# ATTACHMENT 2

Calculation No. 98-024

# APRM - RBM SETPOINT CALCULATION

COOPER NUCLEAR STATION
NRC DOCKET 50-298, DPR-46

Nebraska Public Power District

## DESIGN CALCULATIONS COVER SHEET

| | |
|---|---|
| Title APRM – RBM Setpoint Calculation | Calculation No. 98-024 |
| | Task Identification No. N/A |
| System/Structure NM | Design Change No. N/A |
| Component NM-NAM-AR 2, 3, 4, 5, 6, 7, 8, 9 | Discipline Instrument and Control |
| Classification: [X] Essential [ ] Non-Essential | |

**Calc. Description:**

Determination of the Allowable Values and setpoints for NM-NAM-AR 2, 3, 4, 7, 8, 9 and NM-NAM-AR 5,6. This calculation supersedes the APRM and RBM portions of NEDC 92-050S Rev. 2.

Revision 2
Incorporates the new analytical limits for the Flow Biased Rod Block, Flow Biased Scram, and the Rod Block Clamp for use with MELLLA.
Rearranges steps 4.1.3.4.1 and 4.1.3.4.2 to make the calculation flow better.

~~Revision 1 is the calculation of record for the existing setpoints until MELLLA modification is installed.~~

Revision 3
Changes status from 3 to 1, based on implementation of CED 1999-0117. | Rev 3 ala

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| | | | | | | |
| 3 | 1 | Administrative change of Status to As built Status | Alan L Able<br>5-17-00 | N/A | N/A | W. Frewin<br>5/17/00 |
| 2 | 3 | Determination of new setpoints for the APRM Flow Biased Scram, Flow Biased Rod Block, and Rod Block Clamp. Corrected errors in the GAF setting. | Alan L Able<br>12/30/99 | Robert D. Champlin<br>12-31-99 | Robert D. Champlin<br>1-3-2000 | W FREWIN<br>1/3/2000 |
| 1 | 1 | Revised RBM Setpoints based on 6 month calibration frequency and added COLR and NEDC 92-050S rev 2 to affected documents. | Alan L. Able<br>7/30/98 | Mark E. Unruh<br>7/30/98 | Mark E. Unruh<br>7/30/98 | Elden Plettner Jr.<br>7/31/98 |
| 0 | 1 | Initial Issue supersedes APRM and RBM portion of NEDC 92-050S and resolution of Rev 0 Review comments | Alan L. Able 7/27/98<br>Alan L. Able 7/19/98 | Mark E Unruh 7/27/98<br>Ralph Krause 7/19/98 | Mark E. Unruh 7/27/98<br>Mark E. Unruh (App A,B) 7/23/98<br>Ralph Krause 7/19/98 | Ted Gifford 7/27/98 |
| **Rev. No.** | **Status** | **Revision Description** | **Prepared By/Date** | **Checked or Reviewed By/Date** | **Design Verification/Date** | **Approved By/Date** |

Status Codes

| | |
|---|---|
| 1. As - Built | 3. For Construction |
| 2. Information only | 4. Superseded or Deleted |

Nebraska Public Power District

# DESIGN CALCULATIONS COVER SHEET

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| Rev. No. | Status | Revision Description | Prepared By/Date | Checked or Reviewed By/Date | Design Verification/Date | Approved By/Date |
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| 1 | 1 | Revised RBM Setpoints based on 6 month calibration frequency and added COLR and NEDC 92-050S rev 2 to affected documents. | Alan L Able<br>7/30/98 | Mark E Unruh<br>7/30/98 | Mark E Unruh<br>7/30/98 | Elden Plettner Jr<br>7/31/98 |
| 0 | 1 | Initial Issue supersedes APRM and RBM portion of NEDC 92-050S and resolution of Rev 0 Review comments | Alan L. Able 7/27/98<br>Alan L. Able 7/19/98 | Mark E Unruh 7/27/98<br>Ralph Krause 7/19/98 | Mark E. Unruh 7/27/98<br>Mark E. Unruh (App A,B) 7/23/98<br>Ralph Krause 7/19/98 | Ted Gifford 7/27/98 |

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| — | — | Resolution of Rev.0 Review Comments | 7/27/98 | 7/27/98 | App A & B: 7/23/98 7/23/98 | 7/23/98 |
| 0 | 1 | Initial Issue supersedes APRM and RBM portion of NEDC 92-050S. | 7/19/98 | 7/19/98 | 7/19/98 | |
| Rev. No. | Status | Revision Description | Prepared By/Date | Checked or Reviewed By/Date | Design Verification/Date | Approved By/Date |

Status Codes

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| 1. As - Built | 3. For Construction |
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## DESIGN CALCULATION CROSS REFERENCE INDEX

NEDC 98-024 Preparer: Alan L Able Reviewer: Robert D. Champlin

Rev No. 2 Date: 12-30-99 Date: 12-31-99

| Item No. | DESIGN INPUTS | Rev. No. | PENDING CHANGES TO DESIGN INPUTS |
|---|---|---|---|
| 1 | USAR Section III-7.5.4 | - | |
| 2 | USAR Section VII-5.7 | - | |
| 3 | USAR Section VII-5.8 | - | |
| 4 | USAR Section VII-7.4.3 | - | |
| 5 | NEDC-32676P | 1/97 | |
| 6 | NEDC-31892P | 1 | |
| 7 | GENE-187-27-1292 | 12/92 | |
| 8 | VM1025, Vol. 8, Part 4, Book 1 (GE Type 555 DP Transmitter) | 9/70 | |
| 9 | 197R148, Sheet 2 | N03 | |
| 10 | 197R148, Sheet 3 | N06 | |
| 11 | 197R148, Sheet 4 | N04 | |
| 12 | 197R148, Sheet 11 | N02 | |
| 13 | 197R148, Sheet 13 | N05 | |
| 14 | 791E256, Sheet 9 | N17 | |
| 15 | 791E256, Sheet 10 | N11 | |
| 16 | EQDP 46 | 6 | |
| 17 | GE Spec. 23A1399 | 1 | |
| 18 | GE Spec. 22A2811 | 3 | |
| 19 | GE Spec. Data Sheet 22A281AC | 0 | |
| 20 | GE IDS 248A9730NS | 0 | |
| 21 | GE IDS 234A9301NS | 9 | |
| 22 | GE Spec. 21A1368 | 2 | |
| 23 | VM1177 | 0 | |
| 24 | VM1025, Vol. 4, Part 2 (Neutron Monitoring System) | 8/93 | |
| 25 | VM1025, Vol. 4, Part 1 (Neutron Monitoring Components) | 9/86 | |
| 26 | VM0067 | 8 | |
| 27 | Design and Perf. Spec. 175A9679 | 0 | |
| 28 | Design and Perf. Spec. 235A1386 | 1 | |

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Nebraska Public Power District

## DESIGN CALCULATION CROSS REFERENCE INDEX

NEDC 98-024 Preparer: Alan L Able Reviewer: Robert D. Champlin

Rev No. 2 Date: 12-30-99 Date: 12-31-99

| Item No. | DESIGN INPUTS | Rev. No. | PENDING CHANGES TO DESIGN INPUTS |
|---|---|---|---|
| 29 | 257HA392AD | 4 | |
| 30 | VM1518 | 0 | |
| 31 | VM1575 | 1 | |
| 32 | VM1137 | 1 | |
| 33 | VM1045 | 4 | |
| 34 | DC89-219 | 0 | |
| 35 | DI-004 | - | |
| 36 | VM 1106 | 1 | |
| 37 | GE-NE-L12-00867-01-01 | 1 | |
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Nebraska Public Power District

## DESIGN CALCULATION CROSS REFERENCE INDEX

NEDC 98-024 Preparer: Reviewer: Robert D. Champlin

Rev No. 2 Date: 12-30-99 Date: 12-31-99

| Item No. | Affected Documents | Rev. No. | CHANGE Required | Action Item Tracking Number (If change is required) |
|---|---|---|---|---|
| 1 | Tech Specs 3.3.1.1 | 178 | Yes | CED 1999-0117 |
| 2 | Tech Specs 3.3.2.1 | 178 | No | |
| 3 | TRM Section 3.3.1 | 1 | Yes | CED 1999-0117 |
| 4 | 6.1APRM.303 | 4C1 | Yes | CED 1999-0117 |
| 5 | 6.1APRM.304 | 5 | Yes | CED 1999-0117 |
| 6 | 6.1APRM.305 | 8C1 | Yes | CED 1999-0117 |
| 7 | 6.1RBM.301 | 4 | No | |
| 8 | 6.1RBM.302 | 2 | No | |
| 9 | 6.2APRM.303 | 7C1 | Yes | CED 1999-0117 |
| 10 | 6.2APRM.304 | 5 | Yes | CED 1999-0117 |
| 11 | 6.2APRM.305 | 7 | Yes | CED 1999-0117 |
| 12 | 6.2RBM.301 | 4 | No | |
| 13 | 6.2RBM.302 | 2 | No | |
| 14 | DCD 14 | 2 | No | |
| 15 | DCD 21 | 2 | Yes | CED 1999-0117 |
| 16 | 4.1.5 | 13C1 | No | |
| 17 | 2.3.2.27 | 25 | Yes | CED 1999-0117 |
| 18 | 2.3.2.28 | 32 | Yes | CED 1999-0117 |
| 19 | Core Operating Limits Report | - | No | |
| 20 | 6.1RR.303 | 6 | No | |
| 21 | 6.2RR.303 | 6 | No | |
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Nebraska Public Power District
DESIGN CALCULATIONS SHEET

NEDC: 98-024 Preparer: Reviewer: Robert D. Champlin
Rev. No: 2 Date: 12-30-99 Date: 12-31-99

## REFERENCES

1. USAR Sections III-7.5.4, Flow Control, VII-5.7, Average Power Range Monitor Subsystem; VII-5.8, Rod Block Monitor Subsystem; VII-7.4.3, Rod Block Interlocks.
2. J. E. Walker, P.D. Knecht, Analytical Limits for Cooper Nuclear Station, NEDC-32676P, General Electric Company, San Jose, CA, January 1997.
3. General Electric Report NEDC-31892P, Revision 1, May 1991, Extended Load Line Limit and ARTS Improvement Program Analyses for Cooper Nuclear Station Cycle 14.
4. W.H. Cooley, J.L. Leong, M.A. Smith and S. Wolf, *General Electric Instrument Setpoint Methodology*, NEDC-31336P-A, General Electric Company, San Jose, CA, September 1996.
5. W.H. Cooley, *Setpoint Calculation Guidelines for the Cooper Nuclear Station*, EDE-38-1090, Rev. 0, General Electric Nuclear Energy, San Jose, CA, January 25, 1991.
6. GE Report GENE-187-27-1292, DRF-A00-05122, "Neutron Monitoring New Analytical Limits for Cooper Nuclear Station", December 1992.
7. CNS Engineering Procedure 3.26.3, Rev. 4, Instrument Setpoint and Channel Error Calculation Methodology. △2
8. VM 1025, Volume 8, Part 4, Book 1, (198-4532K16-300C), GE Type 555 Differential Pressure Transmitter Instructions.
9. CNS Surveillance Procedure 6.1APRM.305, Rev 8C1 / 6.2APRM.305, Rev 7, APRM System (Flow Bias and Startup) Channel Calibration
10. CNS Surveillance Procedure 6.1RBM.302, Rev 2 / 6.2RBM.302, Rev 2, RBM Channel Calibration.
11. CNS Surveillance Procedure 6.1RR.303, Rev 6 / 6.2RR.303, Rev 6, Reactor Recirculation Flow Unit Transmitter and Flow Unit Cyclic Channel. △2
12. GE Elementary Diagram Power Range Neutron Monitoring System, 197R148, Sheet 2, Rev. N03; Sheet 3, Rev. N06; Sheet 4, Rev. N04; Sheet 11, Rev. N02; Sheet 13, Rev. N05.
13. GE Elementary Diagram Reactor Protection System, 791E256, Sheet 9, Rev. N17; Sheet 10, Rev. N11.
14. EQDP 46, Rev. 6 Environmental Conditions.
15. GE Letter, J. Leong (GE) to R. Bussard (NPPD), Subject "Cooper Low Power APRM Analytic Limits", Dated October 1, 1992.
16. Cooper Letter, CNS 928823, P. Ballinger (NPPD) to J. Leong (GE), "LPRM Information / APRM Setpoint Review", November 13, 1992.
17. Equipment Data File (EDF).
18. CNS Letter to GE, Guide Lines to Review GE Reference Document, August 15, 1996.
19. Cooper Nuclear Station Improved Technical Specifications.
20. GE Letter, C960911 to CNS (Gautam Sen), Telephone Conversation Confirmation (regarding CNS Setpoint Analysis), September 11, 1996.
21. CNS Instrument and Control Procedure 14.1.2.1, Rev. 11, IAC Test Gauge Calibration.

22. GE Design Specification, 23A1399, Neutron Monitoring System (RBM/ARTS), Rev. 1.
23. CNS IAC Procedure 14.1.40, Rev. 2.1, Fluke 8600A Digital Multimeter Operation and Maintenance.
24. GE Neutron Monitoring System Design Specification, 22A2811, Rev. 3.
25. GE Neutron Monitoring System Design Specification Data Sheet, 22A2811AC, Rev. 0.
26. GE Neutron Monitoring System Instrument Data Sheet, 248A9730NS, Rev. 0.
27. GE Nuclear Boiler Instrument Data Sheet, 234A9301NS, Rev. 9.
28. GE Recirculation Flow Element Specification, 21A1368, Rev. 2.
29. VM 1177, RR Venturi Flow Elements, Rev. 0
30. VM 1025, Volume 4, Part 2, (GEK-34550C), Power Range Neutron Monitoring System (W/ ARTS Modification), August 1993.
31. VM 1025, Volume 4, Part 1, (GEK-34551B), Power Range Neutron Monitoring Components, September 1986.
32. Flow Unit (GE Dwg 791E392NSG1; Design & Perf Spec 225A6445). Also, VM 0067 (GEK-34642D), Flow Unit OMI, January 1995.
33. Local Power Range Monitor Design and Performance Specification, 175A9679 Rev. 0.
34. APRM Page Design and Performance Specification, 235A1386, Rev. 1.
35. Nuclear Engineering Data Book - Nuclear Instrumentation Cooper Station, 257HA392AD Rev. 4.
36. Average Power Range & Flow Converter Specification, 175A8250, Rev. 0
37. VM 1518, DVM Fluke 45, Rev. 0.
38. VM 1575, Pneumatic Calibrator, Crystal Engineering, Rev. 1
39. VM 1137, Ametek Type RK Dead Weight Tester, Rev. 1.
40. VM 1045, Fluke 8600A Digital Multimeter Instruction Manual, Rev. 4
41. Letter, J.S. Charnley (GE) to G. Sen (NPPD), Subject "Analytical Limits for Neutron Monitoring System", December 12, 1996.
42. Memo, P. Ballinger (CNS) to Dr. R. Burch (CNS), "Review of NEDC 92-50S, Rev. 3 and NEDC 95-109, Rev. 1", Dated January 16, 1997.
43. GE Susceptibility Design and Performance Specification, 225A4338, Rev. 0.
44. DC 89-219, ARTS/ELLA Implementation.
45. ST96-084, Determination of Radio Frequency Interference (RFI) by Hello Direct Wireless Headsets in the Control Room.
46. SP97-010, Testing of Permanent Cellular Phones.
47. SP97-009, Testing SAIC Model PDE-4 and PD-4 Teledosimetry and Repeater Units.
48. DI-004, Impell Design Input
49. NUREG-1433, Vol. 1, Rev. 1, Standard Technical Specifications, GE Plants, BWR/4, dated April 1995.

50. VM 1106, Fluke Model 8502A Digital Multimeter Instruction Manual, Rev. 1
51. GE Letter, from D. J. Bouchie (GE) to Elden Plettner (CNS), dated July 8, 1998, APRM Restricted Condition Definition.
52. GE Letter NPPD-R-98062, from Richard Rossi (GE) to Elden Plettner (CNS), dated July 22, 1998, Impact of Questions on APRM/RBM Calculations.
53. GE Calculation GE-NE-A41-00065-01-02-04-05-06-07 Rev. 1, Average Power Range Monitor (APRM), Rod Block Monitor (RBM) and Technical Specification (ARTS) and Power Range Monitoring Setpoint Calculations (NEDC 92-050S, Rev. 3)
54. Cooper Nuclear Station MIG Project, GE-NE-L12-00867-01-01, Rev 1, Reactor Power/Flow Map | 2
55. CED 1999-0117, Cycle 20 Core Reload.

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| NEDC: 98-024 | Preparer: | Reviewer: Robt D. Champlin |
| Rev. No: 2 | Date: 12-30-99 | Date: 12-31-99 |

## 1. PURPOSE

In consideration of the Cooper setpoint verification program in conjunction with a 7.5 month surveillance interval (required 6 months plus 25% grace period), determine the Nominal Trip Setpoint and Allowable Value for the Reactor Protection System (RPS) scrams from the Average Power Range Monitoring High Neutron Flux, Flow Biased, and Low Power (Setdown) High Neutron Flux trip functions. Also considerations of allowable APRM gain adjustment factors (AGAF) of 0.98 to 1.02 will be made (CNS Technical Specifications SR 3.3.1.1.2).

In conjunction with a 7.5 month surveillance interval (required 6 months plus 25% grace period), determine the Nominal Trip Setpoint and Allowable Value for the Rod Block Monitoring System (RBM). The RBM System (NM-NAM-AR5 and NM-NAM-AR6) monitors local neutron flux around a control rod selected for withdrawal, and blocks control rod withdrawal when neutron flux exceeds predefined, power dependent setpoints, Reference 1.

## 2. REQUIREMENTS

2.1 The APRM System (NM-NAM-AR2, NM-NAM-AR3, NM-NAM-AR4, NM-NAM-AR7, NM-NAM-AR8, NM-NAM-AR9) monitors average neutron flux throughout the entire core and provides a rod block and scram at two separate flow-biased setpoints. The APRM system has the further requirement of providing rod blocks and scrams at other lower setpoints when the reactor mode switch is in a mode other than RUN (rod block in STARTUP, and scram in REFUEL or STARTUP and HOT STANDBY), Reference 1. Per References 2, 6, 15, 41, and 54, the Analytical Limits for the APRM Trip Channels are as follows;

| APRM Trip Function | Analytical Limit |
|---|---|
| Flow Biased Scram | 0.66W + 74.8% RTP |
| Flow Biased Rod Block | 0.66W + 63.5% RTP |
| High Neutron Flux Scram | 123.0% RTP |
| Rod Block Clamp | 111.7% RTP |
| Downscale Neutron Flux Rod Block | 0.0% RTP |
| High Flux - Setdown Scram | 17.4% RTP |
| High Flux - Setdown Rod Block | 14.4% RTP |

Where "W " is the two loop recirculation flow rate in percent of rated (rated loop recirculation loop flow rate is that recirculation flow rate which provides 100% core flow at 100% power).

2.2 The APRM, Rod Block Monitor, and Technical Specifications (ARTS) / Extended Load Line Limit Analysis (ELLLA) Implementation of DC-89-219 physically reconfigured the RBM and changed the Analytical Limits of the setpoints for both the RBM and APRM (in RUN mode), Reference 3. Per References 2, 3, and 22, the Analytical Limits for the RBM ARTS Trip Channels and Nominal Trip Setpoints for the Time Delay (Td1) and Time Constants (Tc1, Tc2)* , Reference 44, are as follows;

| RBM Trip Function | Analytical Limit |
|---|---|
| Low Power Setpoint (LPSP) | 30% |
| Intermediate Power Setpoint (IPSP) | 65% |
| High Power Setpoint (HPSP) | 85% |

| | Analytical Limit | MCPR Limit |
|---|---|---|
| Low Trip Setpoint (LTSP) | 117.0% | 1.20 |
| | 120.0% | 1.25 |
| | 123.0% | 1.30 |
| | 125.8% | 1.35 |
| Intermediate Trip Setpoint (ITSP) | 111.2% | 1.20 |
| | 115.2% | 1.25 |
| | 118.0% | 1.30 |
| | 121.0% | 1.35 |
| High Power Setpoint (HTSP) | 107.4% | 1.20 |
| | 110.2% | 1.25 |
| | 113.2% | 1.30 |
| | 116.0% | 1.35 |
| Downscale Trip Setpoint (DTSP) | 89.0%** | *** |

| | NTSP |
|---|---|
| Time Delay 1 (Td1) | 3.5 sec. |
| Time Constant 1 (Tc1) | 0.5 sec. |
| Time Constant 2 (Tc2) | 6 sec. |

* Time Delay 1 (Td1): Delays nulling sequence after rod selection so RBM filtered signal nears equilibrium before calibration; no delay without filter. Adds additional time delay from rod selection to allowable rod withdrawal start.

Time Constant 1 (Tc1): RBM signal filter time constant.

Time Constant 2 (Tc2): Variable APRM signal filter constant. Does not affect RWE transient response.

** The Downscale trip setpoint (DTSP) functions to prevent a rod withdrawal if the selected RBM channel power is too low from its most recent normalized calibration conditions (i.e. 100%). This assures that the calibration (i.e., normalization) performed at the time of rod selection remains valid before permitting withdrawal of the rod. The Analytical Limit was changed from 91% to 89% of reference level per Reference 6. The DTSP limit is not utilized in any licensing bases Rod Withdrawal Error (RWE) analysis or that the range is restricted by design to values considered in the RWE analysis.

*** There is no MCPR limitation associated with the DTSP.

2.3 This calculation is performed in accordance with CNS Engineering Procedure 3.26.3, Instrument Setpoint and Channel Error Calculations (Reference 7).

2.4 The methods used in this calculation are consistent with the requirements of Reg. Guide 1.105 that the GE Instrument Setpoint Methodology (Reference 4) is in compliance.

## 3. ASSUMPTIONS

3.1 The GE APRM/RBM equipment accuracy specification includes the uncertainties due to seismic effect on the equipment located in the Neutron Monitoring System equipment panels. All equipment in these panels are qualified as a unit.

3.2 The recirculation loop flow transmitters are classified as non-essential instruments. These instruments are rigidly mounted and their ZPA (zero period acceleration) during a seismic event would be insignificant. Thus Seismic Effects (SE) will not be considered for this calculation.

3.3 The values of the As Left Tolerance, CTOOL, and CREAD are controlled by 100% testing. Therefore, they are assumed to represent 3 sigma values, Reference 5. Calibrating equipment accuracies are taken as three (3) sigma values due to industry required periodic calibration with high accuracy standards traceable to NIST. The accuracy of the calibration standard is assumed the same as that of the accuracy of the testing equipment, unless otherwise specified.

3.4 The manufacturer does not specify Vendor drift for the RBM signal conditioning equipment (Reference 22). Therefore the value used for Vendor Drift (VD) will be assumed to be equal to the random portion of Vendor Accuracy for 6 months, on a 2-sigma basis (References 4 and 5). The long term Vendor Drift for the RBM trip unit, is assumed to be adequate for the allowed VD within the period between surveillance tests (assumed 3 months), based on GE's experience of this equipment's performance in BWR plants.

3.5 The manufacturer does not specify Vendor drift for the recirculation loop flow transmitters (Reference 8). Therefore the value used for Vendor Drift (VD) will be assumed to be equal to the random portion of Vendor Accuracy for 6 months, on a 2-sigma basis (References 4 and 5).

3.6 For ARTS operation, setpoints for the RBM with filter are considered (Reference 3). Table 10-5(b) of Reference 3 states, for these items that no limitations exist (setpoint does not affect the RWE analysis or the range is restricted by design to values considered in the RWE analysis). The time delay (Td1) and time constant (Tc1, Tc2) settings currently used are assumed to be valid, and it is assumed that no setpoint calculations (using setpoint methodology) are required for these timing functions.

3.7 The APRM/RBM Technical Specification (ARTS) improvement to the RBM does not degrade the instrument accuracy and drift of the system.

3.8 The Radiation Effect (RE) to the equipment in the specified environment does not exceed the normal integrated dose specified in NPPD Environmental Design Conditions document (Reference 48).

3.9 The variation of the LPRM ion chamber output current with ±1 percent change of the ion chamber voltage in the saturated range is negligibly small or equal to zero (Reference 4).

3.10 The APRM/RBM equipment is electrical and is not subject to Overpressure Effects (OPE). The recirculation loop flow transmitter has a design pressure rating of 2,000 psig (Reference 8), well above the normal and accident pressures that will be seen by this instrument.

3.11 It is assumed that the currently installed NMS equipment is the same as that originally supplied by GE other than normal PC board (by GE) electronic upgrades (References 30, 31, and 32).

3.12 Unless otherwise specified, the vendor accuracies are considered to be 2 sigma values.

3.13 The manufacturer does not specify a Power Supply Effect (PSE) for the APRM/RBM Technical Specification (ARTS) equipment and it is assumed to be included in the equipment accuracy.

3.14 The APRM/RBM Technical Specification (ARTS) equipment is subject only to normal ambient environment and are not subject to harsh, post-accident conditions. Trip and accident environmental conditions will be considered equal to normal ambient conditions for the purpose of this calculation. Accuracy Temperature Effect (ATE) and Humidity Effect (HE) will not be considered.

3.15 Static Pressure Effects (SPE) are generally only applicable for differential pressure instruments (References 3 and 4). The SPE will only apply to the recirculation loop flow transmitter for calculations which involve flow signal inputs. Per References 8 and 52, for an assumed 1,000 psig process pressure, the SPE is equal to 0.88% span per 1,000 psig.

3.16 The flow element inaccuracy is assumed by References 28, 29 to be 2% of flow at normal temperature.

3.17 The As Left Tolerance (ALT) allowance for the APRM gain adjustment factor (AGAF) of greater than 1 (NPPD allowables are 0.98 to 1.02) is treated as an ALT of 1% power. This ALT is not included in the APRM Neutron Flux High Rod Block - Setdown or the Neutron Flux High Scram - Setdown, because AGAF is not performed at that low power. The ALT for the LPRMS is assumed to be the same as that of the APRMS, Reference 9.

3.18 The ALT for the recirculation loop flow unit summer output is assumed equal to the sum of the two recirculation flow loop square root unit output, Reference 11.

3.19 The APRM/RBM/Flow Unit equipment meets the requirements of the Susceptibility Design and Performance Specification, Reference 43. For normal plant operations with expected operational transient radio frequency or electromagnetic emissions, there are negligible RFI/EMI Effects (REE). Peak transient REE that may occur during plant maintenance that may affect performance of the APRM/RBM/Flow Unit equipment is not considered in this calculation. APRM/RBM/Flow Unit equipment has been subjected to various testing for determination of effects from REE (References 45, 46 & 47) and the results of these tests show no adverse effect on the components from the introduce REE. Therefore, REE will not be considered for this calculation.

3.20 It is assumed that for all APRM and RBM electronics in the Control Room, the stated accuracy includes temperature effects, so the ATE and DTE values are assumed to be zero.

3.21 Reference 38 gives a temperature accuracy of 0.01% per °F for 30°F to 130°F for a crystal engineering calibrator. Therefore, the temperature accuracy for calibration temperatures from 65°F to 104°F is:

Temperature Accuracy = 0.01%/°F x 39°F = 0.39% F.S..

3.22 Leave Alone Tolerance (LAT) for the APRM and RBM functions is assumed to be equal to ±1.25% power for consistency within this calculation. The use of ±1.25% is conservative since the current procedures (Ref. 9, 10, 11) have a LAT of ±1.25% or less for the identified APRM and RBM functions.

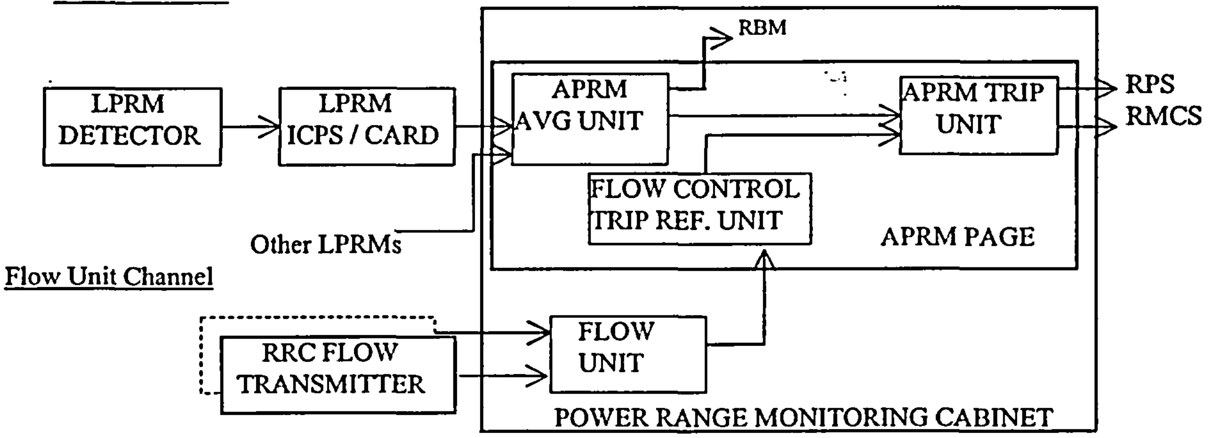
3.23 The use of an ALT of 1.25% for the APRM functions was used during the development of Revision 0 of this calculation in determination of Allowable Values. Changing this value would affect the Allowable Value determination, therefore this value is being maintained and is conservative with regards to the use of 1.00% in current calibration procedures. The ALT for the APRM Rod Block Clamp function is assumed to be 1.25% for the purpose of this calculation. This ALT is consistent with the related APRM functions.

# 4. METHODOLOGY

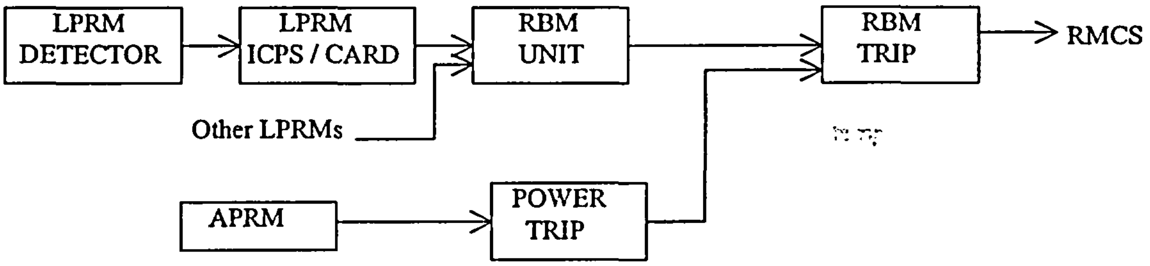
## 4.1 Instrument Channel Arrangement

### 4.1.1 Channel Diagram (References 12, 13, 30)

APRM Channel



RBM Channel



### 4.1.2 Definition of Channels

The APRM channel (loop) consists of the LPRM neutron detector inputs and electronic signal conditioning equipment for the neutron flux trip logic. In addition to above, the flow biased trip logic includes input from the recirculation flow signal. The APRM panel electronics is located in the main control room.

The RBM channel (loop) consists of the LPRM neutron detector inputs along with an APRM power trip reference input. The RBM panel electronics is located in the main control room.

The Flow Unit channel (loop) consist of the recirculation transmitter input to the flow unit which outputs to the APRM and RBM for flow biased trips (also output to Flow Unit Rod Block trip). The recirculation loop flow transmitters are located in the reactor building on instrument rack 25-7, northwest 859' elevation (Reference 11).

### 4.1.3 Instrument Definition and Determination of Device Error Terms

#### 4.1.3.1 Instrument Definition

| | | Reference |
|---|---|---|
| APRM/RBM Channels | | |
| CIC: | NM- NAM-AR2,3,4,7,8,9 (APRMS) | 17 |
| | NM- NAM-AR5,6 (RBMS) | 17 |
| Manufacturer: | GE | 26, 30 |
| Model: | K605 | 52 |
| Upper Range Limit (UR): | 125% | 24, 25, 26 |
| Calibrated Range: | 0-125% Power | 24, 25, 26 |
| Calibrated Span (SP): | 0-125% Power | 24, 25, 26 |
| Output Signal: | 0-10 Vdc | 24, 26 |
| Vendor Perf. Specs: | See Section 4.1.3.3 | |
| Flow Transmitter | | |
| CIC: | RR-FT-110A-D | 17 |
| Manufacturer: | GE | 26, 30 |
| Model: | Type 555 | 8, 27 |
| Upper Range Limit (UR): | 850 in WC | 27 |
| Calibrated Range: | 0-125% Flow | 30 |
| | (-5.7 in WC to 403.2 in WC) | 11 |
| Calibrated Span (SP): | 125%<br>(408.9" WC) | 30 |
| Input Signal: | differential pressure | 11 |
| Output Signal:<br>(across precision 1 ohm resistor) | 10-50 mV | 11 |
| Vendor Perf. Specs: | See Section 4.1.3.3 | |

| Flow Unit | | |
|---|---|---|
| Manuf: | GE | 32 |
| Input Signals (2) | 10 - 50 mA | 32 |
| Output Signal | 0 - 10 Volts | 32 |
| Vendor Perf. Specs: | See Section 4.1.3.3 | |

4.1.3.2 Process and Physical Interfaces

| APRM/RBM/Flow Unit | | Reference |
|---|---|---|
| Calibration Temperature Range: | 60 - 90 °F | 14 |
| Calibration Interval | 6 months (+25% grace) APRM | 19 |
| | 18 months (+25% grace) RBM | 49 |
| Normal Plant Conditions | | |
| Temperature: | 60 - 90 °F | 14 |
| Radiation: | $1.75 \times 10^2$ R (TID, 40 yrs) | 48 |
| Pressure: | 0.10" to 1.0" WG | 14 |
| Humidity: | 40% - 50% R.H. | 14 |
| Trip Environment Conditions - (if required): | | |
| Temperature: | 60 - 90 °F | 14 |
| Radiation: | $1.78 \times 10^2$ R (TID, 40 yrs) | 48 |
| Pressure: | 0.10" to 1.0" WG | 14 |
| Humidity: | 40% - 50% R.H. | 14 |

Temperature Range for Trip condition Error Calculations:

$$\text{Tot. Temp range } (\Delta T_T) = \text{larger of } \left[\begin{array}{c} \text{(max trip temp - min calib temp)} \\ 90 - 60 = 30\ °\text{F} \\ \text{or} \\ \text{(max calib temp - min trip temp)} \\ 90 - 60 = 30\ °\text{F} \end{array}\right.$$

$$= 30\ °\text{F}$$

$$\text{Temp range for DTE calc } (\Delta T_D) = \text{max calib temp - min calib temp}$$

$$= 90 - 60 = 30\ °\text{F}$$

$$\text{Temp range for ATE calc } (\Delta T_{AT}) = \Delta T_T - \Delta T_D$$

$$= 30 - 30 = 0\ °\text{F}$$

Temperature Range for Normal condition Error Calculations:

$$\text{Tot. Temp range } (\Delta T_N) = \text{larger of } \left[\begin{array}{c} \text{(max norm temp - min calib temp)} = 30\ °\text{F} \\ \text{or} \\ \text{(max calib temp - min norm temp)} = 30\ °\text{F} \end{array}\right.$$

$$= 30\ °\text{F}$$

NEDC: 98-024 Preparer: Al Lall Reviewer: Robert D. Champlin
Rev. No: 2 Date: 12-30-99 Date: 12-31-99

Temp range for DTE calc ( $\Delta T_D$ ) = max calib temp - min calib temp
= 90 - 60 = 30 °F

Temp range for ATE calc ($\Delta T_{AN}$) = $\Delta T_N - \Delta T_D$
= 30 - 30 = 0 °F

Seismic Conditions - (if required):

| | | |
|---|---|---|
| Prior to Function: | N/A | Assumption 3.1 |
| During Function: | N/A | Assumption 3.1 |

Process Conditions - (if required):

| | |
|---|---|
| During Calibration: | N/A |
| Worst Case: | N/A |
| During Function: | N/A |

Flow Transmitter

| | | |
|---|---|---|
| Calibration Temperature Range: | 65 - 104 °F | 20 |
| Calibration Interval | 18 months (+25% grace) | 19, 20 |

Normal Plant Conditions

| | | |
|---|---|---|
| Temperature: | 40 - 104 °F | 14 |
| Radiation: | 5.2x10³ R (TID, 40 yrs) | 48 |
| Pressure: | -0.10" to -1.0" WG | 14 |
| Humidity: | 20% - 90% R.H. | 14 |

Trip Environment Conditions

| | | |
|---|---|---|
| Temperature: | 40 - 104 °F | 14 |
| Radiation: | 5.2x10³ R (TID, 40 yrs) | 14 |
| Pressure: | -0.10" to -1.0" WG | 14 |
| Humidity: | 20% - 90% R.H. | 14 |

Temperature Range for Trip condition Error Calculations:

$$\text{Tot. Temp range } (\Delta T_T) = \text{larger of } \begin{cases} \text{(max trip temp - min calib temp)} \\ = 104 - 65 = 39\ ^\circ\text{F} \\ \text{or} \\ \text{(max calib temp - min trip temp)} \\ = 104 - 40 = 64\ ^\circ\text{F} \end{cases}$$

= 64 °F

Temp range for DTE calc ( $\Delta T_D$ ) = max calib temp - min calib temp
= 104 - 65 = 39 °F

Temp range for ATE calc ($\Delta T_{AT}$) = $\Delta T_T - \Delta T_D$
= 64 - 39 = 25 °F

Temperature Range for Normal condition Error Calculations:

Tot. Temp range ( $\Delta T_N$ ) = larger of $\left[\begin{array}{l}\text{(max norm temp - min calib temp)} = 39\ ^\circ F \\ \text{or} \\ \text{(max calib temp - min norm temp)} = 64\ ^\circ F\end{array}\right.$

= 64 °F

Temp range for DTE calc ( $\Delta T_D$ ) = max calib temp - min calib temp
= 104 - 65 = 39 °F

Temp range for ATE calc ( $\Delta T_{AN}$ ) = $\Delta T_N - \Delta T_D$
= 64 - 39 = 25 °F

Seismic Conditions - (if required):

| | | |
|---|---|---|
| Prior to Function: | 0 | Assumption 3.2 |
| During Function: | 0 | Assumption 3.2 |

Process Conditions - (if required):

| | |
|---|---|
| During Calibration: | N/A |
| Worst Case: | N/A |
| During Function: | N/A |

### 4.1.3.3 Determination of Individual Device Accuracies

All accuracy error contributions are random variables unless otherwise noted.

#### 4.1.3.3.1 Vendor Accuracy (VA)

##### 4.1.3.3.1.1 APRM Channel

| Value | Sigma | Reference |
|---|---|---|
| VA (LPRM Card) = 0.8% FS | 2 | 33, 35 |
| VA (LPRM/APRM) = {(0.8 % )/ [SQRT (11 lprms)]} x 125% | | |
| = 0.30% Power | | 35 |
| VA (APRM Avg. Circuit) = 0.8% FS | 2 | 34 |
| = 0.8% x 125% | | |
| = 1.00% Power | | |
| VA (Trip Unit Fixed) = 1%FS | 2 | 34 |
| = 1% x (125%) | | |
| = 1.25% Power | | |
| VA (Trip Unit Flow-Biased) = 1% FS | 2 | 34 |
| = 1% x (125%) | | |
| = 1.25% Power | | |
| VA (Flow Transmitter) = 0.4% Span | 2 | 8 |
| VA (RR Flow Element) = 2% Rated Flow | 2 | 28 |

4.1.3.3.1.2 RBM Channel

| | | |
|---|---|---|
| VA (LPRM Card) = 0.8% FS | 2 | 33, 35 |
| VA (LPRM/RBM) = (0.8% )/ [SQRT (2 lprms)] x 125% | | |
| = 0.707 % Power | | |
| VA (Signal Conditioning Eq.) = 1.32% FS | 2 | 22 |
| = 1.32% x (125%) | | |
| = 1.65% Power | | |
| $VA_i$(Trip Unit) = 0.5% FS | 2 | 22 |
| = 0.5% x (125%) | | |
| = 0.63% Power | | |

4.1.3.3.1.3 Flow Unit

| | | |
|---|---|---|
| $VA_i$ (Flow Unit.)= 2.0 % FS | 2 | 32 |
| $VA_i$ (Flow Transmitter) = 0.4% Span | 2 | 8 |
| $VA_i$ (RR Flow Element) = 2% Rated Flow | 2 | 28 |

4.1.3.3.2 Accuracy Temperature Effect (ATE)

ATE for the recirculation GEMAC 555 flow transmitter per Reference 8, is ±1% span per 100 °F at 100% to 50% span and ± 1% to ±2% of span per 100 °F from 49% to 20% span

As shown in 4.1.3.1 the calibrated span is 408.9 in WC which corresponds to 48.1% of the 850 in WC upper range limit. The temperature coefficient for 48.1% span is obtained by linear extrapolation to be:

$$\text{Temp Coeff} = 1 + 1 \times \frac{50-48.1}{50-20} = 1.06 \text{ \% span per 100 deg F}$$

Therefore, for $ATE_N$ calculation where $\Delta T_{AN} = 25°$ F (from 4.1.3.2)

$ATE_N$ (Flow Transmitter) = 1.06% span x 25° F/100° F = 0.27% span

4.1.3.3.3 Other Errors (Recirculation Flow Loop)

| Value | Sigma | Reference |
|---|---|---|
| OPE: 0 | | Assumption 3.10 |
| SPE: 0.88% span | 2 | Assumption 3.15 |
| SE: 0 | | Assumption 3.2 |
| RE: 0 | | Assumption 3.8 |
| HE: 0 | | Assumption 3.14 |
| PSE: 0 | | Assumption 3.13 |
| REE: 0 | | Assumption 3.19 |

4.1.3.3.4 Accuracy Values

The identified accuracy error contributions are combined using the SRSS method to determine total device accuracy under normal conditions. The device accuracy is normalized to a 2 sigma confidence level, and is given by:

$A_i = 2 \text{ x SQRT}((VA_i/n)^2 + (ATE_i/n)^2 + (OPE_i/n)^2 + (SPE_i/n)^2 +$

$(SE_i/n)^2 + (RE_i/n)^2 + (HE_i/n)^2 + (PSE_i/n)^2 + (REE_i/n)^2) +$

any bias terms

Where the terms inside the square root sign are the random portions of the individual effects, and 'n' is the sigma value associated with each individual effect.

4.1.3.3.4.1 Normal Accuracy

For the APRM and RBM channels, there are several devices in the loop. Thus first the device accuracies under normal conditions will be calculated.

**1. APRM Channel Accuracy**

a) Accuracy of devices in the APRM loop

1. Accuracy of APRM Unit (including LPRM)

$\text{VA (APRM and LPRM)} = 2 \text{ x SQRT }(( VA_{lprm}/2)^2 + VA_{aprm}/2)^2 ))$

$= 2 \text{ x SQRT }((0.30/2)^2 + (1.00/2)^2)$

$= 1.044$ % Power 2 sigma

2. Accuracy of APRM Trip Unit

ATU (Flow Biased Trip Unit) = 1.25 % Power

ATU (Fixed Trip Unit) = 1.25 % Power

b) Accuracy of devices in the flow loop

1. Accuracy of Flow Transmitter

VA GMAC 555 = 0.40% span

SPE GMAC 555 = 0.88% span at 1,000 psig

$A_{FT} = 2\text{x SQRT}[(0.40/2)^2 + (0.88/2)^2 + (0.27/2)^2 ]$

$= 1.00\%$ span $= 4.08$ in WC

The flow error at the output of the flow unit due to this $A_{FT}$ error from both loop transmitters has been calculated in Appendix B to be:

FT Error = 0.7366 % flow

2. Accuracy of Flow Element

The Flow Element error from the venturis used in the flow loops is 2% flow per loop (Ref. 28). The flow error at the output of the flow unit due to this error from both loop flow elements has been calculated in Appendix B to be:

FE Error = 1.414 % flow

3. Accuracy of Flow Unit

The Flow Unit error for is 2% FS (Ref. 32). The flow error at the output of the flow unit due to this error has been calculated in Appendix B to be:

FU Error = 2.5 % flow

4. Total Flow Channel Accuracy

The total flow error due to the 2 transmitters, 2 flow elements and the 1 flow unit is:

$$\text{AFC (ft+ fe + fu)} = 2\sqrt{\left(\frac{0.7366}{2}\right)^2 + \left(\frac{1.414}{2}\right)^2 + \left(\frac{2.5}{2}\right)^2}$$

$$= 2.965 \text{ \% flow}$$

This flow error can be converted to power error by multiplying by the Flow Control Trip Reference (FCTR) slope, which refers to the slope of the power/flow line (Ref. 1).

FCTR slope = 0.66 (W coefficient) (Ref. 54)

Therefore

AFC = 0.66 x 2.965 = 1.957 % power

2

**2. RBM Channel Accuracy**

Accuracy of modules in the RBM loop

1. Accuracy of RBM Unit (including LPRM) from 4.1.3.3.1.2 is

$\text{VA(RBM and LPRM)} = 2 \times \text{SQRT}((0.707/2)^2 + (1.65/2)^2)$

$= 1.80$ % Power

2. Accuracy of RBM Trip Unit 4.1.3.3.1.2 is:

VA (Trip Unit) = 0.63% Power

**3. Total Channel Accuracies**

The total channel accuracies for the various APRM and RBM functions are:

**1. APRM Fixed**

$A_{LN\text{-}fix} = 2 \times \text{SQRT}\,((VA/n)^2\,(\text{lprm} + \text{aprm}) + (ATU/n)^2\,(\text{fixed trip unit}))$

$A_{LN\text{-}fix} = 2 \times \text{SQRT}((1.044/2)^2 + (1.25/2)^2\,)$

$A_{LN\text{-}fix} = 1.63\%$ Power

**2. APRM Flow Biased**

$A_{LN\text{-}fb} = 2 \times \text{SQRT}\,((VA/n)^2\,(\text{lprm} + \text{aprm}) + (ATU/n)^2\,(\text{f.b. trip unit}) + (AFC/n)^2\,(\text{ft+fe+fu}))$

$A_{LN\text{-}fb} = 2 \times \text{SQRT}((1.044/2)^2 + (1.25/2)^2 + (1.957/2)^2)$ 2

$A_{LN\text{-}fb} = 2.55\,\%$ Power

**3. RBM Power Function**

$A_{LN\text{-}RBM\text{-}pwr} = 2 \times \text{SQRT}\,((VA/n)^2\,(\text{lprm} + \text{aprm}) + (ATU/n)^2\,(\text{trip unit})\,)$

$A_{LN\text{-}RBM\text{-}pwr} = 2 \times \text{SQRT}\,((1.044/2)^2 + (0.63/2)^2\,)$

$A_{LN\text{-}RBM\text{-}pwr} = 1.22\%$ Power

**4. RBM Trip Function**

$A_{LN\text{-}RBM\text{-}trip} = 2 \times \text{SQRT}\,((VA/n)^2\,(\text{lprm} + \text{rbm}) + (ATU/n)^2\,(\text{trip unit})\,)$

$A_{LN\text{-}RBM\text{-}trip} = 2 \times \text{SQRT}\,((1.80/2)^2 + (0.63/2)^2\,)$

$A_{LN\text{-}RBM\text{-}trip} = 1.91\%$ Power

#### 4.1.3.3.4.2 Trip Accuracy

Since the normal and trip environments are the same, per assumption 3.14, the accuracy under trip conditions is the same as accuracy under normal conditions.

### 4.1.3.4 Determination of Individual Device Drift

#### 4.1.3.4.1 Drift Temperature Effect (DTE) 2

The only device in the APRM system that has a drift temperature effect is the GEMAC 555 flow transmitter. For this device the error temperature coefficient is 1.06% span per 100°F (from 4.1.3.3.2). Therefore:

$DTE = (1.06\% \,/\, 100°F) \times \Delta T_D$, where $\Delta T_D = 39°F$ (section 4.1.3.2).

$DTE = (1.06/100) \times 39$

$DTE = 0.413\%$ span

This DTE value has been included in the flow transmitter drift shown in 4.1.3.4.2 1(b).

4.1.3.4.2 Vendor Drift (VD)

The drift for APRM Trip Units was derived from analysis of site calibration data, and for the rest of the APRM and RBM processing electronics channels the drifts were derived from vendor drift and accuracy specifications.

<u>1. APRM Channel Drift (6 month + 25% grace = 7.5 months)</u>

a) APRM Electronics Drift

1. LPRM and APRM Unit Drift

The specified drift for the LPRM and APRM Units are:

| | | |
|---|---|---|
| LPRM = 0.8 % FS / 8 Weeks | 2 sigma | (Ref. 33) |
| APRM = 0.5 % FS / 700 Hours | 2 sigma | (Ref. 34) |

the drift times specified in the above specifications are longer than the weekly calibration interval of the APRM electronics based on heat balance and process computer calculations. Therefore, conservatively the above drift values will be used as is (without reduction) in the drift calculation.

As done for VA in 4.1.3.3.1.1, the drift error due to LPRM cards is reduced by the square root of the minimum number of LPRMs in the APRM channel. Thus the APRM electronics drift error is:

$$\text{VD (APRM and LPRM)} = 2\sqrt{\left(\frac{\frac{0.8}{\sqrt{11}}}{2}\right)^2 + \left(\frac{0.5}{2}\right)^2} = 0.555\ \%\ \text{FS}$$

$$= 0.555 \times 1.25\ \%\ \text{Power}$$

$$= 0.694\ \%\ \text{Power}$$

2. APRM Trip Unit Drift

The drift error for the Trip Units was determined by analyzing field data by program Y-GEITAS (and GEITAS) as described in Appendix A. Results of this calculation show that the Trip Units drift for 7.5 month is 1.34 % Power:

DTU (fixed trip) = 1.34 % Power

DTU (flow-biased trip) = 1.34 %

b) Flow Channel Drift

1. Flow transmitter Drift

Specified vendor drift is:

VD (GEMAC 555) = 0.40% span per 6 months Assumption 3.5

Therefore the drift for 22.5 months is:

= 0.40% x SQRT(22.5 mo / 6 mo) for 22.5 mo.

= 0.775 % span

The DTE value for the flow transmitter is:

DTE = 0.413 % span from section 4.1.3.4.1.

Therefore the total drift for the flow transmitter is:

$D_{FT}$ (flow transmitter) =2 x SQRT $((VD_{GEMAC\,555}/n)^2 + (DTE/n)^2)$

$D_{FT} = 2 \times \mathrm{SQRT}((0.775/2)^2 + (0.413/2)^2)$

= 0.878 % span

= 0.00878 fraction of span

to convert flow transmitter drift in % span to % flow, use the method shown in Appendix B (equation 10) and substitute $D_{FT}$ in place of $A_{FT}$. Thus the error due flow transmitter drift is:

FTD = 73.66 x $D_{FT}$ = 0.647 % flow

2. Flow Unit Drift

From Ref. 32 the flow unit drift is specified to be:

$D_{FU}$ = 1.25 % FS / 700 Hours

Since the flow units are checked every month, it is assumed that the above drift is applicable for calculation.

Therefore the error due to flow unit drift is:

FUD = 1.25 x 10/8 = 1.56 % flow

3. Flow Element Drift

The flow element drift is assumed to be negligible.

FED = 0

4. Total Flow Channel Drift

The total drift of the flow channel is:

DFC = 2 x SQRT $((FTD/n)^2 + (FUD/n)^2 + (FED/n)^2)$

$$= 2\sqrt{\left(\frac{0.647}{2}\right)^2 + \left(\frac{1.56}{2}\right)^2} = 1.689 \text{ \% flow}$$

To convert this flow channel error in % flow to % Power, multiply by the FCTR slope shown in 4.1.3.3.4.1

DFC = 0.66 x 1.689 % Power

= 1.12 % Power

2

**2. RBM Channel (6 month + 25% grace = 7.5 months) Drift**

a) LPRM & RBM Unit Drift

The RBM specifications (Ref. 22) does not specify drift for the RBM signal conditioning equipment, hence it is assumed that the drift for 6 months is equal to the vendor accuracy. (Ref. 5)

Thus:

VD (signal cond. equipment) = VA x SQRT( 7.5 mo. / 6 mo.)

= 1.65% x SQRT (7.5 / 6)

= 1.84 % Power

As described in the APRM drift calculation above, the drift of the LPRM electronics is 0.8% FS (or 0.8 x 1.25 = 1.0% Power). Also, for RBM, the minimum number of LPRMs is 2. Therefore the overall drift of the RBM signal conditioning electronics is:

$$\text{VD (RBM and LPRM)} = 2\sqrt{\left(\frac{\frac{1.00}{2}}{2}\right)^2 + \left(\frac{1.84}{2}\right)^2} = 1.91\ \%\ \text{Power}$$

b) RBM Trip Unit Drift

For the RBM Trip Unit, the vendor specification (Ref. 22) states that the drift for the maximum calibration period (assumed to be equal to the maximum previous calibration of 3 months plus 25% grace, or 3.75 months) is 0.4 % FS.

Drift (3.75 month) = (0.4% x 125) % Power = 0.50 % Power

Therefore the drift for 7.5 months is:

DTU (rbm trip) = 0.5% x SQRT (7.5 mo. / 3.75 mo.)
= 0.5% x SQRT (7.5 / 3.75)
= 0.71%

DTU (rbm power) = 0.5% x SQRT (7.5 mo. / 3.75 mo.)
= 0.5% x SQRT (7.5 / 3.75)
= 0.71 % Power

4.1.3.4.3 Drift Values

The total Device Drift Error is calculated by SRSS combination of the random portion of vendor drift and the DTE errors, and normalizing to 2 sigma. Bias errors are added (or subtracted) separately.

$D_i = 2 \times \text{SQRT}( (VD_{Mi} / n)^2 + (DTE_i / n)^2 )$ + any bias terms

The overall drift for the various channels is obtained by SRSS addition of the total drifts of the devices in that channel, and is shown below:

**a) APRM Flow Biased Channel Drift**

$D_{fb} = 2 \times \text{SQRT} [VD^2$ (APRM and LPRM) + $DTU^2$ (Flow Biased Trip Unit) + $DFC^2$ (Flow Channel)]
$= 2 \times \text{SQRT} [(0.694/2)^2 + (1.34/2)^2 + (1.12/2)^2]$
= 1.88 % Power

**b) APRM Fixed Channel Drift**

$D_{fix} = 2 \times \text{SQRT} [VD^2$ (APRM and LPRM) + $DTU^2$ (Fixed Trip Unit)]
$= 2 \times \text{SQRT} [(0.694/2)^2 + (1.34/2^2)]$
= 1.51 % Power

**c) RBM Power Channel Drift**

$D_{RBM\text{-}Pwr} = 2 \times \text{SQRT} [VD^2$ (LPRM and APRM) + $DTU^2$ (RBM Power)]
$= 2 \times \text{SQRT} [(0.694/2)^2 + (0.71/2^2)]$
= 0.99 % Power

**d) RBM Trip Channel Drift**

$D_{RBM\text{-}Trip} = 2 \times \text{SQRT} [VD^2$ (RBM and LPRM) + $DTU^2$ (RBM Trip)]
$= 2 \times \text{SQRT} [(1.91/2)^2 + (0.71/2^2)]$
= 2.04 % Power

4.1.3.5 Establishing As-Left Tolerances

The As-Left Tolerance for the APRM and RBM channels are established as shown below. All values are assumed to be 3-sigma unless otherwise specified.

1. APRM Channels

The basic ALT data for the APRM functions are:

| | Vdc | % Power | Ref. |
|---|---|---|---|
| $ALT_1$ = | 0.10 | 1.25 lprm | Assumption 3.17 |
| $ALT_2$ = | 0.10 | 1.25 aprm nf fixed high scram | Assumption 3.23 |
| $ALT_{2A}$ = | 0.08 | 1.0 aprm downscale rod block | 9 |
| $ALT_{2B}$ = | 0.10 | 1.25 aprm rod block clamp | Assumption 3.23 |
| ALT3 = | 0.10 | 1.25 aprm nf f-b scram | Assumption 3.23 |

| | | | |
|---|---|---|---|
| $ALT_4 =$ | 0.10 | 1.25 aprm nf f-b rod block | Assumption 3.23 |
| $ALT_5 =$ | 0.05 | 0.5 aprm nf setdown scram | 9 |
| $ALT_6 =$ | 0.05 | 0.5 aprm nf setdown rod block | 9 |
| $ALT_7 =$ | | 1.0 (AGAF) | Assumption 3.17 |

2. APRM Flow Reference Channel

The basic ALT data for the APRM flow reference channel are:

| | mVdc/Vdc | %FS | Ref. |
|---|---|---|---|
| $ALT_8 =$ | 0.20 | 0.5 xmit output: 1 mV/1mA | 11 |
| $ALT_9 =$ | 0.01 | 0.01 test current, Sq Rt input | 11 |
| $ALT_{10} =$ | 0.005 | 0.05 Sq Rt Output | 11 |
| $ALT_{11} =$ | 0.01 | 0.1 Summer Output | Assumption 3.18 |

Since the transmitter is spanned to 125% of rated flow multiply %FS by 1.25%flow to obtain %flow for the above ALTs. Therfore:

$ALT_8 = 0.5 \times 1.25\%\text{flow} = 0.625\ \%\text{flow}$

$ALT_9 = 0.01 \times 1.25\%\text{flow} = 0.0125\ \%\text{flow}$

$ALT_{10} = 0.05 \times 1.25\%\text{flow} = 0.0625\ \%\text{flow}$

$ALT_{11} = 0.1 \times 1.25\%\text{flow} = 0.125\ \%\text{flow}$

To convert %flow to %power for the above ALTs, multipy by FCTR = 0.66. Therefore:

$ALT_8 = 0.625 \times 0.66 = 0.41\ \%\text{power}$

$ALT_9 = 0.0125 \times 0.66 = 0.01\%\text{power}$

$ALT_{10} = 0.0625 \times 0.66 = 0.04\%\text{power}$

$ALT_{11} = 0.125 \times 0.66 = 0.08\ \%\text{power}$

3. RBM Channels

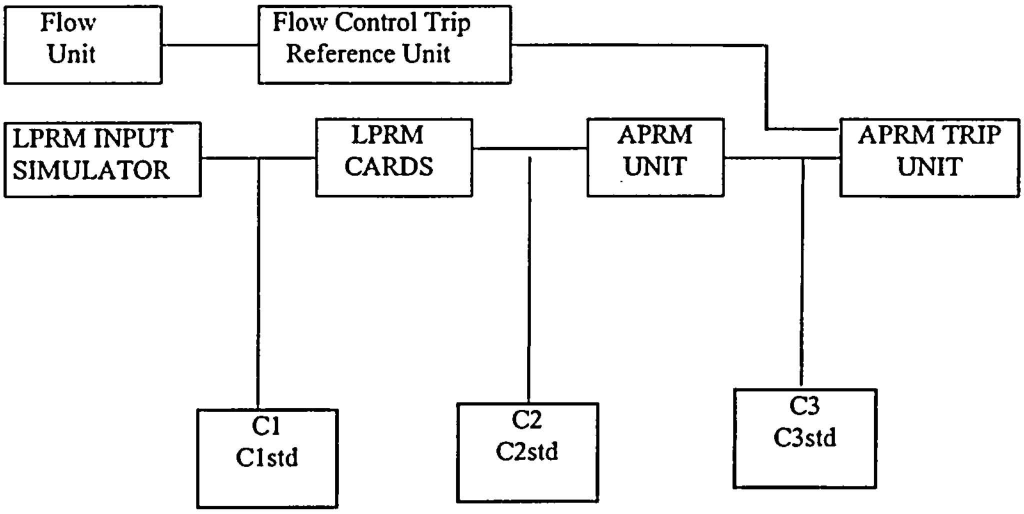
The basic ALT data for the RBM functions are:

| | Vdc | % Power | Ref. |
|---|---|---|---|
| $ALT_{12} =$ | 0.10 | 1.25 lprm | Assumption 3.17 |
| $ALT_{13} =$ | 0.10 | 1.25 lpsp | 10 |
| $ALT_{14} =$ | 0.10 | 1.25 ipsp | 10 |
| $ALT_{15} =$ | 0.10 | 1.25 hpsp | 10 |
| $ALT_{16} =$ | 0.10 | 1.25 dtsp | 10 |
| $ALT_{17} =$ | 0.08 | 1.00 ltsp | 10 |
| $ALT_{18} =$ | 0.10 | 1.25 itsp | 10 |

$ALT_{19}$ = 0.09 1.13 htsp 10

4.1.3.6 Determination of Device Calibration Error (Refs. 9, 12)

1. APRM Channels



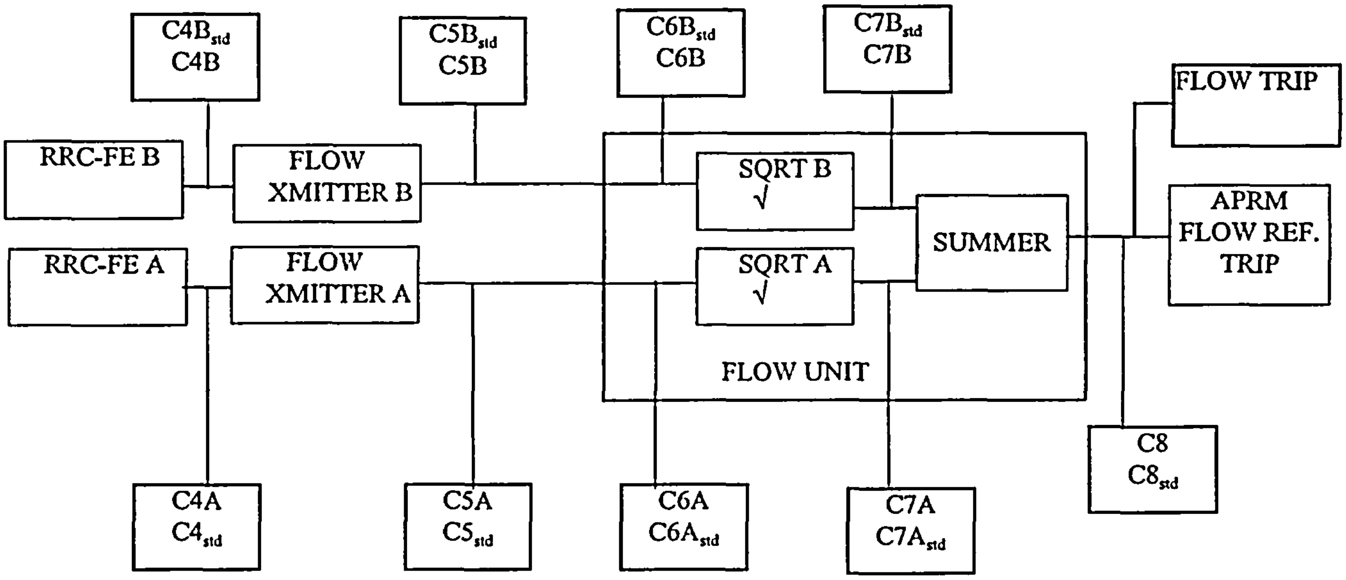
Calibration Equipment

$C_1$ = DVM Fluke 45 or Fluke 8600A
$CSTD_1 = C_1$

$C_2$ = DVM Fluke 45 or Fluke 8600A
$CSTD_2 = C_2$

$C_3$ = DVM Fluke 45 or Fluke 8600A
$CSTD_3 = C_3$

2. APRM Flow Reference Channel (Refs. 9, 11, 12)



Calibration Equipment

$C_{4A,B}$ = Pneumatic Calibrator CE 1120
$CSTD_{4A,B}$ = Dead Weight Tester Ametek RK

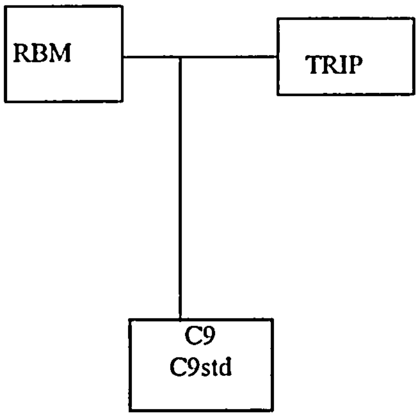
$C_{5A,B}$ = DVM Fluke 45, Fluke 8502A, or Fluke 8600A
$CSTD_{5A,B}$ = $C_{5A,B}$

$C_{6A,B}$ = DVM Fluke 45, Fluke 8502A, or Fluke 8600A
$CSTD_{6A,B}$ = $C_{6A,B}$

$C_{7A,B}$ = DVM Fluke 45, Fluke 8502A, or Fluke 8600A
$CSTD_{7A,B}$ = $C_{7A,B}$

$C_8$ = DVM Fluke 45, Fluke 8502A, or Fluke 8600A
$CSTD_8$ = $C_8$

3. RBM Channel (Refs. 10, 12)



Calibration Equipment

$C_9$ = DVM Fluke 45 or Fluke 8600A
$CSTD_9$ = $C_9$

4.1.3.6.1 Device Calibration Tool Error

The APRM and RBM channels are calibrated using Digital Voltmeters (DVM) which can be the Fluke 45, Fluke 8502A, or Fluke 8600A per References 9, 10. The DVMs are sent off site for calibration against a standard. Therefore the calibration tool error is assumed to be equal to the calibration standard error. The least accurate DVM calibration tool is used as bounding in this calculation. (References 37, 40, 50)

The recirculation flow loop transmitter is calibrated with a pneumatic calibrator which can be an Ametek or Crystal Engineering, per References 11, 21. The least accurate pneumatic calibrator tool is used as bounding in this calculation. The pneumatic calibrator tool is in turn calibrated by an Ametek type RK deadweight tester, Reference 21.

4.1.3.6.2 Device Calibration Error

The Calibration Error ( $C_i$ ) for Device "i" is the SRSS combination of the As Left Tolerance (ALT), and the errors due to input and output calibration tools (including tool accuracy and readability and the error of the calibration standards). Thus, on a 2 sigma basis the calibration error is:

$$C_i = 2 \times SQRT( (ALT_i / n)^2 + (CTOOL_{inp}/ n)_i^2 + (CREAD_{inp} / n)_i^2 + (CSTD_{inp} / n)_i^2 + (CTOOL_{out} / n)_i^2 + (CREAD_{out} /n)_i^2 + (CSTD_{out} / n)_i^2 ) \pm \text{any bias terms}$$

where 'n' is the sigma value associated with each individual term.

4.1.3.6.3 Device Calibration Error Values

Since the values of ALT, CTOOL, CREAD and CSTD are controlled by 100% testing, they are assumed to represent 3 sigma values. Vendor Accuracy is written as "Vendor Accur. or VA" below.

**1. APRM Channels**

| Item | Cal. Instrument | Description | Error |
|---|---|---|---|
| $C_1$ | DVM Fluke 45 | Vendor Accur. | 0.025% reading + 6 digits |
| | Range =10 Vdc | Display Exp | -3 |
| | (Ref. 37) | Temp. Comp. | 0.1 x VA per °C/(T-28) °C |
| | | Resolution | 100 microVdc |
| $CREAD_1$ | N/A (digital) | | |

For DVM 10.000 Vdc = 125% Power on APRM meter, range = 10 Vdc, and maximum calibration temperature 90 deg F = 32 deg C. Therefore,

$$CTOOL_1 = SQRT \{[0.025\% \times 10 \text{ Vdc} + 6 \text{ digits} \times 10^{-3}]^2 + [0.1 \times (0.025\% \times 10 \text{ Vdc} + 6 \text{ digits} \times 10^{-3}) \times (32-28)\ °C]^2 + (100 \text{ microVdc})^2\}$$

$$\begin{aligned} CTOOL_1 &= 0.0092 \text{ Vdc} \\ &= (0.0092 \text{ Vdc} / 10 \text{ Vdc}) \times 100\% = 0.092\ \%\ FS \\ &= 0.092\%\ FS \times (1.25\ \%\ \text{Power}/100\%\ FS) \\ &= 0.115\ \%\ \text{Power} \end{aligned}$$

$CREAD_1 = 0$ Vdc = 0.000% FS = 0.000% Power

And since items $C_2$ and $C_3$ are identical to $C_1$ and use the same range:

$CTOOL_1 = CTOOL_2 = CTOOL_3 = 0.115$ % Power

$CREAD_1 = CREAD_2 = CREAD_3 = 0.000$ % Power

The calibration standard error for each TOOL in the fixed neutron flux channel is conservatively assumed to be equal to the calibration tool error. Therefore:

$CSTD_1 = CSTD_2 = CSTD_3 = 0.115$ % Power

## 2. APRM Flow Reference Channel

| Item | Cal. Instrument | Description | Error |
|---|---|---|---|
| $C_{4A,B}$ | Pneu calib | Vendor Acc. | 0.1% FS + 1 digit |
| | (4 digit display) | Display Exp. | -1 |
| | | Temp. Comp. | 0.39% (Assump. 3.21) |
| | | Read | N/A (digital) (Ref. 38) |
| $CSTD_{4A,B}$ | Ametek RK | VA | 0.05% of ind (Ref. 39) |
| $C_{5A,B}$ | DVM Fluke 45 | (range = 100 mVdc) | |
| | | VA | 0.025% reading + 6 digits |
| | | Disp Exp | -2 |
| | | Temp. Comp. | 0.1 x VA per °C/(T-28) °C |
| | | Resolution | 1 microVdc |
| | | Read | N/A (digital) |
| $C_{6A,B}$ | DVM Fluke 45 | (range = 100 mVdc) | |
| | | VA | 0.025% reading + 6 digits |
| | | Disp Exp | -2 |
| | | Temp. Comp. | 0.1 x VA per °C/(T-28) °C |
| | | Resolution | 1 microVdc |
| | | Read | N/A (digital) |
| $C_{7A,B}$ | DVM Fluke 45 | (range = 10 Vdc) | |
| $C_8$ | DVM Fluke 45 | (range = 10 Vdc) | |

**Calibration Error for $C_{4A,B}$**

Pneumatic calibrator range = 0 - 830 in WC; therefore:

$$
\begin{aligned}
CTOOL_4 &= SQRT[(0.1\%\ FS \times 830\ inWC + 1 \times 10^{-1})^2 \\
&\qquad + (0.39\%\ FS \times 830\ inWC)^2] \\
&= 3.37\ in\ WC\ \text{over span of}\ 408.9\ in\ WC \\
&= (3.37\ in\ WC / 408.9\ in\ WC) \times 100\% = 0.824\%\ FS \\
&= 0.824\%\ FS \times (1.25\ \%\ Power/100\%\ FS) \\
&= 1.03\%\ Power
\end{aligned}
$$

Also,

$CREAD_4 = 0$ or 0.000% FS

**Calibration Error for $CSTD_{4A,B}$**

Unit = Ametek Type RK deadweight tester; Range = 830 in WC

$CSTD_{4A,B}$ = 0.05% x 830
= 0.415 in WC (over span of 408.9 in WC)
= (0.415 in WC / 408.9 in WC) x 100%
= 0.101 % FS x (1.25 % Power/100% FS)
= 0.126% Power

**Calibration Error for $C_{5A,B}$**

Unit: DVM Fluke 45; Range: 100.00 mV dc, Reading = 50.00 mVdc
Max Calib Temp = 40 deg C

Therefore:

$CTOOL_5$ = SQRT{(0.025% x 50 mVdc + 6 x $10^{-2})^2$
+ [0.1 x (0.025% x 50 mVdc + 6 x $10^{-2}$) x 12°C$]^2$
+ (1 microVdc$)^2$}
= 0.113 mVdc
= (0.113 mVdc/40.0 mAdc) x 100%
= 0.283% FS x (1.25 % Power/100% FS)
= 0.353% Power

Also,

$CREAD_5$ = 0 or 0.000% FS

**Calibration Error for $CSTD_{5A,B}$**

Assume calibration standard error is equal to the tool error

$CSTD_5$ = $CTOOL_5$ = 0.353% Power

**Calibration Error for $C_{6A,B}$**

Unit: DVM Fluke 45; Range: 100.00 mV dc, Reading = 50.00 mVdc
Max Calib Temp = 32 deg C

Therefore:

$CTOOL_6$ = SQRT{(0.025% x 50 mVdc + 6 x $10^{-2})^2$
+ [0.1 x (0.025% x 50 mVdc + 6 x $10^{-2}$) x 4°C$]^2$
+ (1 microVdc$)^2$}
= 0.078 mVdc
= (0.078 mVdc/40.0 mAdc) x 100% | 2
= 0.195% FS x (1.25 % Power/100% FS)
= 0.244% Power

Also,

$CREAD_6$ = 0 or 0.000% FS

**Calibration Error for $C_{6,BSTD}$**

Assume calibration standard error is equal to the tool error

$CSTD_6 = CTOOL_6 = 0.244\%$ Power

**Calibration Error for $C_{7A,B}$**

Unit: DVM Fluke 45; Range = 10.000 Vdc at 100% FS

$CTOOL_7 = 0.0092$ Vdc $= 0.092$ % FS

$= 0.092\%$ FS x (1.25 % Power/100% FS)

$= 0.115\%$ Power

$CREAD_7 = 0$ or $0.000\%$ FS

**Calibration Error for $CSTD_{7A,B}$**

Assume calibration standard error is equal to the tool error

$CSTD_7 = CTOOL_7 = 0.115$ % Power

**Calibration Error for $C_8$**

Unit: DVM Fluke 45; Range = 10.000 Vdc at 100% FS

$CTOOL_8 = 0.0092$ Vdc $= 0.092\%$ FS

$= 0.092\%$ FS x (1.25 % Power/100% FS)

$= 0.115\%$ Power

$CREAD_8 = 0$ or $0.000\%$ FS

**Calibration Error for $CSTD_8$**

Assume calibration standard error is equal to the tool error

$CSTD_8 = CTOOL_8 = 0.115\%$ Power

### 3. Overall APRM Channel Calibration Errors

The overall 2 sigma calibration errors for the various APRM functions is obtained by SRSS addition of the 3 sigma loop errors due to calibration tools, calibration standards and As Left Tolerance (ALT). Since all the calibration equipment is well maintained and tested, it is assumed that the $C_i$ and $C_iSTD$ values given above are 3 sigma values. Also, since the instruments are always kept within ALT after calibration, the ALT values listed in the calibration procedures (and shown in 4.1.3.5) represent 3 sigma values. Thus the overall 2 sigma calibration errors for the various APRM functions is obtained from:

$$C_L = 2 \times SQRT\{\Sigma(ALT_i/n)^2 + \Sigma(CTOOL_i/n)^2 + \Sigma(CREAD_i/n)^2 + \Sigma(CSTD_i/n)^2\}$$

**a) For APRM flow biased scram**

$$\begin{aligned}C_{\mathrm{fb\text{-}SCRAM}} = {} & 2 \text{ x SQRT } \{(ALT_1/3)^2 + (ALT_3/3)^2 + (ALT_7/3)^2 + \\ & 2(ALT_8/3)^2 + 2(ALT_9/3)^2 + 2(ALT_{10}/3)^2 + (ALT_{11}/3)^2 \\ & + (CTOOL_1/3)^2 + (CTOOL_2/3)^2 + (CTOOL_3/3)^2 \\ & + 2(CTOOL_4/3)^2 + 2(CTOOL_5/3)^2 + 2(CTOOL_6/3)^2 \\ & + 2(CTOOL_7/3)^2 + (CTOOL_8/3)^2 + (CSTD_1/3)^2 + \\ & (CSTD_2/3)^2 + (CSTD_3/3)^2 + 2(CSTD_{4A,B}/3)^2 + \\ & 2(CSTD_{5A,B}/3)^2 + 2(CSTD_{6A,B}/3)^2 + 2(CSTD_{7A,B}/3)^2 + \\ & (CSTD_8/3)^2\}\end{aligned}$$

$$\begin{aligned}C_{\mathrm{fb\text{-}SCRAM}} = {} & 2 \text{ x SQRT } \{(1.25/3)^2 + (1.25/3)^2 + (1.0/3)^2 + 2(0.41/3)^2 + \\ & 2(0.01/3)^2 + 2(0.04/3)^2 + (0.08/3)^2 + (0.115/3)^2 + \\ & (0.115/3)^2 + (0.115/3)^2 + 2(1.03/3)^2 + 2(0.353/3)^2 + \\ & 2(0.244/3)^2 + 2(0.115/3)^2 + (0.115/3)^2 + (0.115/3)^2 + \\ & (0.115/3)^2 + (0.115/3)^2 + 2(0.126/3)^2 + 2(0.353/3)^2 + \\ & 2(0.244/3)^2 + 2(0.115/3)^2 + (0.115/3)^2\}\end{aligned}$$

| △2

$C_{\mathrm{fb\text{-}SCRAM}} = 1.83\%$ Power | △2

**b) For APRM flow biased rod block**

$$\begin{aligned}C_{\mathrm{fb\text{-}RB}} = {} & 2 \text{ x SQRT } \{(ALT_1/3)^2 + (ALT_4/3)^2 + (ALT_7/3)^2 + 2(ALT_8/3)^2 + \\ & 2(ALT_9/3)^2 + 2(ALT_{10}/3)^2 + (ALT_{11}/3)^2 + (CTOOL_1/3)^2 \\ & + (CTOOL_2/3)^2 + (CTOOL_3/3)^2 + 2(CTOOL_{4A,B}/3)^2 \\ & + 2(CTOOL_{5A,B}/3)^2 + 2(CTOOL_{6A,B}/3)^2 + 2(CTOOL_{7A,B}/3)^2 \\ & + (CTOOL_8/3)^2 + (CSTD_1/3)^2 + (CSTD_2/3)^2 + (CSTD_3/3)^2 \\ & + 2(CSTD_{4A,B}/3)^2 + 2(CSTD_{5A,B}/3)^2 + 2(CSTD_{6A,B}/3)^2 \\ & + 2(CST_{7A,B}/3)^2 + (CSTD_8/3)^2\}\end{aligned}$$

$$\begin{aligned}C_{\mathrm{fb\text{-}RB}} = {} & 2 \text{ x SQRT } \{(1.25/3)^2 + (1.25/3)^2 + (1.0/3)^2 + 2(0.41/3)^2 \\ & + 2(0.01/3)^2 + 2(0.04/3)^2 + (0.08/3)^2 + (0.115/3)^2 + (0.115/3)^2 \\ & + (0.115/3)^2 + 2(1.03/3)^2 + 2(0.353/3)^2 + 2(0.244/3)^2 \\ & + 2(0.115/3)^2 + (0.115/3)^2 + (0.115/3)^2 + (0.115/3)^2 \\ & + (0.115/3)^2 + 2(0.126/3)^2 + 2(0.353/3)^2 + 2(0.244/3)^2 \\ & + 2(0.115/3)^2 + (0.115/3)^2\}\end{aligned}$$

| △2

$C_{\mathrm{fb\text{-}RB}} = 1.83\ \%$ Power | △2

**c) For APRM neutron flux fixed high SCRAM**

$$\begin{aligned}C_{\mathrm{fix\text{-}SCRAM}} = {} & 2 \text{ x SQRT } \{(ALT_1/3)^2 + (ALT_2/3)^2 + (ALT_7/3)^2 \\ & + (CTOOL_1/3)^2 + (CTOOL_2/3)^2 + (CTOOL_3/3)^2 \\ & + (CSTD_1/3)^2 + (CSTD_2/3)^2 + (CSTD_3/3)^2\}\end{aligned}$$

$$\begin{aligned}C_{\mathrm{fix\text{-}SCRAM}} = {} & 2 \text{ x SQRT } \{(1.25/3)^2 + (1.25/3)^2 + (1.0/3)^2 + (0.115/3)^2 \\ & + (0.115/3)^2 + (0.115/3)^2 + (0.115/3)^2 + (0.115/3)^2 \\ & + (0.115/3)^2\}\end{aligned}$$

$C_{\mathrm{fix\text{-}SCRAM}} = 1.37\%$ Power

2

**d) For APRM neutron flux rod block clamp**

$$C_{\text{clamp-RB}} = 2 \text{ x SQRT } \{(ALT_1/3)^2 + (ALT_{2B}/3)^2 + (CTOOL_1/3)^2 + (CTOOL_2/3)^2 + (CTOOL_3/3)^2 + (CSTD_1/3)^2 + (CSTD_2/3)^2 + (CSTD_3/3)^2\}$$

$$C_{\text{clamp-RB}} = 2 \text{ x SQRT } \{(1.25/3)^2 + (1.25/3)^2 + (0.115/3)^2 + (0.115/3)^2 + (0.115/3)^2 + (0.115/3)^2 + (0.115/3)^2 + (0.115/3)^2\}$$

$$C_{\text{clamp-RB}} = 1.19\% \text{ Power}$$

**e) For APRM neutron flux downscale rod block**

$$C_{\text{down-RB}} = 2 \text{ x SQRT } \{(ALT_1/3)^2 + (ALT_{2A}/3)^2 + (CTOOL_1/3)^2 + (CTOOL_2/3)^2 + (CTOOL_3/3)^2 + (CSTD_1/3)^2 + (CSTD_2/3)^2 + (CSTD_3/3)^2\}$$

$$C_{\text{down-RB}} = 2 \text{ x SQRT } \{(1.25/3)^2 + (1.0/3)^2 + (0.115/3)^2 + (0.115/3)^2 + (0.115/3)^2 + (0.115/3)^2 + (0.115/3)^2 + (0.115/3)^2\}$$

$$C_{\text{down-RB}} = 1.08\% \text{ Power}$$

**f) For APRM neutron flux fixed high scram - setdown**

$$C_{\text{set-SCRAM}} = 2 \text{ x SQRT } \{(ALT_1/3)^2 + (ALT_5/3)^2 + (CTOOL_1/3)^2 + (CTOOL_2/3)^2 + (CTOOL_3/3)^2 + (CSTD_1/3)^2 + (CSTD_2/3)^2 + (CSTD_3/3)^2\}$$

$$C_{\text{set-SCRAM}} = 2 \text{ x SQRT } \{(1.25/3)^2 + (0.5/3)^2 + (0.115/3)^2 + (0.115/3)^2 + (0.115/3)^2 + (0.115/3)^2 + (0.115/3)^2 + (0.115/3)^2\}$$

$$C_{\text{set-SCRAM}} = 0.92\% \text{ Power}$$

**g) For APRM neutron flux fixed rod block - setdown**

$$C_{\text{set-RB}} = 2 \text{ x SQRT } \{(ALT_1/3)^2 + (ALT_6/3)^2 + (CTOOL_1/3)^2 + (CTOOL_2/3)^2 + (CTOOL_3/3)^2 + (CSTD_1/3)^2 + (CSTD_2/3)^2 + (CSTD_3/3)^2\}$$

$$C_{\text{set-RB}} = 2 \text{ x SQRT } \{(1.25/3)^2 + (0.5/3)^2 + (0.115/3)^2 + (0.115/3)^2 + (0.115/3)^2 + (0.115/3)^2 + (0.115/3)^2 + (0.115/3)^2\}$$

$$C_{\text{set-RB}} = 0.92 \text{ \% Power}$$

**4. RBM Channel**

| Item | Cal. Instrument | Description | Error |
|---|---|---|---|
| $C_9$ | DVM Fluke 45 | Vendor Accur. | 0.025% reading + 6 digits |
| | Range =10 Vdc | Display Exp | -3 |
| | (Ref. 37) | Temp. Comp. | 0.1 x VA per °C/(T-28) °C |
| | | Resolution | 100 microVdc |
| | | CRead | N/A (digital) |

For DVM 10.000 Vdc = 125% Power on RBM meter, range = 10 Vdc, and maximum calibration temperature 90 deg F = 32 deg C. Therefore,

$$CTOOL_9 = SQRT\ \{[0.025\%\ x\ 10\ Vdc + 6\ digits\ x\ 10^{-3}]^2 + [0.1\ x\ (0.025\%\ x\ 10\ Vdc + 6\ digits\ x\ 10^{-3})\ x\ (32\text{-}28)\ °C]^2 + (100\ microVdc)^2\}$$

$CTOOL_9$ = 0.0092 Vdc

= (0.0092 Vdc / 10 Vdc) x 100% = 0.092 % FS

= 0.092% FS x 1.25 % Power

= 0.115 % Power

$CREAD_9$ = 0 Vdc = 0.000% FS = 0.000% Power

The calibration standard error for the is conservatively assumed to be equal to the calibration tool error. Therefore:

$CSTD_9$ = 0.115 % Power

The overall 2 sigma calibration error including As Left Tolerance (ALT) is calculated from

$$C = 2\ x\ SQRT\{(ALT_i/n)^2 + (CTOOL_i/n)^2 + (CREAD_i/n)^2 + (CSTD_i/n)^2\}$$

This overall calibration errors for the various RBM functions, using the values of $CTOOL_i$ , $CREAD_i$, and $CSTD_i$ from above and the appropriate $ALT_i$ values from 4.1.3.5 subheading 2, are shown below :

**a) For RBM low power setpoint (LPSP)**

$$C_{lpsp} = 2\ x\ SQRT\ \{(ALT_{12}/3)^2 + (ALT_{13}/3)^2 + (CTOOL_9/3)^2 + (CSTD_9/3)^2\}$$

$$C_{lpsp} = 2\ x\ SQRT\ \{(1.25/3)^2 + (1.25/3)^2 + (0.115/3)^2 + (0.115/3)^2\}$$

$C_{lpsp}$ = 1.18 % Power

**b) For RBM intermediate power setpoint (IPSP)**

$$C_{ipsp} = 2\ x\ SQRT\ \{(ALT_{12}/3)^2 + (ALT_{14}/3)^2 + (CTOOL_9/3)^2 + (CSTD_9/3)^2\}$$

$$C_{ipsp} = 2\ x\ SQRT\ \{(1.25/3)^2 + (1.25/3)^2 + (0.115/3)^2 + (0.115/3)^2\}$$

$C_{ipsp}$ = 1.18% Power

**c) For RBM high power setpoint (HPSP)**

$$C_{hpsp} = 2\ x\ SQRT\ \{(ALT_{12}/3)^2 + (ALT_{15}/3)^2 + (CTOOL_9/3)^2 + (CSTD_9/3)^2\}$$

$$C_{hpsp} = 2\ x\ SQRT\ \{(1.25/3)^2 + (1.25/3)^2 + (0.115/3)^2 + (0.115/3)^2\}$$

$C_{hpsp}$ = 1.18% Power

**d) For RBM downscale trip setpoint (DTSP)**

$C_{dtsp} = 2 \times SQRT\ \{(ALT_{12}/3)^2 + (ALT_{16}/3)^2 + (CTOOL_9/3)^2 + (CSTD_9/3)^2\}$

$C_{dtsp} = 2 \times SQRT\ \{(1.25/3)^2 + (1.25/3)^2 + (0.115/3)^2 + (0.115/3)^2\}$

$C_{dtsp} = 1.18\%$ Power

**e) For RBM low trip setpoint (LTSP)**

$C_{ltsp} = 2 \times SQRT\ \{(ALT_{12}/3)^2 + (ALT_{17}/3)^2 + (CTOOL_9/3)^2 + (CSTD_9/3)^2\}$

$C_{ltsp} = 2 \times SQRT\ \{(1.25/3)^2 + (1.00/3)^2 + (0.115/3)^2 + (0.115/3)^2\}$

$C_{ltsp} = 1.07\%$ Power

**f) For RBM intermediate trip setpoint (ITSP)**

$C_{itsp} = 2 \times SQRT\ \{(ALT_{12}/3)^2 + (ALT_{18}/3)^2 + (CTOOL_9/3)^2 + (CSTD_9/3)^2\}$

$C_{itsp} = 2 \times SQRT\ \{(1.25/3)^2 + (1.25/3)^2 + (0.115/3)^2 + (0.115/3)^2\}$

$C_{itsp} = 1.18\%$ Power

**g) For RBM high trip setpoint (HTSP)**

$C_{htsp} = 2 \times SQRT\ \{(ALT_{12}/3)^2 + (ALT_{19}/3)^2 + (CTOOL_9/3)^2 + (CSTD_9/3)^2\}$

$C_{htsp} = 2 \times SQRT\ \{(1.25/3)^2 + (1.13/3)^2 + (0.115/3)^2 + (0.115/3)^2\}$

$C_{htsp} = 1.13\%$ Power

### 4.1.4 Determination of Loop/Channel Values

For this calculation the loop contains several devices, thus the device error values for Accuracy, Drift and Calibration are the same as those for the loop. These values have been reported in Section 4.1.3.

### 4.1.5 Determination of PEA and PMA

**Primary Element Accuracy (PEA):**

APRM Channel

The PEA is a combination of the GE-LPRM sensor sensitivity and sensor non-linearity uncertainties. The sensitivity of the detectors decreases with neutron influence. The average sensitivity loss, and its 2 sigma variation, for all GE LPRM detectors has been determined to be:

Sensor Sensitivity loss = 0.33 % (bias term)
+/- 0.20% (random term) (Reference 4, section 4.5)

The detector non-linearity and its 2 sigma variation (in the power range) has been determined to be:

Sensor Non-linearity = 0.49% (bias term)
+/- 1% (random term) (Reference 4, section 4.5)

The first part of these detector errors represent bias type errors which apply to all detectors whereas the second part are random errors that represent variability amongst the sensors. Assuming a worst case senario where the APRM has the minimum number of operational detectors, the PEA, which on a percent of power basis, is simply obtained by adding the bias terms and taking the SRSS of the random terms, is calculated below. In the calculation, the random error is reduced by the square root of the minimum number of operable LPRMS to one APRM channel which are 11 per Reference 35.

Minimum number of LPRMS per APRM = 11

Therefore, PEA = (0.33 + 0.49) ± (1/ sqrt 11)(sqrt $(0.20^2 + 1^2)$

or PEA (APRM) = 0.82 ± 0.31% power

The first part of the PEA (0.82%) is treated as a drift term (DPEA) and the second part (± 0.31%) as an accuracy term (APEA).

The PEA value for the Westinghouse LPRM sensors installed at the Cooper site is given as 0.7 ± 1% per Reference 52. In the present calculations the GE LPRM PEA error values will be used as they are more conservative.

RBM Channel

PEA is similar to that for the APRMS and equals

0.33% (bias term) +/- 0.20% (random term)

and

0.49% (bias term) +/- 1% (random term), respectively

In the calculation, the random error is reduced by the square root of the minimum number of operable LPRMS to one RBM channel which are 2 per Reference 35.

Minimum number of LPRMS per RBM = 2

Therfore, PEA = (0.33 + 0.49) ± (1/ sqrt 2 )(SQRT $(0.20^2 + 1^2)$

or PEA (RBM) = 0.82 ± 0.72% power

The first part of the PEA (0.82%) is treated as a drift term (DPEA) and the second part (± 0.72%) as an accuracy term (APEA).

The value PEA value for the Westinghouse LPRM sensors installed at the Cooper site is given as 0.7 ± 1% per Reference 52. Since the GE value is larger than the Westinghouse LPRM uncertainty value, the GE value will be used in the calculations.

Flow Unit

The PEA for the flow channel venturis is included in the flow channel uncertainty, therefore no additional uncertainty is necessary, it follows that,

PEA (Flow) =0

**Process Measurement Accuracy (PMA):**

APRM Channel

The PMA is a combination of the APRM tracking and the uncertainty due to neutron noise. Considering the APRM neutron flux, for the MSIV closure transient event, the APRM tracking error is 1.11% and the uncertainty due to neutron noise is typically 2.0%, Reference 4. Flow noise is estimated to be 1.0% rated flow (0.66% power) per References 52 and 54. The tracking error is the uncertainty of the maximum deviation of APRM readings with LPRM failures or bypasses during a power transient. 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. 2

For neutron flux PMA = $2 \times \text{SQRT}\,[(2.0/2)^2 + (1.11/2)^2] = 2.29\%$ power (fixed)

For flow biased, PMA = $2 \times \text{SQRT}[(1.11/2)^2 + (2/2)^2 + (0.66/2)^2] = 2.38\%$ power (flow-biased) 2

RBM

The PMA of the RBM is a combination of the RBM tracking error and the uncertainty due to neutron noise. The uncertainty due to neutron noise is estimated to be the same as the APRM or 2.0% (2-sigma). The error calculated by comparing the reading with all LPRMS operable to readings with different combinations of LPRM failure is estimated to be within 1% (3-sigma) per Reference 52. A 3-sigma confidence level is used because the 1% value is based on testing.

PMA = $2 \times \text{SQRT}\,[(2.0/2)^2 + (1.0/3)^2] = 2.11\%$ power (RBM Power)

PMA = $2 \times \text{SQRT}\,[(2.0/2)^2 + (1.0/3)^2] = 2.11\%$ power (RBM Trip)

### 4.1.6 Determination of Other Error Terms

All error terms to be considered have been accounted for in the previous sections.

### 4.1.7 Calculation of Setpoint Margin and Operating Setpoint

#### 4.1.7.1 Setpoint Margin

The setpoint margin is defined as the margin between the nominal setpoint and the analytic limit. Based on References 5, 7, this margin is given by:

SM = (1.645/N)(SRSS OF RANDOM TERMS) + BIAS TERMS

Where N represents the number of standard deviations with which all the random terms are characterized (normally 2 standard deviations) and 1.645 adjusts the results to a 95% probability (one-sided normal).

The error terms are calculated for trip conditions, and the margin becomes

$$SM = (1.645/N) \times \text{SQRT}\,(A_{LT}^2 + C_L^2 + D_L^2 + PMA^2 + PEA^2) + (\Sigma\ \text{BIAS TERMS})$$

**a). APRM CHANNEL**

**1. Flow Biased Scram**

$SM_{fb\text{-}SCRAM} = [\,(1.645/2) \times SQRT\,(A_{LT\text{-}fb}^2 + C_{fb\text{-}SCRAM}^2 + D_{fb}^2 + PMA^2 + APEA^2)\,] + DPEA$

$= (1.645/2) \times SQRT\,(2.55^2 + 1.83^2 + 1.88^2 + 2.38^2 + 0.31^2) + 0.82$ 2

$= 4.42$ % Power

**2. Flow Biased Rod Block**

$SM_{fb\text{-}RB} = [\,(1.645/2) \times SQRT\,(A_{LT\text{-}fb}^2 + C_{fb\text{-}RB}^2 + D_{fb}^2 + PMA^2 + APEA^2)\,] + DPEA$

$= (1.645/2) \times SQRT\,(2.55^2 + 1.83^2 + 1.88^2 + 2.38^2 + 0.31^2) + 0.82$ 2

$= 4.42$ % Power

**3. Neutron Flux - Fixed High SCRAM**

$SM_{fix\text{-}SCRAM} = [\,(1.645/2) \times SQRT\,(A_{LT\text{-}fix}^2 + C_{fix\text{-}SCRAM}^2 + D_{fix}^2 + PMA^2 + APEA^2)\,] + DPEA$

$= (1.645/2) \times SQRT\,(1.63^2 + 1.37^2 + 1.51^2 + 2.29^2 + 0.31^2) + 0.82$

$= 3.69$% Power

**4. Neutron Flux Rod Block Clamp**

$SM_{clamp\ RB} = [\,(1.645/2) \times SQRT\,(A_{LT\text{-}fix}^2 + C_{clamp\text{-}RB}^2 + D_{fix}^2 + PMA^2 + APEA^2)\,] + DPEA$ 2

$= (1.645/2) \times SQRT\,(1.63^2 + 1.19^2 + 1.51^2 + 2.29^2 + 0.31^2) + 0.82$

$= 3.63$ % Power

**5. Neutron Flux Downscale Rod Block**

$SM_{down\ RB} = [\,(1.645/2) \times SQRT\,(A_{LT\text{-}fix}^2 + C_{down\text{-}RB}^2 + D_{fix}^2 + PMA^2 + APEA^2)\,] + DPEA$

$= (1.645/2) \times SQRT\,(1.63^2 + 1.08^2 + 1.51^2 + 2.29^2 + 0.31^2) + 0.82$

$= 3.60$ % Power

**6. Neutron Flux Fixed High Scram - Setdown**

$SM_{set\text{-}SCRAM} = [\,(1.645/2) \times SQRT\,(A_{LT\text{-}fix}^2 + C_{set\text{-}SCRAM}^2 + D_{fix}^2 + PMA^2 + APEA^2)\,] + DPEA$

$= (1.645/2) \times SQRT\,(1.63^2 + 0.92^2 + 1.51^2 + 2.29^2 + 0.31^2) + 0.82$

$= 3.56$ % Power

7. **Neutron Flux Fixed High Rod Block - Setdown**

$$SM_{set\text{-}RB} = [\,(1.645/2) \times SQRT\,(A_{LT\text{-}fix}^2 + C_{set\text{-}RB}^2 + D_{fix}^2 + PMA^2 + APEA^2)\,] + DPEA$$

$$= (1.645/2) \times SQRT\,(1.63^2 + 0.92^2 + 1.51^2 + 2.29^2 + 0.31^2) + 0.82$$

$$= 3.56\ \%\ \text{Power}$$

**b) RBM CHANNEL**

1. **Low Power Setpoint (LPSP)**

$$SM_{lpsp} = [\,(1.645/2) \times SQRT\,(A_{LT\text{-}RBM\text{-}pwr}^2 + C_{lpsp}^2 + D_{RBM\text{-}pwr}^2 + PMA^2 + APEA^2)\,] + DPEA$$

$$= (1.645/2) \times SQRT\,(1.22^2 + 1.18^2 + 0.99^2 + 2.11^2 + 0.72^2) + 0.82$$

$$= 3.26\ \%\ \text{Power}$$

2. **Intermediate Power Setpoint (IPSP)**

$$SM_{ipsp} = [\,(1.645/2) \times SQRT\,(A_{LT\text{-}RBM\text{-}pwr}^2 + C_{ipsp}^2 + D_{RBM\text{-}pwr}^2 + PMA^2 + APEA^2)\,] + DPEA$$

$$= (1.645/2) \times SQRT\,(1.22^2 + 1.18^2 + 0.99^2 + 2.11^2 + 0.72^2) + 0.82$$

$$= 3.26\ \%\ \text{Power}$$

3. **High Power Setpoint (HPSP)**

$$SM_{hpsp} = [\,(1.645/2) \times SQRT\,(A_{LT\text{-}RBM\text{-}pwr}^2 + C_{hpsp}^2 + D_{RBM\text{-}pwr}^2 + PMA^2 + APEA^2)\,] + DPEA$$

$$= (1.645/2) \times SQRT\,(1.22^2 + 1.18^2 + 0.99^2 + 2.11^2 + 0.72^2) + 0.82$$

$$= 3.26\%\ \text{Power}$$

4. **Downscale Trip Setpoint (DTSP)**

$$SM_{dtsp} = [\,(1.645/2) \times SQRT\,(A_{LT\text{-}RBM\text{-}trip}^2 + C_{dtsp}^2 + D_{RBM\text{-}trip}^2 + PMA^2 + APEA^2)\,] + DPEA$$

$$= (1.645/2) \times SQRT\,(1.91^2 + 1.18^2 + 2.04^2 + 2.11^2 + 0.72^2) + 0.82$$

$$= 3.92\ \%\ \text{Power}$$

5. **Low Trip Setpoint (LTSP)**

$$SM_{ltsp} = [\,(1.645/2) \times SQRT\,(A_{LT\text{-}RBM\text{-}trip}^2 + C_{ltsp}^2 + D_{RBM\text{-}trip}^2 + PMA^2 + APEA^2)\,] + DPEA$$

$$= (1.645/2) \times SQRT\,(1.91^2 + 1.07^2 + 2.04^2 + 2.11^2 + 0.72^2) + 0.82$$

$$= 3.89\ \%\ \text{Power}$$

6. **Intermediate Trip Setpoint (ITSP)**

$SM_{itsp} = [\,(1.645/2) \times SQRT\,(A_{LT\text{-}RBM\text{-}trip}{}^2 + C_{itsp}{}^2 + D_{RBM\text{-}trip}{}^2 + PMA^2 + APEA^2)\,] + DPEA$

$= (1.645/2) \times SQRT\,(1.91^2 + 1.18^2 + 2.04^2 + 2.11^2 + 0.72^2) + 0.82$

$= 3.92$ % Power

7. **High Trip Setpoint (HTSP)**

$SM_{htsp} = [\,(1.645/2) \times SQRT\,(A_{LT\text{-}RBM\text{-}trip}{}^2 + C_{htsp}{}^2 + D_{RBM\text{-}trip}{}^2 + PMA^2 + APEA^2)\,] + DPEA$

$= (1.645/2) \times SQRT\,(1.91^2 + 1.13^2 + 2.04^2 + 2.11^2 + 0.72^2) + 0.82$

$= 3.90$ % Power

4.1.7.2 Nominal Trip Setpoint (NTSP1) Calculation

The Nominal Trip Setpoint (NTSP1) for process variables which increase to trip is given by:

NTSP1 = AL - SM

NTSP1 represents the upper limit (closest to AV) at which the setpoint can be set assuming zero leave alone tolerance in the direction toward the Allowable Value (AV).

a) APRM CHANNEL

1. **Flow Biased Scram**

Flow biased setpoints will be shown in terms of the intercept, since the slope (0.66 W) is a constant 2

$NTSP1_{fb\text{-}SCRAM} = AL - SM_{fb\text{-}SCRAM}$

For this function

AL= 0.66W + 74.8 % Power (Reference 54) 2

Therefore:

$NTSP1_{fb\text{-}SCRAM} =$ 74.8% - 4.42% = 70.38% Power

2. **Flow Biased Rod Block**

$NTSP1_{fb\text{-}RB} = AL - SM_{fb\text{-}RB}$

For this function

AL= 0.66W + 63.5% Power (Reference 54) 2

Therefore:

$NTSP1_{fb\text{-}RB} =$ 63.5% - 4.42% = 59.08% Power

3. **Neutron Flux – Fixed High SCRAM**

$NTSP1_{fix\text{-}SCRAM} = AL - SM_{fix\text{-}SCRAM}$

For this function

| | |
|---|---|
| AL= 123.0% Power | (Reference 2) |

Therefore:

$NTSP1_{fix\text{-}SCRAM} =$ 123.0% - 3.69% = 119.31% Power

4. **Neutron Flux Rod Block Clamp**

$NTSP1_{clamp\ RB} = AL + SM_{clamp\ RB}$

For this function

| | |
|---|---|
| AL= 111.7% Power | (Reference 54) |

Therefore:

$NTSP1_{down\ RB} =$ 111.7% - 3.63% = 108.07% Power

5. **Neutron Flux Downscale Rod Block**

$NTSP1_{down\ RB} = AL + SM_{down\ RB}$

For this function

| | |
|---|---|
| AL= 0.0% Power | (Reference 2) |

Therefore:

$NTSP1_{down\ RB} =$ 0.0% + 3.60% = 3.60% Power

6. **Neutron Flux Fixed High SCRAM - Setdown**

$NTSP1_{set\text{-}SCRAM} = AL - SM_{set\text{-}SCRAM}$

For this function

| | |
|---|---|
| AL= 17.4% Power | (Reference 2) |

Therefore:

$NTSP1_{set\text{-}SCRAM} =$ 17.4% - 3.56% = 13.84 % Power

7. **Neutron Flux Fixed High Rod Block - Setdown**

$NTSP1_{set\text{-}RB} = AL - SM_{set\text{-}RB}$

For this function

| | |
|---|---|
| AL= 14.4% Power | (Reference 2) |

Therefore:

$NTSP1_{set\text{-}RB} =$ 14.4% - 3.56% = 10.84% Power

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**b) RBM CHANNEL**

1. **Low Power Setpoint (LPSP)**

$NTSP1_{lpsp} = AL - SM_{lpsp}$

For this function

| | |
|---|---|
| AL= 30.0% Power | (Reference 2) |

Therefore:

$NTSP1_{lpsp} = 30.0\% - 3.26\% = 26.74\ \%$ Power

2. **Intermediate Power Setpoint (IPSP)**

$NTSP1_{ipsp} = AL - SM_{ipsp}$

For this function

| | |
|---|---|
| AL= 65.0% Power | (Reference 2) |

Therefore:

$NTSP1_{ipsp} = 65.0\% - 3.26\% = 61.74\ \%$ Power

3. **High Power Setpoint (HPSP)**

$NTSP1_{hpsp} = AL - SM_{hpsp}$

For this function

| | |
|---|---|
| AL= 85.0% Power | (Reference 2) |

Therefore:

$NTSP1_{hpsp} = 85.0\% - 3.26\% = 81.74\%$ Power

4. **Downscale Trip Setpoint (DTSP)**

$NTSP1_{dtsp} = AL + SM_{dtsp}$

For this function

| | |
|---|---|
| AL= 89.0% Power | (Reference 2) |

Therefore:

$NTSP1_{dtsp} = 89.0\% + 3.92\% = 92.92\%$ Power

5. **Low Trip† Setpoint (LTSP)**

$NTSP1_{ltsp} = AL - SM_{ltsp}$

For this function

AL= 117.0% Power (Reference 2)

Therefore:

$NTSP1_{ltsp} = 117.0\% - 3.89\% = 113.11\%$ Power

6. **Intermediate Trip† Setpoint (ITSP)**

$NTSP1_{itsp} = AL - SM_{itsp}$

For this function

AL= 111.2% Power (Reference 2)

Therefore:

$NTSP1_{itsp} = 111.2\% - 3.92\% = 107.28\ \%$ Power

7. **High Trip† Setpoint (HTSP)**

$NTSP1_{htsp} = AL - SM_{htsp}$

For this function

AL= 107.4% Power (Reference 2)

Therefore:

$NTSP1_{htsp} = 107.4\% - 3.90\% = 103.50\ \%$ Power

4.1.7.3 Allowable Value Calculation

For this setpoint calculation the process variable increases to trip, so the Allowable Value (AV) is calculated using the following equation (Reference 4):

$$AV = AL - (1.645/N)(\text{SRSS OF RANDOM TERMS}) - \text{BIAS TERMS}$$

Where N represents the number of standard deviations with which all the random terms are characterized (normally 2 standard deviations) and 1.645 adjusts the results to a 95% probability (one-sided normal).

The random errors include the random portion of ALT, CL, PMA, PEA, but exclude drift. Thus,

$$AV = AL - (1.645/N) \times SQRT(A_{LT}^2 + C_L^2 + PMA^2 + PEA^2) - (\Sigma \text{ BIAS TERMS})$$

---

† Note: For the RBM trip setpoints, a MCPR of 1.20 is used, margins are the same for other MCPRs and are summarized in the conclusion (Section 5).

a) APRM CHANNEL

**1. Flow Biased Scram**

Allowable values for flow biased setpoints will be shown in terms of the intercept, since the slope (0.66 W) is a constant.

$$AV_{fb\text{-}SCRAM} = AL - (1.645/2) \times SQRT\,(A_{LT\text{-}fb}^2 + C_{fb\text{-}SCRAM}^2 + PMA^2 + PEA^2)$$

For this function the AL is

$$AL = 0.66W + 74.8\%$$

Therefore

$$AV_{fb\text{-}SCRAM} = 74.8 - (1.645/2) \times SQRT\,(2.55^2 + 1.83^2 + 2.38^2 + 0.31^2)$$ 2

$$= 71.55\ \%\ Power$$

Rounded down conservatively to nearest readable increment:

$$AV_{fb\text{-}SCRAM} = 71.5\%\ Power$$

**2. Flow Biased Rod Block**

Allowable values for flow biased setpoints will be shown in terms of the intercept, since the slope (0.66 W) is a constant.

$$AV_{fb\text{-}RB} = AL - (1.645/2) \times SQRT\,(A_{LT\text{-}fb}^2 + C_{fb\text{-}RB}^2 + PMA^2 + PEA^2)$$

For this function the AL is

$$AL = 0.66W + 63.5\%$$

Therefore,

$$AV_{fb\text{-}RB} = 63.5 - (1.645/2) \times SQRT\,(2.55^2 + 1.83^2 + 2.38^2 + 0.31^2)$$ 2

$$= 60.25\%\ Power$$

Rounded down conservatively to nearest readable increment:

$$AV_{fb\text{-}RB} = 60.0\ \%\ Power$$

**3. Neutron Flux – Fixed High SCRAM**

$$AV_{fix\text{-}SCRAM} = AL - (1.645/2) \times SQRT\,(A_{LT\text{-}fix}^2 + C_{fix\text{-}SCRAM}^2 + PMA^2 + PEA^2)$$

For this function the AL is:

$$AL = 123.0\%$$

Therefore,

$$AV_{fix\text{-}SCRAM} = 123.0\% - (1.645/2) \times SQRT\,(1.63^2 + 1.37^2 + 2.29^2 + 0.31^2)$$

$$= 120.41\ \%\ Power$$

Rounded down conservatively to nearest readable increment:

$$AV_{fix\text{-}SCRAM} = 120.0\ \%\ Power$$

**4. Neutron Flux Rod Block Clamp**

$AV_{clamp\,RB} = AL + (1.645/2) \times SQRT\,(A_{LT\text{-}fix}{}^2 + C_{clamp\text{-}RB}{}^2 + PMA^2 + PEA^2)$

For this function the AL is:

$AL = 111.7\%$

Therefore, 2

$AV_{down\,RB} = 111.7\% - (1.645/2) \times SQRT\,(1.63^2 + 1.19^2 + 2.29^2 + 0.31^2)$

$= 109.17\,\%$ Power

Rounded down conservatively to nearest readable increment:

$AV_{clamp\text{-}RB} = 109.0\,\%$ Power

**5. Neutron Flux Downscale Rod Block**

$AV_{down\,RB} = AL + (1.645/2) \times SQRT\,(A_{LT\text{-}fix}{}^2 + C_{down\text{-}RB}{}^2 + PMA^2 + PEA^2)$

For this function the AL is:

$AL = 0.0\%$

Therefore,

$AV_{down\,RB} = 0.0\% + (1.645/2) \times SQRT\,(1.63^2 + 1.08^2 + 2.29^2 + 0.31^2)$

$= 2.49\,\%$ Power

Rounded up conservatively for ITS implementation consideration:

$AV_{down\,RB} = 3.0\,\%$ Power

**6. Neutron Flux Fixed High SCRAM - Setdown**

$AV_{set\text{-}SCRAM} = AL - (1.645/2) \times SQRT\,(A_{LT\text{-}fix}{}^2 + C_{set\text{-}SCRAM}{}^2 + PMA^2 + PEA^2)$

For this function the AL is

$AL = 17.4\,\%$

Therefore,

$AV_{set\text{-}SCRAM} = 17.4\% - (1.645/2) \times SQRT\,(1.63^2 + 0.92^2 + 2.29^2 + 0.31^2)$

$= 14.95\,\%$ Power

Rounded down conservatively to nearest readable increment:

$AV_{set\text{-}SCRAM} = 14.5\%$ Power

**7. Neutron Flux Fixed High Rod Block - Setdown**

$AV_{set\text{-}RB} = AL - (1.645/2) \times SQRT\,(A_{LT\text{-}fix}{}^2 + C_{fix\text{-}RB}{}^2 + PMA^2 + PEA^2)$

For this function the AL is

$AL = 14.4\,\%$

Therefore,

$$AV_{set\text{-}RB} = 14.4\% - (1.645/2) \times SQRT\,(1.63^2 + 0.92^2 + 2.29^2 + 0.31^2)$$
$$= 11.95\ \%\ \text{Power}$$

Rounded down conservatively to nearest readable increment:

$$AV_{set\text{-}RB} = 11.5\%\ \text{Power}$$

b) RBM CHANNEL

**1. Low Power Setpoint (LPSP)**

$$AV_{lpsp} = AL - (1.645/2) \times SQRT\,(A_{LT\text{-}RBM\text{-}pwr}{}^2 + C_{lpsp}{}^2 + PMA^2 + PEA^2)$$

For this function the AL is

$$AL = 30.0\ \%$$

Therefore,

$$AV_{lpsp} = 30.0\% - (1.645/2) \times SQRT\,(1.22^2 + 1.18^2 + 2.11^2 + 0.72^2)$$
$$= 27.69\ \%\ \text{Power}$$

Rounded down conservatively to nearest readable increment:

$$AV_{lpsp} = 27.5\%\ \text{Power}$$

**2. Intermediate Power Setpoint (IPSP)**

$$AV_{ipsp} = AL - (1.645/2) \times SQRT\,(A_{LT\text{-}RBM\text{-}pwr}{}^2 + C_{ipsp}{}^2 + PMA^2 + PEA^2)$$

For this function the AL is

$$AL = 65.0\ \%$$

Therefore,

$$AV_{ipsp} = 65.0 - (1.645/2) \times SQRT\,(1.22^2 + 1.18^2 + 2.11^2 + 0.72^2)$$
$$= 62.69\ \%\ \text{Power}$$

Rounded down conservatively to nearest readable increment:

$$AV_{ipsp} = 62.5\%\ \text{Power}$$

**3. High Power Setpoint (HPSP)**

$$AV_{hpsp} = AL - (1.645/2) \times SQRT\,(A_{LT\text{-}RBM\text{-}pwr}{}^2 + C_{hpsp}{}^2 + PMA^2 + PEA^2)$$

For this function the AL is

$$AL = 85.0\ \%$$

Therefore,

$$AV_{hpsp} = 85.0\% - (1.645/2) \times SQRT\,(1.22^2 + 1.18^2 + 2.11^2 + 0.72^2)$$
$$= 82.69\ \%\ \text{Power}$$

Rounded down conservatively to nearest readable increment:

$$AV_{hpsp} = 82.5\%\ \text{Power}$$

**4. Downscale Trip Setpoint (DTSP)**

$$AV_{dtsp} = AL - (1.645/2) \times SQRT\,(A_{LT\text{-}RBM\text{-}trip}^2 + C_{dtsp}^2 + PMA^2 + PEA^2)$$

For this function the AL is

$AL = 89.0\ \%$

Therefore,

$$AV_{dtsp} = 89.0\% + (1.645/2) \times SQRT\,(1.91^2 + 1.18^2 + 2.11^2 + 0.72^2)$$
$$= 91.60\%$$

Rounded up conservatively to nearest readable increment:

$AV_{dtsp} = 92.0$ % Power

**5. Low Trip[†] Setpoint (LTSP)**

$$AV_{ltsp} = AL - (1.645/2) \times SQRT\,(A_{LT\text{-}RBM\text{-}trip}^2 + C_{ltsp}^2 + PMA^2 + PEA^2)$$

For this function the AL is

$AL = 117\ \%$

Therefore,

$$AV_{ltsp} = 117.0\% - (1.645/2) \times SQRT\,(1.91^2 + 1.07^2 + 2.11^2 + 0.72^2)$$
$$= 114.42\ \%\ \text{Power}$$

Rounded down conservatively to nearest readable increment:

$AV_{ltsp} = 114.0$ % Power

**6. Intermediate Trip[†] Setpoint (ITSP)**

$$AV_{itsp} = AL - (1.645/2) \times SQRT\,(A_{LT\text{-}RBM\text{-}trip}^2 + C_{itsp}^2 + PMA^2 + PEA^2)$$

For this function the AL is

$AL = 111.2\ \%$

Therefore,

$$AV_{itsp} = 111.2\% - (1.645/2) \times SQRT\,(1.91^2 + 1.18^2 + 2.11^2 + 0.72^2)$$
$$= 108.59\ \%\ \text{Power}$$

Rounded down conservatively to nearest readable increment:

$AV_{itsp} = 108.5$ % Power

**7. High Trip[†] Setpoint (HTSP)**

$$AV_{htsp} = AL - (1.645/2) \times SQRT\,(A_{LT\text{-}RBM\text{-}trip}^2 + C_{htsp}^2 + PMA^2 + PEA^2)$$

For this function the AL is

---

[†] Note: For the RBM trip setpoints, a MCPR of 1.20 is used, margins are the same for other MCPRs and are summarized in the conclusion (Section 5).

AL = 107.4 %

Therefore,

$$AV_{htsp} = 107.4\% - (1.645/2) \times \text{SQRT}\,(1.91^2 + 1.13^2 + 2.11^2 + 0.72^2)$$

$$= 104.81\ \%\ \text{Power}$$

Rounded down conservatively to nearest readable increment:

$$AV_{htsp} = 104.5\ \%\ \text{Power}$$

### 4.1.7.4 LER Avoidance Evaluation

The purpose of the LER Avoidance Evaluation is to assure that there is sufficient margin provided between the Allowable Value and the Nominal Trip Setpoint to avoid violations of the Tech Spec Allowable Value (which, when discovered during surveillance, could lead to LER conditions). The method of avoiding violations of the Allowable Value is to determine the errors that may be present during surveillance testing, examine the margin between the calculated values of NTSP1 and AV, and then adjust NTSP1 to provide added margin if necessary. The following equation is used to determine the errors that would be expected to contribute to a potential LER situation.

Sigma(LER) = (1/N)(SRSS Of RANDOM TERMS)

Where N represents the number of standard deviations with which the random terms are characterized (normally 2 standard deviations).

#### 4.1.7.4.1 Random Terms Included In LER Avoidance

The Random Terms that should be included in the LER Avoidance evaluations include:

Loop Accuracy under Normal plant Condition ($A_{LN}$)
Loop Calibration Error ($C_L$)
Loop Drift ($D_L$)

Process and Primary Element Errors are not included because calibration and surveillance testing are performed using input signals which simulate the process and primary element input.

$$\text{Sigma(LER)} = (1/2)\text{SQRT}\,(A_{LN}^2 + C_L^2 + D_L^2)$$

4.1.7.4.2 LER Margin Calculation

Once the value of Sigma(LER) is determined, the margin between the values of NTSP1 and AV is calculated in terms of Sigma(LER) using the equation below:

Z(LER) = |AV-NTSP1| / Sigma(LER)

This value of Z is then used to determine the probability of violating the Allowable Value by treating the error distribution as a random Normal Distribution, and then determining the area under the curve of the Normal Distribution corresponding to the number of standard deviations represented by Z.

4.1.7.4.3 GE Recommendation

GE recommends that a nominal probability of 90% for avoiding an LER condition be used as the acceptance criterion for the LER Avoidance (or Tech Spec Action Avoidance) Evaluation. For a single instrument channel, the value of Z(LER) corresponding to this 90% criterion is 1.29 or greater. For an instrument channel which is part of a multiple channel logic system a value of Z(LER) greater than 0.81 can assure 90% Tech Spec Action Avoidance criterion.

4.1.7.4.4 Governing Setpoint Determination

**a) APRM CHANNEL**

**1. Flow Biased Scram**

Sigma(LER) = (1/2) x SQRT ($A_{LN\text{-}fb}^2 + C_{fb\text{-}SCRAM}^2 + D_{fb}^2$)

Sigma(LER) = (1/2) x SQRT ($2.55^2 + 1.83^2 + 1.88^2$)

= 1.82

Z(LER) = |AV-NTSP1$_{fb\text{-}SCRAM}$| / Sigma(LER)

= |71.5% - 70.38%| / 1.82

= 0.61

2

Since this value of Z does not correspond to a probability of more than 90% (one sided normal distribution) for a multiple channel (0.81), the NTSP is adjusted as follows:

NTSP2$_{fb\text{-}SCRAM}$ = AV - 0.81 x Sigma (LER)

= 71.5% - 0.81 x 1.82

NTSP$_{fb\text{-}SCRAM}$ = NTSP2$_{fb\text{-}SCRAM}$ = 70.02% Power

2

**2. Flow Biased Rod Block**

$\text{Sigma(LER)} = (1/2) \times \text{SQRT}\,(A_{LN\text{-}fb}^2 + C_{fb\text{-}RB}^2 + D_{fb}^2)$

$\text{Sigma(LER)} = (1/2) \times \text{SQRT}\,(2.55^2 + 1.83^2 + 1.88^2)$

$= 1.82$

$\text{Z(LER)} = |\text{AV-NTSP1}_{fb\text{-}RB}| / \text{Sigma(LER)}$

$= |60.0\% - 59.08\%| / 1.82$

$= 0.50$

Since this value of Z does not correspond to a probability of more than 90% (one sided normal distribution) for a multiple channel (0.81), the NTSP is adjusted as follows:

$\text{NTSP2}_{fb\text{-}RB} = \text{AV} - 0.81 \times \text{Sigma (LER)}$

$= 60.0\% - 0.81 \times 1.82$

$\text{NTSP}_{fb\text{-}RB} = \text{NTSP2}_{fb\text{-}RB} = 58.52\ \%$ Power

**3. Neutron Flux – Fixed High SCRAM**

$\text{Sigma(LER)} = (1/2) \times \text{SQRT}\,(A_{LN\text{-}fix}^2 + C_{fix\text{-}SCRAM}^2 + D_{fix}^2)$

$\text{Sigma(LER)} = (1/2) \times \text{SQRT}\,(1.63^2 + 1.37^2 + 1.51^2)$

$= 1.31$

$\text{Z(LER)} = |\text{AV-NTSP1}_{fix\text{-}SCRAM}| / \text{Sigma(LER)}$

$= |120.0\% - 119.31| / 1.31$

$= 0.53$

Since this value of Z does not correspond to a probability of more than 90% (one sided normal distribution) for a multiple channel (0.81), the NTSP is adjusted as follows:

$\text{NTSP2}_{fix\text{-}SCRAM} = \text{AV} - 0.81 \times \text{Sigma (LER)}$

$= 120.0\% - 0.81 \times 1.31$

$\text{NTSP}_{fix\text{-}SCRAM} = \text{NTSP2}_{fix\text{-}SCRAM} = 118.93\ \%$ Power

**4. Neutron Flux Rod Block Clamp**

$\text{Sigma(LER)} = (1/2) \times \text{SQRT}\,(A_{LN\text{-}fix}^2 + C_{clamp\text{-}RB}^2 + D_{fix}^2)$

$\text{Sigma(LER)} = (1/2) \times \text{SQRT}\,(1.63^2 + 1.19^2 + 1.51^2)$

$= 1.26$

$\text{Z(LER)} = |\text{AV-NTSP1}_{clamp\text{-}RB}| / \text{Sigma(LER)}$

$= |109.0\% - 108.07| / 1.26$

$= 0.73$

Since this value of Z does not correspond to a probability of more than 90% (one sided normal distribution) for a multiple channel (0.81), the NTSP is adjusted as follows:

$\text{NTSP2}_{\text{clamp-RB}} = \text{AV} - 0.81 \times \text{Sigma (LER)}$
$= 109.0\% - 0.81 \times 1.26$
$\text{NTSP}_{\text{clamp-RB}} = \text{NTSP2}_{\text{clamp-RB}} = 107.97\ \%\ \text{Power}$

2

**5. Neutron Flux Downscale Rod Block**

$\text{Sigma(LER)} = (1/2) \times \text{SQRT}\,(A_{\text{LN-fix}}^2 + C_{\text{down-RB}}^2 + D_{\text{fix}}^2)$
$\text{Sigma(LER)} = (1/2) \times \text{SQRT}\,(1.63^2 + 1.08^2 + 1.51^2)$
$= 1.24$
$\text{Z(LER)} = |\text{AV-NTSP1}_{\text{down}}| / \text{Sigma(LER)}$
$= |3.0\% - 3.60| / 1.24$
$= 0.48$

Since this value of Z does not correspond to a probability of more than 90% (one sided normal distribution) for a multiple channel (0.81), the NTSP is adjusted as follows:

$\text{NTSP2}_{\text{down RB}} = \text{AV} + 0.81 \times \text{Sigma (LER)}$
$= 3.0\% + 0.81 \times 1.24$
$\text{NTSP}_{\text{down RB}} = \text{NTSP2}_{\text{down RB}} = 4.00\%\text{Power}$

**6. Neutron Flux Fixed High SCRAM - Setdown**

$\text{Sigma(LER)} = (1/2) \times \text{SQRT}\,(A_{\text{LN-fix}}^2 + C_{\text{set-SCRAM}}^2 + D_{\text{fix}}^2)$
$\text{Sigma(LER)} = (1/2) \times \text{SQRT}\,(1.63^2 + 0.92^2 + 1.51^2)$
$= 1.20$
$\text{Z(LER)} = |\text{AV-NTSP1}_{\text{set-SCRAM}}| / \text{Sigma(LER)}$
$= |14.5\% - 13.84\%| / 1.20$
$= 0.55$

Since this value of Z does not correspond to a probability of more than 90% (one sided normal distribution) for a multiple channel (0.81), the NTSP is adjusted as follows:

$\text{NTSP2}_{\text{set-SCRAM}} = \text{AV} - 0.81 \times \text{Sigma (LER)}$
$= 14.5\% - 0.81 \times 1.20$
$\text{NTSP}_{\text{set-SCRAM}} = \text{NTSP2}_{\text{set-SCRAM}} = 13.52\ \%\ \text{Power}$

**7. Neutron Flux Fixed High Rod Block - Setdown**

Sigma(LER) = $(1/2) \times \mathrm{SQRT}\,(A_{LN\text{-}fix}^2 + C_{set\text{-}RB}^2 + D_{fix}^2)$

Sigma(LER) = $(1/2) \times \mathrm{SQRT}\,(1.63^2 + 0.92^2 + 1.51^2)$

= 1.20

Z(LER) = $|AV\text{-}NTSP1_{set\text{-}RB}|$ / Sigma(LER)

= |11.5% - 10.84%| / 1.20

= 0.55

Since this value of Z does not correspond to a probability of more than 90% (one sided normal distribution) for a multiple channel (0.81), the NTSP is adjusted as follows:

$NTSP2_{set\text{-}RB}$ = AV - 0.81 x Sigma (LER)

= 11.5% - 0.81 x 1.20

$NTSP_{set\text{-}RB} = NTSP2_{set\text{-}RB}$ = 10.52 % Power

**b) RBM CHANNEL**

**1. Low Power Setpoint (LPSP)**

Sigma(LER) = $(1/2) \times \mathrm{SQRT}\,(A_{LN\text{-}RBM\text{-}pwr}^2 + C_{lpsp}^2 + D_{RBM\text{-}pwr}^2)$

Sigma(LER) = $(1/2) \times \mathrm{SQRT}\,(1.22^2 + 1.18^2 + 0.99^2)$

= 0.98

Z(LER) = $|AV\text{-}NTSP1_{lpsp}|$ / Sigma(LER)

= |27.5% - 26.74%| / 0.98

= 0.77

Since this value of Z does not correspond to a probability of more than 90% (one-side normal distribution) for a single channel (1.29), the NTSP is adjusted as follows:

$NTSP2_{lpsp}$ = AV - 1.29 x Sigma (LER)

= 27.5% - 1.29 x 0.98

$NTSP_{lpsp} = NTSP2_{lpsp}$ = 26.23 % Power

**2. Intermediate Power Setpoint (IPSP)**

Sigma(LER) = $(1/2) \times \mathrm{SQRT}\,(A_{LN\text{-}RBM\text{-}pwr}^2 + C_{ipsp}^2 + D_{RBM\text{-}pwr}^2)$

Sigma(LER) = $(1/2) \times \mathrm{SQRT}\,(1.22^2 + 1.18^2 + 0.99^2)$

= 0.98

Z(LER) = $|AV\text{-}NTSP1_{ipsp}|$ / Sigma(LER)

= |62.5% - 61.74%| / 0.98

= 0.77

Since this value of Z does not correspond to a probability of more than 90% (one-side normal distribution) for a single channel (1.29), the NTSP is adjusted as follows:

$NTSP2_{ipsp} = AV - 1.29 \times Sigma\ (LER)$
$= 62.5\% - 1.29 \times 0.98$

$NTSP_{ipsp} = NTSP2_{ipsp} \quad = 61.23\ \%\ Power$

**3. High Power Setpoint (HPSP)**

$Sigma(LER) = (1/2) \times SQRT\ (A_{LN\text{-}RBM\text{-}pwr}{}^2 + C_{hpsp}{}^2 + D_{RBM\text{-}pwr}{}^2)$

$Sigma(LER) = (1/2) \times SQRT\ (1.22^2 + 1.18^2 + 0.99^2)$
$= 0.98$

$Z(LER) = |AV\text{-}NTSP1_{hpsp}| / Sigma(LER)$
$= |82.5\% - 81.74\%| / 0.98$
$= 0.77$

Since this value of Z does not correspond to a probability of more than 90% (one-side normal distribution) for a single channel (1.29), the NTSP is adjusted as follows:

$NTSP2_{hpsp} = AV - 1.29 \times Sigma\ (LER)$
$= 82.5\% - 1.29 \times 0.98$

$NTSP_{hpsp} = NTSP2_{hpsp} \quad = 81.23\ \%\ Power$

**4. Downscale Trip Setpoint (DTSP)**

$Sigma(LER) = (1/2) \times SQRT\ (A_{LN\text{-}RBM\text{-}trip}{}^2 + C_{dtsp}{}^2 + D_{RBM\text{-}trip}{}^2)$

$Sigma(LER) = (1/2) \times SQRT\ (1.91^2 + 1.18^2 + 2.04^2)$
$= 1.52$

$Z(LER) = |AV\text{-}NTSP1_{dtsp}| / Sigma(LER)$
$= |92.0 - 92.92| / 1.52$
$= 0.60$

Since this value of Z does not correspond to a probability of more than 90% (one-side normal distribution) for a single channel (1.29), the NTSP is adjusted as follows:

$NTSP2_{dtsp} = AV + 1.29 \times Sigma\ (LER)$
$= 92.0\% + 1.29 \times 1.52$

$NTSP_{dtsp} = NTSP2_{dtsp} = 93.96\%\ Power$

**5. Low Trip Setpoint (LTSP)**

Sigma(LER) = $(1/2) \times \text{SQRT}\,(A_{LN\text{-}RBM\text{-}trip}{}^2 + C_{ltsp}{}^2 + D_{RBM\text{-}trip}{}^2)$

Sigma(LER) = $(1/2) \times \text{SQRT}\,(1.91^2 + 1.07^2 + 2.04^2)$

= 1.50

Z(LER) = $|AV\text{-}NTSP1_{ltsp}|$ / Sigma(LER)

= |114.0% - 113.11| / 1.50

= 0.59

Since this value of Z does not correspond to a probability of more than 90% (one-side normal distribution) for a single channel (1.29), the NTSP is adjusted as follows:

$NTSP2_{ltsp}$ = AV - 1.29 x Sigma (LER)

= 114.0% - 1.29 x 1.50

$NTSP_{ltsp} = NTSP2_{ltsp}$ = 112.06 % Power

**6. Intermediate Trip Setpoint (ITSP)**

Sigma(LER) = $(1/2) \times \text{SQRT}\,(A_{LN\text{-}RBM\text{-}trip}{}^2 + C_{itsp}{}^2 + D_{RBM\text{-}trip}{}^2)$

Sigma(LER) = $(1/2) \times \text{SQRT}\,(1.91^2 + 1.18^2 + 2.04^2)$

= 1.52

Z(LER) = $|AV\text{-}NTSP1_{itsp}|$ / Sigma(LER)

= |108.5% - 107.28%| / 1.52

= 0.80

Since this value of Z does not correspond to a probability of more than 90% (one-side normal distribution) for a single channel (1.29), the NTSP is adjusted as follows:

$NTSP2_{itsp}$ = AV - 1.29 x Sigma (LER)

= 108.5% - 1.29 x 1.52

$NTSP_{itsp} = NTSP2_{itsp}$ = 106.53 % Power

**7. High Trip Setpoint (HTSP)**

Sigma(LER) = $(1/2) \times \text{SQRT}\,(A_{LN\text{-}RBM\text{-}trip}{}^2 + C_{htsp}{}^2 + D_{RBM\text{-}trip}{}^2)$

Sigma(LER) = $(1/2) \times \text{SQRT}\,(1.91^2 + 1.13^2 + 2.04^2)$

= 1.51

Z(LER) = $|AV\text{-}NTSP1_{htsp}|$ / Sigma(LER)

= |104.5% - 103.5| / 1.51

= 0.66

Since this value of Z does not correspond to a probability of more than 90% (one-side normal distribution) for a single channel (1.29), the NTSP is adjusted as follows:

$NTSP2_{htsp} = AV - 1.29 \times Sigma\ (LER)$
$= 104.5\% - 1.29 \times 1.51$
$NTSP_{htsp} = NTSP2_{htsp} = 102.55\ \%$ Power

4.1.7.5 Selection of Operating Setpoints

It is recommended that the method of using NTSP as the center of the Leave Alone Zone be used. Thus, according to Reference 4, the nominal setpoint is:

NTSP = NTSP2 ± LAT

Where the LAT is the SRSS combination of the leave alone tolerances for all the devices in the loop.

4.1.7.6 Establishing Leave Alone Zones

The LAT for both APRM and RBM functions within this calculation is ± 1.25% Power. (Assumption 3.22)

4.1.7.7 Required Limits Evaluation

The Required Limits Evaluation calculates an adjustment to NTSP for the case when NTSP is set at the center of the leave alone zone. The adjustment assures that with the stack-up of the errors (including leave alone tolerances) for all the devices in the loop, there is enough margin for Technical Specification Action Avoidance (or LER avoidance).

**a) APRM CHANNEL**

**1. Flow Biased Scram**

The Required Limit (RL) of device "i" with the largest LAT in the loop is:

$RL_i = NTSP_{fb\text{-}SCRAM} + LAT_i$
$= 70.02\% + 1.25\% = 71.27\%$

This is compared against $AV_{fb\text{-}SCRAM} = 71.5\%$ from Section 4.1.7.3. Since

$RL_i < AV_{fb\text{-}SCRAM}$,

therefore NTSP need not be adjusted:

$NTSP\ (ADJ)_{fb\text{-}SCRAM} = NTSP_{fb\text{-}SCRAM} = 70.02\ \%$

Rounding down to the nearest readable increment:

$NTSP(ADJ)_{fb\text{-}SCRAM} = 70.0\%$

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**2. Flow Biased Rod Block**

The Required Limit (RL) of device "i" with the largest LAT in the loop is:

$RL_i = NTSP_{fb\text{-}RB} + LAT_i$

$= 58.52\% + 1.25\% = 59.77\%$

This is compared against $AV_{fb\text{-}RB} = 60.0\%$ from Section 4.1.7.3. Since

$RL_i < AV$,

therefore NTSP need not be adjusted:

$NTSP\ (ADJ)_{fb\text{-}RB} = NTSP_{fb\text{-}RB} = 58.52\ \%$

Rounding down to the nearest readable increment:

$NTSP(ADJ)_{fb\text{-}RB} = 58.5\%$

**3. Neutron Flux Fixed High SCRAM**

The Required Limit (RL) of device "i" with the largest LAT in the loop is:

$RL_i = NTSP_{fix\text{-}SCRAM} + LAT_i$

$= 118.93\% + 1.25\% = 120.18\%$

This is compared against $AV_{fix\text{-}SCRAM} = 120.0\%$ from Section 4.1.7.3. Since

$RL_i > AV_{fix\text{-}SCRAM}$,

therefore NTSP needs to be adjusted:

$NTSP\ (ADJ)_{fix\text{-}SCRAM} = AV_{fix\text{-}SCRAM} - LAT = 120.0 - 1.25 = 118.75\ \%$

To determine if further adjustment is needed, the Required Limits of all devices in the loop are calculated, and Sigma(LER, RL) given by the following equation (Ref. 5) is calculated:

$RL_i = NTSP\ (ADJ)_{fix\text{-}SCRAM} + LAT_i$

$= 118.75\% + 1.25\% = 120.00\%$

$$\text{Sigma(LER, RL)} = (1/2) \times \text{SQRT}\{(\Sigma((2/3)(RL_i - NTSP(ADJ)_{fix\text{-}SCRAM}))^2 + C_{fix\text{-}SCRAM}{}^2 + D_{fix}{}^2\ \}$$

For this calculation the loop error values are used which is equivalent to using one device with the error of the whole loop. Thus:

$$\text{Sigma(LER, RL)} = (1/2) \times \text{SQRT}\{((2/3) \times (\ 120.00 - 118.75))^2 + 1.37^2 + 1.51^2\}$$
$$= 1.10\ \%$$

Also compute Z(LER, RL) given by:

$Z(LER, RL) = ABS(AV_{fix\text{-}SCRAM} - NTSP(ADJ)_{fix\text{-}SCRAM}) / Sigma(LER,RL)$

For this case of multiple channel, If

$Z(LER, RL) > 0.81$

then LER avoidance condition is met.

Z(LER, RL) = ABS(120.0 - 118.75) / 1.10
= 1.13

This value of Z(LER, RL) is greater than the Z criterion for multiple channels of 0.81. Therefore the criterion is met without further adjustments.

NTSP $(\mathrm{ADJ})_{\text{fix-SCRAM}}$ = 118.5 % Power (Rounded conservatively to nearest readable increment)

### 4. Neutron Flux Rod Block Clamp

The Required Limit (RL) of device "i" with the largest LAT in the loop is:

$\mathrm{RL}_i = \mathrm{NTSP}_{\text{clamp-RB}} + \mathrm{LAT}_i$
= 107.97% + 1.25% = 109.22%

This is compared against $\mathrm{AV}_{\text{clamp-RB}}$ = 120.0% from Section 4.1.7.3. Since

$\mathrm{RL}_i > \mathrm{AV}_{\text{clamp-RB}}$,

therefore NTSP needs to be adjusted:

NTSP $(\mathrm{ADJ})_{\text{clamp-RB}} = \mathrm{AV}_{\text{clamp-RB}}$ - LAT= 109.0 - 1.25 = 107.75 %

To determine if further adjustment is needed, the Required Limits of all devices in the loop are calculated, and Sigma(LER, RL) given by the following equation (Ref. 5) is calculated:

$\mathrm{RL}_i$ = NTSP $(\mathrm{ADJ})_{\text{clamp-RB}} + \mathrm{LAT}_i$

= 107.75% + 1.25% = 109.00%

$$\text{Sigma(LER, RL)} = (1/2) \times \text{SQRT}\{(\Sigma((2/3)(\mathrm{RL}_i - \mathrm{NTSP(ADJ)}_{\text{clamp-RB}}))^2 + C_{\text{clamp-RB}}^{\;2} + D_{\text{fix}}^{\;2}\}$$

For this calculation the loop error values are used which is equivalent to using one device with the error of the whole loop. Thus:

$$\text{Sigma(LER, RL)} = (1/2) \times \text{SQRT}\{((2/3) \times (109.00 - 107.75))^2 + 1.19^2 + 1.51^2\}$$
$$= 1.04\ \%$$

Also compute Z(LER, RL) given by:

Z(LER, RL) = ABS($\mathrm{AV}_{\text{clamp-RB}}$- NTSP$(\mathrm{ADJ})_{\text{clamp-RB}}$) / Sigma(LER,RL)

For this case of multiple channel, If

Z(LER, RL) > 0.81

then LER avoidance condition is met.

Z(LER, RL) = ABS(109.0 - 107.75) / 1.04
= 1.20

This value of Z(LER, RL) is greater than the Z criterion for multiple channels of 0.81. Therefore the criterion is met without further adjustments.

NTSP $(\mathrm{ADJ})_{\text{clamp-RB}}$ = 107.5 % Power (Rounded conservatively to nearest readable increment)

**5. Neutron Flux Downscale Rod Block**

The Required Limit (RL) of device "i" with the largest LAT in the loop is:

$RL_i = NTSP_{down} - LAT_i$

$= 4.0\% - 1.25\% = 2.75\%$

This is compared against $AV_{down} = 3.0\%$ from Section 4.1.7.3. Since

$RL_i < AV_{down}$,

therefore $NTSP_{down}$ needs to be adjusted:

$NTSP\ (ADJ)_{down} = AV_{down} + LAT = 3.0 + 1.25 = 4.25\ \%$

To determine if further adjustment is needed, the Required Limits of all devices in the loop are calculated, and Sigma(LER, RL) given by the following equation (Ref. 5) is calculated:

$RL_i = NTSP\ (ADJ)_{down} - LAT_i$

$= 4.25\% - 1.25\% = 3.00\%$

$\text{Sigma(LER, RL)} = (1/2) \times \text{SQRT}\{(\Sigma((2/3)(RL_i - NTSP(ADJ)_{down}))^2 + C_{down\text{-}RB}^2 + D_{fix}^2\}$

For this calculation the loop error values are used which is equivalent to using one device with the error of the whole loop. Thus:

$\text{Sigma(LER, RL)} = (1/2) \times \text{SQRT}\{((2/3) \times (3.00 - 4.25))^2 + 1.08^2 + 1.51^2\}$

$= 1.02\ \%$

Also compute Z(LER, RL) given by:

$Z(\text{LER, RL}) = \text{ABS}(AV - NTSP(ADJ)_{down}) / \text{Sigma(LER,RL)}$

For this case of multiple channel, If

$Z(\text{LER, RL}) > 0.81$

then LER avoidance condition is met.

$Z(\text{LER, RL}) = \text{ABS}(3.0 - 4.25) / 1.02$

$= 1.23$

This value of Z(LER, RL) is greater than the Z criterion for multiple channels of 0.81. Therefore the criterion is met without further adjustments.

Final $NTSP\ (ADJ)_{down} = 4.5\ \%$ Power (Rounded conservatively up to nearest readable increment)

**6. Neutron Flux Fixed High SCRAM -Setdown**

The Required Limit (RL) of device "i" with the largest LAT in the loop is:

$RL_i = NTSP_{set\text{-}SCRAM} + LAT_i$

$= 13.52\% + 1.25\% = 14.77\%$

This is compared against $AV_{set\text{-}SCRAM} = 14.5\%$ from Section 4.1.7.3. Since

$RL_i > AV_{set\text{-}SCRAM}$,

therefore $NTSP_{set\text{-}SCRAM}$ needs to be adjusted:

$$\text{NTSP (ADJ)}_{\text{set-SCRAM}} = \text{AV}_{\text{set-SCRAM}} - \text{LAT} = 14.5 - 1.25 = 13.25\ \%$$

To determine if further adjustment is needed, the Required Limits of all devices in the loop are calculated, and Sigma(LER, RL) given by the following equation (Ref. 5) is calculated:

$$\text{RL}_i = \text{NTSP (ADJ)}_{\text{set-SCRAM}} + \text{LAT}_i$$

$$= 13.25\% + 1.25\% = 14.50\%$$

$$\text{Sigma(LER, RL)} = (1/2) \times \text{SQRT}\{(\Sigma((2/3)(\text{RL}_i - \text{NTSP(ADJ)}_{\text{set-SCRAM}}))^2 + C_{\text{set-SCRAM}}^2 + D_{\text{fix}}^2\}$$

For this calculation the loop error values are used which is equivalent to using one device with the error of the whole loop. Thus:

$$\text{Sigma(LER, RL)} = (1/2) \times \text{SQRT}\ \{((2/3) \times (14.5 - 13.25))^2 + 0.92^2 + 1.51^2\}$$
$$= 0.98\ \%$$

Also compute Z(LER, RL) given by:

$$\text{Z(LER, RL)} = \text{ABS}(\text{AV}_{\text{set-SCRAM}} - \text{NTSP(ADJ)}_{\text{set-SCRAM}}) / \text{Sigma(LER,RL)}$$

For this case of multiple channel, If

$$\text{Z(LER, RL)} > 0.81$$

then LER avoidance condition is met.

$$\text{Z(LER, RL)} = \text{ABS}(14.5 - 13.25) / 0.98$$
$$= 1.28$$

This value of Z(LER, RL) is greater than the Z criterion for multiple channels of 0.81. Therefore the criterion is met without further adjustments.

Final $\text{NTSP (ADJ)}_{\text{set-SCRAM}} = 13.0\ \%$ Power (Rounded conservatively to nearest readable increment)

### 7. Neutron Flux Fixed High Rod Block -Setdown

The Required Limit (RL) of device "i" with the largest LAT in the loop is:

$$\text{RL}_i = \text{NTSP}_{\text{set-RB}} + \text{LAT}_i$$
$$= 10.52\% + 1.25\% = 11.77\%$$

This is compared against $\text{AV}_{\text{set-RB}} = 11.5\%$ from Section 4.1.7.3. Since

$$\text{RL}_i > \text{AV}_{\text{set-RB}},$$

therefore $\text{NTSP}_{\text{set-RB}}$ needs to be adjusted:

$$\text{NTSP (ADJ)}_{\text{set-RB}} = \text{AV}_{\text{set-RB}} - \text{LAT} = 11.5 - 1.25 = 10.25\%$$

To determine if further adjustment is needed, the Required Limits of all devices in the loop are calculated, and Sigma(LER, RL) given by the following equation (Ref. 5) is calculated:

$$\text{RL}_i = \text{NTSP (ADJ)}_{\text{set-RB}} + \text{LAT}_i$$

$$= 10.25\% + 1.25\% = 11.5\%$$

$$\text{Sigma(LER, RL)} = (1/2) \times \text{SQRT}\{(\Sigma((2/3)(RL_i - \text{NTSP(ADJ)}_{\text{set-RB}}))^2 + C_{\text{set-RB}}^2 + D_{\text{fix}}^2\}$$

For this calculation the loop error values are used which is equivalent to using one device with the error of the whole loop. Thus:

$$\text{Sigma(LER, RL)} = (1/2) \times \text{SQRT}\ \{((2/3) \times (11.5 - 10.25))^2 + 0.92^2 + 1.51^2\}$$
$$= 0.98\ \%$$

Also compute Z(LER, RL) given by:

$$\text{Z(LER, RL)} = \text{ABS}(AV_{\text{set-RB}} - \text{NTSP(ADJ)}_{\text{set-RB}}) / \text{Sigma(LER,RL)}$$

For this case of multiple channel, If

$$\text{Z(LER, RL)} > 0.81$$

then LER avoidance condition is met.

$$\text{Z(LER, RL)} = \text{ABS}(11.5 - 10.25) / 0.98$$
$$= 1.28$$

This value of Z(LER, RL) is greater than the Z criterion for multiple channels of 0.81. Therefore the criterion is met without further adjustments.

Final NTSP $(\text{ADJ})_{\text{set-RB}}$ = 10.0 % Power (Rounded conservatively to nearest readable increment)

**b) RBM Channel**

**1. Low Power Setpoint (LPSP)**

The Required Limit (RL) of device "i" with the largest LAT in the loop is:

$$RL_i = NTSP_{lpsp} + LAT_i$$
$$= 26.23\% + 1.25\% = 27.48\%$$

This is compared against $AV_{lpsp}$ = 27.5% from Section 4.1.7.3. Since

$$RL_i < AV_{lpsp},$$

therefore $NTSP_{lpsp}$ does not need to be adjusted:

$\text{NTSP (ADJ)}_{lpsp} = NTSP_{lpsp}$ = 26.0 %(Rounded conservatively to nearest readable increment)

**2. Intermediate Power Setpoint (IPSP)**

The Required Limit (RL) of device "i" with the largest LAT in the loop is:

$$RL_i = NTSP_{ipsp} + LAT_i$$
$$= 61.23\% + 1.25\% = 62.48\%$$

This is compared against $AV_{ipsp}$ = 62.5% from Section 4.1.7.3. Since

$$RL_i < AV_{ipsp},$$

therefore $NTSP_{ipsp}$ does not need to be adjusted:

$\text{NTSP (ADJ)}_{ipsp} = NTSP_{ipsp}$ = 61.0 %(Rounded conservatively to nearest readable increment)

### 3. High Power Setpoint (HPSP)

The Required Limit (RL) of device "i" with the largest LAT in the loop is:

$RL_i = NTSP_{hpsp} + LAT_i$

$= 81.23\% + 1.25\% = 82.48\%$

This is compared against $AV_{hpsp} = 82.5\%$ from Section 4.1.7.3. Since

$RL_i < AV_{hpsp}$,

therefore $NTSP_{hpsp}$ does not need to be adjusted:

$NTSP\ (ADJ)_{lpsp} = NTSP_{lpsp} = 81.0\ \%$(Rounded conservatively to nearest readable increment)

### 4. Downscale Trip Setpoint (DTSP)

The Required Limit (RL) of device "i" with the largest LAT in the loop for this decreasing setpoint is:

$RL_i = NTSP_{dtsp} - LAT_i$

$= 93.96\% - 1.25\% = 92.71\%$

This is compared against $AV_{dtsp} = 92.0\%$ from Section 4.1.7.3. Since

$RL_i > AV_{dtsp}$, for this decreasing setpoint

therefore $NTSP_{dtsp}$ does not need to be adjusted:

$NTSP\ (ADJ)_{lpsp} = NTSP_{lpsp} = 94.0\ \%$(Rounded conservatively to nearest readable increment)

### 5. Low Trip Setpoint (LTSP)

The Required Limit (RL) of device "i" with the largest LAT in the loop is:

$RL_i = NTSP_{ltsp} + LAT_i$

$= 112.06\% + 1.25\% = 113.31\%$

This is compared against $AV_{ltsp} = 114.0\%$ from Section 4.1.7.3. Since

$RL_i < AV_{ltsp}$,

therefore $NTSP_{ltsp}$ does not need to be adjusted:

$NTSP\ (ADJ)_{lpsp} = NTSP_{lpsp} = 112.0\ \%$ (Rounded conservatively to nearest readable increment)

### 6. Intermediate Trip Setpoint (ITSP)

The Required Limit (RL) of device "i" with the largest LAT in the loop is:

$RL_i = NTSP_{itsp} + LAT_i$

$= 106.53\% + 1.25\% = 107.78\%$

This is compared against $AV_{itsp} = 108.5\%$ from Section 4.1.7.3. Since

$RL_i < AV_{itsp}$,

therefore $NTSP_{itsp}$ does not need to be adjusted:

$NTSP\ (ADJ)_{lpsp} = NTSP_{lpsp} = 106.5.\%$ (Rounded conservatively to nearest readable increment)

**7. High Trip Setpoint (HTSP)**

The Required Limit (RL) of device "i" with the largest LAT in the loop is:

$RL_i = NTSP_{htsp} + LAT_i$

$= 102.55\% + 1.25\% = 103.8\%$

This is compared against $AV_{htsp} = 104.5\%$ from Section 4.1.7.3. Since

$RL_i < AV_{htsp}$,

therefore $NTSP_{htsp}$ does not need to be adjusted:

$NTSP\ (ADJ)_{lpsp} = NTSP_{lpsp} = 102.5\ \%$ (Rounded conservatively to nearest readable increment)

### 4.1.7.8 Selection of Operating Setpoint

The recommended Operating Setpoints for the APRM and RBM are the NTSP(ADJ) values from section 4.1.7.7

OSP = NTSP(ADJ)

The lower limit of the setpoint (NTSP3) for purposes of performing the spurious trip avoidance calculation is:

$NTSP3 = OSP - (1.645/3) \times SQRT( \Sigma LAT_i^2 )$

### 4.1.7.9 Spurious Trip Avoidance Evaluation

The Spurious Trip Avoidance Evaluation is used to ensure that there is a reasonable probability that spurious trips will not occur using the selected NTSP. The method of avoiding spurious trips is to determine the errors that may be present during normal plant operation and examine the margin between the worst applicable operational transient for which trip is not required, and the lower limit (NTSP3) of selected setpoint.

The following equation is used to determine the errors that would be expected to contribute to a potential spurious trip.

Sigma(STA) = (1/N)(SRSS OF RANDOM TERMS)

$Sigma(STA) = (1/2) \times SQRT\ (A_{LN}^2 + C_L^2 + D_L^2 + PMA^2 + PEA^2)$

Once the value of Sigma (STA) is determined, the margin to the selected NTSP is calculated as shown below:

Z(STA) = | NTSP3 - Operational Limit| / Sigma(STA)

To meet spurious scram avoidance criterion (Ref. 4)

$Z(STA) > 1.65$

If the spurious scram criterion is not violated, no further adjustments are necessary.

**a) APRM CHANNEL**

**1. Flow Biased Scram**

For the flow biased scram, the Operational Limit (OL) is considered to be the flow biased rod block Analytic Limit value.

OL = 0.66W + 63.5 Power 2

$$\text{Sigma(STA)} = (1/2) \times \text{SQRT}\,(A_{LN\text{-}fb}^2 + C_{fb\text{-}SCRAM}^2 + D_{fb}^2 + PEA^2 + PMA^2)$$
$$= (1/2) \times \text{SQRT}\,(2.55^2 + 1.83^2 + 1.88^2 + 0.31^2 + 2.38^2)$$
$$= 2.18$$

For this function

$NTSP_{fb\text{-}SCRAM}$ = 70.0, and therefore: 2

$NTSP3_{fb\text{-}SCRAM}$ = 70.0 - (1.645/3) x 1.25 = 69.31 % Power

$$Z = \text{ABS}|\,NTSP3_{fb\text{-}SCRAM} - OL\,| / \text{Sigma (STA)}$$
$$= \text{ABS}|\,69.31 - 63.5\,| / 2.18$$
$$= 2.66$$

Since this value of Z corresponds to a probability of more than 95% (one-sided normal distribution), 1.65, the $NTSP_{fb\text{-}SCRAM}$ satisfies the STA criteria.

**2. Flow Biased Rod Block**

For the flow biased rod block function, the Operational Limit (OL) is not available. Consequently the spurious trip avoidance evaluation for this setpoint has not been computed.

**3. Neutron Flux Fixed High SCRAM**

For the fixed neutron flux high scram function, the Operational Limit (OL) is considered to be the rod block setpoint at 75% flow. The calculated value rod block setpoint at 75% flow is: 2

OL = Rod Block Setpoint at 75% = 0.66 x 75 + 58.5 = 108.0 % Power

$$\text{Sigma(STA)} = (1/2) \times \text{SQRT}\,(A_{LN\text{-}fix}^2 + C_{fix\text{-}SCRAM}^2 + D_{fix}^2 + PEA^2 + PMA^2)$$
$$= (1/2) \times \text{SQRT}\,(1.63^2 + 1.37^2 + 1.51^2 + 0.31^2 + 2.29^2)$$
$$= 1.74$$

For this function

$NTSP(ADJ)_{fix\text{-}SCRAM}$ = 118.5, therefore:

$NTSP3_{fix\text{-}SCRAM}$ = 118.5 - (1.645/3) x 1.25 = 117.8 % Power

$$Z = \text{ABS}|\,NTSP3_{fix\text{-}SCRAM} - OL\,| / \text{Sigma (STA)}$$
$$= \text{ABS}|\,117.8 - 108.0| / 1.74$$
$$= 5.63$$

2

Since this value of Z corresponds to a probability of more than 95% (one-sided normal distribution),of 1.65, the $\text{NTSP}_{\text{fix-SCRAM}}$ satisfies the STA criteria.

### 4. Neutron Flux Rod Block Clamp

For the rod block clamp function, the Operational Limit (OL) is not available. Consequently the spurious trip avoidance evaluation for this setpoint has not been computed.

### 5. Neutron Flux Downscale Rod Block

For the fixed neutron flux downscale rod block function, the Operational Limit (OL) is not available. Consequently the spurious trip avoidance evaluation for this setpoint has not been computed.

### 6. Neutron Flux Fixed High SCRAM - Setdown

For the Neutron High Flux Scram - Setdown function, the Operational Limit (OL) is considered to be that approximate power level whereby operations personnel would transfer the reactor mode switch to run or 9.5% power.

OL = 9.5% Power

$$\begin{aligned}\text{Sigma(STA)} &= (1/2) \times \text{SQRT}\,(A_{\text{LN-fix}}^2 + C_{\text{set-SCRAM}}^2 + D_{\text{fix}}^2 + \text{PEA}^2 + \text{PMA}^2) \\ &= (1/2) \times \text{SQRT}\,(1.63^2 + 0.92^2 + 1.51^2 + 0.31^2 + 2.29^2) \\ &= 1.67\%\end{aligned}$$

For this function

$\text{NTSP(ADJ)}_{\text{set-SCRAM}} = 13.0\%$, therefore:

$$\text{NTSP3}_{\text{set-SCRAM}} = 13.0 - (1.645/3) \times 1.25 = 12.3\ \%\ \text{Power}$$

$$\begin{aligned}Z &= \text{ABS}|\,\text{NTSP3}_{\text{set-SCRAM}} - \text{OL}\,|\,/\,\text{Sigma (STA)} \\ &= \text{ABS}|\,12.3 - 9.5\,|\,/\,1.67 \\ &= 1.67\end{aligned}$$

Since this value of Z corresponds to a probability of more than 95% (one-sided normal distribution) of 1.65, the $\text{NTSP}_{\text{set-SCRAM}}$ satisfies the STA criteria.

### 7. Neutron Flux Fixed High Rod Block - Setdown

For the fixed neutron flux setdown rod block function, the Operational Limit (OL) is not available. Consequently the spurious trip avoidance evaluation for this setpoint has not been computed.

### b) RBM CHANNEL

Operational limits for these setpoints are not available. Consequently STA for these setpoints have not been computed.

### 4.1.7.10 Elevation Correction

Not applicable to the APRM and RBM channels which are electrical devices. The recirculation loop flow transmitters are differential pressure devices and are not subject to elevation correction.

NEDC: 98-024 Preparer: Reviewer: Robert A Champlin
Rev. No: 2 Date: 12-30-99 Date: 12-31-99

4.1.7.11 Determination of Actual Field Setpoint

Since there is no elevation correction for the APRM and RBM channels:

Actual Field Setpoint (ASP ) = Operating Setpoint (OSP)

## 5. CONCLUSION

For As Left Tolerance (ALT) see section 4.1.3.5, and for the Leave Alone Tolerance (LAT) see section 4.1.7.6.

**a) APRM Channel**

The Analytic Limit (AL), Allowable Value (AV), calculated actual field Setpoints (equal to OSP since there is no elevation correction) for the APRM instruments NM-NAM-AR2,3,4,7,8, 9 are as follows:

| Trip Function | Analytical Limit | Allowable Value | Setpoint (OSP) |
|---|---|---|---|
| 1. Flow Biased Scram | 0.66W + 74.8% | 0.66W + 71.5% | 0.66W + 70.0% |
| 2. Flow Biased Rod Block | 0.66W + 63.5% | 0.66W + 60.0% | 0.66W + 58.5% |
| 3. High Neutron Flux Scram | 123.0% | 120.0% | 118.5% |
| 4. Neutron Flux Rod Block Clamp | 111.7% | 109.0% | 107.5% |
| 5. Downscale Neutron Flux Rod Block | 0.0% | 3.0% | 4.5% |
| 6. High Flux – Setdown Scram | 17.4% | 14.5% | 13.0% |
| 7. High Flux – Setdown Rod Block | 14.4% | 11.5% | 10.0% |

**b) RBM Channel**

The Analytic Limit (AL), Allowable Value (AV), calculated actual field Setpoints (equal to OSP since there is no elevation correction), for the ARTS / RBM instruments NM-NAM-AR5, 6 are as follows:

| Trip Function | MCPR Limit | Analytical Limit | Allowable Value | Setpoint (OSP) |
|---|---|---|---|---|
| 1. Low Power Setpoint (LPSP) | | 30% | 27.5% | 26.0% |
| 2. Intermediate Power Setpoint (IPSP) | | 65% | 62.5% | 61.0% |
| 3. High Power Setpoint (HPSP) | | 85% | 82.5% | 81.0% |
| 4. Downscale Trip Setpoint (DTSP) | | 89.0% | 92.0% | 94.0% |
| 5. Low Trip Setpoint (LTSP) | 1.20 | 117.0% | 114.0% | 112.0% |
| | 1.25 | 120.0% | 117.0% | 115.0% |
| | 1.30 | 123.0% | 120.0% | 118.0% |
| | 1.35 | 125.8% | 123.0% | 121.0% |
| 6. Intermediate Trip Setpoint (ITSP) | 1.20 | 111.2% | 108.5% | 106.5% |
| | 1.25 | 115.2% | 112.5% | 110.5% |
| | 1.30 | 118.0% | 115.0% | 113.0% |
| | 1.35 | 121.0% | 118.0% | 116.0% |
| 7. High Trip Setpoint (HTSP) | 1.20 | 107.4% | 104.5% | 102.5% |
| | 1.25 | 110.2% | 107.5% | 105.5% |
| | 1.30 | 113.2% | 110.5% | 108.5% |
| | 1.35 | 116.0% | 113.0% | 111.0% |

The settings (based on Reference 22 and current site settings per Reference 10) for the ARTS/RBM timing functions are:

| | |
|---|---|
| Time Delay 1 (Td1) | 3.5 sec. ± 0.8 sec. |
| Time Constant 1 (Tc1) | 0.5 sec. ± 0.05 sec. |
| Time Constant 2 (Tc2) | 6.0 sec. ± 1.0 sec. |

Since the field functional testing and calibration cannot functionally meet the stated tolerances of Sections 4.1.3.5 and 4.1.7.6 (as their divisions are smaller than half the smallest division on the meters), the as left and leave alone tolerances can be adjusted. The tolerance adjustment will be such that the encompassed tolerance band is comparable to the tolerance bands stated within this calculation.

The limit closest to the Allowable Value is to be moved further from the Allowable Value to the next value corresponding to half the smallest division of the meter.

The limit furthest from the Allowable Value is to be moved in either direction to the next value corresponding to half the smallest division of the meter.

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DESIGN CALCULATIONS SHEET

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| | | |
|---|---|---|
| Calc No: NEDC 92-50S, Rev. 3 | NPPD Generated Calculation | Review of Non-NPPD Generated Calculation |
| NM-NAM-AR 2, 3, 4, 7, 8, 9 | Prepared By: | |
| NM-NAM-AR 5, 6 | Date: 1997 | Company's Name: General Electric Co. |
| Setpoint Calculation | Checked By: | NPPD Reviewer: |
| | Date: 1997 | Date: July 23 1998 ~~1997~~ MEU 7/23/98 |

## APPENDIX A

### APRM Trip Unit Drift Data Summary

### A.1 Method

The calibration data for the APRM trip units was analyzed by an Excel spreadsheet program (called Y-GEITAS) which was programmed to carry out a statistical analysis of the data similar to that performed by the GE Proprietary Program called GEITAS (General Electric Instrument Trending Analysis System). Only drift data for the APRM trip units was analyzed, since for the APRM system the APRM chassis electronics are calibrated every week (using power distribution calculations by the process computer), and only the trip units are calibrated at the extended calibration interval (7.5 months based on a 6 months interval and the 1.25 grace factor). Moreover, only data for the fixed neutron trip was analyzed, and it was assumed that since this drift was applicable to all APRM trip setpoint calculations.

The program Y-GEITAS provides a quantitative estimate of instrument drift (D), for a specified calibration interval. The methodology for Y-GEITAS drift analysis is the same as GEITAS (described in Reference 3), however for Y-GEITAS only adjacent rather than overlapping intervals were used, assuring complete data is independence. There was sufficent data for this calculation because data was taken for 6 trip units over a 6 year period. An examination of the data showed that there had been no adjustments in the trip settings, so the raw data provided an accurate represention how the instrument drifted over the 6 years, once the accuracy and calibration errors (which are present in every calibration data point) were accounted for. Briefly, the Y-GEITAS program compiles a list of all data pairs separated by a particular calibration interval which do not overlap each other, and calculates the change in calibration value for each pair. These are called the Observed In-Service Differences (OISD), and for each calibration interval a statistically significant number (N) of OISDs are needed to predict drift for that interval. For Y-GEITAS each OISD is a separate and independent measure of the drift of that instrument for the specified calibration interval. Y-GEITAS then performs a number of statistical analyses on the OISD data to compute the values needed for a statistical evaluation of the drift over this interval. Including in this computation is the average OISD, and a measure of the variance in this value about zero called SMAZ (second moment about zero). Expressed as a percent of the instrument span (to make it dimensionless), the square root of the observed SMAZ is:

$$\mathrm{SQRT(SMAZ)_{obs}} = (100/\mathrm{span}) \times \mathrm{SQRT}\,\{\Sigma\,(\mathrm{OISD}_i - \mathrm{OISD}_{avg})^2 / (N - 1) + (\mathrm{OISD}_{avg})^2\}$$

The numerical value of the span used in this equation is not important, since it cancels out in the determination of drift.

Since, as explained in Ref 3, drift is random and can be both positive and negative for any particular calibration interval, square-root of SMAZ is a measure of the "apparent" drift for the calibration interval. The "true" instrument drift can not be directly measured because the measurements include errors due to the accuracy of the instrument, the calibration accuracy, and the errors due to temperature effects within the calibration temperature range. Y-GEITAS computes an allowable value for SQRT(SMAZ) based on an initial 2 sigma estimate of true instrument drift (VD) for the specified calibration interval, and other known instrument errors. The calculational algorithm is as follows:

$$\mathrm{SQRT(SMAZ)_{allowable}} = (100/\mathrm{span}) \times (1/2) \times \mathrm{SQRT}(2VA^2 + 2C^2 + VD^2 + DTE^2)$$

Where A, C, and DTE are the accuracy, calibration error and drift temperature effect for the instrument, all 2 sigma values. Although there are other instruments in the loop, only the trip units have been considered in this calculation, so only the accuracy and calibration error for the trip units are used in this formula. Y-GEITAS then computes the Confirmation Ratio (CR) (defined as the ratio of the experimentally observed to allowable SQRT(SMAZ)), which is a measure of how well the drift has been estimated, assuming the accuracies are estimated correctly and the sample size is adequate.

$$CR = SQRT(SMAZ)_{observed} / SQRT(SMAZ)_{allowable}$$

To determine drift D, the value of $SQRT(SMAZ)_{allowable}$ is adjusted, by adjusting the drift (VD), so that CR is close to unity.

## A.2 Drift

The 7.5 month drift for this calculation was obtained by examining the confirmation ratio for 7.5 month calibration interval. If CR was greater than 1, then the drift value for that interval was assumed to be too low, and if significantly less than 1, the drift was assumed to be too high. The drift input to GEITAS (in terms of the equivalent 6 month drift) was then manually adjusted until the CR was less than one and as close to unity as reasonable. The drift input was made in terms of the equivalent 6 month drift (VD(6 mo)), which when extrapolated to 7.5 month calibration interval according to:

$$VD_{7.5} = VD_6\ SQRT(7.5/6),$$

produced an acceptable CR. Some engineering judgment was used to estimate the acceptable value of CR and hence the drift value used in the setpoint calculation.

The calculational procedure for determining the 7.5 month drift was as follows:

1. The observed drift for 7.5 months was calculated as shown below:

$$D(observed)_{7.5} = SQRT((4 \times (SQRT(SMAZ)_{7.5} \times (span/100) / CR)^2 - 2(A^2 + C^2))$$

2. Since the observed drift was calculated for 7.5 months, no extrapolation was required:

$$D(extrapolated)_{7.5} = D(observed)_{7.5}$$

The drift values are treated as 2 sigma values, because the inputs that go into the drift calculation are 2 sigma.

## A.3 Results

Results of Y-GEITAS analysis are shown in Table A-1, and A-2. Since this calculation was only for the APRM Trip Units, the VA, C and DTE values used in the calculation (and shown in Tables A-1, and A-2) are specifically for the Trip Units and were obtained from the body of this report. VA = 1.25 % was obtained from 4.1.3.3.4.1; C = 0.157 % was obtained from 4.1.3.6.3.1; and DTE = 0 was from assumption 3.20. Table A-1 shows a summary of the SMAZ and CR calculations for the desired extended interval of 7.5 months. Results are also shown for the 3.75 months calibration interval for confirmation. Table A-2 uses the results of the 7.5 month "apparent" drift calculation from site calibration data (Table A-1), to obtain the true instrument drift D for the required 7.5 months calibration interval using the method described above.

The results for APRM trip units are:

$VD_{7.5}$ = 1.34 % power
$D_{7.5}$ = 1.34 % power

| | | |
|---|---|---|
| | Nebraska Public Power District<br>**DESIGN CALCULATIONS SHEET** | Sheet A3 of A7 |
| Calc No: NEDC 92-50S, Rev. 3 | NPPD Generated Calculation | Review of Non-NPPD<br>Generated Calculation |
| NM-NAM-AR 2, 3, 4, 7, 8, 9 | Prepared By: | |
| NM-NAM-AR 5, 6 | Date: 1997 | Company's Name: General Electric Co. |
| Setpoint Calculation | Checked By: | NPPD Reviewer: |
| | Date: 1997 | Date: July 23, 1998 ~~1997~~ 7/23/98 |

These results from the Y-GEITAS program were also verified against results from GEITAS program. GEITAS calculation results are shown in Tables A-3 and A-4, and although GEITAS has more data points (because it uses all data points including those with overlapping intervals), the "apparent drift" values were approximately equal, and the final drift (D) values were the same as those obtained by Y-GEITAS. The drift values shown above are both 2 sigma values, and are used in the main body of this report for calculating the APRM setpoints.

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**DESIGN CALCULATIONS SHEET**

Calc No: NEDC 92-50S, Rev. 3

NPPD Generated Calculation

Review of Non-NPPD Generated Calculation

NM-NAM-AR 2, 3, 4, 7, 8, 9

Prepared By:

NM-NAM-AR 5, 6

Date: 1997

Company's Name: General Electric Co.

Setpoint Calculation

Checked By:

NPPD Reviewer:

Date: 1997

Date: July 23, 1998 ~~1997~~ mEU 7/23/98

Table A-1. Y-GEITAS Calculation

Calc. # 1-7
NM-NAM-AR 2,3,4,7,8,9
APRM.WK3 (Trip Trend #s: 1417,1422,1427,1432,1437,1442)

SUMMARY OF SMAZ CALCULATION FOR APRM TRIP UNITS NM-NAM-AR 2,3,4,7,8,9

CALIBRATION INTERVAL = 7.5 MONTHS; SPAN = 125

ACCURACY = 1.25; CALIB ERROR = 0.157; DRIFT (6 MONTHS) = 1.2; DTE = 0

| INTERVAL (MONTHS) | DATA PTS | OBSERVED $(SMAZ)^{1/2}$ | OBSERVED $(SMAZ)^{1/2}$ (% SP) | ALLOWABLE $(SMAZ)^{1/2}$ (% SP) | CONFIRMATION RATIO |
|---|---|---|---|---|---|
| 3.75 | 100 | 0.5560 | 0.4448 | 0.8592 | 0.5177 |
| 7.5 | 52 | 0.7261 | 0.5809 | 0.8921 | 0.6511 |

Nebraska Public Power District
**DESIGN CALCULATIONS SHEET**

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| | | |
|---|---|---|
| Calc No: NEDC 92-50S, Rev. 3 | NPPD Generated Calculation | Review of Non-NPPD Generated Calculation |
| NM-NAM-AR 2, 3, 4, 7, 8, 9 | Prepared By: | |
| NM-NAM-AR 5, 6 | Date: 1997 | Company's Name: General Electric Co. |
| Setpoint Calculation | Checked By: | NPPD Reviewer: |
| | Date: 1997 | Date: July 23 1998 ~~1997~~ MEY 7/23/98 |

## Table A-2. Drift & LAT Calculation

Calc # = 1-7 (Y-GEITAS)
(Trip Unit only)

SPAN = 125
VA = 1.25
C = 0.157
DTE = 0

| | OBSERVED | EXTRAPOLATED |
|---|---|---|
| VD(6 mo) = | 1.2 | |
| M = | 7.5 | 7.5 |
| VD = | 1.342 | 1.342 |
| D = | 1.342 | 1.342 |
| Let X = Calculated SQRT(SMAZ) | | |
| X = | 0.892 | 0.892 |
| Let Y = Observed SQRT(SMAZ) | | |
| Y = | 0.581 | 0.581 |
| Let CF = Confirmation Ratio | | |
| CF=Y/X = | 0.651 | 0.651 |

Nebraska Public Power District
**DESIGN CALCULATIONS SHEET**

| | | |
|---|---|---|
| Calc No: NEDC 92-50S, Rev. 3 | NPPD Generated Calculation | Review of Non-NPPD Generated Calculation |
| NM-NAM-AR 2, 3, 4, 7, 8, 9 | Prepared By: | |
| NM-NAM-AR 5, 6 | Date: 1997 | Company's Name: General Electric Co. |
| Setpoint Calculation | Checked By: | NPPD Reviewer: |
| | Date: 1997 | Date: 23, 199[illegible] ~~1997~~ |

Table A-3. GEITAS Calculation

Calc. # 1-7
NM-NAM-AR 2,3,4,7,8,9
APRM.WK3 (Trip Trend #s:
1417,1422,1427,1432,1437,
1442)

```
THE GENERAL ELECTRIC COMPANY


SUMMARY OF SMAZ CALCULATIONS FOR:  GE          NM-NAM-AR3   SPAN = 125.0
Largest INTERVAL (in Months) requested:  22

Accuracy =   1.250000    Calibration Error =   0.157000   Drift (6 mos) =   1.200000   DTE =   0.000000

                   OISD                  OBSERVED    OBSERVED    ALLOWABLE
INTERVAL  DATA   MEAN        SMAZ        SQRT(SMAZ)  SQRT(SMAZ)  SQRT(SMAZ)  CONFIRMATION   (Observed, % SP
(Months)  PTS                            (% UR)      (% SP)      (% SP)      RATIO           / Allowable, % SP)
---       -----  ----------  ----------  ----------  ----------  ----------  ----------

  1        846    0.003593    0.111807    0.334375    0.334375    0.859237    0.389154
  2        789   -0.020076    0.129819    0.360304    0.360304    0.859237    0.419330
  3        730   -0.019945    0.146681    0.382990    0.382990    0.859237    0.445733
  4        678   -0.024543    0.165151    0.406388    0.406388    0.859237    0.472964
  5        623   -0.046998    0.190247    0.436173    0.436173    0.859237    0.507629
  6        592   -0.084459    0.196006    0.442725    0.442725    0.859237    0.515254
  7*       592   -0.154189    0.292421    0.540760    0.540760    0.881299    0.613594
  8        568   -0.166197    0.280400    0.529528    0.529528    0.902822    0.586525
  9        573   -0.181640    0.323646    0.568899    0.568899    0.923844    0.615795
 10        560   -0.194714    0.313990    0.560348    0.560348    0.944398    0.593339
 11        559   -0.187764    0.309500    0.556327    0.556327    0.964514    0.576795
 12        548   -0.187007    0.322920    0.568260    0.568260    0.984219    0.577371
 13        555   -0.208577    0.300618    0.548286    0.548286    1.003538    0.546353
 14        560   -0.246286    0.330425    0.574826    0.574826    1.022491    0.562182
 15        568   -0.288732    0.363942    0.603276    0.603276    1.041099    0.579461
 16        592   -0.326892    0.387858    0.622783    0.622783    1.059381    0.587874
 17        608   -0.370789    0.437483    0.661425    0.661425    1.077352    0.613936
 18        614   -0.376417    0.454503    0.674168    0.674168    1.095029    0.615663
 19        605   -0.378050    0.441692    0.664599    0.664599    1.112424    0.597433
 20        594   -0.382222    0.455179    0.674669    0.674669    1.129552    0.597289
 21        559   -0.376673    0.422169    0.649745    0.649745    1.146424    0.566758
 22        520   -0.370000    0.412012    0.641882    0.641882    1.163051    0.551895
```

* The 7 month value of observed $(SMAZ)^{1/2}$ from column 6 from this Table was used in Table A-4 to get extrapolated results for 7.5 month calibration interval.

| | | |
|---|---|---|
| | Nebraska Public Power District<br>**DESIGN CALCULATIONS SHEET** | Sheet A7 of A7 |
| Calc No: NEDC 92-50S, Rev. 3 | NPPD Generated Calculation | Review of Non-NPPD Generated Calculation |
| NM-NAM-AR 2, 3, 4, 7, 8, 9 | Prepared By: | |
| NM-NAM-AR 5, 6 | Date: 1997 | Company's Name: General Electric Co. |
| Setpoint Calculation | Checked By: | NPPD Reviewer: |
| | Date: 1997 | Date: July 23, 1998 ~~1997~~ 7/23/98 |

## Table A-4. Drift & LAT Calculation

Calc # = 1-7 (GEITAS)
(Trip Unit only)

SPAN = 125
VA = 1.25
C = 0.157
DTE = 0

| | OBSERVED | EXTRAPOLATED |
|---|---|---|
| VD(6 mo) = | 1.2 | |
| M = | 7 | 7.5 |
| VD = | 1.296 | 1.342 |
| D = | 1.296 | 1.342 |
| Let X = Calculated SQRT(SMAZ) | | |
| X = | 0.881 | 0.892 |
| Let Y = Observed SQRT(SMAZ) | | |
| Y = | 0.541 | 0.547 |
| Let CF = Confirmation Ratio | | |
| CF=Y/X = | 0.614 | 0.614 |

Nebraska Public Power District
**DESIGN CALCULATIONS SHEET**
NPPD Generated Calculation

Sheet B1 of B3

Calc No: NEDC 92-50S, Rev. 3

Review of Non-NPPD Generated Calculation

NM-NAM-AR 2, 3, 4, 7, 8, 9

Prepared By:

NM-NAM-AR 5, 6

Date: 1997

Company's Name: General Electric Co.

Setpoint Calculation

Checked By:

NPPD Reviewer: Mark E

Date: 1997

Date: July 23, 1998 ~~1997~~ 7/23/98

## APPENDIX B

## APRM Flow Channel Uncertainty Calculation

### B.1Method

a) Flow Transmitter Errors

The total Recirculation flow is the sum of the flows from 2 separate but virtually identical flow loops. There is a flow transmitter in each loop and the output from each transmitter goes to a square root converter and then to a summer. The output of the summer provides a signal proportional to the total recirculation flow.

The flow (Q) in each flow loop is proportional to $\sqrt{\Delta P}$ measured by the loop flow transmitter. The transmitter puts out a 10 - 50 ma signal proportional to ΔP, and this signal goes to the square root converter which outputs a signal S proportional to the $\sqrt{\Delta P}$. Thus for each loop:

$$S = K \times \sqrt{\Delta P} \qquad (1)$$

where K is a constant. The error dS at the output of the square root converter due to an error $d(\Delta P)$ in the transmitter is:

$$dS = (K/2) \times d(\Delta P) / \sqrt{\Delta P} \qquad (2)$$

For a constant transmitter error $d(\Delta P)$, the dS error is a function of the flow and is larger for low flows than for high flows. Assuming that the errors from the 2 transmitters are independent, they can be added by the SRSS method, so the total input error ($dS_T$) from the flow transmitters to the summer is:

$$dS_T = \sqrt{2}\, dS = \sqrt{2} \times (K/2) \times d(\Delta P) / \sqrt{\Delta P} \qquad (3)$$

The summer output (V )is proportional to the sum of the outputs from the 2 square root converters, and for equal outputs from the square root converters, can be written as:

$$V = G \times 2S = G \times 2K \times \sqrt{\Delta P} \qquad (4)$$

where G is a constant. The summer output error due to total input error $dS_T$ from the square root converters is:

$$dV = G \times dS_T = G \times \sqrt{2}\, dS = G \times \sqrt{2} \times (K/2) \times d(\Delta P) / \sqrt{\Delta P} \qquad (5)$$

Combining equations (4) and (5) we get:

$$\frac{dV}{V} = \frac{1}{\sqrt{2}} \times \frac{1}{2} \times \frac{d(\Delta P)}{\Delta P} \qquad (6)$$

For the equipment used in the flow loop, full scale output corresponds to:

Maximum flow = 125% flow

$\sqrt{\Delta P(\text{Full Scale})} = \sqrt{\Delta P(FS)} = 408.9$ in WC

V(max) = 10 volts

Nebraska Public Power District
**DESIGN CALCULATIONS SHEET**
NPPD Generated Calculation

Sheet B2 of B3

Review of Non-NPPD Generated Calculation

Calc No: NEDC 92-50S, Rev. 3

NM-NAM-AR 2, 3, 4, 7, 8, 9

NM-NAM-AR 5, 6

Setpoint Calculation

Prepared By:

Date: 1997

Checked By:

Date: 1997

Company's Name: General Electric Co.

NPPD Reviewer: Mark E Unruh

Date: July 23, 1998 ~~1997~~ MEU 7/23/98

Therefore:

$$10 = G \times 2K \times \sqrt{\Delta P(FS)} \quad \text{, or } K = 5 / \{G \times \sqrt{\Delta P(FS)}\}$$

Substituting this value of K into equation (4) shows that V for any arbitrary flow (or ΔP) is:

$$V = 10 \times \sqrt{\Delta P} / \sqrt{\Delta P(FS)} \qquad \text{(Volts)}$$

This yields:

$$\Delta P = (V^2 / 100) \times \Delta P(FS) \tag{7}$$

Substituting equation (7) into equation (6) gives:

$$dV = \frac{1}{\sqrt{2}} \times 50 \times \frac{d(\Delta P)}{\Delta P(FS)} \times \frac{1}{V} \qquad \text{(Volts)}$$

Let the total transmitter error as a fraction of full scale (or full span) be defined as $A_{FT}$, then:

$$A_{FT} = \frac{d(\Delta P)}{\Delta P(FS)}$$

and

$$dV = \frac{1}{\sqrt{2}} \times 50 \times A_{FT} \times \frac{1}{V} \qquad \text{(Volts)} \tag{8}$$

This error is a function of the voltage V (or flow), and is twice as high at 50% flow than at 100% flow. However, to enable a constant error to be used for setpoint calculation throughout the range of interest, a constant error must be chosen. For the APRM flow biased setpoint calculation the error at 75% flow (or V= 6 volts) has been chosen because it is conservative compared to flow which gives 100% power. At lower flows there is more margin in the analytic limit, and the contribution of the flow error is not significant. Thus the error for APRM flow biased setpoint calculation is:

$$dV \text{ (for setpoint calculation)} = \frac{1}{\sqrt{2}} \times 50 \times A_{FT} \times \frac{1}{6} = 5.893 \times A_{FT} \qquad \text{(Volts)} \tag{9}$$

The corresponding error in flow is given by multiplying equation (9) by the volts required to get 100% flow. As mentioned earlier:

$$V(100\% \text{ flow}) = 8 \text{ volts}$$

Thus the flow error due to the flow transmitters is:

$$\text{FT Error} = \frac{dV}{8} \times 100 \qquad \text{(\% flow)}$$

$$\text{FT Error} = \frac{5.893}{8} \times 100 \times A_{FT} = 73.66 \times A_{FT} \qquad \text{(\% flow)} \tag{10}$$

Note that $A_{FT}$ is the total fractional transmitter error and includes error due to vendor accuracy, SPE, ATE etc.

| | | |
|---|---|---|
| | Nebraska Public Power District<br>**DESIGN CALCULATIONS SHEET** | Sheet B3 of B3 |
| Calc No: NEDC 92-50S, Rev. 3 | NPPD Generated Calculation | Review of Non-NPPD Generated Calculation |
| NM-NAM-AR 2, 3, 4, 7, 8, 9 | Prepared By: | |
| NM-NAM-AR 5, 6 | Date: 1997 | Company's Name: General Electric Co. |
| Setpoint Calculation | Checked By: | NPPD Reviewer: Mark E |
| | Date: 1997 | Date: July 23, 1998 ~~1997~~ MEU 7/23/98 |

b) Flow Element Errors

In addition to flow transmitter error, each of the 2 flow loops also has a Flow Element (FE) Error due the accuracy of the venturis. Assuming the errors from the 2 loops are independent they can be combined using the SRSS method. Also noting that the total flow is equal to the sum of the flows from the 2 loops the total Flow Element Error is:

$$\text{FE Error} = \frac{1}{\sqrt{2}} \times \text{FE Error in \% flow per loop} \qquad (\text{\% flow}) \qquad (11)$$

c) Flow Unit Error

The Flow Unit, consisting of two square root converters and a summer, has an error which must also be considered in determining the overall flow loop error. This value is given in the specifications as percent of full scale output, and can be converted to % flow by multiplying by the ratio of the output corresponding to 100 % flow and the full scale output.

FU Error = FU Error as % FS x (full scale volts / volts for 100% flow)

For the equipment used, the error is:

FU Error = FU Error as % FS x (10/8) (% flow) (12)

B.2Results

a) Flow Transmitter Error

As shown in 4.1.3.3.4.1, the error for the GEMAC555 transmitter is:

$A_{FT}$ = 1.00 % span. = 0.01 fraction of span

Thus, the corresponding flow error for setpoint calculation from equation (10) is:

FT Error = 73.66 x 0.01 = 0.7366 % flow

This value is used as a 2 sigma value in the setpoint calculations.

b) Flow Element Error

As shown in 4.1.3.3.4.1, the flow element error for the venturis used in the plant is:

FE Error per loop = 2.0 % flow per loop

Therefore, from equation (11)

$$\text{FE Error} = \frac{1}{\sqrt{2}} \times 2\,\% = 1.414\ \%\ \text{flow}$$

c) Flow Unit Error

As shown in 4.1.3.3.4.1, the flow unit error is:

FU Error as % FS = 2 %

Therefore, from equation (12)

FU Error = 2 x (10/8) = 2.5 % flow

Correspondence Number: NLS2003111

The following table identifies those actions committed to by Nebraska Public Power District (NPPD) in this document. Any other actions discussed in the submittal represent intended or planned actions by NPPD. They are described for information only and are not regulatory commitments. Please notify the Licensing & Regulatory Affairs Manager at Cooper Nuclear Station of any questions regarding this document or any associated regulatory commitments.

| COMMITMENT | COMMITTED DATE OR OUTAGE |
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