\sigma input5A_{PP})^2 + (\sigma input5A_{CS(PP)})^2]^{0.5}\ \%\ Power$$

$$\sigma input5A = \pm[(0.877496)^2 + (1.341081)^2]^{0.5}\ \%\ Power$$

$$\sigma input5A = \pm 1.602653\%\ Power$$

And

$$\sigma input5AA_{AV} = \pm[(\sigma input5A_{AV})^2 + (\sigma input5A_{CS(PP)})^2]^{0.5} \text{ \% Power}$$

$$\sigma input5AA_{AV} = \pm[(0.5)^2 + (1.341081)^2]^{0.5} \text{ \% Power}$$

$$\sigma input5AA_{AV} = \pm 1.431258\text{\% Power}$$

11.5.1.1.7 Determination of Module Random Error ($\sigma 5A$)

Using the methodology of Reference 3.3,

$$\sigma 5A = \pm[(RA5A_{(1\sigma)})^2 + (RD5A_{(1\sigma)})^2 + (CAL5A)^2 + (ST5A_{(1\sigma)})^2 + (PMA_{RBM(1\sigma)})^2 + (\sigma input5A)^2]^{0.5} \text{ \% CS}$$

However, since σinput5A and $PMA_{RBM(1\sigma)}$ are in terms of percent power while the other terms are percent calibrated span, these terms will be removed from the equation until the combination of the first four terms has been performed and the result converted to percent power by multiplying by 125/100. Then this result will be combined with σinput5A and $PMA_{RBM(1\sigma)}$ using SRSS. Therefore, for this section the equation for $\sigma 5AI$ is:

$$\sigma 5AI = \pm[(RA5A_{(1\sigma)})^2 + (RD5A_{(1\sigma)})^2 + (CAL5A)^2 + (ST5A_{(1\sigma)})^2]^{0.5} \text{ \% CS}$$

$$\sigma 5AI = \pm[(0.565685)^2 + (0.15)^2 + (0.0018)^2 + (0.083333)^2]^{0.5} \text{ \% CS}$$

$$\sigma 5AI = \pm 0.591141\text{\% CS}$$

Converting this to percent power gives:

$$\sigma 5AI_{PP} = \pm\sigma 5AI*(125/100) \text{ \% Power}$$

$$\sigma 5AI_{PP} = \pm 0.591141*(125/100) \text{ \% Power}$$

$$\sigma 5AI_{PP} = \pm 0.738926\text{\% Power}$$

Now this can be combined with σinput5A and $PMA_{RBM(1\sigma}$ using SRSS to obtain $\sigma 5A$.

$$\sigma 5A = \pm[(\sigma 5AI_{PP})^2 + (\sigma input5A)^2 + (PMA_{RBM(1\sigma)})^2]^{0.5} \text{ \% Power}$$

$$\sigma 5A = \pm[(0.738926)^2 + (1.602653)^2 + (0.555)^2]^{0.5} \text{ \% Power}$$

$$\sigma 5A = \pm 1.850009\text{\% Power}$$

And

$$\sigma 5A_{AV} = \pm[(\sigma 5AI_{PP})^2 + (\sigma input5AA_{AV})^2 + (PMA_{RBM(AV)})^2]^{0.5} \text{ \% Power}$$

$$\sigma 5A_{AV} = \pm[(0.738926)^2 + (1.431258)^2 + (0)^2]^{0.5} \text{ \% Power}$$

$$\sigma 5A_{AV} = \pm 1.610749\% \text{ Power}$$

11.5.1.2 Module 5A Non-Random Errors ($\Sigma e5A$)

11.5.1.2.1 Humidity Errors (e5AH)

Since Reference 3.12 does not identify a humidity error term a value of zero will be used per Section 4.3.

e5AH = 0% CS

11.5.1.2.2 Temperature Error (e5AT)

Since Reference 3.12 does not identify a temperature error term a value of zero will be used per Section 4.3.

e5AT = 0% CS

11.5.1.2.3 Radiation Error (e5AR)

Since Reference 3.12 does not identify a radiation error term a value of zero will be used per Section 4.3.

e5AR = 0% CS

11.5.1.2.4 Seismic Error (e5AS)

Per Section 4.7 seismic error for this module is considered negligible.

e5AS = 0% CS

11.5.1.2.5 Static Pressure Effect (e5ASP)

This module is an all electronic device that is not exposed to any pressure other than atmospheric. Therefore, there is no static pressure effect.

e5ASP = 0% CS

11.5.1.2.6 Pressure Error (e5AP)

This module is an all electronic device that is not exposed to any pressure other than atmospheric. Therefore, there is no pressure effect.

e5AP = 0% CS

11.5.1.2.7 Process Errors(e5Ap)

This module is intermediate in the loop and, as such, is not exposed to any process parameters. Therefore, there are no process errors other than that previously discussed in Section 11.5.1.1.5.

$$e5Ap = 0\% \ CS$$

11.5.1.2.8 Power Supply Effects (e5AV)

Since Reference 3.12 does not identify a power supply effect error term a value of zero will be used per Section 4.3.

$$e5AV = 0\% \ CS$$

11.5.1.2.9 Non-Random Input Error (einput5A)

In addition to its own error terms, Module 5A also operates on the error terms from the LPRMs. The non-random error from the LPRMs was kept in three terms since one is in % CS ($\Sigma e4A$) and the other two in % Power (einput4A and einput4A_{AV}). As was done for the random terms the % CS term must be operated on by the RBM gain (G_{RBM}) whereas the % Power terms are not affected by the gain. For N LPRMs being averaged the result is:

$$einput5A_{CS} = G_{RBM}*N*(1/N)*(\Sigma e4A) = G_{RBM}*\Sigma e4A \ \% \ CS$$

$$einput5A_{CS} = 2.5*0 \ \% \ CS$$

$$einput5A_{CS} = 0\% \ CS$$

And

$$einput5A_{PP} = N*(1/N)*(einput4A) = einput4A \ \% \ Power$$

$$einput5A_{PP} = 0.82\% \ Power$$

And for the Allowable Value term:

$$einput5A_{AV} = N*(1/N)*(einput4A_{AV}) = einput4A_{AV} \ \% \ Power$$

$$einput5A_{AV} = 0\% \ Power$$

These three terms will be carried forward to the next section where they will be combined after the % CS terms are converted to % Power.

11.5.1.2.10 Non-Random Error ($\Sigma e5A$)

From Reference 3.3 the non-random error is the algebraic sum of all the above terms.

$$\Sigma e5A_{CS} = \pm(e5AH + e5AT + e5AR + e5AS + e5ASP + e5AP + e5Ap + e5AV + einput5A_{CS})\%\ CS$$

$$\Sigma e5A_{CS} = \pm(0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0)\%\ CS$$

$$\Sigma e5A_{CS} = \pm 0\%\ CS$$

This will now be converted to % Power and added to $einput5A_{PP}$ to obtain the total $\Sigma e5A$.

$$\Sigma e5A = \pm\Sigma e5A_{CS}*(125/100) + einput5A_{PP}\ \%\ Power$$

$$\Sigma e5A = \pm 0*(125/100) + 0.82\ \%\ Power$$

$$\Sigma e5A = \pm 0.82\%\ Power$$

And

$$\Sigma e5A_{AV} = \pm\Sigma e5A_{CS}*(125/100) + einput5A_{AV}\ \%\ Power$$

$$\Sigma e5A_{AV} = \pm 0*(125/100) + 0\ \%\ Power$$

$$\Sigma e5A_{AV} = \pm 0\%\ Power$$

11.5.2 Module 5B (Trip Circuit - Fixed)

Classification of Module

Module 5B receives an analog input from the Averaging and Gain Change Circuitry and provides a bistable output, the state of which depends on the relative magnitudes of the input signal and the reference value. Therefore, Module 5B is a bistable module.

11.5.2.1 Module 5B Random Error ($\sigma 5B$)

This section addresses random uncertainties that have the potential to be expressed in the output of Module 5B.

11.5.2.1.1 Reference Accuracy (RA5B)

Per Section 8.5.1 the reference accuracy for this module is:

RA5B = 1% CS

Per Assumption 5.1, this is assumed to be a 2 sigma value. This is then converted to a 1 sigma value by dividing by 2. In the same step this will be converted to % Power by multiplying by 125/100.

$$RA5B_{(1\sigma)} = \pm(RA5B/2)*(125/100) \text{ \% Power}$$

$$RA5B_{(1\sigma)} = \pm(1/2)*(125/100) \text{ \% Power}$$

$$RA5B_{(1\sigma)} = \pm 0.625\% \text{ Power}$$

11.5.2.1.2 Drift (RD5B)

Per Section 8.5.1 the reference drift for this module is:

RD5B = 1% CS/700 HRS

Table 4.3.6-1 of Reference 3.7 gives the surveillance interval (RD5BTSI) for all trip functions as 13 weeks (quarterly). In addition, a 25% late factor will added to the required value. Per Reference 3.8 drift is considered a random function and can be extended to a longer period by the square root of the ratio of the time periods per Section 2.2.5 of Reference 3.13.

Per Assumption 5.1, the drift value is assumed to be a 2 sigma value. This is then converted to a 1 sigma value by dividing by 2, and then to % Power by multiplying by

125/100. RD5BTSI is converted to hours by multiplying by 168. The one sigma drift is then:

$$RD5B_{(1\sigma)} = \pm(RD5B/2)*(125/100)*[(1.25*RD5BTSI*168)/RD5BT]^{0.5} \text{ \% Power}$$

$$RD5B_{(1\sigma)} = \pm(1/2)*(125/100)*[(1.25*13*168)/700]^{0.5} \text{ \% Power}$$

$$RD5B_{(1\sigma)} = \pm 1.234276\text{\% Power}$$

11.5.2.1.3 Calibration Uncertainty (CAL5B)

The uncertainties associated with calibrating the trip circuits are composed entirely of the uncertainties associated with the DMM used to set the input trip voltage. Per the applicable procedures of Reference 3.5 a Fluke Model 8500A is specified for this function. From Section 9.1 the error associated with this instrument is 0.00018 Vdc ($RAMTE1_{5B}$). Since this is a digital instrument $REMTE1_{5B}$ is equal to zero.

From Reference 3.3,

$$MTE1 = [(RAMTE1/n)^2 + REMTE1^2]^{0.5}$$

where n is the number of standard deviations applicable to the error term. The values of the error terms from Reference 9.1 are already expressed in one sigma terms. Therefore, the value of n is 1.

$$MTE1_{5B} = \pm[(RAMTE1_{5B}/1)^2 + REMTE1_{5B}{}^2]^{0.5} \text{ Vdc}$$

$$MTE1_{5B} = \pm[(0.00018/1)^2 + 0^2]^{0.5} \text{ Vdc}$$

$$MTE1_{5B} = \pm 0.00018 \text{ Vdc}$$

This can be converted to % Power by dividing by the voltage span (SPAN4CIN - the RBM output has the same span as does the APRM) and multiplying by the full scale power (125).

$$MTE1_{5B(PP)} = \pm[(MTE1_{5B}/SPAN4CIN)*125] \text{ \% Power}$$

$$MTE1_{5B(PP)} = \pm[(0.00018/10)*125] \text{ \% Power}$$

$$MTE1_{5B(PP)} = \pm 0.00225\text{\% Power}$$

From Section 5.2 the errors attributed to the calibration standards are considered negligible. Therefore, the only term which contributes to CAL5B is the MTE1 term.

Therefore, for this section

$$CAL5B = \pm MTE1_{5B(PP)} = \pm 0.00225\% \text{ Power}$$

11.5.2.1.4 Setting Tolerance (ST5B)

The setting tolerance listed in the applicable procedures for this function is 0.04 Vdc. This can be converted to % Power by dividing by the voltage span (SPAN4CIN) and multiplying by the full scale power (125).

From Section 2.1.a the given setting tolerances are considered 3 sigma values. Therefore, ST5B must be divided by 3 to make it compatible with the other 1 sigma error terms. Combining this operation with the conversion to percent power gives

$$ST5B_{(1\sigma)} = \pm[(ST5B/SPAN4CIN)*125]/3 \text{ \% Power}$$

$$ST5B_{(1\sigma)} = \pm[(0.04/10)*125]/3 \text{ \% Power}$$

$$ST5B_{(1\sigma)} = \pm 0.166667\% \text{ Power}$$

11.5.2.1.5 Input Uncertainty (σinput5B and σinput5B$_{AV}$)

In addition to its own error terms, the error terms from Module 5A must also be considered. Since the trip circuits perform no function on the input signal σinput5B and σinput5B$_{AV}$ become equal to the random input terms $\sigma 5A$ and $\sigma 5A_{AV}$.

$$\sigma input5B = \pm\sigma 5A = \pm 1.850009\% \text{ Power}$$

And

$$\sigma input5B_{AV} = \pm\sigma 5A_{AV} = 1.610749\% \text{ Power}$$

11.5.2.1.6 Determination of Module Random Error (σ5B)

Using the methodology of Reference 3.3,

$$\sigma 5B = \pm[(RA5B_{(1\sigma)})^2 + (RD5B_{(1\sigma)})^2 + (CAL5B)^2 + (ST5B_{(1\sigma)})^2 + (\sigma input5B)^2]^{0.5} \text{ \% Power}$$

$$\sigma 5B = \pm[(0.625)^2 + (1.234276)^2 + (0.00225)^2 + (0.166667)^2 + (1.850009)^2]^{0.5} \text{ \% Power}$$

$$\sigma 5B = \pm 2.316113\% \text{ Power}$$

And

$$\sigma 5B_{AV} = \pm[(RA5B_{(1\sigma)})^2 + (RD5B_{(1\sigma)})^2 + (CAL5B)^2 + (ST5B_{(1\sigma)})^2 + (\sigma input5B_{AV})^2]^{0.5}\ \%\ Power$$

$$\sigma 5B_{AV} = \pm[(0.625)^2+(1.234276)^2+(0.00225)^2+(0.166667)^2+(1.610749)^2]^{0.5}\ \%\ Power$$

$$\sigma 5B_{AV} = \pm 2.129873\%\ Power$$

11.5.2.2 Module 5B Non-Random Errors ($\Sigma e5B$)

11.5.2.2.1 Humidity Errors (e5BH)

Since Reference 3.12 does not identify a humidity error term a value of zero will be used per Section 4.3.

e5BH = 0% CS

11.5.2.2.2 Temperature Error (e5BT)

Since Reference 3.12 does not identify a temperature error term a value of zero will be used per Section 4.3.

e5BT = 0% CS

11.5.2.2.3 Radiation Error (e5BR)

Since Reference 3.12 does not identify a radiation error term a value of zero will be used per Section 4.3.

e5BR = 0% CS

11.5.2.2.4 Seismic Error (e5BS)

Per Section 4.7 seismic error for this module is considered negligible.

e5BS = 0% CS

11.5.2.2.5 Static Pressure Effect (e5BSP)

This module is an all electronic device that is not exposed to any pressure other than atmospheric. Therefore, there is no static pressure effect.

e5BSP = 0% CS

11.5.2.2.6 Pressure Error (e5BP)

This module is an all electronic device that is not exposed to any pressure other than atmospheric. Therefore, there is no pressure effect.

e5BP = 0% CS

11.5.2.2.7 Process Errors(e5Bp)

This module is intermediate in the loop and, as such, is not exposed to any process parameters. Therefore, there are no process errors.

$e5Bp = 0\%\ CS$

11.5.2.2.8 Power Supply Effects (e5BV)

Since Reference 3.12 does not identify a power supply effect error term a value of zero will be used per Section 4.3.

$e5BV = 0\%\ CS$

11.5.2.2.9 Non-Random Input Error (einput5B)

In addition to its own error terms, the error terms from Module 5A must also be considered. Since the trip circuits perform no function on the input signal, einput5B and $einput5B_{AV}$ become equal to the non-random input term $\Sigma e5A$ and $\Sigma e5A_{AV}$.

$einput5B = \pm\Sigma e5A = \pm 0.82\%\ Power$

And

$einput5B_{AV} = \pm\Sigma e5A_{AV} = \pm 0\%\ Power$

11.5.2.2.10 Non-Random Error ($\Sigma e5B$ and $\Sigma e5B_{AV}$)

From Reference 3.3 the non-random error is the algebraic sum of all the above terms.

$\Sigma e5B = \pm(125/100)*(e5BH + e5BT + e5BR + e5BS + e5BSP + e5BP + e5Bp + e5BV) + einput5B\%\ Power$

$\Sigma e5B = \pm(125/100)*(0 + 0 + 0 + 0 + 0 + 0 + 0 + 0)+ 0.82\%\ Power$

$\Sigma e5B = \pm 0.82\%\ Power$

And

$\Sigma e5B_{AV} = \pm(125/100)*(e5BH + e5BT + e5BR + e5BS + e5BSP + e5BP + e5Bp + e5BV) + einput5B_{AV}\ \%\ Power$

$\Sigma e5B_{AV} = \pm(125/100)*(0 + 0 + 0 + 0 + 0 + 0 + 0 + 0) + 0\ \%\ Power$

$\Sigma e5B_{AV} = \pm 0\%\ Power$

11.5.3 Module 5C (Trip Circuit - Flow Biased)

Classification of Module

Module 5C receives an analog input from the Averaging and Gain Change Circuitry and the Flow Summer (Module 3), and provides a bistable output, the state of which depends on the relative magnitudes of the input signal from the Averaging and Gain Change Circuitry and the reference value, which is a function of the Flow Summer signal. Therefore, Module 5c is a bistable module.

11.5.3.1 Module 5C Random Error (σ5C)

This section addresses random uncertainties that have the potential to be expressed in the output of Module 5C.

11.5.3.1.1 Reference Accuracy (RA5C)

Per Section 8.5.1 the reference accuracy for this module is:

RA5C = 1% CS

Per Assumption 5.1, this is assumed to be a 2 sigma value. This is then converted to a 1 sigma value by dividing by 2. In the same step this will be converted to % Power by multiplying by 125/100.

$$RA5C_{(1\sigma)} = \pm(RA5C/2)*(125/100)\ \%\ Power$$

$$RA5C_{(1\sigma)} = \pm(1/2)*(125/100)\ \%\ Power$$

$$RA5C_{(1\sigma)} = \pm 0.625\%\ Power$$

11.5.3.1.2 Drift (RD5C)

Per Section 8.5.1 the reference drift for this module is:

RD5C = 1% CS/700 HRS

Table 4.3.6-1 of Reference 3.7 gives the surveillance interval (RD5CTSI) for all trip functions as 13 weeks (semi-annually). In addition, a 25% late factor will added to the required value. Per Reference 3.8 drift is considered a random function and can be extended to a longer period by the square root of the ratio of the time periods per Section 2.2.5 of Reference 3.13.

Per Assumption 5.1, the drift value is assumed to be a 2 sigma value. This is then converted to a 1 sigma value by dividing by 2, and then to % Power by multiplying by 125/100. RD5CTSI is converted to hours by multiplying by 168. The one sigma drift is then:

$$RD5C_{(1\sigma)} = \pm(RD5C/2)*(125/100)*[(1.25*RD5CTSI*168)/RD5CT]^{0.5} \text{ \% Power}$$

$$RD5C_{(1\sigma)} = \pm(1/2)*(125/100)*[(1.25*13*168)/700]^{0.5} \text{ \% Power}$$

$$RD5C_{(1\sigma)} = \pm 1.234276\text{\% Power}$$

11.5.3.1.3 Calibration Uncertainty (CAL5C)

The uncertainties associated with calibrating the trip circuits are composed entirely of the uncertainties associated with the DMM used to set the input trip voltage. Per the applicable procedures of Reference 3.5 a Fluke Model 8500A is specified for this function. From Section 9.1 the error associated with this instrument is 0.00018 Vdc ($RAMTE1_{5C}$). Since this is a digital instrument $REMTE1_{5C}$ is equal to zero.

From Reference 3.3,

$$MTE1 = [(RAMTE1/n)^2 + REMTE1^2]^{0.5}$$

where n is the number of standard deviations applicable to the error term. The values of the error terms from Reference 9.1 are already expressed in one sigma terms. Therefore, the value of n is 1.

$$MTE1_{5C} = \pm[(RAMTE1_{5C}/1)^2 + REMTE1_{5C}{}^2]^{0.5} \text{ Vdc}$$

$$MTE1_{5C} = \pm[(0.00018/1)^2 + 0^2]^{0.5} \text{ Vdc}$$

$$MTE1_{5C} = \pm 0.00018 \text{ Vdc}$$

This can be converted to % Power by dividing by the voltage span (SPAN4CIN - Both Fixed and Flow Biased trips have the same input span as the APRM trip circuits) and multiplying by the full scale power (125).

$$MTE1_{5C(PP)} = \pm[(MTE1_{5C}/SPAN4CIN)*125] \text{ \% Power}$$

$$MTE1_{5C(PP)} = \pm[(0.00018/10)*125] \text{ \% Power}$$

$$MTE1_{5C(PP)} = \pm 0.00225\text{\% Power}$$

From Section 5.2 the errors attributed to the calibration standards are considered negligible. Therefore, the only term which contributes to CAL5C is the MTE1 term. Therefore, for this section

$$CAL5C = \pm MTE1_{5C(PP)} = \pm 0.00225\% \text{ Power}$$

11.5.3.1.4 Setting Tolerance (ST5C)

The setting tolerance listed in the applicable procedures for this function is 0.04 Vdc. This can be converted to % Power by dividing by the voltage span (SPAN4CIN) and multiplying by the full scale power (125).

From Section 2.1.a the given setting tolerances are considered 3 sigma values. Therefore, ST4D must be divided by 3 to make it compatible with the other 1 sigma error terms. Combining this operation with the conversion to percent power gives

$$ST5C_{(1\sigma)} = \pm[(ST5C/SPAN4CIN)*125]/3 \ \% \text{ Power}$$

$$ST5C_{(1\sigma)} = \pm[(0.04/10)*125]/3 \ \% \text{ Power}$$

$$ST5C_{(1\sigma)} = \pm 0.166667\% \text{ Power}$$

11.5.3.1.5 Input Uncertainty (σinput5C)

In addition to its own error terms, the error terms from Module 5A and Module 3 must also be considered. Since the trip circuits perform no function on these input signals σinput5C and $\sigma input5C_{AV}$ become equal to the combination by SRSS of the random input terms $\sigma 5A$ and $\sigma 3$, and $\sigma 5A_{AV}$ and $\sigma 3_C$. However, before $\sigma 5A$ and $\sigma 3$, and $\sigma 5A_{AV}$ and $\sigma 3_C$ can be combined, $\sigma 3$ and $\sigma 3_C$ must be converted from % Flow to % Power by multiplying by the slope of the curve in the Flow Controlled Trip Reference Unit. From the applicable procedures in Reference 3.5 this slope ($FCS_{RBM(SP)}$) is equal to 0.66% Power per % Flow. However, per Section 2.2 this slope has been modified to account for setting uncertainties. Therefore,

$$\sigma input5C = \pm[\sigma 5A^2 + (FCS_{RBM}*\sigma 3)^2]^{0.5} \ \% \text{ Power}$$

$$\sigma input5C = \pm\{(1.850009)^2 + [(0.668750)*(2.546521)]^2\}^{0.5} \ \% \text{ Power}$$

$$\sigma input5C = \pm 2.514497\% \text{ Power}$$

For the Allowable Value determination this becomes:

$\sigma input5C_{AV} = \pm[\sigma 5A_{AV}{}^{2} + (FCS_{RBM} * \sigma 3_{C})^{2}]^{0.5}$ % Power

$\sigma input5C_{AV} = \pm[1.610749^{2} + (0.668750 * 1.669197)^{2}]^{0.5}$ % Power

$\sigma input5C_{AV} = \pm 1.959740\%$ Power

11.5.3.1.6 Determination of Module Random Error ($\sigma 5C$ and $\sigma 5C_{AV}$)

Using the methodology of Reference 3.3,

$\sigma 5C = \pm[(RA5C_{(1\sigma)})^{2} + (RD5C_{(1\sigma)})^{2} + (CAL5C)^{2} + (ST5C_{(1\sigma)})^{2} + (\sigma input5C)^{2}]^{0.5}$ % Power

$\sigma 5C = \pm[(0.625)^{2} + (1.234276)^{2} + (0.00225)^{2} + (0.166667)^{2} + (2.514497)^{2}]^{0.5}$ % Power

$\sigma 5C = \pm 2.874811\%$ Power

And

$\sigma 5C_{AV} = \pm[(RA5C_{(1\sigma)})^{2} + (RD5C_{(1\sigma)})^{2} + (CAL5C)^{2} + (ST5C_{(1\sigma)})^{2} + (\sigma input5C_{AV})^{2}]^{0.5}$ % Power

$\sigma 5C_{AV} = \pm[(0.625)^{2}+(1.234276)^{2}+(0.00225)^{2}+(0.166667)^{2}+(1.95974)^{2}]^{0.5}$ % Power

$\sigma 5C_{AV} = \pm 2.404668\%$ Power

11.5.3.2 Module 5C Non-Random Errors ($\Sigma e5C$)

11.5.3.2.1 Humidity Errors (e5CH)

Since Reference 3.12 does not identify a humidity error term a value of zero will be used per Section 4.3.

e5CH = 0% CS

11.5.3.2.2 Temperature Error (e5CT)

Since Reference 3.12 does not identify a temperature error term a value of zero will be used per Section 4.3.

e5CT = 0% CS

11.5.3.2.3 Radiation Error (e5CR)

Since Reference 3.12 does not identify a radiation error term a value of zero will be used per Section 4.3.

e5CR = 0% CS

11.5.3.2.4 Seismic Error (e5CS)

Per Section 4.7 seismic error for this module is considered negligible.

e5CS = 0% CS

11.5.3.2.5 Static Pressure Effect (e5CSP)

This module is an all electronic device that is not exposed to any pressure other than atmospheric. Therefore, there is no static pressure effect.

e5CSP = 0% CS

11.5.3.2.6 Pressure Error (e5CP)

This module is an all electronic device that is not exposed to any pressure other than atmospheric. Therefore, there is no pressure effect.

e5CP = 0% CS

11.5.3.2.7 Process Errors(e5Cp)

This module is intermediate in the loop and, as such, is not exposed to any process parameters. Therefore, there are no process errors.

$$e5Cp = 0\%\ CS$$

11.5.3.2.8 Power Supply Effects (e5CV)

Since Reference 3.12 does not identify a power supply effect error term a value of zero will be used per Section 4.3.

$$e5CV = 0\%\ CS$$

11.5.3.2.9 Non-Random Input Error (einput5C)

In addition to its own error terms, the error terms from Module 5A and Module 3 must also be considered. Since the trip circuits perform no function on these input signals einput5C becomes equal to the combination by algebraic addition of the non-random input terms $\Sigma e5A$ and $\Sigma e3$, and $\Sigma e5A_{AV}$ and $\Sigma e3_{AV}$. However, before $\Sigma e5A$ and $\Sigma e3$, and $\Sigma e5A_{AV}$ and $\Sigma e3_{AV}$ can be combined, $\Sigma e3$ and $\Sigma e3_{AV}$ must be converted from % Flow to % Power by multiplying by the slope of the curve in the Flow Controlled Trip Reference Unit. From the applicable procedures in Reference 3.5 this slope ($FCS_{RBM(SP)}$) is equal to 0.66 % Power per % Flow. However, per Section 2.2 this slope has been modified to account for setting uncertainties. Therefore,

$$einput5C = \pm[\Sigma e5A + (FCS_{RBM}*\Sigma e3)]\ \%\ Power$$

$$einput5C = \pm[0.82 + (0.668750*1.274635)]\ \%\ Power$$

$$einput5C = \pm 1.672412\%\ Power$$

And

$$einput5C_{AV} = \pm[\Sigma e5A_{AV} + (FCS_{RBM}*\Sigma e3)]\ \%\ Power$$

$$einput5C_{AV} = \pm[0 + (0.668750*1.274635)]\ \%\ Power$$

$$einput5C_{AV} = \pm 0.852412\%\ Power$$

11.5.3.2.10 Non-Random Error ($\Sigma e5C$)

From Reference 3.3 the non-random error is the algebraic sum of all the above terms.

$$\Sigma e5C = \pm(125/100)*(e5CH + e5CT + e5CR + e5CS + e5CSP + e5CP + e5Cp + e5CV) + einput5C\%\ Power$$

$$\Sigma e5C = \pm(125/100)*(0 + 0 + 0 + 0 + 0 + 0 + 0 + 0)+ 1.672412\%\ Power$$

$$\Sigma e5C = \pm 1.672412\%\ Power$$

And

$$\Sigma e5C_{AV} = \pm(125/100)*(e5CH + e5CT + e5CR + e5CS + e5CSP + e5CP + e5Cp + e5CV) + einput5C_{AV}\ \%\ Power$$

$$\Sigma e5C_{AV} = \pm(125/100)*(0 + 0 + 0 + 0 + 0 + 0 + 0 + 0) + 0.852412\ \%\ Power$$

$$\Sigma e5C_{AV} = \pm 0.852412\%\ Power$$

11.6 ABB Flow Unit (Module 6)

Classification of Module

Module 6 receives analog inputs from flow transmitters and another flow unit, and provides an output that represents the sum of two flow loops in addition to two bistable outputs representing high flow and mismatch flow. Therefore, Module 6 is both an analog and a bistable module.

11.6.1 Module 6 Analog Section

This portion of the calculation evaluates the uncertainties associated with the square root converters and summer sections of the flow unit.

11.6.1.1 Module 6 Random Error ($\sigma 6$)

This section addresses random uncertainties that have the potential to be expressed in the output of Module 6.

11.6.1.1.1 Reference Accuracy (RA6)

Per Section 8.6.1 the reference accuracy applied to this module is the overall RFM accuracy. Per Reference 3.19 the reference accuracy for this unit is ±1%.

RA6 = 1% CS

Per Assumption 5.1, this is assumed to be a 2 sigma value. This is then converted to a 1 sigma value by dividing by 2.

$RA6_{(1\sigma)} = \pm RA6/2\ \%\ CS$

$RA6_{(1\sigma)} = \pm 1/2\ \%\ CS$

$RA6_{(1\sigma)} = \pm 0.5\%\ CS$

11.6.1.1.2 Drift (RD6)

Per Section 8.6.1 the reference drift applied to this module is the overall RFM drift. Per Reference 3.19 the reference drift for this unit is ±0.5% CS per 30 months. Since this interval is greater than the surveillance interval no adjustment needs to be made.

RD6 = 0.5% CS

Per Assumption 5.1, this is assumed to be a 2 sigma value.

This is then converted to a 1 sigma value by dividing by 2.

$RD6_{(1\sigma)}$ = RD6/2 % CS

$RD6_{(1\sigma)}$ = 0.5/2 % CS

$RD6_{(1\sigma)}$ = ±0.25% CS

11.6.1.1.3 Calibration Uncertainty (CAL6)

The uncertainties associated with calibrating the flow summer are composed of the uncertainties in setting the input signal and the uncertainties in reading the output signal. Per Assumption 5.9 the calibration uncertainties for this module are assumed to be the same as those for Module 3. Therefore, CAL6 is equal to CAL3.

$CAL6 = CAL3_{SUM}$ = ±0.025498% CS

11.6.1.1.4 Setting Tolerance (ST6)

The setting tolerance for the flow summer is the combination of the input and output setting tolerances. Per Assumption 5.9 the setting tolerances for this module are assumed to be the same as those for Module 3. Therefore, ST6 is equal to ST3 and, consequently, $ST6_{(1\sigma)}$ is equal to $ST3_{(1\sigma)}$.

$ST6_{(1\sigma)} = ST3_{(1\sigma)}$ = ±0.04714% CS

11.6.1.1.5 Input Uncertainty (σinput6)

In addition to its own error terms, Module 6 also operates on the error terms from Module 1. Per Assumption 5.9 the calibration uncertainties for this module are assumed to be similar to those for Module 3. Also, since Module 2 had no error terms (RA2, RD2) of its own, its only errors were due to calibration and inputs from Module 1. Therefore, the random error terms σinput6 and $\sigma input6_C$ will be equal to σinput3 and $\sigma input3_C$ for this calculation.

σinput6 = σinput3 = ±1.660348% CS

For the Comparator Trip:

$\sigma input6_C = \sigma input3_C$ = ±0.624245% CS

11.6.1.1.6 Determination of Module Random Error (σ6)

Using the methodology of Reference 3.3, and converting to %

Flow by multiplying by 125/100:

$$\sigma 6 = \pm(125/100) * [(RA6_{(1\sigma)})^2 + (RD6_{(1\sigma)})^2 + (CAL6)^2 + (ST6_{(1\sigma)})^2 + (\sigma input6)^2]^{0.5} \text{ \% Flow}$$

$$\sigma 6 = \pm(125/100) * [(0.5)^2 + (0.25)^2 + (0.025498)^2 + (0.04714)^2 + (1.660348)^2]^{0.5} \text{ \% Flow}$$

$$\sigma 6 = \pm 2.190936\text{\% Flow}$$

For the Comparator Trip:

$$\sigma 6_C = \pm(125/100) * [(RA6_{(1\sigma)})^2 + (RD6_{(1\sigma)})^2 + (CAL6)^2 + (ST6_{(1\sigma)})^2 + (\sigma input6_C)^2]^{0.5} \text{ \% Flow}$$

$$\sigma 6_C = \pm(125/100) * [(0.5)^2 + (0.25)^2 + (0.025498)^2 + (0.04714)^2 + (0.624245)^2]^{0.5} \text{ \% Flow}$$

$$\sigma 6_C = \pm 1.049594\text{\% Flow}$$

11.6.1.2 Module 6 Non-Random Errors ($\Sigma e6$)

Per Section 8.6.1 the errors applied to this module are the overall RFM error terms.

11.6.1.2.1 Humidity Errors (e6H)

Since Reference 3.19 does not identify a humidity error term a value of zero will be used per Section 4.3.

e6H = 0% CS

11.6.1.2.2 Temperature Error (e6T)

Per Reference 3.19 the "Total Flow Voltage Output Temperature Effect" is

e6T = 0.5% CS

11.6.1.2.3 Radiation Error (e6R)

Since Reference 3.19 does not identify a radiation error term a value of zero will be used per Section 4.3.

e6R = 0% CS

11.6.1.2.4 Seismic Error (e6S)

Per Section 4.7 seismic error for this module is considered negligible.

e6S = 0% CS

11.6.1.2.5 Static Pressure Effect (e6SP)

This module is an all electronic device that is not exposed to any pressure other than atmospheric. Therefore, there is no static pressure effect.

e6SP = 0% CS

11.6.1.2.6 Pressure Error (e6P)

This module is an all electronic device that is not exposed to any pressure other than atmospheric. Therefore, there is no pressure effect.

e6P = 0% CS

11.6.1.2.7 Process Errors(e6p)

This module is intermediate in the loop and, as such, is not exposed to any process parameters. Therefore, there are no process errors.

e6p = 0% CS

11.6.1.2.8 Power Supply Effects (e6V)

Since Reference 3.19 does not identify a power supply effect error term a value of zero will be used per Section 4.3.

e6V = 0% CS

11.6.1.2.9 Non-Random Input Error (einput6)

In addition to its own error terms, Module 6 also operates on the error terms from Module 1. Per Assumption 5.9 the calibration uncertainties for this module are assumed to be similar to those for Module 3. Also, since Module 2 had no error terms (e2H, e2T, e2R, e2S, e2SP, e2P, e2p, e2V) of its own, its only errors were due to calibration and inputs from Module 1. Therefore, the random error term einput6 will be equal to einput3 for this calculation.

einput6 = einput3 = ±1.019708% CS

11.6.1.2.10 Non-Random Error (Σe3)

From Reference 3.3 the non-random error is the algebraic sum of all the above terms. In addition, this term can be converted to % Flow by multiplying by 125/100. The result is;

$$\Sigma e6 = \pm(125/100) * (e6H + e6T + e6R + e6S + e6SP + e6P + e6p + e6V + einput6)\% \text{ Flow}$$

$$\Sigma e6 = \pm(125/100) * (0 + 0.5 + 0 + 0 + 0 + 0 + 0 + 0 + 1.019708)\% \text{ Flow}$$

$$\Sigma e6 = \pm 1.899635\% \text{ Flow}$$

11.6.2 Module 6A and 6B(ABB RFM Trip Circuits)

Classification of Module

Module 6A receives an analog input from the Flow Summer (Module 6) and provides a bistable output, the state of which depends on the relative magnitudes of the input signal and the reference value. Therefore, Module 6A is a bistable module.

There are actually two separate trip circuits in each flow unit. The Hi Flow trip looks at the output of the Flow Summer and compares its magnitude to a fixed reference value (Module 6A). The Comparator Trip Circuit looks at the output of the Flow Summer and compares it to the output of a Flow Summer from another RFM (Module 6B) and provides a bistable output, the state of which depends on the relative magnitudes of the two input signals. Therefore, Module 6B is a bistable module. The Comparator Trip will have to combine the error terms from two Flow Summers.

11.6.2.1 Module 6A Random Error ($\sigma 6A$)

This section addresses random uncertainties that have the potential to be expressed in the output of Module 6A.

11.6.2.1.1 Reference Accuracy (RA6A)

Per Section 8.6.1 the reference accuracy for this module is:

RA6A = 1% CS

Per Assumption 5.1, this is assumed to be a 2 sigma value. This is then converted to a 1 sigma value by dividing by 2. In the same step this will be converted to % Flow by multiplying by 125/100.

$$RA6A_{(1\sigma)} = \pm(RA6A/2)*(125/100)\ \%\ Flow$$

$$RA6A_{(1\sigma)} = \pm(1/2)*(125/100)\ \%\ Flow$$

$$RA6A_{(1\sigma)} = \pm 0.625\%\ Flow$$

11.6.2.1.2 Drift (RD6A)

Per Assumption 5.10 drift is assumed to be included in the reference accuracy term. Therefore:

RD6A = 0% CS

Per Assumption 5.1, the drift value is assumed to be a 2 sigma value. This is then converted to a 1 sigma value by dividing by 2, and then to % Flow by multiplying by 125/100.

$$RD6A_{(1\sigma)} = \pm(RD6A/2)*(125/100) \text{ \% Flow}$$

$$RD6A_{(1\sigma)} = \pm(0/2)*(125/100) \text{ \% Flow}$$

$$RD6A_{(1\sigma)} = \pm 0\text{\% Flow}$$

11.6.2.1.3 Calibration Uncertainty (CAL6A)

Per Assumption 5.9 the calibration uncertainties for this module are assumed to be the same as those for Module 3. Therefore, CAL6A is equal to CAL3A.

$$CAL6A = CAL3A = \pm 0.022538\text{\% Flow}$$

11.6.2.1.4 Setting Tolerance (ST6A)

Per Assumption 5.9 the setting tolerances for this module are assumed to be the same as those for Module 3. Therefore, ST6A = ST3A, and consequently, $ST6A_{A(1\sigma)} = ST3A_{A(1\sigma)}$ and $ST6A_{B(1\sigma)} = ST3A_{B(1\sigma)}$.

<u>Upscale Trip:</u>

$$ST6A_{A(1\sigma)} = ST3A_{A(1\sigma)} = \pm 0.416667\text{\% Flow}$$

<u>Comparator Trip:</u>

$$ST6A_{B(1\sigma)} = ST3A_{B(1\sigma)} = \pm 0.333333\text{\% Flow}$$

11.6.2.1.5 Input Uncertainty (σinput6A, σinput6B)

In addition to its own error terms, the error terms from Module 6 must also be considered. Since the trip circuits perform no function on the input signal σinput6A becomes equal to the random input term σ6 for the Hi Flow trip. However, the Comparator Trip is also looking at the output of another RFM so both inputs have a $\sigma6_C$ term impressed on them. Therefore, the uncertainty term σinput6B for the Comparator Trip will combine two $\sigma6_C$ terms by SRSS.

$$\sigma input6A = \pm\sigma 6 = \pm 2.190936\text{\% Flow}$$

And

$$\sigma input6B = \pm(\sigma6_C^2 + \sigma6_C^2)^{0.5} \text{ \% Flow}$$

$$\sigma input6B = \pm(1.049594^2 + 1.049594^2)^{0.5} \text{ \% Flow}$$

$\sigma input6B = \pm 1.48435\%$ Flow

11.6.2.1.6 Determination of Module Random Error ($\sigma 6A$, $\sigma 6B$)

Using the methodology of Reference 3.3,

$$\sigma 6A = \pm[(RA6A_{(1\sigma)})^2 + (RD6A_{(1\sigma)})^2 + (CAL6A)^2 + (ST6A_{A(1\sigma)})^2 + (\sigma input6A)^2]^{0.5}\ \%\ \text{Flow}$$

$$\sigma 6A = \pm[(0.625)^2 + (0)^2 + (0.022538)^2 + (0.416667)^2 + (2.190936)^2]^{0.5}\ \%\ \text{Flow}$$

$$\sigma 6A = \pm 2.316235\%\ \text{Flow}$$

And

$$\sigma 6B = \pm[(RA6A_{(1\sigma)})^2 + (RD6A_{(1\sigma)})^2 + (CAL6A)^2 + (ST6A_{B(1\sigma)})^2 + (\sigma input6B)^2]^{0.5}\ \%\ \text{Flow}$$

$$\sigma 6B = \pm(0.625^2 + 0^2 + 0.022538^2 + 0.333333^2 + 1.48435^2)^{0.5}\ \%\ \text{Flow}$$

$$\sigma 6B = \pm 1.644852\%\ \text{Flow}$$

11.6.2.2 Module 6A Non-Random Errors ($\Sigma e6A$)

11.6.2.2.1 Humidity Errors (e6AH)

Since Reference 3.19 does not identify a humidity error term a value of zero will be used per Section 4.3.

e6AH = 0% CS

11.6.2.2.2 Temperature Error (e6AT)

Since Reference 3.19 does not identify a temperature error term a value of zero will be used per Section 4.3.

e6AT = 0% CS

11.6.2.2.3 Radiation Error (e6AR)

Since Reference 3.19 does not identify a radiation error term a value of zero will be used per Section 4.3.

e6AR = 0% CS

11.6.2.2.4 Seismic Error (e6AS)

Per Section 4.7 seismic error for this module is considered negligible.

e6AS = 0% CS

11.6.2.2.5 Static Pressure Effect (e6ASP)

This module is an all electronic device that is not exposed to any pressure other than atmospheric. Therefore, there is no static pressure effect.

e6ASP = 0% CS

11.6.2.2.6 Pressure Error (e6AP)

This module is an all electronic device that is not exposed to any pressure other than atmospheric. Therefore, there is no pressure effect.

e6AP = 0% CS

11.6.2.2.7 Process Errors(e6Ap)

This module is intermediate in the loop and, as such, is not exposed to any process parameters. Therefore, there are no process errors.

$$e6Ap = 0\% \ CS$$

11.6.2.2.8 Power Supply Effects (e6AV)

Since Reference 3.19 does not identify a power supply effect error term a value of zero will be used per Section 4.3.

$$e6AV = 0\% \ CS$$

11.6.2.2.9 Non-Random Input Error (einput6A, einput6B)

In addition to its own error terms, the error terms from Module 6 must also be considered. Since the trip circuits perform no function on the input signal einput6A becomes equal to the non-random input term Σe6 for the Hi Flow trip. However, the Comparator Trip is also looking at the output of another RFM so the reference input also has a Σe6 term impressed on it. Since these are not random terms, it is expected that their magnitudes would be the same from each Module 6. However, the methodology of Reference 3.3 does not allow the cancellation of non-random terms. Therefore, the total error at the comparator will be the algebraic sum of two Σe6 terms.

$$einput6A = \pm\Sigma e6 = \pm 1.899635\% \ Flow$$

And

$$einput6B = \pm(\Sigma e6 + \Sigma e6) \ \% \ Flow$$

$$einput6B = \pm(1.899635 + 1.899635) \ \% \ Flow$$

$$einput6B = \pm 3.799270\% \ Flow$$

11.6.2.2.10 Non-Random Error ($\Sigma e6A$, $\Sigma e6B$)

From Reference 3.3 the non-random error is the algebraic sum of all the above terms. In addition, all terms except einput6A and einput6B are in % CS and must be multiplied by 125/100 to convert to % Flow.

$$\Sigma e6A = \pm(125/100)*(e6AH + e6AT + e6AR + e6AS + e6ASP + e6AP + e6Ap + e6AV) + einput6A\%\ Flow$$

$$\Sigma e6A = \pm(125/100)*(0 + 0 + 0 + 0 + 0 + 0 + 0 + 0) + 1.899635\ \%\ Flow$$

$$\Sigma e6A = \pm 1.899635\%\ Flow$$

And

$$\Sigma e6B = \pm(125/100)*(e6AH + e6AT + e6AR + e6AS + e6ASP + e6AP + e6Ap + e6AV) + einput6B\%\ Flow$$

$$\Sigma e6B = \pm(125/100)*(0 + 0 + 0 + 0 + 0 + 0 + 0 + 0) + 3.799270\ \%\ Flow$$

$$\Sigma e6B = \pm 3.799270\%\ Flow$$

12.0 INSTRUMENT CHANNEL TOTAL ERRORS

From Reference 3.3 total instrument error is determined by the following equation:

Total Loop Error - Normal Conditions (Ten)

$$Ten = \pm(2\sigma + \Sigma en)$$

For this calculation there are eight different groups of Ten terms. These terms are listed below:

Ten_{AFB}, $Ten_{AFB(AV)}$ - APRM Flow Biased Trips, Two Loop

Ten_{AFBSLO}, $Ten_{AFB(AV)SLO}$ - APRM Flow Biased Trips, Single Loop

Ten_{AF}, $Ten_{AF(AV)}$ - APRM Fixed High Power Trips

Ten_{RFB}, $Ten_{RFB(AV)}$ - RBM Flow Biased Trips

Ten_{RF}, $Ten_{RF(AV)}$ - RBM Fixed Trip

Ten_{RFMU}, $Ten_{RFMU(AV)}$ - Recirculation Flow Monitor - Upscale

Ten_{RFMC}, $Ten_{RFMC(AV)}$ - Recirculation Flow Monitor - Comparator

Ten_{AFLP}, $Ten_{AFLP(AV)}$ - APRM Fixed Low Power Trips

The above terms with an $_{(AV)}$ subscript have had the error terms associated with the process removed and will, therefore, be used in the Allowable Value calculations. The terms without the $_{(AV)}$ subscript are used in the Analytical Limit calculations.

12.1 APRM Flow Biased Trips

Ten_{AFB} and $Ten_{AFB(AV)}$ are made up of the uncertainty terms from the APRM Flow Biased Trip Module 4D. These uncertainty terms include both the uncertainties associated with the APRM neutron signal and the Recirculation Flow Monitor.

12.1.1 Two Loop Operation (Ten_{AFB}, $Ten_{AFB(AV)}$) - Using errors from Sections 11.4.4.1.6.1 and 11.4.4.2.10.1 for TLO, the errors are

$$Ten_{AFB} = \pm(2 * \sigma 4D + \Sigma e4D)$$
$$Ten_{AFB} = \pm(2 * 2.743466 + 1.626207)$$

$$Ten_{AFB} = \pm 7.113139 \text{ \% Power}$$

And the AV total error for TLO is determined as

$$Ten_{AFB(AV)} = \pm(2\sigma 4D_{AV} + \Sigma e4D_{AV})$$
$$Ten_{AFB(AV)} = \pm(2*2.380057 + 0.806207)$$

$$Ten_{AFB(AV)} = \pm 5.566321\% \text{ Power}$$

12.1.2 Single Loop Operation (Ten_{AFB}, $Ten_{AFB(AV)}$) - Using errors from Sections 11.4.4.1.6.2 and 11.4.4.2.10.2 for SLO, the error is

$$Ten_{AFBSLO} = \pm(2 * \sigma 4D_{SLO} + \Sigma e4D_{SLO})$$
$$Ten_{AFBSLO} = \pm(2 * 2.642756 + 1.536982)$$

$$Ten_{AFBSLO} = \pm 6.822494 \% \text{ Power}$$

And the AV total error for SLO is determined as

$$Ten_{AFB(AV)SLO} = \pm(2 * \sigma 4D_{AVSLO} + \Sigma e4D_{AVSLO})$$
$$Ten_{AFB(AV)SLO} = \pm(2 * 2.330580 + 0.716982)$$

$$Ten_{AFB(AV)SLO} = \pm 5.378142\% \text{ Power}$$

12.2 APRM Fixed Trips - Ten_{AF}, $Ten_{AF(AV)}$

Ten_{AF} and $Ten_{AF(AV)}$ are made up of the uncertainty terms from APRM Fixed Trip Module 4C. From Sections 11.4.3.1.6 and 11.4.3.2.10:

$$Ten_{AF} = \pm(2\sigma 4C + \Sigma e4C)\% \text{ Power}$$
$$Ten_{AF} = \pm(2*2.435639 + 0.82)\% \text{ Power}$$
$$Ten_{AF} = \pm 5.691278\% \text{ Power}$$

And

$$Ten_{AF(AV)} = \pm(2\sigma 4C_{AV} + \Sigma e4C_{AV})\% \text{ Power}$$
$$Ten_{AF(AV)} = \pm(2*2.133079 + 0)\% \text{ Power}$$
$$Ten_{AF(AV)} = \pm 4.266158\% \text{ Power}$$

12.3 RBM Flow Biased Trips - Ten_{RFB}, $Ten_{RFB(AV)}$

Ten_{RFB} and $Ten_{RFB(AV)}$ are made up of the uncertainty terms from the RBM Flow Biased Trip Module 5C. These uncertainty terms include both the uncertainties associated with the RBM neutron signal and the Recirculation Flow Monitor. From Sections 11.5.3.1.6 and 11.5.3.2.10:

$$Ten_{RFB} = \pm(2\sigma 5C + \Sigma e5C)\% \text{ Power}$$
$$Ten_{RFB} = \pm(2*2.874811 + 1.672412)\% \text{ Power}$$
$$Ten_{RFB} = \pm 7.422034\% \text{ Power}$$

And

$$Ten_{RFB(AV)} = \pm(2\sigma 5C_{AV} + \Sigma e5C_{AV})\% \text{ Power}$$
$$Ten_{RFB(AV)} = \pm(2*2.404668 + 0.852412)\% \text{ Power}$$
$$Ten_{RFB(AV)} = \pm 5.661747\% \text{ Power}$$

12.4 RBM Fixed Trip - Ten_{RF}, $Ten_{RF(AV)}$

Ten_{RF} and $Ten_{RF(AV)}$ are made up of the uncertainty terms from RBM Fixed Trip Module 5B. From Sections 11.5.2.1.6 and 11.5.2.2.10:

$$Ten_{RF} = \pm(2\sigma 5B + \Sigma e5B)\%\ \text{Power}$$

$$Ten_{RF} = \pm(2*2.316113 + 0.82)\ \%\ \text{Power}$$

$$Ten_{RF} = \pm 5.452226\%\ \text{Power}$$

And

$$Ten_{RF(AV)} = \pm(2\sigma 5B_{AV} + \Sigma e5B_{AV})\%\ \text{Power}$$

$$Ten_{RF(AV)} = \pm(2*2.129873 + 0)\%\ \text{Power}$$

$$Ten_{RF(AV)} = \pm 4.259745\%\ \text{Power}$$

12.5 Recirculation Flow Monitor - Upscale - Ten_{RFMU}, $Ten_{RFMU(AV)}$

Ten_{RFMU} and $Ten_{RFMU(AV)}$ are made up of the uncertainty terms from Recirculation Flow Monitor 3A. From Sections 11.3.3.1.6 and 11.3.3.2.10:

$$Ten_{RFMU} = \pm(2\sigma 3A + \Sigma e3A)\ \%\ \text{Flow}$$

$$Ten_{RFMU} = \pm(2*2.92796 + 1.274635)\%\ \text{Flow}$$

$$Ten_{RFMU} = \pm 7.130555\%\ \text{Flow}$$

And

$$Ten_{RFMU(AV)} = \pm(2\sigma 3A_{AV} + \Sigma e3A)\ \%\ \text{Flow}$$

$$Ten_{RFMU(AV)} = \pm(2*2.207804 + 1.274635)\ \%\ \text{Flow}$$

$$Ten_{RFMU(AV)} = \pm 5.690244\%\ \text{Flow}$$

Note that for the RFM loops there were no non-random terms associated with the process. Therefore, the non-random term $\Sigma e3A$ is applicable to both the AL and AV total error terms.

12.6 Recirculation Flow Monitor - Upscale - Comparator - Ten_{RFMC}, $Ten_{RFMC(AV)}$

Ten_{RFMC} and $Ten_{RFMC(AV)}$ are made up of the uncertainty terms from Recirculation Flow Monitor 3B. From Sections 11.3.3.1.6 and 11.3.3.2.10:

$$Ten_{RFMC} = \pm(2\sigma 3B + \Sigma e3B)\%\ Flow$$

$$Ten_{RFMC} = \pm(2*2.756468 + 2.54927)\%\ Flow$$

$$Ten_{RFMC} = \pm 8.062206\%\ Flow$$

Per Section 4.9 the process variables have already been removed from the uncertainty terms for the comparator trip. Therefore,

$$Ten_{RFMC(AV)} = Ten_{RFMC} = \pm 8.062206\%\ Flow$$

12.7 APRM Fixed Low Power Trips - Ten_{AFLP}, $Ten_{AFLP(AV)}$

Ten_{AFLP} and $Ten_{AFLP(AV)}$ are made up of the uncertainty terms from APRM Fixed Trip Module $4C_{LP}$. From Sections 11.4.3.1.6 and 11.4.3.2.10:

$$Ten_{AFLP} = \pm(2\sigma 4C_{LP} + \Sigma e4C_{LP})\%\ Power$$

$$Ten_{AFLP} = \pm(2*2.150421 + 0.33)\%\ Power$$

$$Ten_{AFLP} = \pm 4.630842\%\ Power$$

For the Allowable Value calculation the uncertainties for the fixed low power trips are the same as for the fixed high power trip. Therefore,

$$Ten_{AFLP(AV)} = Ten_{AF(AV)} = \pm 4.266158\%\ Power$$

13.0 ERROR ANALYSIS SUMMARY & CONCLUSIONS

The total uncertainties applicable to the ABB Flow Unit are smaller than those associated with the GE Flow Unit. Therefore, all calculations will be performed using those terms applicable to the GE Flow Unit since the results will then be conservative for operation using the ABB Flow Unit.

13.1 APRM Flow Biased Trips

The APRM Flow Biased Trips have a different total uncertainty term for both single (Ten_{AFBSLO}) and two (Ten_{AFB}) recirculation loop operation. This results from the difference in the flow biased trip slope for the analytical limits in design input 4.14.

13.1.1 Simulated Thermal Power Upscale (Scram) - Two Loop Operation

Using the Reference 3.34 methodology, the nominal trip setpoint for an upscale or increasing trip is determined as follows:

$$NTSP = AL - Ten$$

For this calculation this becomes:

$$NTSP_{STP2} = AL_{STP2} - Ten_{AFB}$$

For software reasons the AL and NTSP are broken into two parts:

$$AL_{STP2} = FCS_{SP}*W + AL_{STP2OS}$$

$$NTSP_{STP2} = FCS_{SP}*W + NTSP_{STP2OS}$$

Substituting the analytical limit from Design Input 4.14 and the total uncertainty from Section 12.1.1 yields:

$$NTSP_{STP2} = FCS_{SP}*W + (AL_{STP2OS} - Ten_{AFB})$$

$$NTSP_{STP2} = 0.62W + (70.9 - 7.113139)$$

$$NTSP_{STP2} = 0.62W + 63.786861\%, \text{ rounded to } 0.62W + 63.7\ \%\ \text{Power}$$

In a similar fashion the Allowable Value can be calculated using the applicable uncertainty (5.566321% Power) from Section 12.1.1.

$$AV_{STP2} = FCS_{SP}*W + NTSP_{STP2OS} + Ten_{AFB(AV)}$$

$$AV_{STP2} = 0.62W + 63.786861\ \%\ \text{Power} + 5.566321$$

$$AV_{STP2} = 0.62W + 69.353182\%, \text{ rounded to } 0.62W + 69.3\%\ \text{Power}$$

13.1.2 Simulated Thermal Power Upscale (Scram)-Single Loop Operation

Using the Reference 3.34 methodology, the nominal trip setpoint for an upscale or increasing trip is determined as follows:

$$NTSP = AL - Ten$$

For this calculation this becomes:

$$NTSP_{STP1} = AL_{STP1} - Ten_{AFB}$$

For software reasons the AL and NTSP are broken into two parts:

$$AL_{STP1} = FCS_{SP}*W + AL_{STP1OS}$$

$$NTSP_{STP1} = FCS_{SP}*W + NTSP_{STP1OS}$$

Substituting the analytical limit from Design Input 4.14 and the total uncertainty from Section 12.1.2 yields:

$$NTSP_{STP1} = FCS_{SP}*W + AL_{STP1OS} - Ten_{AFB} \text{ \% Power}$$

$$NTSP_{STP1} = 0.55W + 58.33 - 6.822494 \text{ \% Power}$$

$$NTSP_{STP1} = 0.55W+51.507506\text{\%, rounded to } 0.55W + 51.5 \text{ \% Power}$$

In a similar fashion the Allowable Value can be calculated using the applicable uncertainty (5.378142% Power) from Section 12.1.2.

$$AV_{STP1} = FCS_{SP}*W + NTSP_{STP1OS} + Ten_{AFB(AV)} \text{ \% Power}$$

$$AV_{STP1} = 0.55W + 51.507506 + 5.378142 \text{ \% Power}$$

$$AV_{STP1} = 0.55W + 56.885648\text{\%, rounded to } 0.55W + 56.8\text{\%}$$

13.1.3 Simulated Thermal Power Upscale (Rod Block)-Two Loop Operation

Using the Reference 3.34 methodology, the nominal trip setpoint for an upscale or increasing trip is determined as follows:

$$NTSP = AL - Ten$$

For this calculation this becomes:

$$NTSP_{STP2RB} = AL_{STP2RB} - Ten_{AFB}$$

For software reasons the AL and NTSP are broken into two parts:

$$AL_{STP2RB} = FCS_{SP}*W + AL_{STP2RBOS}$$

$$NTSP_{STP2RB} = FCS_{SP}*W + NTSP_{STP2RBOS}$$

Substituting the analytical limit from Design Input 4.14 and the total uncertainty from Section 12.1.1 yields:

$$NTSP_{STP2RB} = FCS_{SP}*W + AL_{STP2RBOS} - Ten_{AFB}$$

$$NTSP_{STP2RB} = 0.62W + 59.47 - 7.113139$$

$$NTSP_{STP2RB} = 0.62W + 52.356861\%, \text{ rounded to } 0.62W + 52.3\ \%$$

In a similar fashion the Allowable Value can be calculated using the applicable uncertainty (5.566321% Power) from Section 12.1.1.

$$AV_{STP2RB} = FCS_{SP}*W + NTSP_{STP2RBOS} + Ten_{AFB(AV)}$$

$$AV_{STP2RB} = 0.62W + 52.356861 + 5.566321$$

$$AV_{STP2RB} = 0.62W + 57.923182\%, \text{ rounded to } 0.62W + 57.9\%$$

13.1.4 Simulated Thermal Power Upscale (Rod Block) - Single Loop

Using the Reference 3.34 methodology, the nominal trip setpoint for an upscale or increasing trip is determined as follows:

$$NTSP = AL - Ten$$

For this calculation this becomes:

$$NTSP_{STP1RB} = AL_{STP1RB} - Ten_{AFB}$$

For software reasons the AL and NTSP are broken into two parts:

$$AL_{STP1RB} = FCS_{SP}*W + AL_{STP1RBOS}$$

$$NTSP_{STP1RB} = FCS_{SP}*W + NTSP_{STP1RBOS}$$

Substituting the analytical limit from Design Input 4.14 and the total uncertainty from Section 12.1.2 yields:

$$NTSP_{STP1RB} = FCS_{SP}*W + AL_{STP1RBOS} - Ten_{AFB}$$

$$NTSP_{STP1RB} = 0.55W + 46.9 - 6.822494$$

$$NTSP_{STP1RB} = 0.55W + 40.077506\%, \text{ rounded to } 0.55W + 40.0\ \%$$

In a similar fashion the Allowable Value can be calculated using the applicable uncertainty (5.378142% Power) from Section 12.1.2.

$$AV_{STP1RB} = FCS_{SP}*W + NTSP_{STP1RBOS} + Ten_{AFB(AV)}\ \%\ Power$$

$$AV_{STP1RB} = 0.55W + 40.077506 + 5.378142\ \%\ Power$$

$$AV_{STP1RB} = 0.55W + 45.455648\%,\ rounded\ to\ 0.55W + 45.4\%$$

13.2 APRM Fixed Trips

The APRM Fixed Trips are divided into two groups, High Power Level Trips and Low Power Level Trips. The uncertainty terms for these trips are Ten_{AF} and Ten_{AFLP} respectively.

13.2.1 Neutron Flux High (Scram)

From Section 10.4 the existing Technical Specifications Nominal Trip Setpoint (NTSP) for this function is ≤118% Power. For this calculation this will be the starting point and the resulting Analytical Limit will be calculated.

From Section 12.2 the total uncertainty for this function is ±5.691278% Power. From Reference 3.3 the relationship between NTSP and AL for an upscale trip is:

$$AL = NTSP + Ten$$

For this calculation this becomes:

$$AL_{FS} = NTSP_{FS} + Ten_{AF} \text{ \% Power}$$

$$AL_{FS} = 118 + 5.691278 \text{ \% Power}$$

$$AL_{FS} = 123.691278\text{\% Power}$$

In a similar fashion the Allowable Value can be calculated using the applicable uncertainty (4.266158% Power) from Section 12.2.

$$AV_{FS} = NTSP_{FS} + Ten_{AF(AV)} \text{ \% Power}$$

$$AV_{FS} = 118 + 4.266158 \text{ \% Power}$$

$$AV_{FS} = 122.266158\text{\% power}$$

13.2.2 Neutron Flux High - Setdown (Scram)

From Section 10.4 the existing Technical Specifications Nominal Trip Setpoint (NTSP) for this function is ≤15% Power. For this calculation this will be the starting point and the resulting Analytical Limit will be calculated.

From Section 12.7 the total uncertainty for this function is ±4.630842% Power. From Reference 3.3 the relationship between NTSP and AL for an upscale trip is:

$$AL = NTSP + Ten$$

For this calculation this becomes:

$$AL_{FSS} = NTSP_{FSS} + Ten_{AFLP}\ \%\ Power$$

$$AL_{FSS} = 15 + 4.630842\ \%\ Power$$

$$AL_{FSS} = 19.630842\%\ Power$$

In a similar fashion the Allowable Value can be calculated using the applicable uncertainty (4.266158% Power) from Section 12.7.

$$AV_{FSS} = NTSP_{FSS} + Ten_{AF(AV)}\ \%\ Power$$

$$AV_{FSS} = 15 + 4.266158\ \%\ Power$$

$$AV_{FSS} = 19.266158\%\ Power$$

These values for AL and AV will not support the existing Tech Spec AV of ≤20 % Power. Therefore, the calculation will be performed using the AL provided in Section 4.14 (and Reference 3.27) (≤25 % Power).

For an upscale trip:

$$NTSP = AL - Ten$$

For this calculation:

$$NTSP_{FSSN} = AL_{FSSN} - Ten_{AFLP}\ \%\ Power$$

$$NTSP_{FSSN} = 25 - 4.630842\ \%\ Power$$

$$NTSP_{FSSN} = 20.369158\%\ Power$$

From this a new AV can be calculated:

$$AV_{FSSN} = NTSP_{FSSN} + Ten_{AF(AV)}\ \%\ Power$$

$$AV_{FSSN} = 20.369158 + 4.266158\ \%\ Power$$

$$AV_{FSSN} = 24.635316\%\ Power$$

13.2.3 Neutron Flux High - Setdown (Rod Block)

From Section 10.4 the existing Technical Specifications Nominal Trip Setpoint (NTSP) for this function is ≤12% Power. For this calculation this will be the starting point and the resulting Analytical Limit will be calculated.

From Section 12.7 the total uncertainty for this function is ±4.630842% Power. From Reference 3.3 the relationship between NTSP and AL for an upscale trip is:

$$AL = NTSP + Ten$$

For this calculation this becomes:

$$AL_{RBS} = NTSP_{RBS} + Ten_{AFLP} \text{ \% Power}$$

$$AL_{RBS} = 12 + 4.630842 \text{ \% Power}$$

$$AL_{RBS} = 16.630842\text{\% Power}$$

In a similar fashion the Allowable Value can be calculated using the applicable uncertainty (4.266158% Power) from Section 12.7.

$$AV_{RBS} = NTSP_{RBS} + Ten_{AF(AV)} \text{ \% Power}$$

$$AV_{RBS} = 12 + 4.266158 \text{ \% Power}$$

$$AV_{RBS} = 16.266158\text{\% Power}$$

These values for AL and AV will not support the existing Tech Spec AV of ≤14 % Power. Therefore, the calculation will be performed using the AL provided in Section 4.14 (and Reference 3.27) (≤19 % Power).

For an upscale trip:

$$NTSP = AL - Ten$$

For this calculation:

$$NTSP_{RBSN} = AL_{RBSN} - Ten_{AFLP} \text{ \% Power}$$

$$NTSP_{RBSN} = 19 - 4.630842 \text{ \% Power}$$

$$NTSP_{RBSN} = 14.369158\text{\% Power}$$

From this a new AV can be calculated:

$$AV_{RBSN} = NTSP_{RBSN} + Ten_{AFAV} \text{ \% Power}$$

$$AV_{RBSN} = 14.369158 + 4.266158 \text{ \% Power}$$

$$AV_{RBSN} = 18.635316\text{\% Power}$$

13.2.4 Neutron Flux Downscale (Rod Block)

From Section 10.4 the existing Technical Specifications Nominal Trip Setpoint (NTSP) for this function is ≥5% Power. For this calculation this will be the starting point and the resulting Analytical Limit will be calculated.

From Section 12.7 the total uncertainty for this function is ±4.630842% Power. From Reference 3.3 the relationship between NTSP and AL for a downscale trip is:

$$AL = NTSP - Ten$$

For this calculation this becomes:

$$AL_{DS} = NTSP_{DS} - Ten_{AFLP} \text{ \% Power}$$

$$AL_{DS} = 5 - 4.630842 \text{ \% Power}$$

$$AL_{DS} = 0.369158\text{\% Power}$$

In a similar fashion the Allowable Value can be calculated using the applicable uncertainty (4.266158% Power) from Section 12.7.

$$AV_{DS} = NTSP_{DS} - Ten_{AF(AV)} \text{ \% Power}$$

$$AV_{DS} = 5 - 4.266158 \text{ \% Power}$$

$$AV_{DS} = 0.733842\text{\% Power}$$

13.2.5 Neutron Flux High Flow Clamped - Two Loop Operation (Scram)

From Section 10.4 the existing Technical Specifications Nominal Trip Setpoint (NTSP) for this function is ≤113.5% Power. For this calculation this will be the starting point and the resulting Analytical Limit will be calculated.

From Section 12.2 the total uncertainty for this function is ±5.691278% Power. From Reference 3.3 the relationship between NTSP and AL for an upscale trip is:

$$AL = NTSP + Ten$$

For this calculation this becomes:

$$AL_{HFC} = NTSP_{HFC} + Ten_{AF} \text{ \% Power}$$

$$AL_{HFC} = 113.5 + 5.691278 \text{ \% Power}$$

AL_{HFC} = 119.19128% Power

In a similar fashion the Allowable Value can be calculated using the applicable uncertainty (4.266158% Power) from Section 12.2.

$AV_{HFC} = NTSP_{HFC} + Ten_{AF(AV)}$ % Power

AV_{HFC} = 113.5 + 4.266158 % Power

AV_{HFC} = 117.766158% Power

13.2.6 Neutron Flux High Flow Clamped - Single Loop Operation (Scram)

From Design Input 4.14, the revised Analytical Limit (AL) resulting from Power Uprate for this function is 113.8% Power. Using this and the total uncertainty for this function from Section 12.2 of ±5.691278% Power, the resulting Nominal Trip Setpoint (NTSP) will be calculated. From Reference 3.34 the relationship between NTSP and AL for an upscale trip is:

NTSP = AL - Ten

For this calculation this becomes:

$NTSP_{HFCSLO} = AL_{HFCSLO} - Ten_{AF}$ % Power

$NTSP_{HFCSLO}$= 113.8 % - 5.691278%

$NTSP_{HFCSLO}$= 108.108722%, rounded to 108.1%

In a similar fashion the Allowable Value can be calculated using the applicable uncertainty (4.266158% Power) from Section 12.2.

$AV_{HFCSLO} = NTSP_{HFCSLO} + Ten_{AF(AV)}$ % Power

AV_{HFCSLO}= 108.108722 + 4.266158 % Power

AV_{HFCSLO}= 112.37488 % Power, rounded to 112.3 % Power

13.3 RBM Flow Biased Trips

The RBM Flow Biased Trips have the same total uncertainty term (Ten_{RFB}) whether in Two Recirculation Loop Operation or Single Recirculation Loop Operation. This is because there are no changes made to the method of operation of the Recirculation Flow Monitor for either Single or Two Loop Operation. Therefore, the error analysis for the RFM is the same.

13.3.1 Upscale Trip - Two Loop Operation

From Section 10.5 the existing Nominal Trip Setpoint (NTSP) for this function is ≤0.66W + 45% Power. For this calculation this will be the starting point and the resulting Analytical Limit will be calculated.

From Section 12.3 the total uncertainty for this function is ±7.422034% Power. From Reference 3.3 the relationship between NTSP and AL for an upscale trip is:

$$AL = NTSP + Ten$$

For this calculation this becomes:

$$AL_{RBM2} = NTSP_{RBM2} + Ten_{RFB}$$

For software reasons the AL and NTSP are broken into two parts:

$$AL_{RBM2} = FCS_{RBM(SP)} * W + AL_{RBM2OS}$$

$$NTSP_{RBM2} = FCS_{RBM(SP)} * W + NTSP_{RBM2OS}$$

Substituting and solving yields:

$$AL_{RBM2} = FCS_{RBM(SP)} * W + NTSP_{RBM2OS} + Ten_{RFB} \ \% \text{ Power}$$

$$AL_{RBM2} = 0.66W + 45 + 7.422034 \ \% \text{ Power}$$

$$AL_{RBM2} = 0.66W + 52.422034 \ \% \text{ Power}$$

In a similar fashion the Allowable Value can be calculated using the applicable uncertainty (5.661747% Power) from Section 12.3.

$$AV_{RBM2} = FCS_{RBM(SP)} * W + NTSP_{RBM2OS} + Ten_{RFB(AV)} \ \% \text{ Power}$$

$$AV_{RBM2} = 0.66W + 45 + 5.661747 \ \% \text{ Power}$$

$$AV_{RBM2} = 0.66W + 50.661747\% \text{ Power}$$

13.3.2 Upscale Trip - Single Loop Operation

From Section 10.5 the existing Nominal Trip Setpoint (NTSP) for this function is ≤0.66W + 39.7% Power. For this calculation this will be the starting point and the resulting Analytical Limit will be calculated.

From Section 12.3 the total uncertainty for this function is ±7.422034% Power. From Reference 3.3 the relationship between NTSP and AL for an upscale trip is:

$$AL = NTSP + Ten$$

For this calculation this becomes:

$$AL_{RBM1} = NTSP_{RBM1} + Ten_{RFB}$$

For software reasons the AL and NTSP are broken into two parts:

$$AL_{RBM1} = FCS_{RBM(SP)}*W + AL_{RBM1OS}$$

$$NTSP_{RBM1} = FCS_{RBM(SP)}*W + NTSP_{RBM1OS}$$

Substituting and solving yields:

$$AL_{RBM1} = FCS_{RBM(SP)}*W + NTSP_{RBM1OS} + Ten_{RFB}\ \%\ Power$$

$$AL_{RBM1} = 0.66W + 39.7 + 7.422034\ \%\ Power$$

$$AL_{RBM1} = 0.66W + 47.122034\ \%\ Power$$

In a similar fashion the Allowable Value can be calculated using the applicable uncertainty (5.661747% Power) from Section 12.3.

$$AV_{RBM1} = FCS_{RBM(SP)}*W + NTSP_{RBM1OS} + Ten_{RFB(AV)}\ \%\ Power$$

$$AV_{RBM1} = 0.66W + 39.7 + 5.661747\ \%\ Power$$

$$AV_{RBM1} = 0.66W + 45.361747\%\ Power$$

13.4 RBM Downscale Trip

From Section 10.4 the existing Technical Specifications Nominal Trip Setpoint (NTSP) for this function is ≥5% Power. For this calculation this will be the starting point and the resulting Analytical Limit will be calculated.

From Section 12.4 the total uncertainty for this function is ±5.452226% Power. From Reference 3.3 the relationship between NTSP and AL for a downscale trip is:

$$AL = NTSP - Ten$$

For this calculation this becomes:

$$AL_{RBMDS} = NTSP_{RBMDS} - Ten_{RF} \text{ \% Power}$$

$$AL_{RBMDS} = 5 - 5.452226 \text{ \% Power}$$

$$AL_{RBMDS} = -0.452226\text{\% Power}$$

In a similar fashion the current Allowable Value can be calculated using the applicable uncertainty (4.259745% Power) from Section 12.4. The starting point will be the current NTSP.

$$AV_{RBMDSC} = NTSP_{RBMDS} - Ten_{RF(AV)} \text{ \% Power}$$

$$AV_{RBMDSC} = 5 - 4.259745 \text{ \% Power}$$

$$AV_{RBMDSC} = 0.740255\text{\% Power}$$

Since a negative power is not possible a new calculation will be performed starting with AL equal to 0 (Section 4.14 and Reference 3.27) and determining a new NTSP.

$$NTSP_{DSN} = AL_0 + Ten_{RF} \text{ \% Power}$$

$$NTSP_{DSN} = 0 + 5.452226 \text{ \% Power}$$

$$NTSP_{DSN} = 5.452226\text{\% Power}$$

In a similar fashion the Allowable Value can be calculated using the applicable uncertainty (4.259745% Power) from Section 12.4. For ease of calibration, the new NTSP will be selected to be 5.5%, $NTSP_{RBMDSS}$, and this will be the starting point.

$$AV_{RBMDS} = NTSP_{RBMDSS} - Ten_{RF(AV)} \text{ \% Power}$$

$$AV_{RBMDS} = 5.5 - 4.259745 \text{ \% Power}$$

AV_{RBMDS} = 1.240255% Power

13.5 Recirculation Flow Monitor - Upscale

From Section 10.3 the existing Technical Specifications Nominal Trip Setpoint (NTSP) for this function is ≤108% Flow. For this calculation this will be the starting point and the resulting Analytical Limit (AL) will be calculated.

From Section 12.5 the total uncertainty for this function is ±7.130555% Flow. From Reference 3.3 the relationship between NTSP and AL for an upscale trip is:

$$AL = NTSP + Ten$$

For this calculation this becomes:

$$AL_{RFMU} = NTSP_{RFMU} + Ten_{RFMU}\ \%\ Flow$$

$$AL_{RFMU} = 108 + 7.130555\ \%\ Flow$$

$$AL_{RFMU} = 115.130555\%\ Flow$$

In a similar fashion the Allowable Value can be calculated using the applicable uncertainty (5.690244% Flow) from Section 12.5.

$$AV_{RFMU} = NTSP_{RFMU} + Ten_{RFMU(AV)}\ \%\ Flow$$

$$AV_{RFMU} = 108 + 5.690244\ \%\ Flow$$

$$AV_{RFMU} = 113.690244\%\ Flow$$

13.6 Recirculation Flow Monitor - Comparator

From Section 10.3 the existing Technical Specifications Nominal Trip Setpoint (NTSP) for this function is ≤10% Flow. For this calculation this will be the starting point and the resulting Analytical Limit (AL) will be calculated.

From Section 12.6 the total uncertainty for this function is ±8.062206% Flow. From Reference 3.3 the relationship between NTSP and AL for an upscale trip is:

$$AL = NTSP + Ten$$

For this calculation this becomes:

$$AL_{RFMC} = NTSP_{RFMC} + Ten_{RFMC} \text{ \% Flow}$$

$$AL_{RFMC} = 10 + 8.062206 \text{ \% Flow}$$

$$AL_{RFMC} = 18.062206\text{\% Flow}$$

Per Section 4.9 the process term has already been removed from the uncertainty terms for the comparator trip. Therefore,

$$AV_{RFMC} = AL_{RFMC} = 18.062206\text{\% Flow}$$

14.0 CONCLUSIONS

This calculation indicates that the following Nominal Trip Setpoints and Allowable Values are acceptable except for the RBM Downscale Trip function for which a new setpoint needed to be calculated. Use of the setpoint values either validated or determined by this calculation provides a high degree of confidence that the Allowable Values will not be exceeded during normal operating conditions.

14.1 APRM Flow Biased Trips

14.1.1 Simulated Thermal Power Upscale (Scram) - Two Loop Operation

Analytical Limit: 0.62W + 70.9 % Power
Tech Spec AV: 0.62W + 69.3 % Power
Tech Spec NTSP: 0.62W + 63.7 % Power

Calibration setpoint: Since the setpoint is calibrated at a specific drive flow, the nominal setpoint should be set at least 0.04 Vdc below the corresponding Tech Spec NTSP with a tolerance of +/- 0.04 Vdc. For example, with an 80% drive flow, the Tech Spec NTSP is 113.3% (0.62*80 +63.7). Since 113.3% on a 125% scale corresponds to 9.064 Vdc on a 10 Vdc scale [10Vdc*113.3%/125%], a setpoint of 9.020 +/- 0.04 Vdc is recommended for 80% drive flow.

14.1.2 Simulated Thermal Power Upscale (Scram) Single Loop Operation

Analytical Limit: 0.55W + 58.33 % Power
Tech Spec AV: 0.55W + 56.8 % Power
Tech Spec NTSP: 0.55W + 51.5 % Power

Calibration setpoint: Since the setpoint is calibrated at aspecific drive flow, the nominal setpoint should be set at least 0.04 Vdc below the corresponding Tech Spec NTSP with an tolerance of +/- 0.04 Vdc. For example, with an 80% drive flow, the Tech Spec NTSP is 95.5% (0.55*80 +51.5). Since 95.5% on a 125% scale corresponds to 7.640 Vdc on a 10 Vdc scale [10Vdc*95.5%/125%], a setpoint of 7.600 +/- 0.04 Vdc is recommended for 80% drive flow.

14.1.3 Simulated Thermal Power Upscale (Rod Block) Two Loop Operation

Analytical Limit: 0.62W + 59.47 % Power
Tech Spec AV: 0.62W + 57.9 % Power
Tech Spec NTSP: 0.62W + 52.3 % Power

Calibration setpoint: Since the setpoint is calibrated at a specific drive flow, the nominal setpoint should be set at least 0.04 Vdc below the corresponding Tech Spec NTSP with a tolerance of +/- 0.04 Vdc. For example, with an 80% drive flow, the Tech Spec NTSP is 101.9% (0.62*80 +52.3). Since 101.9% on a 125% scale corresponds to 8.152 Vdc on a 10 Vdc scale [10Vdc*101.9%/125%], a setpoint of 8.110 +/- 0.04 Vdc is recommended for 80% drive flow.

14.1.4 Simulated Thermal Power Upscale (Rod Block) Single Loop Operation

Analytical Limit: 0.55W + 46.9 % Power
Tech Spec AV: 0.55W + 45.4 % Power
Tech Spec NTSP: 0.55W + 40 % Power

Calibration setpoint: Since the setpoint is calibrated at a specific drive flow, the nominal setpoint should be set at least 0.04 Vdc below the corresponding Tech Spec NTSP with a tolerance of +/- 0.04 Vdc. For example, with an 80% drive flow, the Tech Spec NTSP is 84.0% (0.55*80 +40.0). Since 84.0% on a 125% scale corresponds to 6.720 Vdc on a 10 Vdc scale [10Vdc*84.0%/125%], a setpoint of 6.680 +/- 0.04 Vdc is recommended for 80% drive flow.

14.2 APRM Fixed Trips

14.2.1 Neutron Flux High (Scram)

Tech Spec NTSP: 118 % Power
Tech Spec AV: 120 % Power
Calculated AV: 122.27 % Power
Calculated AL: 123.69 % Power

Reference 3.27 requested that these values be evaluated against two Analytical Limits, 122.4 and 124.2 % Power. As shown above this calculation will not support an AL of 122.4. It does show, however, that there is positive margin between the calculated AL and 124.2 % Power. The Reload Analysis must be changed to justify the use of a new AL of 124.2 % Power.

14.2.2 Neutron Flux High - Setdown (Scram)

Tech Spec NTSP: 15 % Power
Tech Spec AV: 20 % Power
Calculated AV: 19.27 % Power

Calculated AL: 19.63 % Power

AL: (from Ref. 3.27)	25 % Power
Calculated NTSP: (from Ref. 3.27 AL)	20.37 % Power
Calculated AV: (from Ref. 3.27 AL)	24.64 % Power

This calculation shows that an AL as low as approximately 20.5 % Power would support the existing Tech Spec NTSP and AV. However, using an AL of 25 % Power gives a positive margin of more than 4 % Power between the existing AV and the AV calculated from an AL of 25 % Power.

14.2.3 Neutron Flux High - Setdown (Rod Block)

Tech Spec NTSP:	12 % Power
Tech Spec AV:	14 % Power
Calculated AV:	16.27 % Power
Calculated AL:	16.63 % Power
AL: (from Ref. 3.27)	19 % Power
Calculated NTSP: (from Ref. 3.27 AL)	14.37 % Power
Calculated AV: (from Ref. 3.27 AL)	18.64 % Power

This calculation shows that the existing Tech Spec NTSP and AV are supported by an AL of 16.63 % Power. Therefore, there is greater than 2 % Power positive margin between the calculated AL and that proposed in Reference 3.27.

14.2.4 Neutron Flux Downscale (Rod Block)

Tech Spec NTSP:	5 % Power
Tech Spec AV:	3 % Power
Calculated AV:	0.73 % Power
Calculated AL:	0.37 % Power

Reference 3.27 proposed an AL of 0% Power for this function.

This calculation shows that there is a 0.37 % Power positive margin between the this and the calculated AL.

14.2.5 Neutron Flux High Flow Clamped - Two Loop Operation (Scram)

Tech Spec NTSP:	113.5 % Power
Tech Spec AV:	115.5 % Power
Calculated AV:	117.77 % Power
Calculated AL:	119.19 % Power

Reference 3.27 requests that these results be evaluated against ALs of 115.5% Power and 119.5% Power. As shown above this calculation will not support an AL of 115.5. However, there is a positive margin of about 0.3% Power between the calculated AL and the 119.5% Power value proposed by Reference 3.27. The Reload Analysis must be changed to justify the use of a new AL of 119.5 % Power.

14.2.6 Neutron Flux High Flow Clamped-Single Loop Operation (Scram)

Analytical Limit:	113.8 %
Tech Spec NTSP:	108.1 %
Tech Spec AV:	112.3 %

The calibration setpoint should be at least 0.04 Vdc below the Tech Spec NTSP with a tolerance of +/- 0.04 Vdc. Since 108.1% on a 125% scale corresponds with 8.648 Vdc on a 10 Vdc scale, [10Vdc*108.1%/125%], a setpoint of 8.600 +/- 0.04 Vdc is recommended.

14.3 RBM Flow Biased Trips

14.3.1 Upscale Trip - Two Loop Operation

Tech Spec NTSP:	0.66W + 45 % Power
Tech Spec AV:	0.66W + 48 % Power
Calculated AV:	0.66W + 50.66 % Power
Calculated AL:	0.66W + 52.42 % Power

This shows a positive margin of over 2.5 % Power between the calculated AV and Tech Spec AV for the current NTSP, and a positive margin of over 1.5 % Power between the calculated AL and the calculated AV. From Reference 3.27, current LaSalle transient analyses do not take credit for this AL. Therefore, this calculated AL is considered acceptable.

14.3.2 Upscale Trip - Single Loop Operation

Tech Spec NTSP:	0.66W + 39.7 % Power
Tech Spec AV:	0.66W + 42.7 % Power
Calculated AV:	0.66W + 45.36 % Power

Calculated AL: 0.66W + 47.12 % Power

This shows a positive margin of over 2.5 % Power between the calculated AV and Tech Spec AV for the current NTSP, and a positive margin of over 1.5 % Power between the calculated AL and the calculated AV. From Reference 3.27, current LaSalle transient analyses do not take credit for this AL. Therefore, this calculated AL is considered acceptable.

14.4 RBM Downscale Trip

Tech Spec NTSP:	5 % Power
Tech Spec AV:	3 % Power
Calculated AL:	-0.452226 % Power
AL: (from Ref. 3.27)	0 % Power
Calculated NTSP: (from Ref. 3.27 AL)	5.45 % Power
Selected NTSP: (from Section 13.4)	5.50 % Power
Calculated AV: (from Ref. 3.27 AL and selected setpoint)	1.24 % Power

The present procedural setpoint for this function is 0.404 Vdc which is equivalent to 5.05% Power. Therefore, this should be changed to at least 5.5% Power in order to be compatible with the uncertainties evaluated in this calculation (Section 13.4).

14.5 Recirculation Flow Monitor - Upscale

Tech Spec NTSP:	108 % Flow
Tech Spec AV:	111 % Flow
Calculated AV:	113.69 % Flow
Calculated AL:	115.13 % Flow

Reference 3.27 requested that these values be evaluated against an AL of 116% Flow. As the calculation shows there is a positive margin of about 0.87% Flow between the calculated AL and that of Reference 3.27.

14.6 Recirculation Flow Monitor - Comparator

Tech Spec NTSP:	10 % Flow
Tech Spec AV:	11 % Flow
Calculated AV:	18.06 % Flow
Calculated AL:	18.06 % Flow

Reference 3.27 requested that these values be evaluated against an AL of 19% Flow. This calculation indicates that there is positive margin between the calculated AL and the value from Reference 3.27.

14.7 From References 3.5.s and 3.5.t, the required accuracy for the pneumatic calibrator is specified as ±2.0" W.C. For the normal temperatures involved in the Reactor Building, i.e., up to 118 °F, the calculated accuracy of the Wallace and Tiernan pneumatic calibrator exceeds this value (Section 9.2). Therefore, the calibration procedures should be revised to indicate the increased uncertainty or to limit the ambient temperature allowed during calibration.

14.8 In accordance with Design Input 10.3, the recirculation flow monitor upscale trip setpoint calibration tolerance shall not exceed ±0.1 Vdc and the recirculation flow monitor comparator trip setpoint calibration tolerance shall not exceed ±0.08 Vdc.

CALCULATION NO. L-001345		PAGE 174 of 191

15.0 CALCULATION SPREADSHEET

Symbol	Formula or Input Value	Value	Units
RA_{FE}	1	1	% CS
$CS_{FT(MIN)}$	247.4	247.4	"WC
$CS_{FT(MAX)}$	448.7	448.7	"WC
CS_{FT}	$CS_{FT(MIN)}$	247.4	"WC
UR_{FT}	750	750	"WC
$UR_{FT(CS)}$	UR_{FT}/CS_{FT}	3.031528	CS
RA1	0.25	0.25	% CS
$CALTEMP_{FT}$	60	60	°F
$MAXTEMP_{FT}$	118	118	°F
e1T	$(0.5*UR_{FT(CS)} + 0.5)*(MAXTEMP_{FT} - CALTEMP_{FT})/100$	1.169143	% CS
$RA1_{(1\sigma)}$	RA1/2	0.125	% CS
RD_{FT}	0.2	0.2	% UR/ 30 mo.
RD1	$UR_{FT(CS)}*RD_{FT}$	0.606306	% CS
$RD1_{(1\sigma)}$	RD1/2	0.303153	% CS
PSE_{FT}	0.005	0.005	%CS/V
ΔV_{FT}	0.5 Vdc	0.5	Vdc
$SPZE_{FT}$	0.25	0.25	%UR/2000 PSI
$SPZE_{FT(1\sigma)}$	$(SPZE_{FT}/2)*(STAPR_{FT}/2000)*(UR_{FT}/CS_{FT})$	0.194207	% CS
$STAPR_{FT}$	1025	1025	PSI
$SPSE_{FT}$	0.25	0.25	%CS/1000 PSI
$SPSE_{FT(1\sigma)}$	$SPSE_{FT}/2$	0.125	% CS
SE_{FT}	0.25	0.25	% UR

REVISION NO.	0			

$SE_{FT(CS)}$	$UR_{FT(CS)}*SE_{FT}$	0.757882	% CS
$CS_{FT(OUT)}$	16	16	mVdc
$RAMTE1_{FT}$	2.149835	2.149835	" WC
$REMTE1_{FT}$	0	0	" WC
$RAMTE2_{FT}$	0.034961	0.034961	mVdc
$REMTE2_{FT}$	0	0	mVdc
$MTE1_{FT}$	$((RAMTE1_{FT}/1)^2 + REMTE1_{FT}{}^2)^{0.5}$	2.149835	" WC
$MTE1_{FT(CS)}$	$(MTE1_{FT}/CS_{FT})*100$	0.868971	% CS
$MTE2_{FT}$	$((RAMTE2_{FT}/1)^2 + REMTE2_{FT}{}^2)^{0.5}$	0.034961	mVdc
$MTE2_{FT(CS)}$	$(MTE2_{FT}/CS_{FT(OUT)})*100$	0.218506	% CS
$CAL1_{FT}$	$(MTE1_{FT(CS)}{}^2 + MTE2_{FT(CS)}{}^2)^{0.5}$	0.896022	% CS
$ST_{FT(IN)}$	0.5	0.5	" WC
$ST_{FT(IN)(CS)}$	$(ST_{FT(IN)}/CS_{FT})*100$	0.202102	% CS
$ST_{FT(OUT)}$	0.08	0.08	mVdc
$ST_{FT(OUT)(CS)}$	$(ST_{FT(OUT)}/CS_{FT(OUT)})*100$	0.500000	% CS
$ST1_{(1\sigma)}$	$[(ST_{FT(IN)(CS)}/3)^2 + (ST_{FT(OUT)(CS)}/3)^2]^{0.5}$	0.179767	% CS
$\sigma input1$	2.5	2.5	% CS
$\sigma input1_C$	0	0	% CS
$\sigma 1$	$[(RA1_{(1\sigma)})^2 + (RD1_{(1\sigma)})^2 + (CAL1_{FT})^2 + (ST1_{(1\sigma)})^2 + (SPSE_{FT(1\sigma)})^2 + (SPZE_{FT(1\sigma)})^2 + (\sigma input1)^2]^{0.5}$	2.691847	% CS
$\sigma 1_C$	$[(RA1_{(1\sigma)})^2 + (RD1_{(1\sigma)})^2 + (CAL1_{FT})^2 + (ST1_{(1\sigma)})^2 + (SPSE_{FT(1\sigma)})^2 + (SPZE_{FT(1\sigma)})^2 + (\sigma input1_C)^2]^{0.5}$	0.998018	% CS
e1H	0	0	% CS
e1R	0	0	% CS
e1S	0	0	% CS
e1SP	0	0	% CS
e1P	0	0	% CS

COMMONWEALTH EDISON COMPANY

CALCULATION NO. L-001345		PAGE 176 of 191

e1p	0	0	% CS
e1V	$PSE_{FT}*\Delta V_{PS}$	0.002500	% CS
einput1	0	0	% CS
Σe1	e1H + e1T + e1R + e1S + e1SP + e1P + e1p + e1V + einput1	1.171643	% CS
RA2	0	0	% CS
$RA2_{(1\sigma)}$	RA2/2	0	% CS
RD2	0	0	% CS
$RD2_{(1\sigma)}$	RD2/2	0	% CS
$RAMTE1_{SR}$	0.017205	0.017205	mVdc
$REMTE1_{SR}$	0	0	mVdc
$RAMTE2_{SR}$	0.001803	0.001803	Vdc
$REMTE2_{SR}$	0	0	Vdc
$MTE1_{SR}$	$((RAMTE1_{SR}/1)^2 + REMTE1_{SR}{}^2)^{0.5}$	0.017205	mVdc
$MTE1_{SR(CS)}$	$(MTE1_{SR(OUT)}/CS_{SR(OUT)})*100$	0.089610	% CS
$CS_{SR(OUT)}$	10	10	Vdc
OP_{SR}	6	6	Vdc
$MTE1_{SR(OUT)}$	$(3.125*MTE1_{SR})/OP_{SR}$	0.008961	Vdc
$MTE2_{SR}$	$((RAMTE2_{SR}/n)^2 + REMTE2_{SR}{}^2)^{0.5}$	0.001803	Vdc
$MTE2_{SR(CS)}$	$(MTE2_{SR}/CS_{SR(OUT)})*100$	0.018030	% CS
$CAL2_{SR}$	$((MTE1_{SR(CS)})^2 + (MTE2_{SR(CS)})^2)^{0.5}$	0.091406	% CS
$ST_{SR(IN)}$	0.05	0.05	mVdc
$ST_{SR(OUT)}$	0.025	0.025	Vdc
$ST_{SR(IN)(OUT)}$	$(3.125*ST_{SR(IN)})/OP_{SR}$	0.026042	Vdc
$ST_{SR(IN)(CS)}$	$(ST_{SR(IN)(OUT)}/CS_{SR(OUT)})*100$	0.260420	% CS
$ST_{SR(OUT)(CS)}$	$(ST_{SR(OUT)}/CS_{SR(OUT)})*100$	0.250000	% CS
$ST2_{(1\sigma)}$	$((ST_{SR(IN)(CS)}/3)^2 + (ST_{SR(OUT)(CS)}/3)^2)^{0.5}$	0.120332	% CS
$\sigma 1_{MV}$	$(\sigma 1/100)*CS_{FT(OUT)}$	0.430696	mVdc
$\sigma 1_{MVC}$	$(\sigma 1_C/100)*CS_{FT(OUT)}$	0.159683	mVdc

REVISION NO.	0			

σinput2_{V}	$(3.125*\sigma 1_{MV})/OP_{SR}$	0.224321	Vdc
σinput2_{VC}	$(3.125*\sigma 1_{MVC})/OP_{SR}$	0.083168	Vdc
σinput2	$(\sigma\text{input2}_{V}/CS_{SR(OUT)})*100$	2.243210	% CS
σinput2_{C}	$(\sigma\text{input2}_{VC}/CS_{SR(OUT)})*100$	0.831680	% CS
$\sigma 2$	$[(RA2_{(1\sigma)})^{2} + (RD2_{(1\sigma)})^{2} + (CAL2)^{2} + (ST2_{(1\sigma)})^{2} + (\sigma\text{input2})^{2}]^{0.5}$	2.248294	% CS
$\sigma 2_{c}$	$[(RA2_{(1\sigma)})^{2} + (RD2_{(1\sigma)})^{2} + (CAL2_{SR})^{2} + (ST2_{(1\sigma)})^{2} + (\sigma\text{input2}_{c})^{2}]^{0.5}$	0.845297	% CS
$\Sigma e1_{MV}$	$(\Sigma e1/100)*CS_{FT(OUT)}$	0.187463	mVdc
einput2_{V}	$(3.125*\Sigma e1_{MV})/OP_{SR}$	0.097637	Vdc
einput2	$(\text{einput2}_{V}/CS_{SR(OUT)})*100$	0.976370	% CS
$\Sigma e2$	einput2	0.976370	% CS
RA3	2	2	% CS
$RA3_{(1\sigma)}$	RA3/2	1	% CS
RD3	1.25	1.25	% CS
$RD3_{(1\sigma)}$	RD3/2	0.625	% CS
$RAMTE1_{SUM}$	0.001803	0.001803	Vdc
$REMTE1_{SUM}$	0	0	Vdc
$MTE1_{SUM}$	$(RAMTE1_{SUM}/n)^{2} + REMTE1_{SUM}{}^{2}]^{0.5}$	0.001803	Vdc
$MTE1_{SUM(CS)}$	$(MTE1_{SUM}/CS_{SR(OUT)})*100$	0.018030	% CS
$MTE2_{SUM(CS)}$	$MTE1_{SUM(CS)}$	0.018030	% CS
$CAL3_{SUM}$	$[(MTE1_{SUM(CS)})^{2} + (MTE2_{SUM(CS)})^{2}]^{0.5}$	0.025498	% CS
$ST_{SUM(IN)}$	0.01	0.01	Vdc
$ST_{SUM(OUT)}$	0.01	0.01	Vdc
$CS_{SUM(OUT)}$	10	10	Vdc
$ST_{SUM(IN)(CS)}$	$(ST_{SUM(IN)}/CS_{SUM(OUT)})*100$	0.100000	% CS
$ST_{SUM(OUT)(CS)}$	$(ST_{SUM(OUT)}/CS_{SUM(OUT)})*100$	0.100000	% CS
$ST3_{(1\sigma)}$	$[(ST_{SUM(IN)(CS)}/3)^{2} + (ST_{SUM(OUT)(CS)}/3)^{2}]^{0.5}$	0.047140	% CS

$V_{SUM(IN)}$	7.66	7.66	Vdc
$V_{SUM(OUT)}$	8	8	Vdc
G_{SUM}	$V_{SUM(OUT)}/V_{SUM(IN)}$	1.044386	V/V
$\sigma2_3$	$\sigma2*(G_{SUM}/2)$	1.174043	% CS
$\sigma2_{3C}$	$\sigma2_C*(G_{SUM}/2)$	0.441408	% CS
σinput3	$[(\sigma2_3)^2 + (\sigma2_3)^2]^{0.5}$	1.660348	% CS
$\sigma input3_C$	$[(\sigma2_{3C})^2 + (\sigma2_{3C})^2]^{0.5}$	0.624245	% CS
σ3	$(125/100)*[(RA3_{(1\sigma)})^2 + (RD3_{(1\sigma)})^2 + (CAL3)^2 + (ST3_{(1\sigma)})^2 + (\sigma input3)^2]^{0.5}$	2.546521	% Flow
$\sigma3_C$	$(125/100)*[(RA3_{(1\sigma)})^2 + (RD3_{(1\sigma)})^2 + (CAL3_{SUM})^2 + (ST3_{(1\sigma)})^2 + (\sigma input3_C)^2]^{0.5}$	1.669197	% Flow
einput3	$\Sigma e2_3 + \Sigma e2_3$	1.019708	% CS
$\Sigma e2_3$	$\Sigma e2*(G_{SUM}/2)$	0.509854	% CS
Σe3	(125/100)*(einput3)	1.274635	% Flow
RA3A	1	1	% CS
$RA3A_{(1\sigma)}$	±ROUND[(RA3A/2)*(125/100),6]	0.625	% Flow
RD3A	1	1	% CS
RD3AT	RD4CT	700	HRS
RD3ATSI	13	13	Weeks
$RD3A_{(1\sigma)}$	$(RD3A/2)*(125/100)*[(1.25*RD3ATSI*168)/RD3AT]^{0.5}$	1.234276	% Flow
$RAMTE1_{3A}$	$RAMTE1_{SUM}$	0.001803	Vdc
$REMTE1_{3A}$	$REMTE1_{SUM}$	0	Vdc
$MTE1_{3A}$	$[(RAMTE1_{3A}/1)^2 + REMTE1_{3A}{}^2]^{0.5}$	0.001803	Vdc
$SPAN_{SUM}$	10	10	Vdc
$MTE1_{3A(PF)}$	$(MTE1_{3A}/SPAN_{SUM})*125$	0.022538	% Flow
CAL3A	$MTE1_{3A(PF)}$	0.022538	% Flow
ST3AA	0.1	0.1	Vdc
$ST3AA_{(1\sigma)}$	$[(ST3AA/SPAN_{SUM})*125]/3$	0.416667	% Flow
ST3AB	0.08	0.08	Vdc
$ST3AB_{(1\sigma)}$	$[(ST3AB/SPAN_{SUM})*125]/3$	0.333333	% Flow

$\sigma input3A$	$\sigma 3$	2.546521	% Flow
$\sigma input3A_{AV}$	$\sigma 3_C$	1.669197	% Flow
$\sigma input3B$	$(\sigma 3_C{}^2 + \sigma 3_C{}^2)^{0.5}$	2.360601	% Flow
$\sigma 3A$	$[(RA3A_{(1\sigma)})^2 + (RD3A_{(1\sigma)})^2 + (CAL3A)^2 + (ST3AA_{(1\sigma)})^2 + (\sigma input3A)^2]^{0.5}$	2.927960	% Flow
$\sigma 3B$	$[(RA3A_{(1\sigma)})^2 + (RD3A_{(1\sigma)})^2 + (CAL3A)^2 + (ST3AB_{(1\sigma)})^2 + (\sigma input3B)^2]^{0.5}$	2.756468	% Flow
$\sigma 3A_{AV}$	$[(RA3A_{(1\sigma)})^2 + (RD3A_{(1\sigma)})^2 + (CAL3A)^2 + (ST3AA_{(1\sigma)})^2 + (\sigma input3A_{AV})^2]^{0.5}$	2.207804	% Flow
einput3A	$\Sigma e3$	1.274635	% Flow
einput3B	$\Sigma e3 + \Sigma e3$	2.54927	% Flow
$\Sigma e3A$	einput3A	1.274635	% Flow
$\Sigma e3B$	einput3B	2.54927	% Flow
RA4A	1	1	% Power
$RA4A_{(1\sigma)}$	RA4A/2	0.5	% Power
RD4A	1	1	% Power
RD4AT	700	700	HRS
RD4ATSI	700	700	HRS
$RD4A_{(1\sigma)}$	$(RD4A/2)(1250/700)^{0.5}$	0.5	% Power
RV4ACURS	10	10	Vdc
$RA4A_{DMM}$	0.005	0.005	Vdc
$RAMTE1_{4A(DMM)}$	$(RA4A_{DMM}/RV4ACURS)*100$	0.05	% CS
$RAMTE2_{4A(DMM)}$	$RAMTE1_{4A(DMM)}$	0.05	% CS
$RAMTE1_{4A(CURS)}$	1	1	% CS
$MTE1_{4A}$	$[(RAMTE1_{4A(DMM)}/1)^2 + (RAMTE1_{4A(CURS)}/2)^2 + (REMTE1_{4A(DMM)})^2 + (REMTE1_{4A(CURS)})^2]^{0.5}$	0.502494	% CS
$REMTE1_{4A(DMM)}$'	0	0	% CS

$REMTE1_{4A(CURS)}$	0	0	% CS
$REMTE2_{4A(DMM)}$	0	0	% CS
$MTE2_{4A}$	$(RAMTE2_{4A(DMM)})^2 + (REMTE2_{4A(DMM)})^2$	0.05	% CS
CAL4A	$[(MTE1_{4A})^2 + (MTE2_{4A})^2]^{0.5}$	0.504975	% CS
$ST4A_{DMM}$	$RAMTE1_{4A(DMM)}$	0.05	% CS
$ST4A_{CURS}$	$RAMTE1_{4A(CURS)}$	1	% CS
$ST4A_{(1\sigma)}$	$\{[(ST4A_{DMM})*(2/3)]^2 + (ST4A_{CURS}/3)^2 + [(ST4A_{DMM})*(2/3)]^2\}^{0.5}$	0.336650	% CS
SSL_B	0.33	0.33	% Power
SNL_B	0.49	0.49	% Power
SSL_R	0.20	0.2	% Power
SNL_R	1	1	% Power
$PEA_{4A(B)}$	$SSL_B + SNL_B$	0.82	% Power
LPR	ROUND(15/100,6)	0.15	%/%
$PEA_{4A(LPB)}$	SSL_B	0.33	% Power
$PEA_{4A(R)}$	$[(SSL_R)^2 + (SNL_R)^2]^{0.5}$	1.019804	% Power
$PEA_{4A(LPR)}$	$PEA_{4A(R)}$	1.019804	% Power
$\sigma input4A$	$PEA_{4A(R)}$	1.019804	% Power
$\sigma input4A_{LP}$	$PEA_{4A(LPR)}$	1.019804	% Power
$\sigma input4A_{AV}$	0	0	% Power
einput4A	$PEA_{4A(B)}$	0.82	% Power
$einput4A_{LP}$	$PEA_{4A(LPB)}$	0.33	% Power
$einput4A_{AV}$	0	0.000000	% Power
$\sigma 4A$	$[(CAL4A)^2 + (ST4A_{(1\sigma)})^2]^{0.5}$	0.606904	% CS
$\sigma 4A_{PP}$	$[(RA4A_{(1\sigma)})^2 + (RD4A_{(1\sigma)})^2]^{0.5}$	0.707107	% Power
$\Sigma e4A$	0	0	% CS

RA4B	0.8	0.8	% CS
RD4B	0.5	0.5	% CS
$RA4B_{(1\sigma)}$	RA4B/2	0.4	% CS
$RD4B_{(1\sigma)}$	RD4B/2	0.25	% CS
G_{APRM}	2.5	2.5	(None)
$RAMTE1_{4B}$	0	0	% CS
$REMTE1_{4B}$	0	0	% CS
$RAMTE2_{4B}$	0	0	% CS
$REMTE2_{4B}$	0	0	% CS
$MTE1_{4B}$	$[(RAMTE1_{4B}/2)^2 + REMTE1_{4B}{}^2]^{0.5}$	0	% CS
$MTE2_{4B}$	$[(RAMTE2_{4B}/2)^2 + REMTE2_{4B}{}^2]^{0.5}$	0	% CS
CAL4B	$[(MTE1_{4B})^2 + (MTE2_{4B})^2]^{0.5}$	0	% CS
ST4B	0.02	0.02	(None)
$ST4B_{\%}$	ST4B*100	2	% Power
$ST4B_{(1\sigma)}$	$ST4B_{\%}*(100/125)/3$	0.533333	% CS
TRAC	1.11	1.11	% Power
NN	2.0	2	% Power
PMA	$(TRAC^2 + NN^2)^{0.5}$	2.287378	% Power
$PMA_{1\sigma}$	PMA/2	1.143689	% Power
PMA_{FB}	TRAC	1.11	% Power
$PMA_{FB(1\sigma)}$	$PMA_{FB}/2$	0.555	% Power
PMA_{LP}	0	0	% Power
PMA_{AV}	0	0	% Power
N	14	14	LPRM
$\sigma input4B_{CS}$	$(\sigma 4A*G_{APRM})/N^{0.5}$	0.405505	% CS
$\sigma input4B_{PP}$	$[(\sigma input4A)^2 + (\sigma 4A_{PP})^2]^{0.5}/N^{0.5}$	0.331663	% Power
$\sigma input4B_{PP(LP)}$	$[(\sigma input4A_{LP})^2 + (\sigma 4A_{PP})^2]^{0.5}/N^{0.5}$	0.331663	% Power

$\sigma input4B_{AV}$	$[(\sigma input4A_{AV})^2 + (\sigma 4A_{PP})^2]^{0.5}/N^{0.5}$	0.188982	% Power
$\sigma 4BI$	$[(RA4B_{(1\sigma)})^2 + (RD4B_{(1\sigma)})^2 + (CAL4B)^2 + (ST4B_{(1\sigma)})^2 + (\sigma input4B_{CS})^2]^{0.5}$	0.819377	% CS
$\sigma 4BI_{PP}$	$\sigma 4BI*(125/100)$	1.024221	% Power
$\sigma 4B$	$[(\sigma 4BI_{PP})^2 + (\sigma input4B_{PP})^2 + (PMA_{1\sigma})^2]^{0.5}$	1.570686	% Power
$\sigma 4B_{FB}$	$[(\sigma 4BI_{PP})^2 + (\sigma input4B_{PP})^2 + (PMA_{FB(1\sigma)})^2]^{0.5}$	1.211220	% Power
$\sigma 4B_{LP}$	$[(\sigma 4BI_{PP})^2 + (\sigma input4B_{PP(LP)})^2 + (PMA_{LP})^2]^{0.5}$	1.076582	% Power
$\sigma 4B_{AV}$	$[(\sigma 4BI_{PP})^2 + (\sigma input4B_{AV})^2 + (PMA_{AV})^2]^{0.5}$	1.041510	% Power
$einput4B_{CS}$	$G_{APRM}*\Sigma e4A$	0	% CS
$einput4B_{PP}$	einput4A	0.82	% Power
$einput4B_{PP(LP)}$	$einput4A_{LP}$	0.33	% Power
$einput4B_{AV}$	$einput4A_{AV}$	0	% Power
$\Sigma e4B_{CS}$	$einput4B_{CS}$	0	% CS
$\Sigma e4B$	$\Sigma e4B_{CS}*(125/100) + einput4B_{PP}$	0.82	% Power
$\Sigma e4B_{LP}$	$\Sigma e4B_{CS}*(125/100) + einput4B_{PP(LP)}$	0.33	% Power
$\Sigma e4B_{AV}$	$\Sigma e4B_{CS}*(125/100) + einput4B_{AV}$	0	% Power
RA4C	1	1	% CS
$RA4C_{(1\sigma)}$	(RA4C/2)*(125/100)	0.625	% Power
RD4C	1	1	% CS
RD4CT	700	700	HRS
RD4CTSI	26	26	weeks
$RD4C_{(1\sigma)}$	$(RD4C/2)*(125/100)*[(1.25*RD4CTSI*168)/RD4CT]^{0.5}$	1.745530	% Power
$RAMTE1_{4C}$	0.000180	0.000180	Vdc
$REMTE1_{4C}$	0	0	Vdc
$MTE1_{4C}$	$[(RAMTE1_{4C}/1)^2 + REMTE1_{4C}{}^2]^{0.5}$	0.000180	Vdc
$MTE1_{4C(PP)}$	$(MTE1_{4C}/SPAN_{4CIN})*125$	0.002250	% Power

SPAN4CIN	10	10	Vdc
CAL4C	MTE1$_{4C(PP)}$	0.002250	% Power
ST4C	0.04	0.04	Vdc
ST4C$_{(1\sigma)}$	[(ST4C/SPAN4CIN)*125]/3	0.166667	% Power
σinput4C	σ4B	1.570686	% Power
σinput4C$_{LP}$	σ4B$_{LP}$	1.076582	% Power
σinput4C$_{AV}$	σ4B$_{AV}$	1.041510	% Power
σ4C	$[(RA4C_{(1\sigma)})^2 + (RD4C_{(1\sigma)})^2 + (CAL4C)^2 + (ST4C_{(1\sigma)})^2 + (\sigma input4C)^2]^{0.5}$	2.435639	% Power
σ4C$_{LP}$	$[(RA4C_{(1\sigma)})^2 + (RD4C_{(1\sigma)})^2 + (CAL4C)^2 + (ST4C_{(1\sigma)})^2 + (\sigma input4C_{LP})^2]^{0.5}$	2.150421	% Power
σ4C$_{AV}$	$[(RA4C_{(1\sigma)})^2 + (RD4C_{(1\sigma)})^2 + (CAL4C)^2 + (ST4C_{(1\sigma)})^2 + (\sigma input4C_{AV})^2]^{0.5}$	2.133079	% Power
einput4C	Σe4B	0.82	% Power
einput4C$_{LP}$	Σe4B$_{LP}$	0.33	% Power
einput4C$_{AV}$	Σe4B$_{AV}$	0	% Power
Σe4C	einput4C	0.82	% Power
Σe4C$_{LP}$	einput4C$_{LP}$	0.33	% Power
Σe4C$_{AV}$	einput4C$_{AV}$	0	% Power
RA4D	1	1	% CS
RA4D$_{1\sigma}$	(RA4D/2)*(125/100)	0.625	% Power
RD4D	1	1	% CS
RD4DT	700	700	HRS
RD4DTSI	26	26	Weeks
RD4D$_{(1\sigma)}$	$(RD4D/2)*(125/100)*[(1.25*RD4DTSI*168)/RD4DT]^{0.5}$	1.745530	% Power
RAMTE1$_{4D}$	RAMTE1$_{4C}$	0.000180	Vdc
REMTE1$_{4D}$	0	0	Vdc

$MTE1_{4D}$	$(RAMTE1_{4D}/1^2 + REMTE1_{4D}{}^2)^{0.5}$	0.000180	Vdc
$MTE1_{4D(PP)}$	$(MTE1_{4D}/SPAN4CIN)*125$	0.002250	% Power
CAL4D	$MTE1_{4D(PP)}$	0.002250	% Power
ST4D	0.04	0.04	Vdc
$ST4D_{(1\sigma)}$	[(ST4D/SPAN4CIN)*125]/3	0.166667	% Power
FCS_{SPTLO}	0.62	0.62	% Pow/ % Flow
FCS	$FCS_{SP} + [(0.04+0.04)/0.08]/80$	0.632500	% Pow/ % Flow
σinput4D	$[\sigma 4B_{FB}{}^2 + (FCS*\sigma 3)^2]^{0.5}$	2.015273	% Power
$\sigma input4D_{AV}$	$[\sigma 4B_{AV}{}^2 + (FCS*\sigma 3_C)^2]^{0.5}$	1.483033	% Power
σ4D	$[(RA4D_{(1\sigma)})^2 + (RD4D_{(1\sigma)})^2 + (CAL4D)^2 + (ST4D_{(1\sigma)})^2 + (\sigma input4D)^2]^{0.5}$	2.743466	% Power
$\sigma 4D_{AV}$	$[(RA4D_{(1\sigma)})^2 + (RD4D_{(1\sigma)})^2 + (CAL4D)^2 + (ST4D_{(1\sigma)})^2 + (\sigma input4D_{AV})^2]^{0.5}$	2.380057	% Power
einput4D	Σe4B + (FCS*Σe3)	1.626207	% Power
$einput4D_{AV}$	$\Sigma e4B_{AV} + (FCS*\Sigma e3)$	0.806207	% Power
Σe4D	einput4D	1.626207	% Power
$\Sigma e4D_{AV}$	$einput4D_{AV}$	0.806207	% Power
RA5A	0.8	0.8	% CS
$RA5A_{NULL}$	1	1	% Point
$RA5A_{(1\sigma)}$	$\{(RA5A/2)^2 + [(100/125)*(RA5A_{NULL}/2)]^2\}^{0.5}$	0.565685	% CS
RD5A	0.3	0.3	% CS
$RD5A_{(1\sigma)}$	RD5A/2	0.15	% CS
$RAMTE1_{5A}$	0.000180	0.000180	Vdc
$REMTE1_{5A}$	0	0	Vdc
$MTE1_{5A}$	$[(RAMTE1_{5A}/1)^2 + REMTE1_{5A}{}^2]^{0.5}$	0.000180	Vdc
$SPAN_{RBM}$	10	10	Vdc

CAL5A	$(MTE1_{5A}/SPAN_{RBM})*100$,	0.001800	% CS
ST5A	0.025	0.025	Vdc
$ST5A_{(1\sigma)}$	$[(ST5A/SPAN_{RBM})*100]/3$	0.083333	% CS
PMA_{RBM}	1.11	1.11	% Power
$PMA_{RBM(1\sigma)}$	$PMA_{RBM}/2$	0.555	% Power
$PMA_{RBM(AV)}$	0	0	% Power
N_{RBM}	2	2	LPRM
G_{RBM}	G_{APRM}	2.5	(None)
$\sigma input5A_{CS}$	$(\sigma 4A*G_{RBM})/(N_{rbm})^{0.5}$	1.072865	% CS
$\sigma input5A_{PP}$	$[(\sigma input4A)^{2} + (\sigma 4A_{PP})^{2}]^{0.5}/(N_{RBM})^{0.5}$	0.877497	% Power
$\sigma input5A_{AV}$	$[(\sigma input4A_{AV})^{2} + (\sigma 4A_{PP})^{2}]^{0.5}/(N_{RBM})^{0.5}$	0.500000	% Power
$\sigma input5A_{CS(PP)}$	$\sigma input5A_{CS}(125/100)$	1.341081	% Power
$\sigma input5A$	$[(\sigma input5A_{PP})^{2} + (\sigma input5A_{CS(PP)})^{2}]^{0.5}$	1.602653	% Power
$\sigma input5AA_{AV}$	$[(\sigma input5A_{AV})^{2} + (\sigma input5A_{CS(PP)})^{2}]^{0.5}$	1.431258	% Power
$\sigma 5AI$	$[(RA5A_{(1\sigma)})^{2} + (RD5A_{(1\sigma)})^{2} + (CAL5A)^{2} + (ST5A_{(1\sigma)})^{2}]^{0.5}$	0.591141	% CS
$\sigma 5AI_{PP}$	$\sigma 5AI*(125/100)$	0.738926	% Power
$\sigma 5A$	$[(\sigma 5AI_{PP})^{2} + (\sigma input5A)^{2} + (PMA_{RBM(1\sigma)})^{2}]^{0.5}$	1.850009	% Power
$\sigma 5A_{AV}$	$[(\sigma 5AI_{PP})^{2}+(\sigma input5AA_{AV})^{2}+(PMA_{RBM(AV)})^{2}]^{0.5}$	1.610749	% Power
$einput5A_{CS}$	$G_{RBM}*\Sigma e4A$	0	% CS
$einput5A_{PP}$	einput4A	0.82	% Power
$einput5A_{AV}$	$einput4A_{AV}$	0	% Power
$\Sigma e5A_{CS}$	$einput5A_{CS}$	0	% CS
$\Sigma e5A$	$\Sigma e5A_{CS}*(125/100) + einput5A_{PP}$	0.82	% Power

$\Sigma e5A_{AV}$	$\Sigma e5A_{CS}*(125/100) + einput5A_{AV}$	0	% Power
RA5B	RA4C	1	% CS
$RA5B_{(1\sigma)}$	$(RA5B/2)*(125/100)$	0.625	% Power
RD5B	RD4C	1	% CS
RD5BTSI	13	13	Weeks
RD5BT	RD4CT	700	HRS
$RD5B_{(1\sigma)}$	$(RD5B/2)*(125/100)*[(1.25*RD5BTSI*168)/RD5BT]^{0.5}$	1.234276	% Power
$RAMTE1_{5B}$	$RAMTE1_{4C}$	0.000180	Vdc
$REMTE1_{5B}$	$REMTE1_{4C}$	0	Vdc
$MTE1_{5B}$	$[(RAMTE1_{5B}/1)^2 + REMTE1_{5B}{}^2]^{0.5}$	0.000180	Vdc
$MTE1_{5B(PP)}$	$(MTE1_{5B}/SPAN4CIN)*125$	0.002250	% Power
CAL5B	$MTE1_{5B(PP)}$	0.002250	% Power
ST5B	0.04	0.04	Vdc
$ST5B_{(1\sigma)}$	$(ST5B/SPAN4CIN)*125]/3$	0.166667	% Power
$\sigma input5B$	$\sigma 5A$	1.850009	% Power
$\sigma input5B_{AV}$	$\sigma 5A_{AV}$	1.610749	% Power
$\sigma 5B$	$[(RA5B_{(1\sigma)})^2 + (RD5B_{(1\sigma)})^2 + (CAL5B)^2 + (ST5B_{(1\sigma)})^2 + (\sigma input5B)^2]^{0.5}$	2.316113	% Power
$\sigma 5B_{AV}$	$[(RA5B_{(1\sigma)})^2 + (RD5B_{(1\sigma)})^2 + (CAL5B)^2 + (ST5B_{(1\sigma)})^2 + (\sigma input5B_{AV})^2]^{0.5}$	2.129873	% Power
einput5B	$\Sigma e5A$	0.82	% Power
$einput5B_{AV}$	$\Sigma e5A_{AV}$	0	% Power
$\Sigma e5B$	einput5B	0.82	% Power
$\Sigma e5B_{AV}$	$einput5B_{AV}$	0	% Power
RA5C	RA4D	1	% CS
$RA5C_{(1\sigma)}$	$(RA5C/2)*(125/100)$	0.625	% Power
RD5C	RD4D	1	% CS

RD5CT	RD4DT	700	HRS
RD5CTSI	RD5BTSI	13	Weeks
$RD5C_{(1\sigma)}$	$(RD5C/2)*(125/100)*[(1.25*RD5CTSI*168)/RD5CT]^{0.5}$	1.234276	% Power
$RAMTE1_{5C}$	0.00018	0.000180	Vdc
$REMTE1_{5C}$	0	0	Vdc
$MTE1_{5C}$	$(RAMTE1_{5C}/1)^{2} + REMTE1_{5C}{}^{2}]^{0.5}$	0.000180	Vdc
$MTE1_{5C(PP)}$	$(MTE1_{5C}/SPAN4CIN)*125$	0.002250	% Power
CAL5C	$MTE1_{5C(PP)}$	0.002250	% Power
ST5C	0.04	0.04	Vdc
$ST5C_{(1\sigma)}$	$[(ST5C/SPAN4CIN)*125]/3$	0.166667	% Power
$FCS_{RBM(SP)}$	0.66	0.66	% Pow/ % Flow
FCS_{RBM}	$FCS_{RBM(SP)} + [(0.04+0.03)/0.08]/100$	0.668750	%Pow/ %Flow
$\sigma input5C_{AV}$	$[\sigma 5A_{AV}{}^{2} + (FCS_{RBM}*\sigma 3_{C})^{2}]^{0.5}$	1.959740	% Power
$\sigma input5C$	$[\sigma 5A^{2} + (FCS_{RBM}*\sigma 3)^{2}]^{0.5}$	2.514497	% Power
$\sigma 5C$	$(RA5C_{(1\sigma)})^{2} + (RD5C_{(1\sigma)})^{2} + (CAL5C)^{2} + (ST5C_{(1\sigma)})^{2} + (\sigma input5C)^{2}]^{0.5}$	2.874811	% Power
$\sigma 5C_{AV}$	$[(RA5C_{(1\sigma)})^{2} + (RD5C_{(1\sigma)})^{2} + (CAL5C)^{2} + (ST5C_{(1\sigma)})^{2} + (\sigma input5C_{AV})^{2}]^{0.5}$	2.404668	% Power
einput5C	$\Sigma e5A + (FCS_{RBM}*\Sigma e3)$	1.672412	% Power
$einput5C_{AV}$	$\Sigma e5A_{AV} + (FCS_{RBM}*\Sigma e3)$	0.852412	% Power
$\Sigma e5C$	einput5C	1.672412	% Power
$\Sigma e5C_{AV}$	$einput5C_{AV}$	0.852412	% Power
Ten_{AFB}	$2\sigma 4D + \Sigma e4D$	7.113139	% Power
$Ten_{AFB(AV)}$	$2\sigma 4D_{AV} + \Sigma e4D_{AV}$	5.566321	% Power
Ten_{AF}	$2\sigma 4C + \Sigma e4C$	5.691278	% Power
$Ten_{AF(AV)}$	$2\sigma 4C_{AV} + \Sigma e4C_{AV}$	4.266158	% Power

Ten_{AFLP}	$2\sigma 4C_{LP} + \Sigma e4C_{LP}$	4.630842	% Power
$Ten_{AFLP(AV)}$	$Ten_{AF(AV)}$	4.266158	% Power
Ten_{RFB}	$2\sigma 5C + \Sigma e5C$	7.422034	% Power
$Ten_{RFB(AV)}$	$2\sigma 5C_{AV} + \Sigma e5C_{AV}$	5.661747	% Power
Ten_{RF}	$2\sigma 5B + \Sigma e5B$	5.452226	% Power
$Ten_{RF(AV)}$	$2\sigma 5B_{AV} + \Sigma e5B_{AV}$	4.259745	% Power
Ten_{RFMU}	$2\sigma 3A + \Sigma e3A$	7.130555	% Flow
$Ten_{RFMU(AV)}$	$2\sigma 3A_{AV} + \Sigma e3A$	5.690244	% Flow
Ten_{RFMC}	$2\sigma 3B + \Sigma e3B$	8.062206	% Flow
$Ten_{RFMC(AV)}$	Ten_{RFMC}	8.062206	% Flow
AL_{STP2OS}	70.9	70.9	% Power
$NTSP_{STP2OS}$	$AL_{STP2OS} - Ten_{AFB}$	63.786861	63.7
AV_{STP2}	$NTSP_{STP2OS} + Ten_{AFB(AV)}$	69.353182	69.3
AL_{STP1OS}	58.33	58.33	% Power
$NTSP_{STP1OS}$	$AL_{STP1OS} - Ten_{AFE}$	51.507506	51.5
AV_{STP1}	$NTSP_{STP1OS} + Ten_{AFB(AV)}$	56.885648	56.8
$AL_{STP2RBOS}$	59.47	59.47	% Power
$NTSP_{STP2RBOS}$	$AL_{STP2RBOS} - Ten_{AFB}$	52.36	52.3
AV_{STP2RB}	$NTSP_{STP2RBOS} + Ten_{AFB(AV)}$	57.923182	57.9
$AL_{STP1RBOS}$	46.9	46.90	% Power
$NTSP_{STP1RBOS}$	$AL_{STP1RBOS} - Ten_{AFB}$	40.077506	40.0
AV_{STP1RB}	$NTSP_{STP1RBOS} + Ten_{AFB(AV)}$	45.4556	45.4
$NTSP_{FS}$	118	118	% Power
AL_{FS}	$NTSPFS + Ten_{AF}$	123.691278	% Power
AV_{FS}	$NTSP_{FS} + Ten_{AF(AV)}$	122.266158	% Power
$NTSP_{FSS}$	15	15	% Power

AL_{FSS}	$NTSP_{FSS} + Ten_{AFLP}$	19.630842	% Power
AV_{FSS}	$NTSP_{FSS} + Ten_{AF(AV)}$	19.266158	% Power
AL_{FSSN}	25	25	% Power
$NTSP_{FSSN}$	$AL_{FSSN} - Ten_{AFLP}$	20.369158	% Power
AV_{FSSN}	$NTSP_{FSSN} + Ten_{AFAV}$	24.635316	% Power
$NTSP_{RBS}$	12	12	% Power
AL_{RBS}	$NTSP_{RBS} + Ten_{AFLP}$	16.630842	% Power
AV_{RBS}	$NTSP_{RBS} + Ten_{AF(AV)}$	16.266158	% Power
AL_{RBSN}	19	19	% Power
$NTSP_{RBSN}$	$AL_{RBSN} - Ten_{AFLP}$	14.369158	% Power
AV_{RBSN}	$NTSP_{RBSN} + Ten_{AFAV}$	18.635316	% Power
$NTSP_{DS}$	5	5	% Power
AL_{DS}	$NTSP_{DS} - Ten_{AFLP}$	0.369158	% Power
AV_{DS}	$NTSP_{DS} - Ten_{AF(AV)}$	0.733842	% Power
$NTSP_{HFC}$	113.5	113.5	% Power
AL_{HFC}	$NTSP_{HFC} + Ten_{AF}$	119.191278	% Power
AV_{HFC}	$NTSP_{HFC} + Ten_{AF(AV)}$	117.766158	% Power
$NTSP_{RBM2OS}$	45	45	% Power
AL_{RBM2OS}	$NTSP_{RBM2OS} + Ten_{RFB}$	52.422034	% Power
AV_{RBM2}	$NTSP_{RBM2OS} + Ten_{RFB(AV)}$	50.661747	% Power
$NTSP_{RBM1OS}$	39.7	39.7	% Power
AL_{RBM1OS}	$NTSP_{RBM1OS} + Ten_{RFB}$	47.122034	% Power
AV_{RBM1}	$NTSP_{RBM1OS} + Ten_{RFB(AV)}$	45.361747	% Power
$NTSP_{RBMDS}$	5	5	% Power
AL_{RBMDS}	$NTSP_{RBMDS} - Ten_{RF}$	-0.452226	% Power
AL_0	0	0	% Power
$NTSP_{DSN}$	$AL_0 + Ten_{RF}$	5.452226	% Power

AV_{RBMDS}	$NTSP_{RBMDSS}$ - $Ten_{RF(AV)}$	1.240255	% Power
$NTSP_{RFMU}$	108	108	% Flow
AL_{RFMU}	$NTSP_{RFMU}$ + Ten_{RFMU}	115.130555	% Flow
AV_{RFMU}	$NTSP_{RFMU}$ + $Ten_{RFMU(AV)}$	113.690244	% Flow
$NTSP_{RFMC}$	10	10	% Flow
AL_{RFMC}	$NTSP_{RFMC}$ + Ten_{RFMC}	18.062206	% Flow
AV_{RFMC}	AL_{RFMC}	18.062206	% Flow
RA6	1	1	% CS
$RA6_{1\sigma}$	RA6/2	0.5	% CS
RD6	0.5	0.5	% CS
$RD6_{1\sigma}$	RD6/2	0.25	% CS
CAL6	$CAL3_{SUM}$	0.025498	% CS
$ST6_{(1\sigma)}$	$ST3_{(1\sigma)}$	0.047140	% CS
σinput6	σinput3	1.660348	% CS
$\sigma input6_C$	$\sigma input3_C$	0.624245	% CS
σ6	$(125/100)*[(RA6_{(1\sigma)})^2 + (RD6_{(1\sigma)})^2 + (CAL6)^2 + (ST6_{(1\sigma)})^2 + (\sigma input6)^2]^{0.5}$	2.190936	% Flow
$\sigma 6_C$	$(125/100)*[(RA6_{(1\sigma)})^2 + (RD6_{(1\sigma)})^2 + (CAL6)^2 + (ST6_{(1\sigma)})^2 + (\sigma input6_C)^2]^{0.5}$	1.049594	% Flow
e6T	0.5	0.5	% CS
einput6	einput3	1.019708	% CS
Σe6	(125/100)*(e6T + einput6)	1.899635	% Flow
RA6A	1	1	% CS
$RA6A_{(1\sigma)}$	(RA6A/2)*(125/100)	0.625	% Flow
RD6A	0	0	% CS
$RD6A_{(1\sigma)}$	(RD6A/2)*(125/100)	0	% Flow
CAL6A	CAL3A	0.022538	% Flow
$ST6AA_{(1\sigma)}$	$ST3AA_{(1\sigma)}$	0.416667	% Flow
$ST6AB_{(1\sigma)}$	$ST3AB_{(1\sigma)}$	0.333333	% Flow

σinput6A	σ6	2.190936	% Flow
σinput6B	$(\sigma 6_C{}^2 + \sigma 6_C{}^2)^{0.5}$	1.484350	% Flow
σ6A	$[(RA6A_{(1\sigma)})^2 + (RD6A_{(1\sigma)})^2 + (CAL6A)^2 + (ST6A_{(1\sigma)})^2 + (\sigma input6A)^2]^{0.5}$	2.316235	% Flow
σ6B	$[(RA6A_{(1\sigma)})^2 + (RD6A_{(1\sigma)})^2 + (CAL6A)^2 + (ST6A_{(1\sigma)})^2 + (\sigma input6B)^2]^{0.5}$	1.644852	% Flow
einput6A	Σe6	1.899635	% Flow
einput6B	Σe6 + Σe6	3.799270	% Flow
Σe6A	einput6A	1.899635	% Flow
Σe6B	einput6B	3.799270	% Flow
AV_{RBMDSC}	$NTSP_{RBMDS} - Ten_{RF(AV)}$	0.740255	% Power
$NTSP_{RBMDSS}$	5.5	5.500000	% Power
FCS_{SPSLO}	0.55	0.55	%Pwr/%Flo
FCS_{SLO}	$FCS_{SPSLO} + [(0.04+0.04)/0.08]/80$	0.562500	%Pwr/%Flo
$\sigma input4D_{SLO}$	$[\sigma 4B_{FB}{}^2 + (FCS_{SLO} * \sigma 3)^2]^{0.5}$	1.875867	% Power
$\sigma input4D_{AVSLO}$	$[\sigma 4B_{AV}{}^2 + (FCS_{SLO} * \sigma 3_C)^2]^{0.5}$	1.402255	% Power
$\sigma 4D_{SLO}$	$[(RA4D_{(1\sigma)})^2 + (RD4D_{(1\sigma)})^2 + (CAL4D)^2 + (ST4D_{(1\sigma)})^2 + (\sigma input4D_{SLO})^2]^{0.5}$	2.642756	% Power
$\sigma 4D_{AVSLO}$	$[(RA4D_{(1\sigma)})^2 + (RD4D_{(1\sigma)})^2 + (CAL4D)^2 + (ST4D_{(1\sigma)})^2 + (\sigma input4D_{AVSLO})^2]^{0.5}$	2.330580	% Power
$einput4D_{SLO}$	Σe4B + (FCS*Σe3)	1.536982	% Power
$einput4D_{AVSLO}$	$\Sigma e4B_{AV}$ + (FCS*Σe3)	0.716982	% Power
$\Sigma e4D_{SLO}$	$einput4D_{SLO}$	1.536982	% Power
$\Sigma e4D_{AVSLO}$	$einput4D_{AVSLO}$	0.716982	% Power
Ten_{AFBSLO}	$2\sigma 4D_{SLO} + \Sigma e4D_{SLO}$	6.822494	% Power
$Ten_{AFBAVSLO}$	$2\sigma 4D_{AVSLO} + \Sigma e4D_{AVSLO}$	5.378142	% Power
AL_{HFCSLO}	113.8	113.8	% Power
$NTSP_{HFCSLO}$	$AL_{HFCSLO} - Ten_{AF}$	108.108722	108.1
AV_{HFCSLO}	$NTSP_{HFCSLO} + Ten_{AF(AV)}$	112.374880	112.3

FINAL

CC-AA-309 - ATTACHMENT 1 - Design Analysis Approval

Page 1 of 2

DESIGN ANALYSIS NO.: L-001345
Major REV Number: 2
Minor Rev Number: A
PAGE NO. 1 of 9

[ ] 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) I04

DISCIPLINE CODE: (C011) I

SYSTEM CODE: (C011) C51

TITLE: Average Power Range Monitor (APRM), Rod Block Monitor (RBM) and Recirculation Flow Monitor (RFM) Bistable Loop Accuracy for Rod Block and Scram Functions

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

ATTRIBUTES (C016)

TYPE	VALUE	TYPE	VALUE
Elevation	N/A		
Software	N/A		

COMPONENT EPN: (C014 Panel)

EPN	TYPE
See Calculation Section 1	

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

Type/Sub	Document Number	Input (Y/N)
CALC/ENG	L-001345 Revision 2	Yes
/		
/		
/		
/		
/		
/		

REMARKS:

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

DESIGN ANALYSIS NO. L-001345 **REV:** 2A **PAGE NO.** 2 of 9

Revision Summary (including EC's incorporated): This revision will incorporate a new limit for the RBM flow biased setpoint. Sections 3.5, 3.7, 3.15, 3.34, 3.35, 4.14, 10.5, 12.3, 12.4,13.3, 14.3 and 15.0 have been changed.

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

Design impact review completed? [X] Yes [ ] N/A, Per EC#:__332360/61____
(If yes, attach impact review sheet)

Prepared by: ___R. Fredricksen ________/ ________________/ 8/31/01
Print Sign Date

Reviewed by: ___W. C. Kirchhoff ________/ Cu Kirchhoff ____/ 8/31/01
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 Murskyj / 8/31/01 /
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#, EC# etc.)____________________

CALCULATION TABLE OF CONTENTS

CALCULATION NO. **L-001345** **REV. NO. 2A** **PAGE NO. 3 OF 9**

CALCULATION PAGE

Purpose/Objective

In April 2001 both the Unit 1 and Unit 2 COLR were revised for the implementation of Improved Technical Specifications. As part of that COLR change, the Rod Withdrawal Error accident was analyzed assuming that the RBM would not cause a rod block, and it set a new value of the Trip Setpoint (TS) and Allowable Value (AV) for the RBM flow biased setpoint.

This calculation will revise the setpoint calculation for the RBM flow biased trip to incorporate this new information from the COLR.

Calculations

1. Revise section 3.5

3.5 LaSalle Station Procedures

Subsections e. and n. to read:

e. LIS-NR-105A, Rev. 12, "Unit 1 Rod Block Monitor Calibration."
LIS-NR-105B, Rev. 10, "Unit 1 Rod Block Monitor Calibration."
n. LIS-NR-205A, Rev. 5, 'Unit 2 Rod Block Monitor Calibration.'
LIS-NR-205B, Rev. 5, 'Unit 2 Rod Block Monitor Calibration.'

2. Revise section 3.7 to read as follows:

3.7 LaSalle Station Technical Specification Unit 1, Amendment No. 147, dated March 30, 2001 and Technical Specification Unit 2, Amendment No. 133, dated March 30, 2001

3. Revise section 3.15 to read as follows:

3.15 Technical Reference Manual LaSalle 1 and 2; Appendix I, Core Operating Limits Report, LaSalle Unit 1 Cycle 9 dated May 2001, and Appendix J, Core Operating Limits Report, LaSalle Unit 2 Cycle 9 dated August 2001 .

4. Revise section 3.34 to read as follows:

3.34 NES-EIC-20.04, Revision 3, "Analysis of Instrument Channel Setpoint Error and Instrument Loop Accuracy."

5. Add new reference

3.35 ER-AA-520, INSTRUMENT PERFORMANCE TRENDING, Revision 0

6. Revise Section 4.14 and applicable table entrees as follows:

4.14 Analytical Limits and Allowable Values Inputs

From References 3.27 and 3.33, Analytical Limit inputs are provided for all non-flow biased setpoints and the APRM Flow Biased Trip functions (flow biased and clamp). Reference 3.15 provides the Allowable Values for the RBM Upscale Trips. There is no Analytical Limit, as the rod block is not considered in the Rod Withdrawal Error Analysis as stated in Reference 3.15. The information provided by References 3.15, 3.27, and 3.33 is summarized below:

Bistable	AL	AV	Reference
Rod Block Monitor Trips			
RBM Upscale (Rod Block), Two Recirc Loop Operation	None	0.66W + 54 % *	3.15
RBM Upscale (Rod Block), Single Recirc Loop Operation	None	0.66W + 48.7% *	3.15

*** Clamped with the Allowable Value not to exceed the AV For recirculation loop flow (W) of 100%.**

7. Revise section 10.5 for the Upscale setpoints as follows:

10.5 RBM Calibration

<u>RBM Upscale (Two Recirculation Loop Operation)</u>

Instrument Setpoint: **(100% Flow)**	**9.320Vdc (116.5%)**
Allowable Range:	**9.280 to 9.360 Vdc (±0.040 Vdc)**
Calibrated Trip Setpoint: **(Section 13.3.1)**	**≤0.66W + 50.5 % (116.5 %)**
Nominal Trip Setpoint: **(Reference 3.15)**	**≤0.66W + 51.0 % (117.0 %)**
Tech Spec LCO: **(Reference 3.15)**	**≤0.66W + 54.0 % (120.0 %)** **Clamped ≤ the AV for 100% Flow**
Analytic Limit:	**None**

RBM Upscale (Single Recirculation Loop Operation)

Instrument Setpoint: **(100% Flow)**	**8.880 Vdc (111.0%)**
Allowable Range:	**8.840 to 8.920 Vdc (±0.040 Vdc)**
Calibration Trip Setpoint: **(Section 13.3.2)**	**$\leq 0.66W + 45.0$ % (111.0%)**
Nominal Trip Setpoint: **(Reference 3.15)**	**$\leq 0.66W + 45.7$ % (111.7%)**
Tech Spec LCO: **(Reference 3.15)**	**$\leq 0.66W + 48.7$% (114.7%)** **Clamped ≤ the AV for 100% Flow**
Analytic Limit:	**None**

8. Revise section 12.3 and 12.4 as indicated below:

12.3 RBM Flow Biased Trips - Ten_{RFB}, $\text{Ten}_{RFB(AV)}$

Ten_{RFB} and $\text{Ten}_{RFB(AV)}$ are made up of the uncertainty terms from the RBM Flow Biased Trip Module 5C. Because the RBM is not used in the COLR for accident or transient analysis this setpoint is a Level 2 setpoint as defined in Reference 3.34 Appendix D, thus the uncertainty is computed as follows.

$$\text{Ten}_{RFB} = \pm(\sigma 5C + \Sigma e5C)\%\ \text{Power} \qquad \text{[Ref 3.34]}$$
$$\text{Ten}_{RFB(AV)} = \pm(\sigma 5C_{AV} + \Sigma e5C_{AV})\%\ \text{Power} \qquad \text{[Ref 3.34]}$$

These uncertainty terms include both the uncertainties associated with the RBM neutron signal and the Recirculation Flow Monitor. From Sections 11.5.3.1.6 and 11.5.3.2.10:

$$\text{Ten}_{RFB} = \pm(2.874811 + 1.672412)\%\ \text{Power}$$
$$\text{Ten}_{RFB} = \pm\ 4.55\ \%\ \text{Power}$$

And

$$\text{Ten}_{RFB(AV)} = \pm(2.404668 + 0.852412)\%\ \text{Power}$$
$$\text{Ten}_{RFB(AV)} = \pm\ 3.26\ \%\ \text{Power}$$

12.4 RBM Fixed Trip - Ten_{RF}, $Ten_{RF(AV)}$

Because the RBM is not used in the COLR for accident or transient analysis this setpoint is a Level 2 setpoint as defined in Reference 3.34 Appendix D, thus the uncertainty is computed as follows:

$Ten_{RF} = \pm(\sigma 5B + \Sigma e5B)\%$ **Power** **[Ref 3.34]**
$Ten_{RF(AV)} = \pm(\sigma 5B_{AV} + \Sigma e5B_{AV})\%$ **Power** **[Ref 3.34]**

Ten_{RF} and $Ten_{RF(AV)}$ are made up of the uncertainty terms from RBM Fixed Trip Module 5B. From Sections 11.5.2.1.6 and 11.5.2.2.10:

$Ten_{RF} = \pm(2.316113 + 0.82)$ **% Power**
$Ten_{RF} = \pm 3.14$ **% Power**

And

$Ten_{RF(AV)} = \pm(2.129873 + 0)\%$ **Power**
$Ten_{RF(AV)} = \pm 2.13$ **% Power**

9. Revise section 13.3 as indicated below:

13.3 RBM Flow Biased Trips

The RBM Flow Biased Trips have the same total uncertainty term (Ten_{RFB}) whether in Two Recirculation Loop Operation or Single Recirculation Loop Operation. This is because there are no changes made to the method of operation of the Recirculation Flow Monitor for either Single or Two Loop Operation. Therefore, the error analysis for the RFM is the same.

13.3.1 Upscale Trip - Two Loop Operation

From Section 10.5 the existing Technical Specification Nominal Trip Setpoint (NTSP) for this function is ≤0.66W +51% Power with the setpoint clamped at a value corresponding to when W=100% Flow. Because this setpoint is not used in safety analysis, as specified in Reference 3.15, the Trip Setpoint listed in Reference 3.15 will be considered as a nominal setpoint. The setpoint will be checked against the AV listed in Reference 3.15 to ensure that the as-found value when calibrating the Upscale trip will not exceed the AV.

$AV_{RBM2} = NTSP + Ten_{RFB(AV)}$ **% Power**
$AV_{RBM2} = 0.66*W + 51 + Ten_{RFB(AV)}$ **% Power**

$AV_{RBM2} = 0.66W + 51 + 3.26$ % Power
$AV_{RBM2} = 0.66W + 54.26$ % Power

Because the computed AV is in excess of the Reference 3.15 value, the fixed offset of the final NTSP should be lowered at least 0.26 %. For conservatism, the final calibration NTSP should be:

$NTSP_{RBM2} = 0.66W + 50.5$ % Power

The RBM backup trip value should be calibrated in such a manner as to ensure that it is always higher than the required value needed for the NTSP.

13.3.2 Upscale Trip - Single Loop Operation

From Section 10.5 the existing Technical Specification Nominal Trip Setpoint (NTSP) for this function is ≤0.66W +45.7% Power with the setpoint clamped at a value corresponding to when W=100% Flow. Because this setpoint is not used in safety analysis, as specified in Reference 3.15, the Trip Setpoint listed in Reference 3.15 will be considered as a nominal setpoint. The setpoint will be checked against the AV listed in Reference 3.15 to ensure that the as-found value when calibrating the Upscale trip will not exceed the AV.

$AV_{RBM1} = NTSP + Ten_{RFB(AV)}$ % Power
$AV_{RBM1} = 0.66{*}W + 45.7 + Ten_{RFB(AV)}$ % Power
$AV_{RBM1} = 0.66W + 45.7 + 3.26$ % Power
$AV_{RBM1} = 0.66W + 48.96$ % Power

Because the computed AV is in excess of the Reference 3.15 value, the fixed offset of the final NTSP should be lowered at least 0.26 %. For conservatism, the final calibration NTSP should be:

$NTSP_{RBM1} = 0.66W + 45.0$ % Power

The RBM backup trip value should be calibrated in such a manner as to ensure that it is always higher than the required value needed for the NTSP.

10. Revise section 14.3 as indicated below:

14.3 RBM Flow Biased Trips

14.3.1 Upscale Trip - Two Loop Operation

Calibrated NTSP	0.66W + 50.5% Power
Tech Spec NTSP:	0.66W + 51 % Power
Tech Spec AV:	0.66W + 54 % Power
Extended Tolerance	± 0.75% Power

Extended tolerance selected at 1.5 times setting tolerance to provide an ET value for Trending as described in ER-AA-520.

14.3.2 Upscale Trip - Single Loop Operation

Calibrated NTSP	0.66W + 45.0 % Power
Tech Spec NTSP:	0.66W + 45.7 % Power
Tech Spec AV:	0.66W + 48.7 % Power
Extended Tolerance	± 0.75% Power

Extended tolerance selected at 1.5 times setting tolerance to provide an ET value for trending as described in ER-AA-520.

11. Revise the applicable sections of 15.0 as follows:

15.0 CALCULATION SPREADSHEET

Symbol	Formula or Input Value	Value	Units
$NTSP_{RBM2OS}$	51	51	% Power
AL_{RBM2OS}	(Deleted)		
AV_{RBM2}	$NTSP_{RBM2OS} + Ten_{RFB(AV)}$	54.26	% Power
$NTSP_{RBM1OS}$	45.7	45.7	% Power
AL_{RBM1OS}	(Deleted)		
AV_{RBM1}	$NTSP_{RBM1OS} + Ten_{RFB(AV)}$	48.96	% Power

ATTACHMENT 1
Design Analysis Approval
Page 1 of 2

DESIGN ANALYSIS NO.: L-001345 **PAGE NO.** 1 OF 4
Major REV Number: 002 **Minor Rev Number:** B

[ ] 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) I04

DISCIPLINE CODE: (C011) I

SYSTEM CODE: (C011) C51

TITLE:

Average Power Range Monitor (APRM), Rod Block Monitor (RBM), and Recirculation Flow Monitor (RFM) Bistable Loop Accuracy for Rod Block and Scram Functions.

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

ATTRIBUTES (C016)

TYPE	VALUE	TYPE	VALUE
Elevation	Misc		
Software			

COMPONENT EPN: (C014 Panel)

EPN	TYPE
See Section 1.0 of Rev. 2	

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

Type/Sub	Document Number	Input (Y/N)
CAL/ENG	L-002884	Y
DCD/~~EC~~ EVAL	EC-338271	Y

REMARKS:

ATTACHMENT 1
Design Analysis Approval
Page 2 of 2

DESIGN ANALYSIS NO. L-001345 REV: 002B PAGE NO. 2 OF 4

Revision Summary (including EC's incorporated):

The purpose of this minor Revision 002B is to add calculation L-002884, Rev. 000, "Measurement and Test Equipment (M&TE) Acceptability Evaluation" prepared for EC-338271 as a reference in Section 3.0 – REFERENCES and Section 9.0 – CALIBRATION INSTRUMENT DATA. This minor revision will also establish cross-reference between these two calculations.

Electronic Calculation Data Files: See Attachments C and D.
(Program Name, Version, File Name extension/size/date/hour/min)

Design impact review completed? [ ] Yes [X] N/A, Per EC#: <u>**EC-338271**</u>
(If yes, attach impact review sheet)
Prepared by: **R. H. LOW** / R H Low / **08/10/02**
- Print Sign Date
Reviewed by: **T. VAN WYK** / Van Wyk / **08/11/02**
- Print Sign Date
<u>**Method of Review:**</u> [X] Detailed [ ] Alternate [ ] Test
This Design Analysis supersedes: **N/A** **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: : L. Campo / R Campo / 8-12-02
- Print Sign Date

<u>**External Design Analysis Review**</u> **(Attachment 3 Attached)**
Reviewed by: R. FREDRICKSON / / 8/12/02
- Print Sign Date
Approved by: Mark Mursky / / 8/14/02
- Print Sign Date

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

NES-G-14.01
Effective Date:
04/14/00

CALCULATION TABLE OF CONTENTS

CALCULATION NO. L-001345 **REV. NO. 002B** **PAGE NO. 3**

E-FORM

CALCULATION PAGE

CALCULATION NO. L-001345	**REVISION NO. 002B**	**PAGE NO. 4 of 4**

NOTE:
Section numbers referred to in the section headers in this minor revision are in accordance with the calculation format in use at the time of this minor revision. Section numbers referred to in the body of each section are the actual section numbers in the record calculation.

5.0 References

Add calculation L-002884, Rev. 000, "Measurement and Test Equipment (M&TE) Acceptability Evaluation" as the last reference in Section 3.0.

6.0 Calculations

Add the following sentence to the end of the second paragraph of Section 9.0, Calibration Instrument Data.

> "Refer to calculation L-002884 for use of M&TE less accurate than that listed."

Final
[Last Page]

E-FORM

Exelon Nuclear

ATTACHMENT 2
Design Analysis Minor Revision Cover Sheet

CC-AA-309-1001
Revision 0

Last Page No. 4

Analysis No. L-001345 **Revision 2C**
EC/ECR No. EC 331766 **Revision 0**
Title: Average Power Range Monitor (APRM), Rod Block Monitor (RBM), and Recirculation Flow Monitor (RFM) Bistable Loop Accuracy for Rod Block and Scram Functions

Station(s) LaSalle
Unit No.: 1 and 2
Safety Class SR
System Code C51

Is this Design Analysis Safeguards? Yes ☐ No ☒
Does this Design Analysis Contain Unverified Assumptions? Yes ☐ No ☒
ATI/AR#

Description of Change

Section 14.1 is revised to change the examples for the flow bias calibration setpoints to indicate the corresponding values at a drive flow of 75% instead of 80%. References for the calibration procedures are also revised.

Disposition of Changes (include additional pages as required)
Add pages 1 through 4 of minor revision 002C.

Preparer W. Kirchhoff 3/3/04
Print Name Sign Name

Reviewer V. Shah 3/3/04
Print Name Sign Name

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

Approver BYRON GINTER 4/21/04
Print Name Sign Name

(For External Analyses Only)
Exelon Reviewer
Print Name Sign Name

Approver
Print Name Sign Name

CALCULATION TABLE OF CONTENTS

CALCULATION NO. L-001345 **REV. NO. 002C** **PAGE NO. 2**

1.0 Purpose/Scope

The purpose of this revision is to revise the discussion related to the calibration setpoints in section 14.0 Conclusions for APRM Flow Biased Trips. Section 14.1 is revised to change the examples for the flow bias calibration setpoints to indicate the corresponding values at a drive flow of 75% instead of 80%. This change is being made for consistency with the calibration procedures (references 3.5u, 3.5v, 3.5w, 3.5x) which currently use a simulated drive flow of 75%. The change was made to the calibration procedures because at 80% flow the transition from the flow biased line to the fixed clamped setpoint occurs. This transition was found to interfere with the calibration. The change does not affect the calibration setpoint. References for the calibration procedures are also revised.

3.0 References

References 3.5.a, b, c, d and 3.5 j, k, m, n are superseded by the references indicated below:

3.5.u LIS-NR-103A Revision 7, UNIT 1 AVERAGE POWER RANGE MONITOR CHANNELS A, C, AND E ROD BLOCK AND SCRAM CALIBRATION
3.5.v LIS-NR-103B Revision 6, UNIT 1 AVERAGE POWER RANGE MONITOR CHANNELS B, D, AND F ROD BLOCK AND SCRAM CALIBRATION
3.5.w LIS-NR-203A Revision 6, UNIT 2 AVERAGE POWER RANGE MONITOR CHANNELS A, C, AND E ROD BLOCK AND SCRAM CALIBRATION
3.5.x LIS-NR-203A Revision 6, UNIT 2 AVERAGE POWER RANGE MONITOR CHANNELS B, D, AND F ROD BLOCK AND SCRAM CALIBRATION

14.0 Conclusion

Replace section 14.1 with the following:

14.1. APRM Flow Biased Trips

14.1.1 Simulated Thermal Power Upscale (Scram) – Two Loop Operation

Analytical Limit:	0.62W + 70.9 % Power
Tech Spec AV:	0.62W + 69.3 % Power
Tech Spec NTSP:	0.62W + 63.7 % Power

Calibration setpoint: Since the setpoint is calibrated at a specific drive flow, the nominal setpoint should be set at least 0.04 Vdc below the corresponding Tech Spec NTSP with a tolerance of +/- 0.04 Vdc. For example, with a 75% drive flow, the Tech Spec NTSP is 110.2% (0.62*75 + 63.7). Since 110.2% on a 125% scale corresponds to 8.816 Vdc on a 10 Vdc scale [10Vdc*110.2%/125%], a setpoint of 8.776 +/- 0.04 Vdc is recommended for 75% drive flow.

14.1.2 Simulated Thermal Power Upscale (Scram) – Single Loop Operation

Analytical Limit:	0.55W + 58.33 % Power
Tech Spec AV:	0.55W + 56.8 % Power
Tech Spec NTSP:	0.55W + 51.5 % Power

Calibration setpoint: Since the setpoint is calibrated at a specific drive flow, the nominal setpoint should be set at least 0.04 Vdc below the corresponding Tech Spec NTSP with a tolerance of +/- 0.04 Vdc. For example, with a 75% drive flow, the Tech Spec NTSP is 92.75% (0.55*75 + 51.5). Since 92.75% on a 125% scale corresponds to 7.420 Vdc on a 10 Vdc scale [10Vdc*92.75%/125%], a setpoint of 7.38 +/- 0.04 Vdc is recommended for 75% drive flow.

14.1.3 Simulated Thermal Power Upscale (Rod Block) – Two Loop Operation

Analytical Limit:	0.62W + 59.47 % Power
Tech Spec AV:	0.62W + 57.9 % Power
Tech Spec NTSP:	0.62W + 52.3 % Power

Calibration setpoint: Since the setpoint is calibrated at a specific drive flow, the nominal setpoint should be set at least 0.04 Vdc below the corresponding Tech Spec NTSP with a tolerance of +/- 0.04 Vdc. For example, with a 75% drive flow, the Tech Spec NTSP is 98.8 % (0.62*75 + 52.3). Since 98.8 % on a 125% scale corresponds to 7.904 Vdc on a 10 Vdc scale [10Vdc*98.8 %/125%], a setpoint of 7.864 +/- 0.04 Vdc is recommended for 75% drive flow.

14.1.4 Simulated Thermal Power Upscale (Rod Block) – Single Loop Operation

Analytical Limit:	0.55W + 46.9 % Power
Tech Spec AV:	0.55W + 45.4 % Power
Tech Spec NTSP:	0.55W + 40.0 % Power

Calibration setpoint: Since the setpoint is calibrated at a specific drive flow, the nominal setpoint should be set at least 0.04 Vdc below the corresponding Tech Spec NTSP with a tolerance of +/- 0.04 Vdc. For example, with a 75% drive flow, the Tech Spec NTSP is 81.25% (0.55*75 + 40.0). Since 81.25% on a 125% scale corresponds to 6.500 Vdc on a 10 Vdc scale [10Vdc*81.25%/125%], a setpoint of 6.460 +/- 0.04 Vdc is recommended for 75% drive flow.

ATTACHMENT 2
Design Analysis Minor Revision Cover Sheet

Design Analysis (Minor Revision) | **Last Page No.** ^{6} 49

Analysis No.: ^{1} L-001345 | **Revision:** ^{2} 002D

Title: ^{3} Average Power Range Monitor (APRM), Rod Block Monitor (RBM), and Recirculation Flow Monitor (RFM) Bistable Loop Accuracy for Rod Block and Scram Functions

EC/ECR No.: ^{4} 12/8/09 ~~377849~~ 375883 | **Revision:** ^{5} 0

Station(s): ^{7} LaSalle
Unit No.: ^{8} 1 and 2
Safety/QA Class: ^{9} SR
System Code(s): ^{10} C51

Is this Design Analysis Safeguards Information? ^{11} **Yes** ☐ **No** ☒ If yes, see SY-AA-101-106
Does this Design Analysis contain Unverified Assumptions? ^{12} **Yes** ☐ **No** ☒ If yes, ATI/AR#: ______
This Design Analysis SUPERCEDES: ^{13} ______ **in its entirety.**

Description of Changes (list affected pages): ^{14}

1) Determine Tech Spec AV's and NTSP's for the APRM flow biased trips based on analytical limit changes due to thermal power optimization.
2) Determine ALT/AFT for APRM flow biased trips for use in instrument performance trending.
3) Determine total uncertainty based on the replacement ABB RFM uncertainties instead of the previously installed GE Flow Units.
4) Determine flow biased APRM trip errors based on 75% calibration flow.
5) Deleted section 15.0 (calculation spreadsheet),
6) Corrected a computation error in Section 11.5.3.1.5.
7) Corrected the application of vendor provided performance specifications for the ABB RFM upscale and comparator trip functions.

List of Affected Pages: This minor revision affects numerous pages of revision 2 which includes the following sections: 1.0, 2.0, 3.0, 4.0, 5.0, 7.0, 8.0, 9.0, 11.0, 12.0, 13.0, 14.0, and 15.0. The following sections of minor revision 2A are affected: reference 3.4, and sections 12.3, 13.3.1, and 13.3.2. The following sections of minor revision 2C are also affected: sections 14.1.1, 14.1.2, 14.1.3, and 14,1,4.

Disposition of Changes: ^{15}
This minor calculation revision is in support of Thermal Power Optimization and identifies permanent calculation changes required during the next major revision to this calculation.

	Print Name	Sign Name	Date
Preparer: ^{16}	David Cujko (Sargent & Lundy)	for D. Cujko	12-07-09

Method of Review: ^{17} **Detailed Review** ☒ **Alternate Calculations** ☐ **Testing** ☐

	Print Name	Sign Name	Date
Reviewer: ^{18}	AMARTEJ S. LUTHRA		12-07-09

Review Notes: ^{19} Independent review ☒ Peer review ☐

(For External Analyses Only)

	Print Name	Sign Name	Date
External Approver: ^{20}	W. A. BARASA	WABarasa	12-07-09
Exelon Reviewer ^{21}	THOMAS J. VAN WYK		12/9/09
Exelon Approver: ^{22}	Vikram Shah		12/15/09

TABLE OF CONTENTS

1.0 PURPOSE AND OBJECTIVE

The purpose of this Minor Revision is listed below:

1. The Unit 1 and Unit 2 analytical limits for the APRM flow biased trips are being revised per the thermal power optimization project. This revision recalculates the Technical Specification allowable values (AV's) and nominal trip setpoints (NTSP's) for the APRM flow biased trips based on the analytical limit changes.

2. This revision determines as-left / as-found tolerances for the APRM flow biased trips for use in instrument performance trending.

3. Subsequent to the issuance of analysis L-001345, revision 2, the GE recirculation flow units have been replaced with ABB recirculation flow monitors (RFM's). All results that are dependent on recirculation flow measurement uncertainties are impacted by the ABB RFM replacements. Therefore, this minor revision re-determines total instrument uncertainty and results for the following functions: a) APRM flow biased trips, b) RBM flow biased trips, and c) RFM upscale and comparator trip results.

4. Revise Section 2.2 (and subsequently impacted sections) to address the calibration flow rate change from 80% to 75% as detailed in minor revision 2C.

5. Section 15.0, "Calculation Spreadsheet", is being deleted. This spreadsheet was included for reference, and it was utilized for verifying computations. It is no longer required and is therefore being deleted.

6. The value determined for FCS_{RBM} (0.668750) in Section 11.5.3.1.5 will be revised to correct a previous computation error.

7. Corrected the application of vendor provided performance specifications for the ABB RFM upscale and comparator trip functions.

NOTE: Changes or revisions to existing portions of the calculation are identified by a combination of either bold, underlined, or italic text in lieu of revision bars. Added text or new text or sections are indicated as such, and are NOT identified by bold, underlined, or italic text.

2.0 METHODOLOGY AND ACCEPTANCE CRITERIA

1. Revise Section 2.1.d as follows:

   d. Static Pressure Span Effects

   References ***3.5.s, 3.5.t, and 3.5.y, 3.5.z*** state that a 1% of span correction has been included in the calibration to compensate for the static pressure span effect. However, References 3.14 states that there is a plus/minus correction uncertainty associated with this compensation. Therefore, this uncertainty will be included as a random error term in this calculation. Although the vendor gives this error term as a percent of reading, it will be considered as percent calibrated span which simplifies the calculation and is conservative.

2. Revise Section 2.2 to address the calibration flow rate change from 80% to 75% as detailed in minor revision 2C.

$$\text{Slope}_{\text{NEW}} = \text{Slope}_{\text{SP}} + [(T^+ + T^-)/0.08]/\Delta\text{Flow}$$

   This will be used for both APRM and RBM flow biased error calculations. For the APRM's, the tolerance (T^+, T^-) is ±0.04 Vdc and the calibration flow (ΔFlow) is ***75% flow*** (Section 10.4). For the RBM's, the tolerance (T^+, T^-) is ±0.04 Vdc and the calibration flow ((ΔFlow) is 100% flow (Section 10.5).

3. Add new Section 2.4 as indicated below:

   2.4 The methodology for determining as-left / as-found tolerances for APRM flow biased trip calibrations and surveillances, for each individually calibrated component or circuit (or module), is as follows:

   Module As-Left Tolerance (ALT):

$$\text{ALT} = \pm[\text{RA}^2 + \text{MTE}^2 + \text{RE}_{\text{MTE}}^2]^{0.5}$$

   Module As-Found Tolerance (AFT):

$$\text{AFT} = \pm[\text{RA}^2 + \text{RD}^2 + \text{MTE}^2 + \text{RE}_{\text{MTE}}^2]^{0.5}$$

   where,

   RA = Module Reference Accuracy
   RD = Module Vendor Specified Instrument Drift
   MTE = Module Measurement and Test Equipment (M&TE) Error
   RE_{MTE} = Module M&TE Readability

   If a particular calibrated component or circuit (or module) is not provided with a reference accuracy specification, the setting tolerance applied during module calibration will be used in place of the reference accuracy specification.

3.0 REFERENCES

1. Add new references as indicated below:

   3.5.y LIS-RR-101A, Rev. 12, "Unit 1 Recirculation Flow Converter A Calibration."
   LIS-RR-101B, Rev. 12, "Unit 1 Recirculation Flow Converter B Calibration."
   LIS-RR-101C, Rev. 11, "Unit 1 Recirculation Flow Converter C Calibration."
   LIS-RR-101D, Rev. 14, "Unit 1 Recirculation Flow Converter D Calibration."

   3.5.z LIS-RR-201A, Rev. 12, "Unit 2 Recirculation Flow Converter A Calibration."
   LIS-RR-201B, Rev. 11, "Unit 2 Recirculation Flow Converter B Calibration."
   LIS-RR-201C, Rev. 11, "Unit 2 Recirculation Flow Converter C Calibration."
   LIS-RR-201D, Rev. 12, "Unit 2 Recirculation Flow Converter D Calibration."

2. Revise Reference 3.34 as follows: (Note that this supersedes the minor rev 2A change to this reference)

   3.34 NES-EIC-20.04, ***Rev. 5***, "Analysis of Instrument Channel Setpoint Error and Instrument Loop Accuracy."

3. Add new reference as indicated below: (Note: see minor rev 2A for reference 3.35, "ER-AA-520 and minor rev 2B for reference 3.35.a, "L-002884")

   3.36 GE Task Report 0000-0106-6103-R0, DRF 0000-0096-1158, Rev.0. Class III, November 2009 "Project Task Report, Exelon Nuclear, LaSalle Units 1 and 2 Thermal Power Optimization, Task T0506: TS Instrument Setpoints."

   3.37 Fluke 45 User Manual, PN855981, January 1989, Rev. 4, 7/97

4.0 DESIGN INPUTS

1. Revise Section 4.1 as follows:

4.1 Accuracy for Flow Transmitters

The procedures of ***References 3.5.s, 3.5.t, and 3.5.y, 3.5.z*** indicate that there are five different calibrated spans for the 16 flow transmitters covered by this calculation. Since some of the uncertainty terms depend on the calibrated span and/or the transmitters upper range, the lowest value of the calibrated span will be used for all flow loops since this will produce conservative results.

2. Revise Section 4.14 and applicable table entrees as follows:

4.14 Analytical Limits and Allowable Values Inputs

From References 3.27, ***3.33, and 3.36*** Analytical Limit inputs are provided for all non-flow biased setpoints and the APRM Flow Biased Trip functions (flow biased and clamp). Reference 3.15 provides the Allowable Values for the RBM Upscale Trips. There is no Analytical Limit, as the rod block is not considered in the Rod Withdrawal Error Analysis as stated in Reference 3.15. The information provided by References 3.15, 3.27, ***3.33, and 3.36*** is summarized below:

Bistable	AL	AV	Reference
APRM Flow Biased Trips			
Flow Biased STP Scram -TLO	***0.61W + 69.76%***		***3.36***
Flow Biased STP Scram -SLO	***0.54W + 57.39%***		***3.36***
Flow Biased STP Rod Block -TLO	***0.61W + 58.51%***		***3.36***
Flow Biased STP Rod Block -SLO	***0.54W + 46.14%***		***3.36***

3. Add new Section 4.15 as follows:

4.15 References 3.5.y and 3.5.z indicate the original GE recirculation flow units have been replaced with ABB recirculation flow monitors (RFM's). Therefore, all total channel errors that are dependent on recirculation flow measurement uncertainties will be based on the ABB RFM's. This applies to the following functions: a) APRM flow biased trips, b) RBM flow biased trips, and c) RFM upscale and comparator trip results.

4. Add new Section 4.16

4.16 Error Propagation through ABB RFM Square Root Converter

With Reference to Appendix B of Reference 3.34, input errors are propagated through the ABB RFM square root converter circuit as follows:

$\sigma_{OUT} = (k)(\sigma_{ERROR})/[2(x)^{0.5}]$

$e_{OUT} = (k)(e_{ERROR})/[2(x)^{0.5}]$

where,

σ_{OUT} = random output error
e_{OUT} = non-random output error
k = gain
σ_{ERROR} = random input error
e_{ERROR} = non-random input error
x = input span

Determining the value of k:

Per Appendix B of Reference 3.34, the equation for a square root converter is,

$$y = k(x)^{0.5}$$

In Units of Vdc: where y is the output span (10 Vdc) and x is the input span (10 Vdc) per References 3.5.y and 3.5.z. Solving for k,

$$\begin{aligned} k &= y/(x)^{0.5} \\ &= 10\text{ Vdc} / (10\text{ Vdc})^{0.5} \\ &= 3.162278\text{ Vdc/Vdc}^{0.5} \end{aligned}$$

From Section 4.10, the point of interest is 75% Flow. The input span (x) at 75% Flow is determined as follows:

$$\begin{aligned} (75\%\text{ Flow}) / (125\%\text{ Flow}) &= [(x_{75\%})^{0.5}]/[10\text{ Vdc})^{0.5}] \\ x_{75\%} &= 3.6\text{ Vdc} \end{aligned}$$

In Units of % CS: where y is the output span (100 % CS) and x is the input span (100 % CS) per References 3.5.y and 3.5.z. Solving for k,

$$\begin{aligned} k &= y/(x)^{0.5} \\ &= 100\ \%\text{ CS} / (100\ \%\text{ CS})^{0.5} \\ &= 10\ \%\text{ CS}/\ \%\text{ CS}^{0.5} \end{aligned}$$

From Section 4.10, the point of interest is 75% Flow. The input span (x) at 75% Flow is determined as follows:

$$\begin{aligned} (75\%\text{ Flow}) / (125\%\text{ Flow}) &= [(x_{75\%})^{0.5}]/[100\ \%\text{ CS})^{0.5}] \\ x_{75\%} &= 36\ \%\text{ CS} \end{aligned}$$

5. Add new Section 4.17

4.17 Error Propagation through ABB RFM Summer

With Reference to Appendix B of Reference 3.34, input errors are propagated through the ABB RFM summer circuit as follows:

$$\sigma_{OUT} = [(k1*\sigma_{ERROR\ X})^2 + (k2*\sigma_{ERROR\ Y})^2]^{0.5}$$
$$e_{OUT} = (k1*e_{ERROR\ X}) + (k2*e_{ERROR\ Y})$$

where,

σ_{OUT} = random output error

e_{OUT} = non-random output error
k1 = gain input 1
k2 = gain input 2
$\sigma_{ERROR\ X}$ = random input error X
$\sigma_{ERROR\ Y}$ = random input error Y
$e_{ERROR\ X}$ = non-random input error X
$e_{ERROR\ Y}$ = non-random input error Y

The summer inputs are equally weighted, therefore, k1 = k2 = 0.5.

5.0 ASSUMPTIONS

1. Delete Section 5.7 as follows:

~~Since the ABB designed flow unit has not yet been installed, it will be assumed that this flow unit will be mounted in the same general area as is the present flow unit. Therefore, the environmental parameters for the current flow unit will be assumed to be applicable to the new ABB flow units.~~

2. Delete Section 5.9 as follows:

~~Since there have been no procedures generated for calibrating the ABB designed flow unit it will be assumed that, when developed, they will be similar to those used to calibrate the GE designed flow unit. Therefore, the MTE and ST terms derived for the GE flow units will be assumed applicable to the calibration of the ABB flow unit.~~

3. Revise Section 5.11 as follows:

Based on the information contained in References 3.4 and 3.16 it will be assumed that LaSalle is using a Wallace and Tiernan Model 65-120 instrument when the procedures of References ***3.5.s, 3.5.t and 3.5.y, 3.5.z*** call for a Pneumatic Calibrator.

7.0 PROCESS PARAMETERS

1. Revise Section 7.0 as follows:

The temperature of the fluid has, however, dropped to reactor building ambient temperature by the time it reached the location of the transmitters. Based on References ***3.5.s, 3.5.t and 3.5.y, 3.5.z,*** 100% Flow in these flow loops is equal to 55,000 GPM.

8.0 LOOP ELEMENT DATA

1. Revise section 8.6.1 as follows to correct the accuracy specification for the comparator and upscale trips: (Note that Revision 2 currently incorrectly applies the trip and total flow uncertainty as independent; however, they are dependent.)

Comparator Trip Accuracy:	***2 % CS (based on 1% trip setpoint error plus 1% total flow signal error)***
Upscale Trip Accuracy:	***2 % CS (based on 1% trip setpoint error plus 1% total flow signal error)***

2. Revise section 8.6.2 as follows:

8.6.2 Environmental Parameters at Flow Unit Location (Zone LC1A from EWCS) (Reference 3.6, Table 3.11-24) ~~***[It is assumed that this flow unit will be mounted in the same general area as is the present flow unit]***~~

Temperature (°F)	72 - 74
Relative Humidity (%)	35 - 45
Radiation	1×10^3 rads gamma(integrated)

9.0 CALIBRATION INSTRUMENT DATA

1. ABB RFM calibration procedures (References 3.5.y and 3.5.z), invokes use of a Fluke 45 to calibrate the recirculation flow transmitters. Therefore, revise the table in section 9.0 by adding the following MTE error information for a Fluke 45, slow reading rate, (100 mVdc Rng) as follows: (see section 9.1 changes below for determination of this uncertainty,). The ±0.012141 mVdc uncertainty value is utilized, because the maximum reading will be 20 mVdc at the transmitter location, and the environment during calibration should not exceed 104°F.

Calibration Instrument	MTE Error [1σ]	Evaluation Parameters
MTE for all DMM Calibrations		
Fluke 45 Slow (100 mVdc Rng)	***±0.012141 mVdc***	***@20 mVdc, 104°F***

2. Revise Section 9.2 as follows:

   9.2 Pressure Measurement Error Evaluation

   References ***3.5.s, 3.5.t and 3.5.y, 3.5.z*** specify the use of a "Pneumatic Calibrator, 0-850"W.C. (Accuracy: ±2.0"W.C., minimum)."

3. Section 9.1: Add the following DMM measurement error evaluation for a Fluke 45, slow reading rate, (100 mVdc Range) as follows under Section 9.1:

FLUKE 45 SLOW READING RATE RANGE: 100 mVdc

Manufacturer's Specifications (from Reference 3.37)
Reference Accuracy (RA)† = ±(0.025%(RDG) + 6(digits)) [2σ]
Resolution (RES) = 0.001 mV
Temperature Effect* (TE) = ±(0.1(Accuracy Spec.)/°C) (ΔT) [2σ]
† 1 Year Accuracy Specification
* From 0°C to 18°C and 28°C to 50°C

Temperature Differential (ΔT)
64.4 → 82.4°F (18 → 28°C) Temperature Effect Not Applicable
104°F = 40.0°C → ΔT = (40.0 – 28.0)°C = 12.0°C
122°F = 50.0°C → ΔT = (50.0 – 28.0)°C = 22.0°C

Total Measurement Error (MTE)
MTE $= \pm[(RA/2 + TE/2)^2 + RES^2]^{1/2}$ [1σ]

Maximum Zone Temp.	MTE at RDG = 20 mV	MTE at RDG = 50 mV
64.4 → 82.4°F	±0.005590 mV	±0.009304 mV
104°F	±0.012141 mV	±0.020375 mV
122°F	±0.017628 mV	±0.029617 mV

11.0 MODULE ERRORS

11.1 MODULE 1 (FLOW TRANSMITTER)

1. Revise Section 11.1.1.3 as follows:

11.1.1.3 Calibration Uncertainty (CAL1)

The uncertainties associated with calibrating the flow transmitters are composed of the uncertainties in setting the input signal and the uncertainties in reading the output signal. References ***3.5.s, 3.5.t and 3.5.y, 3.5.z*** do not give a particular instrument to be used for setting the input during calibration. Rather, they simply indicate a "Pneumatic Calibrator, 0-850" W.C. (accuracy: ±2.0" W.C., minimum)" is required. Per Assumption 5.11 LaSalle is assumed to be using a Wallace and Tiernan Model 65-120 instrument for this input monitoring function. For the maximum temperature applicable to this location the accuracy given by Reference 3.4 for this instrument is 2.149835" W.C. This is the value that will be used in this calculation. The reading error term ($REMTEI_{FT}$) is included in total MTE error term given in Reference 3.4. Therefore, a value of 0 will be used for $REMTE1_{FT}$ for this calculation.

The instrument specified by the procedures ***(References 3.5.s and 3.5.t)*** for measurement of the flow transmitter output is a Fluke 8600A DMM. For the voltage range of interest for this calculation the reference accuracy, from Reference 3.4, is 0.034961 mVdc. ($RAMTE2_{FT}$). Since this is a digital instrument, there is no reading error associated with its use ($REMTE2_{FT} = 0$). ***The instrument specified by the procedures (References 3.5.y and 3.5.z) for measurement of the flow transmitter output is a Fluke 45 DMM. For the voltage range of interest, for this calculation, the reference accuracy, from Section 9.0, is ±0.012141 mVdc. The Fluke 45 is a digital output device, and therefore, the reading error is considered to be the least significant increment of the display (or resolution) (see Reference 3.34). Per section 9.1, reading error is included in the uncertainty value. Since the uncertainty of a Fluke 8600A bounds the uncertainty of a Fluke 45, the Fluke 8600A will be evaluated in the following analysis.***

2. Revise Section 11.1.1.4 as follows:

11.1.1.4 Setting Tolerance (ST1)

From References ***3.5.s, 3.5.t and 3.5.y, 3.5.z*** the setting tolerance for the flow transmitters' output ($ST_{FT(OUT)}$) is 0.08 mVdc.

3. Revise Section 11.1.1.5 as follows:

11.1.1.5 Static Pressure Span Effect (Correction Uncertainty) ($SPSE_{FT}$)

References ***3.5.s, 3.5.t and 3.5.y, 3.5.z*** state that a 1% of span correction has been included in the calibration to compensate for the static pressure span effect.

4. Revise Section 11.1.2.5 as follows:

11.1.2.5 Static Pressure Effect (e1SP)

From References ***3.5.s, 3.5.t and 3.5.y, 3.5.z***, these instruments have been compensated for static pressure effect during calibration.

11.4.4 Module 4D (Trip Circuit – Flow Biased)

1. Revise section 11.4.4 as follows:

Module 4D receives an analog input from the Averaging Circuitry and the ***ABB RFM (Module 6)***, and provides a bistable output, the state of which depends on the relative magnitudes of the input signal from the Averaging Circuitry and the reference value, which is a function of the ***ABB RFM flow*** signal. Therefore, Module 4D is a bistable module.

2. Revise section 11.4.4.1.5 as follows to evaluate uncertainties from the ABB RFM instead of uncertainties from the GE Flow Units. Refer to section 11.6 of this minor revision for determination of ABB RFM uncertainties.

11.4.4.1.5 Input Uncertainty (σinput4D)

The Module 4D input error (σinput4D) is the SRSS combination of random input terms from Module 4B ($\sigma 4B_{FB}$) and Module ***6 (σ6) (per section 4.15).*** However, ***σ6*** must be converted from % Flow to % Power using the flow biased trip slope adjustment from Section 2.2 which accounts for setting uncertainties.

3. Revise section 11.4.4.1.5.1 as follows to a) evaluate uncertainties from the ABB RFM (σ6 and $\sigma 6_C$ values from section 11.6.1.1.6) instead of uncertainties from the GE Flow Units, b) evaluate the AL value per Reference 3.36, and c) apply the 75% calibration flow rate as detailed previously per section 2.2 changes:

11.4.4.1.5.1 Two Loop Operation (TLO) – From Design Input 4.14, the TLO flow biased slope (FCS_{SP}) is ***0.61*** which is adjusted as

$$\begin{aligned} FCS &= FCS_{SP} + [(0.04+0.04) / 0.08] / \mathit{75} \\ &= \mathbf{\mathit{0.61}} + [(0.04+0.04) / 0.08] / \mathit{75} \\ &= \mathbf{\mathit{0.623333}} \end{aligned}$$

The module 4D input uncertainty for TLO is determined as

$$\begin{aligned} \sigma input4D &= \pm[\sigma 4B_{FB}^2 + (FCS * \boldsymbol{\sigma 6})^2]^{0.5} \\ \sigma input4D &= \pm[1.21122^2 + (\mathbf{\mathit{0.623333 * 2.112581}})^2]^{0.5} \end{aligned}$$

$$\sigma input4D = \pm\mathbf{\mathit{1.789169\ Power}}$$

And the module 4D AV uncertainty for TLO is determined as

$$\begin{aligned} \sigma input4D_{AV} &= \pm[\sigma 4B_{AV}^2 + (FCS * \boldsymbol{\sigma 6_C})^2]^{0.5} \\ \sigma input4D_{AV} &= \pm[1.041510^2 + (\mathbf{\mathit{0.623333 * 1.035450}})^2]^{0.5} \end{aligned}$$

$$\sigma input4D_{AV} = \pm\mathbf{\mathit{1.225285\ \%\ Power}}$$

4. Revise section 11.4.4.1.5.2 as follows to a) evaluate uncertainties from the ABB RFM ($\sigma 6$ and $\sigma 6_C$ values from section 11.6.1.1.6) instead of uncertainties from the GE Flow Units, b) evaluate the AL value per Reference 3.36, and c) apply the 75% calibration flow rate as detailed previously per section 2.2 changes:

11.4.4.1.5.2 Single Loop Operation (SLO) – From Design Input 4.14, the SLO flow biased slope (FCS_{SPSLO}) is ***<u>0.54</u>*** which is adjusted as

$$\begin{aligned} FCS_{SLO} &= FCS_{SPSLO} + [(0.04+0.04) / 0.08] / \boldsymbol{75} \\ &= \boldsymbol{0.54} + [(0.04+0.04) / 0.08] / \boldsymbol{75} \\ &= \boldsymbol{0.553333} \end{aligned}$$

The module 4D input uncertainty for SLO is determined as

$$\begin{aligned} \sigma input4D_{SLO} &= \pm[\sigma 4B_{FB}{}^2 + (FCS_{SLO} * \boldsymbol{\sigma 6})^2]^{0.5} \\ \sigma input4D_{SLO} &= \pm[1.21122^2 + (\boldsymbol{0.553333 * 2.112581})^2]^{0.5} \end{aligned}$$

$$\sigma input4D_{SLO} = \pm\boldsymbol{1.683307\ \%\ Power}$$

And the module 4D AV uncertainty for SLO is determined as

$$\begin{aligned} \sigma input4D_{AVSLO} &= \pm[\sigma 4B_{AV}{}^2 + (FCS_{SLO} * \boldsymbol{\sigma 6_C})^2]^{0.5} \\ \sigma input4D_{AVSLO} &= \pm[1.041510^2 + (\boldsymbol{0.553333 * 1.035450})^2]^{0.5} \end{aligned}$$

$$\sigma input4D_{AVSLO} = \pm\boldsymbol{1.188702\ \%\ Power}$$

5. Revise section 11.4.4.1.6.1 as follows:

$$\begin{aligned} \sigma 4D &= \pm[RA4D_{(1\sigma)}{}^2 + RD4D_{(1\sigma)}{}^2 + CAL4D^2 + ST4D_{(1\sigma)}{}^2 + \sigma input4D^2]^{0.5} \\ \sigma 4D &= \pm[0.625^2 + 1.74553^2 + 0.00225^2 + 0.166667^2 + \boldsymbol{1.789169}^2]^{0.5} \end{aligned}$$

$$\sigma 4D = \pm\ \boldsymbol{2.581939}\ \%\ \text{Power}$$

And the module 4D AV random error is

$$\begin{aligned} \sigma 4D_{AV} &= \pm[RA4D_{(1\sigma)}{}^2 + RD4D_{(1\sigma)}{}^2 + CAL4D^2 + ST4D_{(1\sigma)}{}^2 + \sigma input4D_{AV}{}^2]^{0.5} \\ \sigma 4D_{AV} &= \pm[0.625^2 + 1.74553^2 + 0.00225^2 + 0.166667^2 + \boldsymbol{1.225285}^2]^{0.5} \end{aligned}$$

$$\sigma 4D_{AV} = \pm\ \boldsymbol{2.228588}\ \%\ \text{Power}$$

6. Revise section 11.4.4.1.6.2 as follows:

$$\begin{aligned} \sigma 4D_{SLO} &= \pm[RA4D_{(1\sigma)}{}^2 + RD4D_{(1\sigma)}{}^2 + CAL4D^2 + ST4D_{(1\sigma)}{}^2 + \sigma input4D_{SLO}{}^2]^{0.5} \\ \sigma 4D_{SLO} &= \pm[0.625^2 + 1.74553^2 + 0.00225^2 + 0.166667^2 + \boldsymbol{1.683307}^2]^{0.5} \end{aligned}$$

$$\sigma 4D_{SLO} = \pm\ \boldsymbol{2.509742}\ \%\ \text{Power}$$

And the module 4D AV random error is

$$\begin{aligned} \sigma 4D_{AVSLO} &= \pm[RA4D_{(1\sigma)}{}^2 + RD4D_{(1\sigma)}{}^2 + CAL4D^2 + ST4D_{(1\sigma)}{}^2 + \sigma input4D_{AVSLO}{}^2]^{0.5} \\ \sigma 4D_{AVSLO} &= \pm[0.625^2 + 1.74553^2 + 0.00225^2 + 0.166667^2 + \boldsymbol{1.188702}^2]^{0.5} \end{aligned}$$

$\sigma 4D_{AVSLO}$ = ± ***2.208686***% Power

7. Revise section 11.4.4.2.9.1 as follows to evaluate uncertainties from the ABB RFM (Σ6 value from section 11.6.1.2.10) instead of uncertainties from the GE Flow Units:

einput4D = ±[Σe4B + (FCS * ***Σe6***)]
einput4D = ±[0.82 + ***(0.623333 * 1.845461***)]

einput4D = ± ***1.970337 % Power***

And the module 4D AV error for TLO is determined as

einput4D_{AV} = ±[Σe4B_{AV} + (FCS * ***Σe6***)]
einput4D_{AV} = ±[0 + ***(0.623333 * 1.845461***)]

einput4D_{AV} = ± ***1.150337 % Power***

8. Revise section 11.4.4.2.9.2 as follows to evaluate uncertainties from the ABB RFM (Σ6 value from section 11.6.1.2.10) instead of uncertainties from the GE Flow Units:

einput4D_{SLO} = ±[Σe4B + (FCS * ***Σe6***)]
einput4D_{SLO} = ±[0.82 + ***(0.553333 * 1.845461***)]

einput4D_{SLO} = ± ***1.841154 % Power***

And the module 4D AV error for SLO is determined as

einput4D_{AVSLO} = ±[Σe4B_{AV} + (FCS * ***Σe6***)]
einput4D_{AVSLO} = ±[0 + ***(0.553333 * 1.845461***)]

einput4D_{AVSLO} = ±***1.021154 % Power***

9. Revise section 11.4.4.2.10.1 as follows:

Σe4D = ±(125/100)*(e4DH + e4DT + e4DR + e4DS + e4DSP + e4DP + e4Dp + e4DV) + einput4D

Σe4D = ±(125/100)*(0 + 0 + 0 + 0 + 0 + 0 + 0 + 0) + ***1.970337***

Σe4D = ±***1.970337*** % Power

And the module 4D AV error for TLO is determined as

Σe4D_{AV}= ±(125/100)*(e4DH + e4DT + e4DR + e4DS + e4DSP + e4DP + e4Dp + e4DV) + einput4D_{AV}

Σe4D_{AV}= ±(125/100)*(0 + 0 + 0 + 0 + 0 + 0 + 0 + 0) + ***1.150337***

Σe4D_{AV}= ±***1.150337*** % Power

10. Revise section 11.4.4.2.10.2 as follows:

$$\Sigma e4D_{SLO} = \pm(125/100)*(e4DH + e4DT + e4DR + e4DS + e4DSP + e4DP + e4Dp + e4DV) + einput4D_{SLO}$$

$$\Sigma e4D_{SLO} = \pm(125/100)*(0 + 0 + 0 + 0 + 0 + 0 + 0 + 0) + \boldsymbol{\mathit{1.841154}}$$

$$\Sigma e4D_{SLO} = \pm\boldsymbol{\mathit{1.841154}}\ \%\ \text{Power}$$

And the module 4D AV error for SLO is determined as

$$\Sigma e4D_{AVSLO} = \pm(125/100)*(e4DH + e4DT + e4DR + e4DS + e4DSP + e4DP + e4Dp + e4DV) + einput4D_{AVSLO}$$

$$\Sigma e4D_{AVSLO} = \pm(125/100)*(0 + 0 + 0 + 0 + 0 + 0 + 0 + 0) + \boldsymbol{\mathit{1.021154}}$$

$$\Sigma e4D_{AVSLO} = \pm\boldsymbol{\mathit{1.021154}}\ \%\ \text{Power}$$

11.5.3 Module 5C (Trip Circuit – Flow Biased)

1. Revise section 11.5.3 as follows:

Module 5C receives an analog input from the Averaging Circuitry and Gain Change Circuitry the ***ABB RFM (Module 6)***, and provides a bistable output, the state of which depends on the relative magnitudes of the input signal from the Averaging and Gain Change Circuitry and the reference value, which is a function of the ***ABB RFM flow*** signal. Therefore, Module 5C is a bistable module.

2. Revise section 11.5.3.1.5 as follows to evaluate uncertainties from the ABB RFM ($\sigma 6$ and $\sigma 6_C$ values from section 11.6.1.1.6) instead of uncertainties from the GE Flow Units. Refer to section 11.6 of this minor revision for determination of ABB RFM uncertainties. This minor revision also corrects the computation of FCS_{RBM}.

11.5.3.1.5 Input Uncertainty ($\sigma input5C$)

In addition to its own error terms, the error terms from Module 5A and ***Module 6*** must also be considered. Since the trip circuits perform no function on these input signals $\sigma input5C$ and $\sigma input5C_{AV}$ become equal to the combination by SRSS of the random input terms $\sigma 5A$ and ***$\sigma 6$***, and $\sigma 5A_{AV}$ and ***$\sigma 6_C$***. However, before $\sigma 5A$ and ***$\sigma 6$***, and $\sigma 5A_{AV}$ and ***$\sigma 6_C$*** can be combined, ***$\sigma 6$*** and σ***6_C*** must be converted from % Flow to % Power by multiplying by the slope of the curve in the Flow Controlled Trip Reference Unit. From the applicable procedures in Reference 3.5 this slope ($FCS_{RBM(SP)}$) is equal to 0.66% Power per % Flow. However, per Section 2.2 this slope has been modified to account for setting uncertainties. Therefore,

$$\begin{aligned}\boldsymbol{FCS_{RBM}} &= \boldsymbol{FCS_{RBM(SP)} + [(0.04+0.04) / 0.08] / 100}\\ &= \boldsymbol{0.66 + [(0.04+0.04) / 0.08] / 100}\\ &= \boldsymbol{0.670000}\end{aligned}$$

therefore,

$$\sigma input5C = \pm[\sigma 5A^2 + (FCS_{RBM} * \boldsymbol{\sigma 6})^2]^{0.5} \text{ \% Power}$$
$$\sigma input5C = \pm[1.850009^2 + (\boldsymbol{0.670000 * 2.112581})^2]^{0.5} \text{ \% Power}$$

$$\sigma input5C = \pm\boldsymbol{2.329372} \text{ \% Power}$$

For the Allowable Value Determination this becomes:

$$\sigma input5C_{AV} = \pm[\sigma 5A_{AV}{}^2 + (FCS_{RBM} * \boldsymbol{\sigma 6_C})^2]^{0.5} \text{ \% Power}$$
$$\sigma input5C_{AV} = \pm[1.610749^2 + (\boldsymbol{0.670000 * 1.0354501})^2]^{0.5} \text{ \% Power}$$

$$\sigma input5C_{AV} = \pm\boldsymbol{1.753797} \text{ \% Power}$$

3. Revise section 11.5.3.1.6 as follows:

$$\sigma 5C = \pm[(RA5C_{(1\sigma)})^2 + (RD5C_{(1\sigma)})^2 + (CAL5C)^2 + (ST5C_{(1\sigma)})^2 + (\sigma input5C)^2]^{0.5} \text{ \% Power}$$
$$\sigma 5C = \pm[(0.625)^2 + (1.234276)^2 + (0.00225)^2 + (0.166667)^2 + (\boldsymbol{2.329372})^2]^{0.5} \text{ \% Power}$$

$$\sigma 5C = \pm\ \boldsymbol{2.714373} \text{ \% Power}$$

And,

$$\sigma 5C_{AV} = \pm[(RA5C_{(1\sigma)})^2 + (RD5C_{(1\sigma)})^2 + (CAL5C)^2 + (ST5C_{(1\sigma)})^2 + (\sigma input5C_{AV})^2]^{0.5} \text{ \% Power}$$
$$\sigma 5C_{AV} = \pm[(0.625)^2 + (1.234276)^2 + (0.00225)^2 + (0.166667)^2 + (\boldsymbol{1.753797})^2]^{0.5} \text{ \% Power}$$

$$\sigma 5C_{AV} = \pm\ \boldsymbol{2.240011} \text{ \% Power}$$

4. Revise section 11.5.3.2.9 as follows to evaluate uncertainties from the ABB RFM (Σ6 value from section 11.6.1.2.10) instead of uncertainties from the GE Flow Units. Also corrected the computation of FCS_{RBM}:

11.5.3.2.9 Non-Random Input Error (einput5C)

In addition to its own error terms, the error terms from Module 5A and ***Module 6*** must also be considered. Since the trip circuits perform no function on these input signals einput5C and $\Sigma input5C_{AV}$ become equal to the combination by SRSS of the random input terms Σe5A and ***Σe6***, and $\Sigma e5A_{AV}$ and $\boldsymbol{\Sigma e6_{AV}}$. However, before Σe5A and ***Σe6***, and $\Sigma e5A_{AV}$ and $\boldsymbol{\Sigma e6_{AV}}$ can be combined, ***Σe6*** and $\boldsymbol{\Sigma e6_{AV}}$ must be converted from % Flow to % Power by multiplying by the slope of the curve in the Flow Controlled Trip Reference Unit. From the applicable procedures in Reference 3.5 this slope ($FCS_{RBM(SP)}$) is equal to 0.66% Power per % Flow. However, per Section 2.2 this slope has been modified to account for setting uncertainties. Therefore,

$$einput5C = \pm[\Sigma e5A + (FCS_{RBM} * \boldsymbol{\Sigma e6})]\text{\% Power}$$
$$einput5C = \pm[0.82 + (\boldsymbol{0.670000 * 1.845461})] \text{ \% Power}$$

$$einput5C = \pm\boldsymbol{2.056459} \text{ \% Power}$$

And

$$einput5C_{AV} = \pm[\Sigma e5A_{AV} + (FCS_{RBM} * \boldsymbol{\Sigma e6})]\text{\% Power}$$
$$einput5C_{AV} = \pm[0 + (\boldsymbol{0.670000 * 1.845461})] \text{ \% Power}$$

$$einput5C_{AV} = \pm\boldsymbol{1.236459} \text{ \% Power}$$

5. Revise section 11.5.3.2.10 as follows:

$\Sigma e5C$ = ±(125/100)*(e5CH + e5CT + e5CR + e5CS + e5CSP + e5CP + e5Cp + e5CV) + einput5C % Power

$\Sigma e5C$ = ±(125/100)*(0 + 0 + 0 + 0 + 0 + 0 + 0 + 0) + ***2.056459*** % Power

$\Sigma e5C$ = ± ***2.056459 %*** Power

And

$\Sigma e5C_{AV}$ = ±(125/100)*(e5CH + e5CT + e5CR + e5CS + e5CSP + e5CP + e5Cp + e5CV) + einput5C_{AV} % Power

$\Sigma e5C_{AV}$ = ±(125/100)*(0 + 0 + 0 + 0 + 0 + 0 + 0 + 0) + ***1.236459*** % Power

$\Sigma e5C_{AV}$ = ±***1.236459 %*** Power

11.6.1 Module 6 Analog Section

1. Section 11.6.1.1.3: Delete existing text under section 11.6.1.1.3 and replace with the following new text as follows:

11.6.1.1.3 Calibration Uncertainty (CAL6)

Per References 3.5.y and 3.5.z, this module contains circuits which are calibrated individually. These circuits consists of: 1) input isolators (one for each recirculation flow loop), 2) square root converters, 3) a summer, and 4) an analog output isolator (which provides the total output flow signal).

The uncertainties associated with calibrating the ABB RFM circuits consist of the uncertainties in setting the input signal and the uncertainties in reading the output signal. References 3.5.y and 3.5.z specify use of Fluke 45 DMM's for measurement of voltage input and output signals. For the voltage range of interest for this calculation (0 – 10 Vdc and with control room environments per References 3.5.y and 3.5.z), the reference accuracy for a Fluke 45 is ±0.002462 Vdc (see section 9.0). The Fluke 45 is a digital output device, and therefore, the reading error is considered to be the least significant increment of the display (or resolution) (see Reference 3.34). Per section 9.1, reading error is included in the ±0.002462 Vdc uncertainty value.

From Section 5.2, errors attributed to calibration standards are considered negligible. Therefore, the only terms which contribute to calibration uncertainty (CAL) are uncertainties associated with measuring input calibration signals (MTE1) and output calibration signals (MTE2).

Calibration uncertainties associated with the ABB RFM is determined below:

a) Input Isolators

The input isolators are calibrated by applying a measured pressure input signal into the flow transmitter while measuring the output of the isolator with a Fluke 45. The uncertainty associated with measuring the transmitter input signal is determined in Section 11.1.1.3 and is listed below:

$\mathrm{MTE1}_{\mathrm{II\ (CS)}} = \mathrm{MTE1}_{\mathrm{FT\ (CS)}} = \pm 0.868971\ \%\ \mathrm{CS}$ [1σ]

The uncertainty associated with measuring the output from the isolator is determined above as,

$\mathrm{MTE2}_{\mathrm{II}} = \mathrm{MTE}_{45} = \pm 0.002462\ \mathrm{Vdc}$ [1σ]

These uncertainties are converted to equivalent output values at the square root converter and then to equivalent output values at the summer. However, $\mathrm{MTE1}_{\mathrm{II\ (CS)}}$ is first converted to a voltage value by multiplying it by the input isolator calibration span (10 Vdc) and dividing by 100%.

$\mathrm{MTE1}_{\mathrm{II}} = (\mathrm{MTE1}_{\mathrm{II\ (CS)}})*(\ 10\ \mathrm{Vdc} / 100\ \%\ \mathrm{CS})$
$= \pm(0.868971\%\ \mathrm{CS})*(10\ \mathrm{Vdc} / 100\ \%\ \mathrm{CS})$
$= \pm 0.086897\ \mathrm{Vdc}$ [1σ]

Convert to equivalent square root converter output value by utilizing equations and the operating point of interest (75% flow = 3.6 Vdc) determined in Section 4.16:

$$y = (k)(\sigma_{\mathrm{ERROR}})/[2(x)^{0.5}]$$

by substitution,

$\mathrm{MTE1}_{\mathrm{II\ (SR\ OUT)}} = \pm[(3.162278\ \mathrm{Vdc/Vdc}^{0.5})*(\mathrm{MTE1}_{\mathrm{II}})]/[2(3.6\ \mathrm{Vdc})^{0.5}]$
$= \pm[(3.162278\ \mathrm{Vdc/Vdc}^{0.5})*(0.086897\ \mathrm{Vdc})]/[2(3.6\ \mathrm{Vdc})^{0.5}]$
$= \pm 0.072414\ \mathrm{Vdc}$ [1σ]

$\mathrm{MTE2}_{\mathrm{II\ (SR\ OUT)}} = \pm[(3.162278\ \mathrm{Vdc/Vdc}^{0.5})*(\mathrm{MTE2}_{\mathrm{II}})]/[2(3.6\ \mathrm{Vdc})^{0.5}]$
$= \pm[(3.162278\ \mathrm{Vdc/Vdc}^{0.5})*(0.002462\ \mathrm{Vdc})]/[2(3.6\ \mathrm{Vdc})^{0.5}]$
$= \pm 0.002052\ \mathrm{Vdc}$ [1σ]

Convert to equivalent summer output value by utilizing equations determined in Section 4.17:

$$\sigma_{\mathrm{OUT}} = [(k1*\sigma_{\mathrm{ERROR\ X}})^2 + (k2*\sigma_{\mathrm{ERROR\ Y}})^2]^{0.5}$$

by substitution,

$\mathrm{MTE1}_{\mathrm{II\ (SUM\ OUT)}} = \pm[(k1*\mathrm{MTE1}_{\mathrm{II\ (SR\ OUT)}})^2 + (k2*\ \mathrm{MTE1}_{\mathrm{II\ (SR\ OUT)}})^2]^{0.5}$
$= \pm[(0.5*0.072414\ \mathrm{Vdc})^2 + (0.5*0.072414\ \mathrm{Vdc})^2]^{0.5}$
$= \pm 0.051204\ \mathrm{Vdc}$ [1σ]

$\mathrm{MT2}_{\mathrm{II\ (SUM\ OUT)}} = \pm[(k1*\mathrm{MTE2}_{\mathrm{II\ (SR\ OUT)}})^2 + (k2*\ \mathrm{MTE2}_{\mathrm{II\ (SR\ OUT)}})^2]^{0.5}$
$= \pm[(0.5*0.002052\ \mathrm{Vdc})^2 + (0.5*0.002052\ \mathrm{Vdc})^2]^{0.5}$
$= \pm 0.001451\ \mathrm{Vdc}$ [1σ]

Note that $\mathrm{MTE1}_{\mathrm{II}}$ is already included in the determination of Module 1 random input uncertainty (1σ) determined in Section 11.1.1.8 and will therefore not be included in the determination of CAL6.

b) Square Root Converters

The square root converters are calibrated by applying a measured input signal with a Fluke 45 while measuring the output of the converter with another Fluke 45. The uncertainties associated with measuring the square root converter input and output signals (MTE1 and MTE2, respectively) was determined above as:

$$MTE1_{SR} = MTE_{45} = \pm 0.002462\ Vdc \quad [1\sigma]$$
$$MTE2_{SR} = MTE_{45} = \pm 0.002462\ Vdc \quad [1\sigma]$$

Convert $MTE1_{SR}$ to an equivalent square root converter output value by utilizing equations and the operating point of interest (75% flow = 3.6 Vdc) determined Section 4.16:

$$y = (k)(\sigma_{ERROR})/[2(x)^{0.5}]$$

by substitution,

$$\begin{aligned} MTE1_{SR\ (SR\ OUT)} &= \pm[(3.162278\ Vdc/Vdc^{0.5})*(MTE1_{SR})]/[2(3.6\ Vdc)^{0.5}] \\ &= \pm[(3.162278\ Vdc/Vdc^{0.5})*(0.002462\ Vdc)]/[2(3.6\ Vdc)^{0.5}] \\ &= \pm 0.002052\ Vdc \quad [1\sigma] \end{aligned}$$

Convert to equivalent summer output value by utilizing equations determined in Section 4.17:

$$\sigma_{OUT} = [(k1*\sigma_{ERROR\ X})^2 + (k2*\sigma_{ERROR\ Y})^2]^{0.5}$$

by substitution,

$$\begin{aligned} MTE1_{SR\ (SUM\ OUT)} &= \pm[(k1*\ MTE1_{SR\ (SR\ OUT)})^2 + (k2*\ MTE1_{SR\ (SR\ OUT)})^2]^{0.5} \\ &= \pm[(0.5*0.002052\ Vdc)^2 + (0.5*0.002052\ Vdc)^2]^{0.5} \\ &= \pm 0.001451\ Vdc \quad [1\sigma] \end{aligned}$$

$$\begin{aligned} MTE2_{SR\ (SUM\ OUT)} &= \pm[(k1*\ MTE2_{SR})^2 + (k2*\ MTE2_{SR})^2]^{0.5} \\ &= \pm[(0.5*0.002462\ Vdc)^2 + (0.5*0.002462\ Vdc)^2]^{0.5} \\ &= \pm 0.001741\ Vdc \quad [1\sigma] \end{aligned}$$

c) Summer

The summer is calibrated by applying two measured input signals with two Fluke 45's ($MTE1_{SUM}$) while measuring the output of the summer with a third Fluke 45 ($MTE2_{SUM}$). The uncertainties associated with measuring the summer input and output signals ($MTE1_{SUM}$ and $MTE2_{SUM}$, respectively) was determined above as:

$$MTE1_{SUM} = MTE_{45} = \pm 0.002462\ Vdc \quad [1\sigma]$$
$$MTE2_{SUM} = MTE_{45} = \pm 0.002462\ Vdc \quad [1\sigma]$$

Convert to equivalent summer output value by utilizing equations determined in Section 4.17:

$$\sigma_{OUT} = [(k1*\sigma_{ERROR\ X})^2 + (k2*\sigma_{ERROR\ Y})^2]^{0.5}$$

by substitution,

$$\begin{aligned} MTE1_{SUM\ (SUM\ OUT)} &= \pm[(k1*MTE1_{SUM})^2 + (k2*MTE1_{SUM})^2]^{0.5} \\ &= \pm[(0.5*0.002462\ Vdc)^2 + (0.5*0.002462\ Vdc)^2]^{0.5} \\ &= \pm 0.001741Vdc \quad [1\sigma] \end{aligned}$$

d) Output Isolator

The output isolator is calibrated by applying a measured input signal with a Fluke 45 while measuring the output with another Fluke 45. The uncertainties associated with measuring the isolator input and output signals (MTE1 and MTE2, respectively) was determined above as:

$MTE1_{OI} = MTE_{45} = \pm 0.002462$ Vdc [1σ]
$MTE2_{OI} = MTE_{45} = \pm 0.002462$ Vdc [1σ]

e) Determine Total Calibration Uncertainty (CAL6):

Using the methodology of Reference 3.34:

$$CAL6_{VDC} = \pm[(MTE2_{II\ (SUM\ OUT)})^2 + (MTE1_{SR\ (SUM\ OUT)})^2 + (MTE2_{SR\ (SUM\ OUT)})^2 + (MTE1_{SUM\ (SUM\ OUT)})^2 + (MTE2_{SUM})^2 + (MTE1_{OI})^2 + (MTE2_{OI})^2]^{0.5}$$

$$= \pm[(0.001451\ Vdc)^2 + (0.001451\ Vdc)^2 + (0.001741\ Vdc)^2 + (0.001741 Vdc)^2 + (0.002462\ Vdc)^2 + (0.002462\ Vdc)^2 + (0.002462\ Vdc)^2]^{0.5}$$

$$= \pm 0.005335\ Vdc \quad [1\sigma]$$

Convert to % CS by multiplying by 100% and dividing by 10 Vdc

$$CAL6 = \pm(0.005335\ Vdc)(100\%\ CS / 10\ Vdc)$$
$$= \pm\ 0.053350\ \%\ CS \quad [1\sigma]$$

2. Section 11.6.1.1.4: Delete existing text under section 11.6.1.1.4 and replace with the following new text as follows:

11.6.1.1.4 Setting Tolerance (ST6)

Per References 3.5.y and 3.5.z, this module contains circuits which are calibrated individually. These circuits consists of: 1) input isolators (one for each recirculation flow loop), 2) square root converters, 3) a summer, and 4) an analog output isolator (which provides the total output flow signal). The setting tolerances associated with calibrating the ABB RFM circuits consist of a combination of the input calibration tolerances (T1) and output calibration tolerances (T2). Setting tolerance uncertainties associated with the ABB RFM is determined below:

a) Input Isolators

Per References 3.5.y and 3.5.z, calibration tolerances associated with calibrating the input isolator are,

$T1_{II} = 0$
$T2_{II} = \pm 0.05$ Vdc

These uncertainties are 3σ values and must be converted to 1σ values by dividing by three. These uncertainties are converted to equivalent output values at the square root converter and then to equivalent output values at the summer. Convert to equivalent square root converter output value by utilizing equations and the operating point of interest (75% flow = 3.6 Vdc) determined in Section 4.16:

$$y = (k)(\sigma_{ERROR})/[2(x)^{0.5}]$$

by substitution,

$T2_{II\ (SR\ OUT)}$ $= \pm[(3.162278\ Vdc/Vdc^{0.5})*(T2_{II}/3)]/[2(3.6\ Vdc)^{0.5}]$
$= \pm[(3.162278\ Vdc/Vdc^{0.5})*(0.05\ Vdc/3)]/[2(3.6\ Vdc)^{0.5}]$
$= \pm 0.013889\ Vdc$ $[1\sigma]$

Convert to equivalent summer output value by utilizing equations determined in Section 4.17:

$$\sigma_{OUT} = [(k1*\sigma_{ERROR\ X})^2 + (k2*\sigma_{ERROR\ Y})^2]^{0.5}$$

by substitution,

$T2_{II\ (SUM\ OUT)}$ $= \pm[(k1*T2_{II\ (SR\ OUT)})^2 + (k2*T2_{II\ (SR\ OUT)})^2]^{0.5}$
$= \pm[(0.5*0.013889\ Vdc)^2 + (0.5*0.013889\ Vdc)^2]^{0.5}$
$= \pm 0.009821\ Vdc$ $[1\sigma]$

b) Square Root Converters

Per References 3.5.y and 3.5.z, calibration tolerances associated with calibrating the square root converters are,

$T1_{SR}$ = ±0.050 Vdc
$T2_{SR}$ = ±0.025 Vdc

These uncertainties are 3σ values and must be converted to 1σ values by dividing by three. Convert $T1_{SR}$ to an equivalent square root converter output value by utilizing equations and the operating point of interest (75% flow = 3.6 Vdc) determined Section 4.16:

$$y = (k)(\sigma_{ERROR})/[2(x)^{0.5}]$$

by substitution,

$T1_{SR\ (SR\ OUT)}$ $= \pm[(3.162278\ Vdc/Vdc^{0.5})*(T1_{SR}/3)]/[2(3.6\ Vdc)^{0.5}]$
$= \pm[(3.162278\ Vdc/Vdc^{0.5})*(0.050\ Vdc/3)]/[2(3.6\ Vdc)^{0.5}]$
$= \pm 0.013889\ Vdc$

Convert to equivalent summer output value by utilizing equations determined in Section 4.17:

$$\sigma_{OUT} = [(k1*\sigma_{ERROR\ X})^2 + (k2*\sigma_{ERROR\ Y})^2]^{0.5}$$

by substitution,

$T1_{SR\ (SUM\ OUT)}$ $= \pm[(k1*T1_{SR\ (SR\ OUT)})^2 + (k2*T1_{SR\ (SR\ OUT)})^2]^{0.5}$
$= \pm[(0.5*0.013889\ Vdc)^2 + (0.5*0.013889\ Vdc)^2]^{0.5}$
$= \pm 0.009821\ Vdc$ $[1\sigma]$

$T2_{SR\ (SUM\ OUT)}$ $= \pm[(k1*\ T2_{SR})^2 + (k2*\ T2_{SR})^2]^{0.5}$
$= \pm[(0.5*0.025\ Vdc/3)^2 + (0.5*0.025\ Vdc/3)^2]^{0.5}$
$= \pm 0.005893\ Vdc$ $[1\sigma]$

c) Summer

Per References 3.5.y and 3.5.z, calibration tolerances associated with calibrating the summer are,

$T1_{SUM}$ = 0
$T2_{SUM}$ = ±0.010 Vdc

These uncertainties are 3σ values and must be converted to 1σ values by dividing by three.

$T2_{SUM}$ = ±0.010 Vdc /3
= ±0.003333 Vdc [1σ]

d) Output Isolator

Per References 3.5.y and 3.5.z, calibration tolerances associated with calibrating the output isolator are,

$T1_{OI}$ = 0
$T2_{OI}$ = ±0.010 Vdc

These uncertainties are 3σ values and must be converted to 1σ values by dividing by three.

$T2_{OI}$ = ±0.010 Vdc /3
= ±0.003333 Vdc [1σ]

e) Determine Total Setting Tolerance Uncertainty (ST6):

Using the methodology of Reference 3.34:

$$ST6_{VDC} = \pm[(T2_{II\,(SUM\,OUT)})^2 + (T1_{SR\,(SUM\,OUT)})^2 + (T2_{SR\,(SUM\,OUT)})^2 + (T2_{SUM})^2 + (T2_{OI})^2]^{0.5}$$

$$= \pm[(0.009821\text{ Vdc})^2 + (0.009821\text{ Vdc})^2 + (0.005893\text{ Vdc})^2 + (0.003333\text{ Vdc})^2 + (0.003333\text{ Vdc})^2]^{0.5}$$

$$= \pm 0.015807\text{ Vdc} \qquad [1\sigma]$$

Convert to % CS by multiplying by 100% and dividing by 10 Vdc

ST6 = ±(0.015807 Vdc)(100% CS / 10 Vdc)
= ± 0.158070 % CS [1σ]

3. Section 11.6.1.1.5: Delete existing text under section 11.6.1.1.5 and replace with the following new text as follows:

11.6.1.1.5 Input Uncertainty (σinput6)

In addition to its own error terms, Module 6 also operates on the error terms from Module 1. Therefore, the random error term (1σ) from the flow transmitter must be transferred through the ABB RFM from input to output per Section 4.16 and 4.17. The resultant term will be σinput6 and $\sigma input6_C$ for this module. From Section 11.1.1.8,

σ1 = ±2.691847 % CS [1σ]

For the Comparator Trip

$$\sigma 1_C \quad = \quad \pm 0.998018\%\ \mathrm{CS} \qquad [1\sigma]$$

The errors are transferred through the ABB RFM as follows:

Per References 3.5.y and 3.5.z, this module contains circuits which contain square root converters and a summer. These uncertainties are converted to equivalent output values at the square root converters and then to equivalent output values at the summer. Convert to equivalent square root converter output value by utilizing equations and the operating point of interest (75% flow = 36 % CS) determined in Section 4.16:

$$y \quad = (k)(\sigma_{\mathrm{ERROR}})/[2(x)^{0.5}]$$

by substitution,

$$\begin{aligned}
\sigma\mathrm{input}6_{(\mathrm{SR})} &= \pm[(10\ \%\ \mathrm{CS}/\%\ \mathrm{CS}^{0.5})*(\sigma 1)]/[2(36\ \%\ \mathrm{CS})^{0.5}] \\
&= \pm[(10\ \%\ \mathrm{CS}/\%\ \mathrm{CS}^{0.5})*(2.691847\ \%\ \mathrm{CS})]/[2(36\ \%\ \mathrm{CS})^{0.5}] \\
&= \pm 2.243206\ \%\ \mathrm{CS} \qquad [1\sigma]
\end{aligned}$$

$$\begin{aligned}
\sigma\mathrm{input}6_{\mathrm{C(SR)}} &= \pm[(10\ \%\ \mathrm{CS}/\%\ \mathrm{CS}^{0.5})*(\sigma 1_{\mathrm{C}})]/[2(36\ \%\ \mathrm{CS})^{0.5}] \\
&= \pm[(10\ \%\ \mathrm{CS}/\%\ \mathrm{CS}^{0.5})*(0.998018\ \%\ \mathrm{CS})]/[2(36\ \%\ \mathrm{CS})^{0.5}] \\
&= \pm 0.831682\ \%\ \mathrm{CS} \qquad [1\sigma]
\end{aligned}$$

Convert to equivalent summer output value by utilizing equations determined in Section 4.17:

$$\sigma_{\mathrm{OUT}} \quad = [(k1*\sigma_{\mathrm{ERROR\ X}})^2 + (k2*\sigma_{\mathrm{ERROR\ Y}})^2]^{0.5}$$

by substitution,

$$\begin{aligned}
\sigma\mathrm{input}6 &= \pm[(k1*\sigma\mathrm{input}6_{(\mathrm{SR})})^2 + (k2*\sigma\mathrm{input}6_{(\mathrm{SR})})^2]^{0.5} \\
&= \pm[(0.5*2.243206\ \%\ \mathrm{CS})^2 + (0.5*2.243206\ \%\ \mathrm{CS})^2]^{0.5} \\
&= \pm 1.586186\ \%\ \mathrm{CS} \qquad [1\sigma]
\end{aligned}$$

$$\begin{aligned}
\sigma\mathrm{input}6_{\mathrm{C}} &= \pm[(k1*\sigma\mathrm{input}6_{\mathrm{C\ (SR)}})^2 + (k2*\sigma\mathrm{input}6_{\mathrm{C\ (SR)}})^2]^{0.5} \\
&= \pm[(0.5*0.831682\ \%\ \mathrm{CS})^2 + (0.5*0.831682\ \%\ \mathrm{CS})^2]^{0.5} \\
&= \pm 0.588088\ \%\ \mathrm{CS} \qquad [1\sigma]
\end{aligned}$$

4. Revise section 11.6.1.1.6 as follows:

11.6.1.1.6 Determination of Module Random Error (σ6)

Using the methodology of Reference 3.3, and converting to % Flow by multiplying by 125/100:

$$\begin{aligned}
\sigma 6 &= \pm(125/100)*[(\mathrm{RA}6_{(1\sigma)})^2 + (\mathrm{RD}6_{(1\sigma)})^2 + (\mathrm{CAL}6)^2 + (\mathrm{ST}6_{(1\sigma)})^2 + (\sigma\mathrm{input}6)^2]^{0.5}\ \%\ \mathrm{Flow} \\
&= \pm(125/100)*[(0.5)^2 + (0.25)^2 + (\boldsymbol{0.053350})^2 + (\boldsymbol{0.158070})^2 + (\boldsymbol{1.586186})^2]^{0.5}\ \%\ \mathrm{Flow} \\
&= \pm\boldsymbol{2.112581}\ \%\ \mathrm{Flow} \qquad [1\sigma]
\end{aligned}$$

For the Comparator Trip:

$$\sigma 6_{\mathrm{C}} \quad = \quad \pm(125/100)*[(\mathrm{RA}6_{(1\sigma)})^2 + (\mathrm{RD}6_{(1\sigma)})^2 + (\mathrm{CAL}6)^2 + (\mathrm{ST}6_{(1\sigma)})^2 + (\sigma\mathrm{input}6_{\mathrm{C}})^2]^{0.5}\ \%\ \mathrm{Flow}$$

= $\pm(125/100)*[(0.5)^2 + (0.25)^2 + (\boldsymbol{0.053350})^2 + (\boldsymbol{0.158070})^2 + (\boldsymbol{0.588088})^2]^{0.5}$ % Flow
= ±***1.035450*** % Flow [1σ]

11.6.1.2 Module 6 Non-Random Errors (Σe6)

1. Section 11.6.1.2.9: Delete existing text under section 11.6.1.2.9 and replace with the following new text as follows:

11.6.1.2.9 Non-Random Input Error (einput6)

In addition to its own error terms, Module 6 also operates on the error terms from Module 1. Therefore, the non-random error term (Σe1) from the flow transmitter must be transferred through the ABB RFM from input to output per Section 4.16 and 4.17. The resultant term will be einput6 for this module. From Section 11.1.2.10,

Σe1 = 1.171643 % CS

The errors are transferred through the ABB RFM as follows:

Per References 3.5.y and 3.5.z, this module contains circuits which contain square root converters and a summer. These uncertainties are converted to equivalent output values at the square root converters and then to equivalent output values at the summer. Convert to equivalent square root converter output value by utilizing equations and the operating point of interest (75% flow = 36 % CS) determined in Section 4.16:

$y = (k)(e_{ERROR})/[2(x)^{0.5}]$

by substitution,

$einput6_{(SR)} = \pm[(10\ \%\ CS/\%\ CS^{0.5})*(\Sigma e1)]/[2(36\ \%\ CS)^{0.5}]$
$= \pm[(10\ \%\ CS/\%\ CS^{0.5})*(1.171643\ \%\ CS)]/[2(36\ \%\ CS)^{0.5}]$
$= \pm 0.976369\ \%\ CS$

Convert to equivalent summer output value by utilizing equations determined in Section 4.17:

$e_{OUT} = (k1*e_{ERROR\ X}) + (k2*e_{ERROR\ Y})$

by substitution,

$einput6 = \pm(k1*einput6_{(SR)}) + (k2*einput6_{(SR)})$
$= \pm(0.5*0.976369\ \%\ CS) + (0.5*0.976369\ \%\ CS)$
$= \pm 0.976369\ \%\ CS$

2. Revise 11.6.1.2.10 as follows:

11.6.1.2.10 Non-Random Error ***(Σe6)***

From Reference 3.3 the non-random error is the algebraic sum of all the above terms. In addition, this term can be converted to % Flow by multiplying by 125/100. The result is;

$\Sigma e6 = \pm(125/100)*(e6H + e6T + e6R + e6S + e6SP + e6P + e6p + e6V + einput6)$ % Flow
$= \pm(125/100)*(0 + 0.5+ 0 + 0 + 0 + 0 + 0 + 0 + \mathbf{\mathit{0.976369}})$ % Flow
$= \pm\mathbf{\mathit{1.845461}}$ % Flow

11.6.2.1 Module 6A Random Error (σ6A)

1. Revise Section 11.6.2.1.1 as follows to correct RA6A reference accuracy determination:

Per Section 8.6.1, the reference accuracy for this module is:

RA6A = ***±2 % CS (based on 1% trip setpoint error plus 1% total flow signal error)***

Per Assumption 5.1, this is assumed to be a 2 sigma value. This is then converted to a 1 sigma value by dividing by 2. In the same step this will be converted to % Flow by multiplying by 125/100.

$RA6A_{(1\sigma)} = \pm(RA6A/2 * (125/100)$ % Flow
$RA6A_{(1\sigma)} = \pm$***(2 % CS/2)*** * (125/100) % Flow
$RA6A_{(1\sigma)} = \pm$***1.25 % Flow (overall RFM uncertainty from input through actuation)***

2. Section 11.6.2.1.3: Delete existing text under section 11.6.2.1.3 and replace with the following new text as follows:

11.6.2.1.3 Calibration Uncertainty (CAL6A and CAL6B)

CAL6A:

Per References 3.5.y and 3.5.z, this module is a bistable, and it specifies use of a Fluke 45 DMM for measurement of voltage input signals while monitoring the module for actuation. For the voltage range of interest for this calculation (0 – 10 Vdc and with control room environments per References 3.5.y and 3.5.z), the reference accuracy for a Fluke 45 is ±0.002462 Vdc (from Section 9.0). The Fluke 45 is a digital output device, and therefore, the reading error is considered to be the least significant increment of the display (or resolution) (see Reference 3.34). Per section 9.1, reading error is included in the uncertainty value. From Section 5.2, errors attributed to calibration standards are considered negligible. Therefore, the only terms which contribute to calibration uncertainty (CAL) are uncertainties associated with measuring input calibration signals (MTE1) and output calibration signals (MTE2).

Since there is only one MTE used to calibrate this module,

$CAL6A_{VDC} = MTE_{45} = \pm 0.002462$ Vdc [1σ]

Convert to % Flow by multiplying by 125% Flow and dividing by 10 Vdc.

CAL6A = ±(0.002462 Vdc)(125% Flow / 10 Vdc)
= ± 0.030775 % Flow [1σ]

CAL6B:

Per References 3.5.y and 3.5.z, this module is a bistable that compares two input signals and actuates upon specified deviations. References 3.5.y and 3.5.z specifies use of two Fluke 45 DMM's for measurement of voltage input signals while monitoring the module for actuation. For the voltage range of interest for this calculation (0 – 10 Vdc and with control room environments per References 3.5.y and 3.5.z), the reference accuracy for a Fluke 45 is ±0.002462 Vdc (from Section 9.0) which includes reading error.

This module is modeled as a summer to combine the two measured input signals by utilizing equations determined in Section 4.17. It is calibrated by applying two measured input signals with two Fluke 45 DMM's ($MTE1_D$ and $MTE2_D$) while monitoring it for actuation. The uncertainties associated with measuring the input and signals ($MTE1_D$ and $MTE2_D$) was determined above as:

$MTE1_D = MTE_{45} = \pm 0.002462$ Vdc [1σ]
$MTE2_D = MTE_{45} = \pm 0.002462$ Vdc [1σ]

Utilizing equations in Section 4.17,

$$\sigma_{OUT} = [(k1 * \sigma_{ERROR\ X})^2 + (k2 * \sigma_{ERROR\ Y})^2]^{0.5}$$

by substitution,

$$CAL6B_{VDC} = \pm[(k1 * MTE1_D)^2 + (k2 * MTE2_D)^2]^{0.5}$$
$$= \pm[(0.5 * 0.002462\ Vdc)^2 + (0.5 * 0.002462\ Vdc)^2]^{0.5}$$
$$= \pm 0.001741\ Vdc \quad [1\sigma]$$

Convert to % Flow by multiplying by 125% Flow and dividing by 10 Vdc.

$$CAL6B = \pm(0.001741\ Vdc)(125\%\ Flow / 10\ Vdc)$$
$$= \pm\ 0.021763\ \%\ Flow \quad [1\sigma]$$

3. Section 11.6.1.1.4: Delete existing text under section 11.6.1.1.4 and replace with the following new text as follows:

11.6.2.1.4 Setting Tolerance (ST6A and ST6B)

ST6A:

Per References 3.5.y and 3.5.z, the calibration tolerance for setting this module is,

$T6A = \pm 0.1$ Vdc

This uncertainty is a 3σ values and must be converted to 1σ values by dividing by three.

$$ST6A_{VDC} = \pm(T6A)/3$$
$$= \pm(0.1\ Vdc)/3$$
$$= \pm 0.033333\ Vdc \quad [1\sigma]$$

Convert to % Flow by multiplying by 125% Flow and dividing by 10 Vdc.

$$ST6A = \pm(0.033333\ Vdc)(125\ \%\ Flow / 10\ Vdc)$$
$$= \pm\ 0.416663\ \%\ Flow \quad [1\sigma]$$

ST6B:

Per References 3.5.y and 3.5.z, this module is a bistable that compares two input signals and actuates upon specified deviations. From References 3.5.y and 3.5.z, the calibration tolerances for setting the two inputs signals are:

T6B1 = ±0.1 Vdc
T6B2 = ±0.01 Vdc

These uncertainties are a 3σ values and must be converted to 1σ values by dividing by three.

$$
\begin{aligned}
ST6B1_{VDC} &= \pm(T6B1)/3\\
&= \pm(0.1\ Vdc)/3\\
&= \pm 0.033333\ Vdc && [1\sigma]
\end{aligned}
$$

$$
\begin{aligned}
ST6B2_{VDC} &= \pm(T6B2)/3\\
&= \pm(0.01\ Vdc)/3\\
&= \pm 0.003333\ Vdc && [1\sigma]
\end{aligned}
$$

This module is modeled as a summer to combine the two measured input tolerances by utilizing equations determined in Section 4.17.

$$\sigma_{OUT} = [(k1*\sigma_{ERROR\ X})^2 + (k2*\sigma_{ERROR\ Y})^2]^{0.5}$$

by substitution,

$$
\begin{aligned}
ST6B_{VDC} &= \pm[(k1*ST6B1_{VDC})^2 + (k2*ST6B2_{VDC})^2]^{0.5}\\
&= \pm[(0.5*0.033333\ Vdc)^2 + (0.5*0.003333\ Vdc)^2]^{0.5}\\
&= \pm 0.016750 Vdc && [1\sigma]
\end{aligned}
$$

Convert to % Flow by multiplying by 125% Flow and dividing by 10 Vdc.

$$
\begin{aligned}
ST6B &= \pm(0.016750\ Vdc)(125\%\ Flow\ /\ 10\ Vdc)\\
&= \pm\ 0.209375\ \%\ Flow && [1\sigma]
\end{aligned}
$$

4. Section 11.6.2.1.5: Delete existing text under section 11.6.2.1.5 and replace with the following new text as follows:

11.6.2.1.5 Input Uncertainty (σinput6A and σinput6B)

In addition to its own error terms, Modules 6A and 6B also operate on the error terms from Module 6. Therefore, the random error terms (σ6 and $\sigma6_C$) from Module 6 must be transferred through Modules 6A and 6B. The resultant terms will be σinput6A and σinput6B for this module. However since σ6 and $\sigma6_C$ includes the total flow Reference Accuracy ($RA6_{(1\sigma)}$) as noted in section 11.6.1.1.6, $RA6_{(1\sigma)}$ will be subtracted from the values of σ6 and σ6c to determine σinput6A and σinput6B. This is because the reference accuracy of Module 6A (RA6A) is expressed in terms of total overall uncertainty.

$$
\begin{aligned}
\sigma input6A &= \pm\ (125\%\ Flow/100\%\ CS)[[(100\%\ CS\ /125\%\ Flow)*(\sigma6)]^2 - (RA6_{(1\sigma)})^2]^{0.5}\\
&= \pm\ (125\%\ Flow/100\%\ CS)[[(100\%\ CS\ /125\%\ Flow)*(2.112581)]^2 - (0.5\ \%\ CS)^2]^{0.5}\\
&= \pm 2.018012\ \%\ Flow
\end{aligned}
$$

$$
\begin{aligned}
\sigma input6A_{AV} &= \pm\ (125\%\ Flow/100\%\ CS)[[(100\%\ CS\ /125\%\ Flow)*(\sigma6_C)]^2 - (RA6_{(1\sigma)})^2]^{0.5}\\
&= \pm\ (125\%\ Flow/100\%\ CS)[[(100\%\ CS\ /125\%\ Flow)*(1.035450)]^2 - (0.5\ \%\ CS)^2]^{0.5}
\end{aligned}
$$

= ±0.825549 % Flow

For the Comparator Trip, input errors are combined by modeling the comparator as a summer per equations in section 4.17, because the comparator is influenced by two input uncertainties. As such, the process errors will cancel each other (see section 4.9). Therefore, $\sigma input6A_{AV}$ will be utilized to determine $\sigma input6B$ as follows:

$$\sigma input6B = \pm[(k1*\sigma input6A_{AV})^2 + (k2*\sigma input6A_{AV})^2]^{0.5}$$
$$= \pm[(0.5*0.825549 \text{ \% Flow})^2 + (0.5*0.825549 \text{ \% Flow})^2]^{0.5}$$
$$= \pm 0.583751 \text{ \% Flow} \quad [1\sigma]$$

(Note that use of $\sigma 6$ and $\sigma 6_C$ values in this determination is slightly conservative, because the values of $\sigma 6$ and $\sigma 6_C$ includes calibration and setting tolerance uncertainties associated with the ABB RFM output isolator, and the output isolator does not contribute uncertainty to the bistable circuits. Impact due to this conservatism is negligible compared to the other error terms.)

5. Section 11.6.2.1.6: Delete existing text under section 11.6.2.1.6 and replace with the following new text as follows:

11.6.2.1.6 Determination of Module Random Error (σ6A, σ6B)

Using the methodology of Reference 3.3,

$$\sigma 6A = \pm[(RA6A_{(1\sigma)})^2 + (RD6A_{(1\sigma)})^2 + (CAL6A)^2 + (ST6A_{(1\sigma)})^2 + (\sigma input6A)^2]^{0.5} \text{ \% Flow}$$
$$= \pm[(1.25)^2 + (0)^2 + (0.030775)^2 + (0.416663)^2 + (2.018012)^2]^{0.5} \text{ \% Flow}$$
$$= \pm 2.410275 \text{ \% Flow} \quad [1\sigma]$$

$$\sigma 6A_{AV} = \pm[(RA6A_{(1\sigma)})^2 + (RD6A_{(1\sigma)})^2 + (CAL6A)^2 + (ST6A_{(1\sigma)})^2 + (\sigma input6A_{AV})^2]^{0.5} \text{ \% Flow}$$
$$= \pm[(1.25)^2 + (0)^2 + (0.030775)^2 + (0.416663)^2 + (0.825549)^2]^{0.5} \text{ \% Flow}$$
$$= \pm 1.555180 \text{ \% Flow} \quad [1\sigma]$$

$$\sigma 6B = \pm[(RA6A_{(1\sigma)})^2 + (RD6A_{(1\sigma)})^2 + (CAL6B)^2 + (ST6B_{(1\sigma)})^2 + (\sigma input6B)^2]^{0.5} \text{ \% Flow}$$
$$= \pm[(1.25)^2 + (0)^2 + (0.021763)^2 + (0.209375)^2 + (0.583751)^2]^{0.5} \text{ \% Flow}$$
$$= \pm 1.395556 \text{ \% Flow} \quad [1\sigma]$$

11.6.2.2 Module 6A Non-Random Errors (Σe6A)

1. Section 11.6.2.2.9: Delete existing text under section 11.6.2.2.9 and replace with the following new text as follows:

11.6.2.2.9 Non-Random Input Error (einput6A and einput6B)

In addition to its own error terms, Modules 6A and 6B also operate on the error terms from Module 6. Therefore, the non-random error term (Σe6) from the Module 6 must be transferred through the ABB Bitable from input to output. The resultant terms will be einput6A and einput6. From Section 11.1.2.10,

$$einput6A = \Sigma e6 \quad \pm 1.845461 \text{ \% Flow}$$

For the Comparator Trip, input errors are combined by modeling the comparator as a summer per equations in section 4.17.

einput6B = ±(k1* Σe6) + (k2* Σe6)
= ±(0.5*1.845461 % Flow) + (0.5*1.845461 % Flow)
= ±1.845461 % Flow [1σ]

2. Revise section 11.6.2.2.10 as follows:

11.6.2.2.10 Non-Random Error (Σe6A, Σe6B)

From Reference 3.3 the non-random error is the algebraic sum of all the above terms. In addition, all terms except einput6A and einput6B are in % CS and must be multiplied by 125/100 to convert to % Flow.

Σe6A = ±(125/100)*(e6AH + e6AT + e6AR + e6AS + e6ASP + e6AP + e6Ap + e6AV) + einput6A % Flow

= ±(125/100)*(0 + 0+ 0 + 0 + 0 + 0 + 0 + 0) + ***1.845461*** % Flow
= ±***1.845461*** % Flow

Σe6B = ±(125/100)*(e6AH + e6AT + e6AR + e6AS + e6ASP + e6AP + e6Ap + e6AV) + einput6B % Flow

= ±(125/100)*(0 + 0+ 0 + 0 + 0 + 0 + 0 + 0) + ***1.845461*** % Flow
= ±***1.845461*** % Flow

12.0 INSTRUMENT CHANNEL TOTAL ERRORS

1. Revise section 12.1.1 as follows by applying the recalculated module errors:

$$Ten_{AFB} = \pm(2 * \sigma 4D + \Sigma e4D)$$
$$Ten_{AFB} = \pm(2 * \mathbf{\mathit{2.581939}} + \mathbf{\mathit{1.970337}})$$

$$Ten_{AFB} = \pm \mathbf{\mathit{7.134215}} \text{ \% Power}$$

And the AV total error for TLO is determined as

$$Ten_{AFB(AV)} = \pm(2 * \sigma 4D_{AV} + \Sigma e4D_{AV})$$
$$Ten_{AFB(AV)} = \pm(2 * \mathbf{\mathit{2.228588}} + \mathbf{\mathit{1.150337}})$$

$$Ten_{AFB(AV)} = \pm \mathbf{\mathit{5.607513}} \text{\% Power}$$

2. Revise section 12.1.2 as follows by applying the recalculated module errors:

$$Ten_{AFBSLO} = \pm(2 * \sigma 4D_{SLO} + \Sigma e4D_{SLO})$$
$$Ten_{AFBSLO} = \pm(2 * \mathbf{\mathit{2.509742}} + \mathbf{\mathit{1.841154}})$$

$$Ten_{AFBSLO} = \pm \mathbf{\mathit{6.860638}} \text{ \% Power}$$

And the AV total error for SLO is determined as

$$Ten_{AFB(AV)\,SLO} = \pm(2 * \sigma 4D_{AVSLO} + \Sigma e4D_{AVSLO})$$
$$Ten_{AFB(AV)\,SLO} = \pm(2 * \mathbf{\mathit{2.208686}} + \mathbf{\mathit{1.021154}})$$

$$Ten_{AFB(AV)\,SLO} = \pm \mathbf{\mathit{5.438526}} \text{ \% Power}$$

3. Revise section 12.3 as follows by applying the recalculated module errors and Level 2 methodology defined in minor revision 2A:

$$Ten_{RFB} = \pm(\sigma 5C + \Sigma e5C) \text{ \% Power} \qquad \text{[Ref 3.34]}$$
$$Ten_{RFB(AV)} = \pm(\sigma 5C_{AV} + \Sigma e5C_{AV}) \text{ \% Power} \qquad \text{[Ref 3.34]}$$

These uncertainty terms include both the uncertainties associated with the RBM neutron signal and the Recirculation Flow Monitor. From Sections 11.5.3.1.6 and 11.5.3.2.10:

$$Ten_{RFB} = \pm(\mathbf{\mathit{2.714373}} + \mathbf{\mathit{2.056459}}) \text{ \% Power}$$
$$Ten_{RFB} = \pm \mathbf{\mathit{4.770832}} \text{ \% Power}$$

And

$$Ten_{RFB(AV)} = \pm(\mathbf{\mathit{2.240011}} + \mathbf{\mathit{1.236459}}) \text{ \% Power}$$
$$Ten_{RFB(AV)} = \pm \mathbf{\mathit{3.476470}} \text{ \% Power}$$

4. Revise section 12.5 as follows by applying the errors from the ABB RFM

Ten_{RFMU} and $Ten_{RFMU(AV)}$ are made up of the uncertainty terms from Recirculation Flow Monitor ***6A***. From Sections ***11.6.2.1.6 and 11.6.2.2.10***:

$$Ten_{RFMU} = \pm(2\sigma 6A + \Sigma e6A)\ \%\ \text{Flow}$$
$$Ten_{RFMU} = \pm(2 * 2.410275 + 1.845461)\ \%\ \text{Flow}$$
$$Ten_{RFMU} = \pm 6.666011\ \%\ \text{Flow}$$

And

$$Ten_{RFMU(AV)} = \pm(2\sigma 6A_{AV} + \Sigma e6A)\ \%\ \text{Flow}$$
$$Ten_{RFMU(AV)} = \pm(2 * 1.555180 + 1.845461)\ \%\ \text{Flow}$$
$$Ten_{RFMU(AV)} = \pm 4.955821\%\ \text{Flow}$$

Note that for the RFM loops there were no non-random terms associated with the process. Therefore, the non-random term ***Σe6A*** is applicable to both the AL and AV total error terms.

5. Revise section 12.6 as follows by applying the errors from the ABB RFM

Ten_{RFMC} and $Ten_{RFMC(AV)}$ are made up of the uncertainty terms from Recirculation Flow Monitor ***6B***. From Sections ***11.6.2.1.6 and 11.6.2.2.10***:

$$Ten_{RFMC} = \pm(2\sigma 6B + \Sigma e6B)\ \%\ \text{Flow}$$
$$Ten_{RFMC} = \pm(2 * 1.516003 + 1.845461)\ \%\ \text{Flow}$$
$$Ten_{RFMC} = \pm 4.877467\ \%\ \text{Flow}$$

Per Section 4.9, the process variables have already been removed from the uncertainty terms for the comparator trip. Therefore,

$$Ten_{RFMC(AV)} = Ten_{RFMC} = \pm 4.877467\ \%\ \text{Flow}$$

13.0 ERROR ANALYSIS SUMMARY

1. Delete section 13.0 and replace with the following:

~~***The total uncertainties applicable to the ABB Flow Unit are smaller than those associated with the GE Flow Unit. Therefore, all calculations will be performed using those terms applicable to the GE Flow Unit since the results will then be conservative for operation using the ABB Flow Unit.***~~

Per section 4.15, the GE Flow Units have been replaced with ABB RFM Flow Units. Therefore, calculation results are based on ABB RFM Flow Unit uncertainties.

2. Revise section 13.1.1 as follows:

$NTSP_{STP2} = FCS_{SP}*W + (AL_{STP2OS} - Ten_{AFB})$
$NTSP_{STP2} = 0.61*W + (69.76 - 7.134215)$
$NTSP_{STP2} = 0.61*W + 62.625785$, ***rounded to*** $0.61W + 62.6$ ***% Power***

In similar fashion the Allowable Value can be calculated using the applicable uncertainty (***5.607513*** % Power) from Section 12.1.1

$AV_{STP2} = FCS_{SP}*W + NTSP_{STP2OS} + Ten_{AFB(AV)}$
$AV_{STP2} = 0.61*W + 62.625785 + 5.607513$
$AV_{STP2} = 0.61*W + 68.233298$, ***rounded to*** $0.61W + 68.2$ ***% Power***

3. Revise section 13.1.2 as follows:

$NTSP_{STP1} = FCS_{SP}*W + (AL_{STP1OS} - Ten_{AFB})$
$NTSP_{STP1} = 0.54*W + (57.39 - 6.860638)$
$NTSP_{STP1} = 0.54*W + 50.529362$, ***rounded to*** $0.54W + 50.5$ ***% Power***

In similar fashion the Allowable Value can be calculated using the applicable uncertainty (***5.438526*** % Power) from Section 12.1.2

$AV_{STP1} = FCS_{SP}*W + NTSP_{STP1OS} + Ten_{AFB(AV)}$
$AV_{STP1} = 0.54*W + 50.529362 + 5.438526$
$AV_{STP1} = 0.54*W + 55.967888$, ***rounded to*** $0.54W + 55.9$ ***% Power***

4. Revise section 13.1.3 as follows:

$NTSP_{STP2RB} = FCS_{SP}*W + (AL_{STP2RBOS} - Ten_{AFB})$
$NTSP_{STP2RB} = 0.61*W + (58.51 - 7.134215)$
$NTSP_{STP2RB} = 0.61*W + 51.375785$, ***rounded to*** $0.61W + 51.3$ ***% Power***

In similar fashion the Allowable Value can be calculated using the applicable uncertainty (***5.607513*** % Power) from Section 12.1.1

$AV_{STP2RB} = FCS_{SP}*W + NTSP_{STP2RBOS} + Ten_{AFB(AV)}$
$AV_{STP2RB} = 0.61*W + 51.375785 + 5.607513$
$AV_{STP2RB} = 0.61*W + 56.983298$, ***rounded to*** $0.61W + 56.9$ ***% Power***

5. Revise section 13.1.4 as follows:

$NTSP_{STP1RB} = FCS_{SP}*W + (AL_{STP1RBOS} - Ten_{AFB})$

$NTSP_{STP1RB} = \boldsymbol{0.54*W + (46.14 - 6.860638)}$

$NTSP_{STP1RB} = \boldsymbol{0.54*W + 39.279362}$***, rounded to*** $\boldsymbol{0.54W + 39.2}$ ***% Power***

In similar fashion the Allowable Value can be calculated using the applicable uncertainty (***5.438526*** % Power) from Section 12.1.2

$AV_{STP1RB} = FCS_{SP}*W + NTSP_{STP1RBOS} + Ten_{AFB(AV)}$

$AV_{STP1RB} = \boldsymbol{0.54*W + 39.279362 + 5.438526}$

$AV_{STP1RB} = \boldsymbol{0.54*W + 44.717888}$***, rounded to*** $\boldsymbol{0.54W + 44.7}$ ***% Power***

6. Revise section 13.3.1 as follows with new total uncertainty and in accordance with minor revision 2A of this analysis:

$AV_{RBM2} = NTSP + Ten_{RFB(AV)}$ % Power

$AV_{RBM2} = 0.66*W + 51 + \boldsymbol{3.476470}$ % Power

$AV_{RBM2} = 0.66*W + \boldsymbol{54.476470}$ % Power

Because the computed AV is in excess of the Reference 3.15 value, the fixed offset of the final NTSP should be lowered at least ***0.48*** %. For conservatism, the final calibration NTSP should be:

$NTSP_{RBM2} = 0.66W + 50.5\%$ Power

7. Revise section 13.3.2 as follows with new total uncertainty and in accordance with minor revision 2A of this analysis:

$AV_{RBM1} = NTSP + Ten_{RFB(AV)}$ % Power

$AV_{RBM1} = 0.66*W + 45.7 + \boldsymbol{3.476470}$ % Power

$AV_{RBM1} = 0.66*W + \boldsymbol{49.176470}$ % Power

Because the computed AV is in excess of the Reference 3.15 value, the fixed offset of the final NTSP should be lowered at least ***0.48*** %. For conservatism, the final calibration NTSP should be:

$NTSP_{RBM1} = 0.66W + 45.0\%$ Power

8. Revise section 13.5 as follows:

From Section 12.5 the total uncertainty for this function is ±***6.666011***% Flow. From Reference 3.3 the relationship between NTSP and AL for an upscale trip is:

$AL_{RFMU} = NTSP_{RFMU} + Ten_{RFMU}$ % Flow

$AL_{RFMU} = 108 + \boldsymbol{6.666011}$ % Flow

$AL_{RFMU} = \boldsymbol{114.666011}$ % Flow

In similar fashion the Allowable Value can be calculated using the applicable uncertainty (***4.955821*** % Flow) from Section 12.5.

$AV_{RFMU} = NTSP_{RFMU} + Ten_{RFMU(AV)}$ % Flow

AV_{RFMU} = 108 + ***4.955821*** % Flow
AV_{RFMU} = ***112.955821***% Flow

9. Revise section 13.6 as follows:

From Section 12.6 the total uncertainty for this function is ±***4.877467***% Flow. From Reference 3.3 the relationship between NTSP and AL for an upscale trip is:

AL_{RFMC} = $NTSP_{RFMC} + Ten_{RFMC}$ % Flow
AL_{RFMC} = 10 + ***4.877467*** % Flow
AL_{RFMC} = ***14.877467*** % Flow

Per Section 4.9 the process term has already been removed from the uncertainty terms for the comparator trip. Therefore,

AV_{RFMU} = AL_{RFMC} = ***14.877467*** % Flow

10.0 Add a new section 13.7 and subsections for as-left / as-found tolerances for the APRM flow biased trips for use in instrument performance trending as follows:

13.7 As-Left / As-Found Tolerances For APRM Flow Biased Trips

As-Left / As-Found Tolerances (ALT's /AFT's) are determined for calibrated components, circuits, and modules associated with the APRM flow biased trips. As-Left / As-Found Tolerances are determined in accordance with the methodology provided in section 2.4 as follows:

Module As-Left Tolerance (ALT):

$$ALT = \pm[RA^2 + MTE^2 + RE_{MTE}{}^2]^{0.5}$$

Module As-Found Tolerance (AFT):

$$AFT = \pm[RA^2 + RD^2 + MTE^2 + RE_{MTE}{}^2]^{0.5}$$

where,

RA = Module Reference Accuracy
RD = Module Vendor Specified Instrument Drift
MTE = Module Measurement and Test Equipment (M&TE) Error
RE_{MTE} = Module M&TE Readability

If a particular calibrated component or circuit (or module) is not provided with a reference accuracy specification, the setting tolerance applied during module calibration will be used in place of the reference accuracy specification.

The APRM flow biased trips consists of the following calibrated components or circuits, (or modules):

a) Recirculation Flow Transmitters (Module 1)
b) ABB RFM Input Isolators (Module 6_{II})

c) ABB RFM Square Root Converters (Module 6_{SR})
d) ABB RFM Summer (Module 6_{SUM})
e) ABB RFM Output Isolator (Module 6_{OI})
f) APRM Flow Biased Trip Circuit (Module 4D).

As-Left / As-Found Tolerances are determined for each of these modules per the above methodology as follows:

13.7.1 Recirculation Flow Transmitters (Module 1) As-Left / As-Found Tolerances

a) RA: From section 11.1.1.1,

$$RA1_{FT} = \pm 0.25\ \%\ CS$$

b) RD: From section 11.1.1.2,

$$RD1_{FT} = \pm 0.606306\ \%\ CS$$

c) MTE Uncertainty: From Section 11.1.1.3, the uncertainty of the test equipment used to calibrate module 1 input setting is ±0.868971 % CS (1σ) which includes MTE readability uncertainty. This uncertainty value is converted to a 2-sigma value as follows:

$$\begin{aligned} MTE1_{FT\ IN} &= \pm 2 * (0.868971\ \%\ CS) \\ &= \pm 1.737942\ \%\ CS \end{aligned}$$

Per Section 11.1.1.3, the DMM used to calibrate the transmitter output is a Fluke 45 which has an uncertainty of ±0.012141 mVdc (1σ). Per References 3.5.y and 3.5.z, the calibrated span is 16 mVdc. This uncertainty is converted to units of % CS and converted to a 2-sigma value as follows:

$$\begin{aligned} MTE1_{FT\ OUT} &= \pm 2 * [(0.012141\ mVdc / 16\ mVdc) * 100\ \%\ CS)] \\ &= \pm 0.151763\ \%\ CS \end{aligned}$$

therefore,

$$\begin{aligned} MTE1_{FT} &= \pm[MTE1_{FT\ IN}{}^{2} + MTE1_{FT\ OUT}{}^{2}]^{0.5} \\ &= \pm[(1.737942\ \%\ CS)^{2} + (0.151763\ \%\ CS)^{2}]^{0.5} \\ &= \pm 1.744556\ \%\ CS \end{aligned}$$

d) RE: As noted above, $MTE1_{FT\ IN}$ includes reading error. Per section 11.1.1.3, the reading error associated with the DMM is included in the uncertainty value. Therefore,

$$RE1_{FT\ MTE} = 0$$

e) ALT / AFT: By substitution into section 13.7 equations ALT1 and AFT1 are determined and converted into transmitter calibrated output units of mVdc,

$$\begin{aligned} ALT1_{FT} &= \pm[RA1_{FT}{}^{2} + MTE1_{FT}{}^{2} + RE1_{FT\ MTE}{}^{2}]^{0.5} \\ &= \pm(16\ mVdc/100\ \%\ CS)*[(0.25\ \%\ CS)^{2} + (1.744556\ \%\ CS)^{2} + (0)^{2}]^{0.5} \\ &= \pm 0.281980\ mVdc,\ (\text{rounded to } \pm 0.282\ mVdc) \end{aligned}$$

$$\begin{aligned} AFT1_{FT} &= \pm[RA1_{FT}{}^2 + RD1_{FT}{}^2 + MTE1_{FT}{}^2 + RE1_{FT\,MTE}{}^2]^{0.5} \\ &= \pm(16\ \text{mVdc}/100\ \%\ \text{CS})*[(0.25\ \%\ \text{CS})^2 + (0.606306\ \%\ \text{CS})^2 \\ &\quad + (1.744556\ \%\ \text{CS})^2 + (0)^2]^{0.5} \\ &= \pm 0.298201\ \text{mVdc, (rounded to } \pm 0.298\ \text{mVdc)} \end{aligned}$$

The calculated As-Left Tolerance ($ALT1_{FT}$) bounds the flow transmitter setting tolerance which is 0.08 mVdc per Reference 3.5.y and 3.5.z.

13.7.2 ABB RFM (Module 6) As-Left / As-Found Tolerances

Per section 8.6, the ABB RFM reference accuracy is provided as an overall accuracy specification. Accuracy specifications are not provided for individually calibrated circuits. Therefore, per methodology provided in section 2.4, setting tolerances for individually calibrated circuits will be substituted.

$$RA = ST$$

Additionally, the ABB RFM drift specification is also provided as an overall accuracy specification (±0.5 % CS). Drift specifications are not provided for individually calibrated circuits. As such, the drift associated with each calibrated circuit will be divided between the four calibrated RFM circuits (input isolator, square root converter, summer, and output isolator). Drift is considered to be a random uncertainty. Therefore, drift for each individually calibrated RFM circuit is considered to be,

$$\begin{aligned} Drift_{(CS)} &= \pm[(0.5\ \%CS)^2/4]^{0.5} \\ &= \pm 0.25\ \%\ \text{CS} \end{aligned}$$

Per References 3.5.y and 3.5.z, the calibrated span is 10 Vdc, and drift uncertainty is converted to units of Vdc as follows:

$$\begin{aligned} Drift &= \pm(0.25\ \%\ \text{CS} / 100\ \%\ \text{CS}) * 10\ \text{Vdc} \\ &= \pm 0.025000\ \text{Vdc} \end{aligned}$$

13.7.2.1 ABB RFM Input Isolator Circuit (Module 6_{II}) As-Left / As-Found Tolerances

a) RA: From References 3.5.y and 3.5.z and section 13.7.2 reference accuracy is,

$$RA6_{II} = ST6_{II} = \pm 0.05\ \text{Vdc}$$

b) RD: From section 13.7.2 drift is,

$$RD6_{II} = \pm 0.025000\ \text{Vdc}$$

c) MTE Uncertainty: From Section 11.6.1.1.3.a, the uncertainty of the test equipment used to calibrate module 6_{II} input setting is ±0.868971 % CS (1σ) which includes MTE readability uncertainty. This value is converted to a 2-sigma value and converted to units of Vdc as follows:

$$\begin{aligned} MTE6_{II\,IN} &= \pm 2 * (0.868971\ \%\ \text{CS} / 100\ \%\ \text{CS}) * 10\ \text{Vdc} \\ &= \pm 0.173794\ \text{Vdc} \end{aligned}$$

From section 11.6.1.1.3.a, the uncertainty of the DMM used to calibrate module 6_{II} output is ±0.002462 Vdc. This uncertainty value is converted to a 2-sigma value as follows:

$$MTE6_{II\ OUT} = \pm 2 * (0.002462\ Vdc)$$
$$= \pm 0.004924\ Vdc$$

therefore,

$$MTE6_{II} = \pm[MTE6_{II\ IN}{}^2 + MTE6_{II\ OUT}{}^2]^{0.5}$$
$$= \pm[(0.173794\ Vdc)^2 + (0.004924\ Vdc)^2]^{0.5}$$
$$= \pm 0.173864\ Vdc$$

d) RE: As noted above, $MTE6_{II\ IN}$ includes reading error. Per section 11.6.1.1.3, the reading error associated with the DMM is included in the uncertainty value. Therefore,

$$RE6_{II\ MTE} = 0$$

e) ALT /AFT: By substitution into the section 13.7 equations $ALT6_{II}$ and $AFT6_{II}$ are determined as follows:

$$ALT6_{II} = \pm[RA6_{II}{}^2 + MTE6_{II}{}^2 + RE6_{II\ MTE}{}^2]^{0.5}$$
$$= \pm[(0.05\ Vdc)^2 + (0.173864\ Vdc)^2 + (0)^2]^{0.5}$$
$$= \pm 0.180911\ Vdc,\ (\text{rounded to } \pm 0.181\ Vdc)$$

$$AFT6_{II} = \pm[RA6_{II}{}^2 + RD6_{II}{}^2 + MTE6_{II}{}^2 + RE6_{II\ MTE}{}^2]^{0.5}$$
$$= \pm[(0.05\ Vdc)^2 + (0.025000\ Vdc)^2 + (0.173864\ Vdc)^2 + (0)^2]^{0.5}$$
$$= \pm 0.182630\ Vdc,\ (\text{rounded to } \pm 0.183\ Vdc)$$

The calculated As-Left Tolerance ($ALT6_{II}$) bounds the input isolator setting tolerance which is 0.05 Vdc per Reference 3.5.y and 3.5.z.

13.7.2.1.2 ABB RFM Square Root Converter Circuit (Module 6_{SR}) As-Left / As-Found Tolerances

a) RA: From section 13.7.2, RA = ST. From References 3.5.y and 3.5.z, there is an input setting tolerance (±0.05 Vdc) and an output setting tolerance (±0.025 Vdc). Therefore,

$$RA6_{SR\ IN} = ST6_{SR\ IN} = \pm 0.05\ Vdc$$
$$RA6_{SR\ OUT} = ST6_{SR\ OUT} = \pm 0.025\ Vdc$$

Convert $RA6_{SR\ IN}$ to an equivalent square root converter output value by utilizing equations and the calibrate flow value (75% flow = 3.6 Vdc) determined Section 4.16:

$$y = (k)(\sigma_{ERROR})/[2(x)^{0.5}]$$

by substitution, $RA6_{SR\ IN}$ is converted to equivalent square root converter output value ($RA6_{SR\ IN\ EQ}$)

$$RA6_{SR\ IN\ EQ} = \pm[(3.162278\ Vdc/Vdc^{0.5})*(\ RA6_{SR\ IN})]/[2(3.6\ Vdc)^{0.5}]$$
$$= \pm[(3.162278\ Vdc/Vdc^{0.5})*(\ 0.05\ Vdc)]/[2(3.6\ Vdc)^{0.5}]$$
$$= \pm 0.041667\ Vdc$$

therefore,

$$\begin{aligned} RA6_{SR} &= \pm[RA6_{SR\ IN\ EQ}{}^2 + RA6_{SR\ OUT}{}^2]^{0.5} \\ &= \pm[(0.041667\ \text{Vdc})^2 + (0.025\ \text{Vdc})^2]^{0.5} \\ &= \pm 0.048592\ \text{Vdc} \end{aligned}$$

b) RD: From section 13.7.2 drift is,

$$RD6_{SR} = \pm 0.025000\ \text{Vdc}$$

c) From section 11.6.1.1.3.b, the uncertainty associated with the DMM used for measuring the input setting for module 6_{SR} is ±0.002462 Vdc (1σ). This value is converted to an equivalent square root converter output value by utilizing equations and calibrated flow value (75% flow = 3.6 Vdc) determined Section 4.16:

$$y = (k)(\sigma_{ERROR})/[2(x)^{0.5}]$$

By substitution, $MTE6_{SR\ IN}$ is converted to equivalent square root converter output value ($MTE6_{SR\ IN\ EQ}$):

$$\begin{aligned} MTE6_{SR\ IN\ EQ\ (1\sigma)} &= \pm[(3.162278\ \text{Vdc/Vdc}^{0.5})*(\ RA6_{SR\ IN})]/[2(3.6\ \text{Vdc})^{0.5}] \\ &= \pm[(3.162278\ \text{Vdc/Vdc}^{0.5})*(0.002462\ \text{Vdc})]/[2(3.6\ \text{Vdc})^{0.5}] \\ &= \pm 0.002052\ \text{Vdc} \end{aligned}$$

This value is converted to a 2-sigma value,

$$\begin{aligned} MTE6_{SR\ IN\ EQ} &= \pm(2 * 0.002052\ \text{Vdc}) \\ &= \pm 0.004104\ \text{Vdc} \end{aligned}$$

From section 11.6.1.1.3.b, the uncertainty associated with the DMM used for measuring the output setting for module 6_{SR} is ±0.002462 Vdc (1σ). This value is converted to a 2-sigma value,

$$\begin{aligned} MTE6_{SR\ OUT} &= \pm(2 * 0.002462\ \text{Vdc}) \\ &= \pm 0.004924\ \text{Vdc} \end{aligned}$$

therefore,

$$\begin{aligned} MTE6_{SR} &= \pm[\ MTE6_{SR\ IN\ EQ}{}^2 + RA6_{SR\ OUT}{}^2]^{0.5} \\ &= \pm[(0.004104\ \text{Vdc})^2 + (0.004924\ \text{Vdc})^2]^{0.5} \\ &= \pm 0.006410\ \text{Vdc} \end{aligned}$$

d) RE: Per section 11.6.1.1.3, the reading error associated with the DMM is included in the uncertainty value. Therefore,

$$RE6_{SR\ MTE} = 0$$

e) By substitution into the section 13.7 equations, $ALT6_{SR}$ and $AFT6_{SR}$ are determined as follows:

$$\begin{aligned} ALT6_{SR} &= \pm[RA6_{SR}{}^2 + MTE6_{SR}{}^2 + RE6_{SR\ MTE}{}^2]^{0.5} \\ &= \pm[(0.048592\ \text{Vdc})^2 + (0.006410\ \text{Vdc})^2 + (0)^2]^{0.5} \\ &= \pm 0.\ 049013\ \text{Vdc, (rounded to } \pm 0.049\ \text{Vdc)} \end{aligned}$$

$$\begin{aligned} AFT6_{SR} &= \pm[RA6_{SR}{}^2 + RD6_{SR}{}^2 + MTE6_{SR}{}^2 + RE6_{SR\ MTE}{}^2]^{0.5} \\ &= \pm[(0.048592\ \text{Vdc})^2 + (0.025000\ \text{Vdc})^2 + (0.006410\ \text{Vdc})^2 + (0)^2]^{0.5} \\ &= \pm 0.\ 055021\ \text{Vdc, (rounded to } \pm 0.055\ \text{Vdc)} \end{aligned}$$

The calculated As-Left Tolerance ($ALT6_{SR}$) bounds the square root converter setting tolerance which is 0.025 Vdc per Reference 3.5.y and 3.5.z.

13.7.2.1.3 ABB RFM Summer Circuit (Module 6_{SUM}) As-Left / As-Found Tolerances

a) RA: From section 13.7.2, RA = ST. From References 3.5.y and 3.5.z, the output setting tolerance is ±0.010 Vdc. Therefore,

$$RA6_{SUM} = \quad ST6_{SUM} = \quad \pm 0.010 \text{ Vdc}$$

b) RD: From section 13.7.2 drift is,

$$RD6_{SUM} = \quad \pm 0.025000 \text{ Vdc}$$

c) From section 11.6.1.1.3.c, the uncertainty associated with the two DMM's used for measuring the input setting for module 6_{SUM} is ±0.002462 Vdc (1σ). This value is converted to an equivalent summer output value by utilizing equations determined Section 4.17:

$$\sigma_{OUT} = [(k1 * \sigma_{ERROR\ X})^2 + (k2 * \sigma_{ERROR\ Y})^2]^{0.5}$$

by substitution,

$$\begin{aligned} MTE6_{SUM\ IN\ EQ(1\sigma)} &= \pm[(k1 * MTE6_{SUM\ IN})^2 + (k2 * MTE6_{SUM\ IN})^2]^{0.5} \\ &= \pm[(0.5 * 0.002462 \text{ Vdc})^2 + (0.5 * 0.002462 \text{ Vdc})^2]^{0.5} \\ &= \pm 0.001741 \text{Vdc} \end{aligned}$$

This value is converted to a 2-sigma value,

$$\begin{aligned} MTE6_{SUM\ IN\ EQ} &= \pm(2 * 0.001741 \text{Vdc}) \\ &= \pm 0.003482 \text{ Vdc} \end{aligned}$$

From section 11.6.1.1.3.c, the uncertainty associated with the DMM used for measuring the output setting for module 6_{SUM} is ±0.002462 Vdc (1σ). This value is converted to a 2-sigma value,

$$\begin{aligned} MTE6_{SUM\ OUT} &= \pm(2 * 0.002462 \text{ Vdc}) \\ &= \pm 0.004924 \text{ Vdc} \end{aligned}$$

therefore,

$$\begin{aligned} MTE6_{SUM} &= \pm[\ MTE6_{SUM\ IN\ EQ}{}^2 + RA6_{SUM\ OUT}{}^2]^{0.5} \\ &= \pm[(0.003482 \text{ Vdc})^2 + (0.004924 \text{ Vdc})^2]^{0.5} \\ &= \pm 0.006031 \text{ Vdc} \end{aligned}$$

d) RE: Per section 11.6.1.1.3, the reading error associated with the DMM is included in the uncertainty value. Therefore,

$$RE6_{SR\ MTE} = \quad 0$$

e) By substitution into the section 13.7 equations, $ALT6_{SR}$ and $AFT6_{SR}$ are determined as follows:

$$\begin{aligned}ALT6_{SUM} &= \pm[RA6_{SUM}{}^{2} + MTE6_{SUM}{}^{2} + RE6_{SUM\ MTE}{}^{2}]^{0.5}\\ &= \pm[(0.010\ Vdc)^{2} + (0.006031\ Vdc)^{2} + (0)^{2}]^{0.5}\\ &= \pm 0.\ 011678\ Vdc,\ (\text{rounded to } \pm 0.012\ Vdc)\end{aligned}$$

$$\begin{aligned}AFT6_{SUM} &= \pm[RA6_{SUM}{}^{2} + RD6_{SUM}{}^{2} + MTE6_{SR}{}^{2} + RE6_{SUM\ MTE}{}^{2}]^{0.5}\\ &= \pm[(0.010\ Vdc)^{2} + (0.025000\ Vdc)^{2} + (0.006031\ Vdc)^{2} + (0)^{2}]^{0.5}\\ &= \pm 0.\ 027593\ Vdc,\ (\text{rounded to } = \pm 0.028\ Vdc)\end{aligned}$$

The calculated As-Left Tolerance ($ALT6_{SUM}$) bounds the summer setting tolerance which is 0.01 Vdc per Reference 3.5.y and 3.5.z.

13.7.2.4 ABB RFM Output Isolator Circuit (Module 6_{OI}) As-Left / As-Found Tolerances

a) RA: From References 3.5.y and 3.5.z and section 13.7.2 reference accuracy is,

$$RA6_{OI} = ST6_{OI} = \pm 0.010\ Vdc$$

b) RD: From section 13.7.2 drift is,

$$RD6_{OI} = \pm 0.025000\ Vdc$$

c) MTE Uncertainty: From section 11.6.1.1.3.d, the uncertainty of the DMM used to calibrate module 6_{OI} input is ±0.002462 Vdc. This uncertainty value is converted to a 2-sigma value as follows:

$$\begin{aligned}MTE6_{OI\ OUT} &= \pm 2 * (0.002462\ Vdc)\\ &= \pm 0.004924\ Vdc\end{aligned}$$

From section 11.6.1.1.3.d, the uncertainty of the DMM used to calibrate module 6_{OI} output is ±0.002462 Vdc. This uncertainty value is converted to a 2-sigma value as follows:

$$\begin{aligned}MTE6_{OI\ OUT} &= \pm 2 * (0.002462\ Vdc)\\ &= \pm 0.004924\ Vdc\end{aligned}$$

therefore,

$$\begin{aligned}MTE6_{OI} &= \pm[MTE6_{OI\ IN}{}^{2} + MTE6_{OI\ OUT}{}^{2}]^{0.5}\\ &= \pm[(0.004924\ Vdc)^{2} + (0.004924\ Vdc)^{2}]^{0.5}\\ &= \pm 0.006964\ Vdc\end{aligned}$$

d) RE: Per section 11.6.1.1.3, the reading error associated with the DMM is included in the uncertainty value. Therefore,

$$RE6_{OI\ MTE} = 0$$

e) ALT /AFT: By substitution into the section 13.7 equations $ALT6_{OI}$ and $AFT6_{OI}$ are determined as follows:

$$ALT6_{OI} = \pm[RA6_{OI}{}^{2} + MTE6_{OI}{}^{2} + RE6_{OI\ MTE}{}^{2}]^{0.5}$$

$$= \pm[(0.010\ \text{Vdc})^2 + (0.006964\ \text{Vdc})^2 + (0)^2]^{0.5}$$

$$= \pm 0.012186\ \text{Vdc, (rounded to } \pm 0.012\ \text{Vdc)}$$

$$AFT6_{OI} = \pm[RA6_{OI}{}^2 + RD6_{OI}{}^2 + MTE6_{OI}{}^2 + RE6_{OI\ MTE}{}^2]^{0.5}$$

$$= \pm[(0.010\ \text{Vdc})^2 + (0.025000\ \text{Vdc})^2 + (0.006964\ \text{Vdc})^2 + (0)^2]^{0.5}$$

$$= \pm 0.027812\ \text{Vdc, (rounded to } \pm 0.028\ \text{Vdc)}$$

The calculated As-Left Tolerance ($ALT6_{OI}$) bounds the output isolator setting tolerance which is 0.01 Vdc per Reference 3.5.y and 3.5.z.

13.7.3 APRM Flow Biased Trip Circuit (Module 4D) As-Left / As-Found Tolerances

a) RA: From sections 11.4.4.1.1,

$$RA4D_{(1\sigma)} = \pm\ 0.625\ \%\ \text{Power}$$

This uncertainty value is converted to a 2-sigma value as follows:

$$RA4D = \pm 2 * (0.625\ \%\ \text{Power})$$

$$= \pm 1.250000\ \%\ \text{Power}$$

b) RD: From section 11.4.4.1.2,

$$RD4D_{(1\sigma)} = \pm 1.74553\ \%\ \text{Power}$$

This uncertainty value is converted to a 2-sigma value as follows:

$$RD4D = \pm 2 * (1.74553\ \%\ \text{Power})$$

$$= \pm 3.491060\ \%\ \text{Power}$$

c) MTE Uncertainty: Module 4D is calibrated by applying a simulated power input signal along with a simulated 75% recirculation flow input signal. The simulated power input signal is adjusted while the simulated 75% flow input signal is kept constant while monitoring the module for trip actuation. Both input signals are measured by a Fluke Model 8500A which per section 11.4.4.1.3, has an uncertainty of ±0.00018 Vdc (1σ). Therefore uncertainty associated with power and flow signal measurement is,

$$MTE4D_{POWER\ (1\sigma)\ VDC} = \pm 0.00018\ \text{Vdc}$$

$$MTE4D_{FLOW\ (1\sigma)\ VDC} = \pm 0.00018\ \text{Vdc}$$

Per 3.5.y and 3.5.z, the calibrated span is 10 Vdc. $MTE4D_{POWER\ (1\sigma)\ VDC}$ is converted to units of % Power and converted into a 2-sigma value as follows:

$$MTE4D_{POWER} = \pm 2*(0.00018\ \text{Vdc} / 10\ \text{Vdc}) * 125\ \%\ \text{Power}$$

$$= \pm 0.004500\ \%\ \text{Power}$$

Per 3.5.y and 3.5.z, the calibrated span is 10 Vdc. $MTE4D_{FLOW\ (1\sigma)\ VDC}$ is converted to units of % Power and converted into a 2-sigma value as follows:

$$MTE4D_{FLOW} = \pm 2*(0.00018\ \text{Vdc} / 10\ \text{Vdc}) * 125\ \%\ \text{Flow}$$

$$= \pm 0.004500\ \%\ \text{Flow}$$

$MTE4D_{POWER}$ and $MTE4D_{FLOW}$ are converted to an equivalent output value by applying the methodology established in sections 11.4.4.1.5.1 and 11.4.4.1.5.2.

For Two Loop Operation (TLO):

$$\begin{aligned}
MTE4D_{TLO} &= \pm[\, MTE4D_{POWER}{}^{2} + (0.623333 * MTE4D_{FLOW})^{2}]^{0.5} \\
&= \pm[(0.004500\ \%\ Power)^{2} + ((0.623333)*(\,0.004500\ \%\ Flow))^{2}]^{0.5} \\
&= \pm\ 0.005303\ \%\ Power
\end{aligned}$$

For single Loop Operation (SLO):

$$\begin{aligned}
MTE4D_{SLO} &= \pm[\, MTE4D_{POWER}{}^{2} + (0.553333 * MTE4D_{FLOW})^{2}]^{0.5} \\
&= \pm[(0.004500\ \%\ Power)^{2} + ((0.553333)*(\,0.004500\ \%\ Flow))^{2}]^{0.5} \\
&= \pm\ 0.005143\ \%\ Power
\end{aligned}$$

d) RE: The DMM is a digital output device, and therefore, the reading error is considered to be the least significant increment of the display (or resolution) (see Reference 3.34). Per section 9.1, reading error is included in the uncertainty value.

$$RE4D_{MTE} = 0$$

e) ALT / AFT: By substitution into section 13.7 equations ALT4D and AFT4D are determined and converted into module 4D calibrated output units of Vdc,

For Two Loop Operation (TLO):

$$\begin{aligned}
ALT4D_{TLO} &= \pm(10\ Vdc\ /\ 125\%\ Power)*[RA4D^{2} + MTE4D_{TLO}{}^{2} + RE4D_{MTE}{}^{2}]^{0.5} \\
&= \pm(10\ Vdc\ /\ 125\%\ Power)*\ [(1.250000\ \%\ Power)^{2} \\
&\quad + (0.005303\ \%\ Power)^{2} + (0)^{2}]^{0.5} \\
&= \pm 0.100001\ Vdc,\ (rounded\ to\ \pm 0.100\ Vdc)
\end{aligned}$$

$$\begin{aligned}
AFT4D_{TLO} &= \pm(10\ Vdc\ /\ 125\%\ Power)*[RA4D^{2} + RD4D^{2} + MTE4D_{TLO}{}^{2} \\
&\quad + RE4D_{MTE}{}^{2}]^{0.5} \\
&= \pm(10\ Vdc\ /\ 125\%\ Power)*\ [(1.250000\ \%\ Power)^{2} \\
&\quad + (3.491060\ \%\ Power)^{2} \\
&\quad + (0.005303\ \%\ Power)^{2} + (0)^{2}]^{0.5} \\
&= \pm 0.296648\ Vdc,\ (rounded\ to\ \pm 0.297\ Vdc)
\end{aligned}$$

For Single Loop Operation (SLO):

$$\begin{aligned}
ALT4D_{SLO} &= \pm(10\ Vdc\ /\ 125\%\ Power)*[RA4D^{2} + MTE4D_{SLO}{}^{2} + RE4D_{MTE}{}^{2}]^{0.5} \\
&= \pm(10\ Vdc\ /\ 125\%\ Power)*\ [(1.250000\ \%\ Power)^{2} \\
&\quad + (0.005143\ \%\ Power)^{2} + (0)^{2}]^{0.5} \\
&= \pm 0.100001\ Vdc,\ (rounded\ to\ \pm 0.100\ Vdc)
\end{aligned}$$

$$\begin{aligned}
AFT4D_{SLO} &= \pm(10\ Vdc\ /\ 125\%\ Power)*[RA4D^{2} + RD4D^{2} + MTE4D_{SLO}{}^{2} \\
&\quad + RE4D_{MTE}{}^{2}]^{0.5} \\
&= \pm(10\ Vdc\ /\ 125\%\ Power)*\ [(1.250000\ \%\ Power)^{2}
\end{aligned}$$

$+ (3.491060 \text{ \% Power})^2$
$+ (0.005143 \text{ \% Power})^2 + (0)^2]^{0.5}$

$= \pm 0.296648$ Vdc, (rounded to ±0.297 Vdc)

From the above results, impact on ALT and AFT due to TLO vs. SLO is negligible.

The calculated As-Left Tolerance (ALT4D) bounds the Module 4D setting tolerance which is 0.04 Vdc per section 11.4.4.1.4.

14.0 CONCLUSIONS

1. Revise Section 14.1 as follows:

14.1.1 Simulated Thermal Power Upscale (Scram) - Two Loop Operation

Analytical Limit: ___0.61W + 69.76___ % Power
Tech Spec AV: ___0.61W + 68.2___ % Power
Tech Spec NTSP: ___0.61W + 62.6___ % Power

Calibration setpoint: Since the setpoint is calibrated at a specific drive flow, the nominal setpoint should be set at least 0.04 Vdc below the corresponding Tech Spec NTSP with a tolerance of +/- 0.04 Vdc. For example, with an 75% drive flow, the Tech Spec NTSP is ___108.35% (0.61___*75 +___62.6)___. Since ___108.35___% on a 125% scale corresponds to ___8.668 Vdc___ on a 10 Vdc scale [10Vdc*___108.35___%/125%], a setpoint of ___8.628___ +/- 0.04 Vdc is recommended for 75% drive flow.

14.1.2 Simulated Thermal Power Upscale (Scram) Single Loop Operation

Analytical Limit: ___0.54W + 57.39___ % Power
Tech Spec AV: ___0.54W + 55.9___ % Power
Tech Spec NTSP: ___0.54W + 50.5___ % Power

Calibration setpoint: Since the setpoint is calibrated at a specific drive flow, the nominal setpoint should be set at least 0.04 Vdc below the corresponding Tech Spec NTSP with an tolerance of +/- 0.04 Vdc. For example, with an 75% drive flow, the Tech Spec NTSP is ___91.00% (0.54___*75 + ___50.5___). Since ___91.00%___ on a 125% scale corresponds to ___7.280 Vdc___ on a 10 Vdc scale [10Vdc*___91.00%___/125%], a setpoint of ___7.240___ +/- 0.04 Vdc is recommended for 75% drive flow.

14.1.3 Simulated Thermal Power Upscale (Rod Block) Two Loop Operation

Analytical Limit: ___0.61W + 58.51___ % Power
Tech Spec AV: ___0.61W + 56.9___ % Power
Tech Spec NTSP: ___0.61W + 51.3___ % Power

Calibration setpoint: Since the setpoint is calibrated at a specific drive flow, the nominal setpoint should be set at least 0.04 Vdc below the corresponding Tech Spec NTSP with a tolerance of +/- 0.04 Vdc. For example, with an 75% drive flow, the Tech Spec NTSP is ___97.05% (0.61___*75 +___51.3)___. Since ___97.05%___ on a 125% scale corresponds to ___7.764 Vdc___ on a 10 Vdc scale [10Vdc*___97.05%___/125%], a setpoint of ___7.724___ +/- 0.04 Vdc is recommended for 75% drive flow.

14.1.4 Simulated Thermal Power Upscale (Rod Block) Single Loop Operation

Analytical Limit: ___0.54W + 46.14___ % Power
Tech Spec AV: ___0.54W + 44.7___ % Power
Tech Spec NTSP: ___0.54W + 39.2___ % Power

Calibration setpoint: Since the setpoint is calibrated at a specific drive flow, the nominal setpoint should be set at least 0.04 Vdc below the corresponding Tech Spec NTSP with a tolerance of +/- 0.04 Vdc. For example, with an 75% drive flow, the Tech Spec NTSP is ___79.70% (0.54___*75 +___39.2)___. Since ___79.70%___ on a 125% scale corresponds to ___6.376 Vdc___ on a 10 Vdc scale [10Vdc*___79.70%___/125%), a setpoint of ___6.336___ +/- 0.04 Vdc is recommended for 75% drive flow.

2. Revise Section 14.5 as follows:

14.5 Recirculation Flow Monitor - Upscale

Tech Spec NTSP: 108 % Flow
Tech Spec AV: 111 % Flow
Calculated AV: ***112.95*** % Flow
Calculated AL: ***114.66*** % Flow

Reference 3.27 requested that these values be evaluated against an AL of 116 % Flow. As the calculation shows there is a positive margin of about ***1.34*** % Flow between the calculated AL and that of Reference 3.27.

3. Revise Section 14.6 as follows:

14.6 Recirculation Flow Monitor - Comparator

Tech Spec NTSP: 10 % Flow
Tech Spec AV: 11 % Flow
Calculated AV: ***14.87*** % Flow
Calculated AL: ***14.87*** % Flow

Reference 3.27 requested that these values be evaluated against an AL of 19 % Flow. This calculation indicates that there is positive margin between the calculated AL and the value from Reference 3.27.

4. Revise Section 14.7 as follows:

14.7 From References ***3.5.s, 3.5.t, and 3.5.y, 3.5.z***, the required accuracy for the pneumatic calibrator is specified as ±2.0" W.C. For the normal temperatures involved in the Reactor Building, i.e., up to 118 °F, the calculated accuracy of the Wallace and Tiernan pneumatic calibrator exceeds this value (Section 9.2). Therefore, the calibration procedures should be revised to indicate the increased uncertainty or to limit the ambient temperature allowed during calibration.

5. Add the following new conclusion section 14.9:

14.9 As-Left / As-Found Tolerances for APRM Flow Biased Trips are:

Recirculation Flow Transmitters (Module 1):
$ALT1_{FT}$ = ±0.282 mVdc
$AFT1_{FT}$ = ±0.298 mVdc

ABB RFM Input Isolator Circuit (Module 6_{II}):
$ALT6_{II}$ = ±0.181 Vdc
$AFT6_{II}$ = ±0.183 Vdc

ABB RFM Square Root Converter Circuit (Module 6_{SR}):
$ALT6_{SR}$ = ±0.049 Vdc

$AFT6_{SR}$ = ±0.055 Vdc

ABB RFM Summer Circuit (Module 6_{SUM}):

$ALT6_{SUM}$ = ±0.012 Vdc
$AFT6_{SUM}$ = ±0.028 Vdc

ABB RFM Output Isolator Circuit (Module 6_{OI});

$ALT6_{OI}$ = ±0.012 Vdc
$AFT6_{OI}$ = ±0.028 Vdc

APRM Flow Biased Trip Circuit (Module 4D);

ALT4D = ±0.100 Vdc
AFT4D = ±0.297 Vdc)

The calculated As-Left Tolerances for the above modules bounds the module setting tolerances as noted in sections 13.7.1, 13.7.2, and 13.7.3.

15.0 CALCULATION SPREADSHEET

1. Delete section 15.0 in its entirety. This spreadsheet was included for reference only, and it was utilized for verifying computations. It is no longer required and is therefore being deleted.

FINAL PAGE