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Serial: RA-23-0120
May 31, 2023

10 CFR 50.90

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

H. B. ROBINSON STEAM ELECTRIC PLANT, UNIT NO. 2
DOCKET NO. 50-261 / RENEWED LICENSE NO. DPR-23

SUBJECT: Supplemental Information Regarding Addition of Feedwater Isolation on Steam Generator Level High-High to Technical Specification 3.3.2

REFERENCES:

1. Duke Energy letter, *License Amendment Request to Add Feedwater Isolation on Steam Generator Level High-High to Technical Specification 3.3.2 and Update the List of Analytical Methods Used in the Determination of Core Operating Limits*, dated September 21, 2022 (ADAMS Accession No. ML22264A149)
2. NRC email, *Request for Additional Information to Duke's Request for Robinson to Add Feedwater Isolation Function to TS 3.3.2 and Remove Obsolete Content from TSs 2.1.1.1 and 5.6.5.b (EPID L-2022-LLA-0137)*, dated January 11, 2023 (ADAMS Accession No. ML23011A015)
3. Duke Energy letter, *Response to Request for Additional Information (RAI) Regarding Addition of Feedwater Isolation on Steam Generator Level High-High to Technical Specification 3.3.2*, dated February 9, 2023 (ADAMS Accession No. ML23040A426)

Ladies and Gentlemen:

In Reference 1, Duke Energy Progress, LLC (Duke Energy) submitted a license amendment request (LAR) to modify the Technical Specifications (TS) for H. B. Robinson Steam Electric Plant (RNP), Unit No. 2. The proposed amendment would add a new function to TS 3.3.2, “Engineered Safety Feature Actuation System (ESFAS) Instrumentation,” Table 3.3.2-1 for Feedwater Isolation on Steam Generator (SG) level high-high (i.e., SG overfill protection). In addition, proposed revisions to TS 2.1.1.1 and TS 5.6.5.b were included to reflect the removal of analytical methods no longer applicable for the determination of RNP core operating limits. In Reference 2, the Nuclear Regulatory Commission (NRC) staff requested additional information regarding Reference 1. Duke Energy responded to the Reference 2 request for additional information (RAI) in Reference 3.

In the Reference 1 LAR, the following was stated regarding the Allowable Value (AV) for the high-high SG level setpoint:

> "…The AV associated with this setpoint is computed as follows:
>
> AV ≤ SP + GAFT, where SP = calibrated setpoint
> AV ≤ 75% Span + 1.16% Span
> AV ≤ 76.16% Span
>
> …"

Attachment 1 of Reference 3 provided RNP calculation RNP-I/INST-1070, "Steam Generator Narrow Range Level Loop Uncertainty and Scaling Calculation," Revision 14. Section 8.0 of RNP-I/INST-1070, Revision 14 stated (note the opposite inequality sign compared to the Reference 1 equation above):

> "…the Allowable Value (AV) associated with this setpoint is computed as follows:
>
> AV ≥ SP + GAFT, where SP = calibrated setpoint
> AV ≥ 75% Span + 1.16% Span
> AV ≥ 76.16% Span
>
> …"

In order to clarify computation of the AV limit as well as the acceptable surveillance measured setpoint range, RNP-I/INST-1070 has been revised. Revision 16 of RNP-I/INST-1070 is provided in Attachment 1 of this letter and provides the appropriate clarification in Section 8.0. Note that changes made to RNP-I/INST-1070 are described in the revision summary included in RNP-I/INST-1070 and notated with revision numbering and revision bars on affected pages.

The conclusions of the No Significant Hazards Consideration and Environmental Consideration in the original LAR are unaffected by this supplemental information.

This submittal contains no new regulatory commitments.

Duke Energy is notifying the state of South Carolina by transmitting a copy of this letter to the state official.

Should you have any questions concerning this letter, or require additional information, please contact Ryan Treadway, Director – Nuclear Fleet Licensing, at 980-373-5873.

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

Executed on May 31, 2023.

Sincerely,

Laura A. Basta
Site Vice President

Attachments:
1. RNP-I/INST-1070, "Steam Generator Narrow Range Level Loop Uncertainty and Scaling Calculation," Revision 16

cc: (all with Enclosure)

L. Dudes, Regional Administrator USNRC Region II
J. Zeiler, NRC Senior Resident Inspector
L. Haeg, NRR Project Manager
M. Mahoney, NRR Project Manager

A. Wilson, Attorney General (SC)
R. S. Mack, Assistant Bureau Chief, Bureau of Environmental Health Services (SC)
L. Garner, Manager, Radioactive and Infectious Waste Management Section (SC)

Attachment 1

RNP-I/INST-1070, “Steam Generator Narrow Range Level Loop Uncertainty and Scaling Calculation,” Revision 16

(124 pages follow)

DUKE ENERGY

Facility Code :	RNP
Applicable Facilities :	RNP
Document Number :	RNP-I/INST-1070
Document Revision Number :	016
Document EC Number :	
Change Reason :	AD-EG-ALL-1117
Document Title :	STEAM GENERATOR NARROW RANGE LEVEL LOOP UNCERTAINTY AND SCALING CALCULATION

Daji, Vijay D	Preparer	5/17/2023
Ray, Christy L	Design Verifier	5/17/2023
Abbott, Jeff	Supervisor	5/17/2023

Notes :

Calculation Cover Sheet

Steam Generator Narrow Range Level Loop Uncertainty and Scaling Calculation
(LT-474, LT-475, LT-476, LT-484, LT-485, LT-486, LT-494, LT-495, LT-496)

Title including structures, systems, and components

Calculation Number: RNP-I/INST-1070 Rev # 16

System: 3005 DSD List: ☐ Yes ☒ No

[BNP, HNP, RNP] Sub-Type: IE Microfiche Attachment List: ☐ Yes ☒ No

Quality Level A Priority E: ☐ Yes ☒ No

☐ All
☐ BNP Unit ______ ☐ CNS Unit ______ ☐ HNP Unit ______
☐ MNS Unit ______ ☐ ONS Unit ______ ☒ RNP Unit 2
☐ WLS Unit ______ ☐ HAR Unit ______
☐ General Office ☐ Keowee Hydro Station

Originated By	Design Verification Review By	Approved By
Signature Electronically Approved	Signature Electronically Approved	Signature Electronically Approved
	Verification Method 1 ☒ 2 ☐ 3 ☐ Other ☐	
Printed Name Vijay Daji	Printed Name Christy Ray	Printed Name Jeff Abbott
Date Electronically Dated	Date Electronically Dated	Date Electronically Dated

☐ **YES** ☒ **NO** Check Box for Multiple Originators or Design Verifiers (see next page)

For Vendor Calculations:

Vendor: ______________________ Vendor Document #: ______________

Owner's Review By: ______________________ Date: ______________________

Approval By: ______________________ Date: ______________________

LIST OF AFFECTED PAGES

Calculation Number:	**RNP-I/INST-1070**	
Revision Number:	**16**	

Body of Calculation (including appendices)				**Supporting Documents**				
Rev. #	*Pages Revised*	*Pages Deleted*	*Pages Added*	*Rev. #*	*Type*	*Pages Revised*	*Pages Deleted*	*Pages Added*
14	i - x			11	Attachment A		1	
14	1 - 105			3	Attachment B			1
				3	Attachment C			1
				3	Attachment D			1
				11	Attachment E		1	
				11	Attachment F			2
				11	Attachment G			2
				14	Attachment H			1
15	ii, v, 88			15	Attachment H		1	
					Attachment H			1
16	ii, v, 9, 10, 87, 88, 93, 94	i	i	16	Attachment H		1	
					Attachment H			1

Revision Summary

Revision	Summary
0	Initial Issue
1	Revised calculation to consider seismic uncertainties. The format of the calculation was revised to follow the calculation methodology presented in EGR-NGGC-0153.
2	Revised calculation to treat static pressure effects as dependent variables as required by EGR-NGGC-0153.
3	Revised to incorporate post uprate parameter values. This revision also implements Westinghouse letters NSAL-02-3 R1 and NSAL-02-4 to address additional error terms. In addition, Westinghouse letter PGN-02-59, "SG Water Level Fluid Velocity Effect Term Reduction" was incorporated into setpoint analyses in this calculation. Changed recorder to the Yokogawa VR204 to reflect changes from EC 47208.
4	Revised calculation to update reference to HBR2-11260 per EC 3604. Verified containment reanalysis assumptions are included in the calculation.
5	Revised to incorporate changes from NSAL 03-09 and WCAP-161115-P as evaluated in Engineering Change 59047 and incorporate new IR values as determined by RNP-I/EQ-1175.
6	Revised calculation to address NCR 035247 (Hagan Room Temperature issue) as well as the increase in maximum control room temperature (AR 00359636). In addition, the instrument uncertainty calculation for use in EOP setpoint calculations has been modified to address the maximum containment temperature assumed when normal containment setpoints are used in the EOPs. Also since EOP setpoints are rounded to the nearest half division in the conservative direction, the need to include readability errors in the determination of the instrument uncertainty is not necessary. Thus, the readability error has been removed from the uncertainty calculation. The format of the calculation was also modified slightly and is consistent with EGR-NGGC-0017, Rev. 7. This calculation was revised as a portion of EC 83170.
7	"High Steam Generator valve interlock setpoint" revised to "High Steam Generator alarm setpoint" on p. 88 of calculation per AR 596218.
8	Revised calculation to support setpoint changes associated with Zachry's Numerical Analysis Division calculation NAI-1664-005 "Containment Analysis with GOTHIC." NAI-1664-005 calculates a new maximum containment temperature following an accident, changing the existing assumption in Section 5.2 from 280°F to 340°F. This calculation was revised as a portion of EC 80767, Attachment E. Added Design Input explaining calculation of Specific Gravity. Calculation forms updated to EGR-NGGC-0017 Rev. 8. In Section 6.4.2 Summary, the Negative accPME %Span values for 30% and 50% fluid height were incorrect in Revision 7 (they were not used for any EOP setpoint values); these have been corrected in Revision 8 (the values did not include FRE) (See NCR 620161).
9	Calculation was revised for changes due to EC 75690, Deletion of the Steam Flow/Feed Flow Mismatch Reactor Trip. All information solely for the support of this trip was deleted from the calculation. There were dual output comparators which were changed to single output but no calc changes were required since specifications do not change between the 2 comparators.

10	For EOP use, the adverse containment setpoints can be based on the maximum temperature expected when the EOP steps containing adverse containment setpoints are reached. This is at least 100 seconds after the reactor trip, so the high containment temperatures (above 280°F) that is documented in the MSLB analysis (EC 80767) will not impact the EOP setpoint. This revision to RNP-I/INST-1070 will add a calculation of the PMA at 280°F for use in the EOP Setpoint calculations. This calculation was revised as a portion of EC 83171 Revision 2.
11	Revised calculation to incorporate change at H. B. Robinson from an 18 month fuel cycle to a 24 month fuel cycle: i) added References 4.2.7, 4.2.8, 4.2.9, 4.5.13, 4.5.15 thru 4.5.21, 4.6.5, 4.7.22, 4.7.23 and 4.7.24, deleted Reference 4.7.6, and updated Reference revision levels; ii) added Design Inputs 5.26, 5.27, and 5.28; iii) added Attachments F and G and deleted Attachments A and E, iv) updated Instrument Identification Table and associated calculation Sections to reflect proper make/model numbers for installed equipment; v) incorporated transmitter and indicator analyzed drift from calculations RNP-I/INST-1212 Rev. 0 and RNP-I/INST-1215 Rev. 0 respectively; vi) re-calculated transmitter, isolator, and indicator TDU's for normal, accident and EOP conditions where applicable; vii) re-calculated indicator, recorder, ERFIS, and AMSAC TLU's for normal, accident, and EOP conditions where applicable; viii) re-calculated Low and Low Low SG Level alarm TLU's, post seismic TLU for the Hi Level Valve Interlock, and Low Low SG Level Rx Trip TLU, all requiring no setpoint changes; ix) listed impact to RNP-I/INST-1103 Rev. 5 EOP setpoints in Section 8.5; and x) performed minor editorial corrections.
12	This revision incorporates ECs 411961, 413069 and 401424 and AR 2231413, which made the following changes: • EC 411961 replaced level transmitters LT-474, LT-475, LT-476, LT-484, LT-485, LT-486, LT-494, LT-495 and LT-496 with a Rosemount model 3154ND2R2F1E7. • CMU EC 413069 replaced the FR-488 and FR-498 control room recorders with a DX1004N model recorder (performed under Fleet spec EC 410155). Note that previous EC 407891 replaced the FR-478 recorder with a DX1004N model recorder, but did not update this calculation for conservatism. This revision changes also FR-478 to reflect the DX1004N model that was previously installed. • EC 401424 revised the containment temperature evaluations listed in RNP-I/EQ-1175, which caused downstream impacts to calculation RNP-I/INST-1070. AR 2231413 identifed that calculation RNP-I/INST-1070 Section 8 does not identify the UFSAR as a potentially impacted document. This revision revises Section 8 of this calculation to specify the UFSAR as a potentially impacted document.
13	The Plant Parameters Document (PPD) has been replaced by the Safety Analysis Inputs Manual (SAIM) Robinson Nuclear Plant (RNP) starting at Cycle 33. The new SAIM document is not an exact replacement for the PPD, and may not contain all the content once found in the PPD. Historically, PPDs have been previously issued as a Fuels calculation prior to the cycle start date, and end at the beginning of a new operating cycle when a new PPD (Fuels Calculation) is issued for the next operating cycle. The PPDs have been referenced in numerous ways in numerous documents throughout the years, from generic references to specific values listed in specific tables. In some RNP-I/INST and RNP-F/NFSA calculations, the cycle specific PPD calculation may be listed as an affected document as it may provide an input or use an output from the calculation. Starting at R2C33 RNP-I/INST calculations will be updated to clarify references to the new SAIM cycle specific document, or another document if necessary.

13	Revise Reference 4.7.3, RNP-F/NFSA-0230, RNP Cycle 30 PPD, to SAIM RNP-000, NGO Safety Analysis Inputs Manual (SAIM) Robinson Nuclear Plant (RNP). Updated Amendment for Reference 4.7.2 to 263. Updated UFSAR Revision to 28 for Reference 4.7.1. Add Reference 4.7.25 EC 415220 Revision 1, R2C33 Safety Analysis Site Implementation Revised Design Input 5.10, clarified reference to Main Steam Safety Valves versus SG Safety Relief Valves. Revised Design Input 5.13, clarified the Analytic Limit used in the Safety Analysis for the High Level Valve Interlock Setpoint. Added Reference 4.7.3 to Design Input 5.15. Reinstated Attachments on the List of Affected Pages that were inadvertently deleted in previous revision. Clarified References throughout calculation. Section 8.0, Incorporated the more conservative Steam Generator Level Valve Interlock Analytic Value (92 % Span versus 97.77% Span in the Margin Calculation.
14	In Revision 14 of this calculation file the High Steam Generator Level Valve Interlock ESFAS trip setpoint (= 75 %) is evaluated against an analytic steam generator level limit of 97% assumed in the updated RNP UFSAR Chapter 15.1.2, Increase in Feedwater Flow (IFF) transient analysis (Reference 4.2.10), performed in-house using NRC approved Duke methodology. The current UFSAR 15.1.2 IFF analysis (performed by Framatone) did not credit the above trip setpoint and therefore the setpoint is not currently included in the Technical Specifications. A license amendment request (LAR) will be submitted to the NRC to add this trip function to Technical Specification Table 3.3.2-1. Once the LAR is approved plant implementation of the trp function will be initiated. A Technical Specificaton Allowable Value (AV) is calculated for the High Steam Generator Level Valve Interlock ESFAS trip setpoint in Section 8.0. A new administrative procedure on uncertainty and setpoint analysis is incorporated via Reference 4.6.6. The former administrative procedure (Reference 4.6.1) is kept due to referenced material not available in the new administrative procedure.
15	An error discovered in the determination of the Tech. Spec. Allowable Value (AV), for the High Steam Generator Level Valve Interlock ESFAS trip setpoint, in Section 8.0, is corrected (NCR 02466713). The inequality sign for the allowable value is changed to "≤". The correct inequality sign was used in the LAR that was submitted to the NRC to add the High Steam Generator Valve Interlock to the Technical Specifications. Therefore, no other documents are affected by this change.
16	The following summarizes the changes made in Rev. 16: Page 9 of 105: Updated amendment number of Reference 4.7.2 to the current version. Page 10 of 105: Corrected typographical error – changes Value to Valve. Page 87/88 of 105: Calculation of the High SG Level Valve Interlock Setpoint (increasing setpoint) Allowable Value (AV) and its application is clarified. Page 93/94 of 105: Calculation of the Low Low SG Level Reactor Trip Setpoint (decreasing setpoint) Allowable Value (AV) and its application is clarified.

DOCUMENT INDEXING TABLE

The purpose of this table is to create document cross-references in the Document Management System and equipment cross-references in the Equipment Data Base.

Document Type	Document Number	Function	Relationship to this Calculation	Action
CALC	INST-I/INST-1212	IN	Reference	ADD/RETAIN
CALC	INST-I/INST-1215	IN	Reference	ADD/RETAIN
PROC	MST-013	IN	Reference	ADD/RETAIN
PROC	PIC-005-1	IN	Reference	ADD/RETAIN
PROC	PIC-005-2	IN	Reference	ADD/RETAIN
PROC	PIC-005-4	IN	Reference	ADD/RETAIN
PROC	PIC-005-6	IN	Reference	ADD/RETAIN
PROC	PIC-005-8	IN	Reference	ADD/RETAIN
PROC	PIC-005-9	IN	Reference	ADD/RETAIN
PROC	PIC-005-10	IN	Reference	ADD/RETAIN
PROC	EOP-ECA-0.0	IN	Reference	ADD/RETAIN
PCHG	EC 97661	IN	Reference	ADD/RETAIN
CALC	RNP-M/MECH-1651	OUT	Document affected by results	ADD/RETAIN
NF	SAIM RNP-000	IN	Reference	ADD/RETAIN

Table of Contents

LIST OF ATTACHMENTS PAGES

1.0 OBJECTIVE

This calculation computes the loop uncertainties associated with the indication, recording, and trip functions provided by the Steam Generator Narrow Range Level instrumentation loops. The loops addressed in this calculation also provide input to the Emergency Response Facility Information System (ERFIS) and AMSAC. Uncertainties at the input to the ERFIS and AMSAC are calculated. Uncertainties are calculated for normal, accident, and seismic conditions. This calculation develops the Reactor Protection System (RPS) setpoint associated with each instrument loop. This calculation also calculates the Allowable Value for the RPS setpoint addressed in this calculation. Uncertainties associated with the control functions provided by the Steam Generator Level loops are not calculated.

The RNP UFSAR Chapter 15.1.2, Increase in Feedwater Flow (IFF) transient analysis, was performed in-house in calculation file RNP-F/NFSA-0356 (Reference 4.2.10) using NRC approved Duke methodology. The analysis credited feedwater isolation on high-high SG NR level. Since this trip is not currently included in the Technical Specifications, a license amendment request (LAR) will be submitted to the NRC to add this trip to Technical Specification Table 3.3.2-1. The current UFSAR Section 15.1.2 evaluation will remain the licensing basis until the LAR is approved, at which time the analysis in this calculation file will be implemented via the markups documented in Appendices A (UFSAR Markup), B (REDSAR Markup), and C (SAIM Markup) of Reference 4.2.10.

The Duke analysis performed in Reference 4.2.10 credits a conservative High Steam Generator Level Valve Interlock Analytic Value of 97%, i.e. when the level in any steam generator reaches 97% the associated main feedwater regulating valve closes and trips the main feedwater pumps. Section 8.0 of this calculation file is updated accordingly and an allowable value (AV) of the Steam Generator Level Valve Interlock setpoint is determined. The implementation of this change is managed by Reference 4.7.26.

The instrument loops containing the following components are addressed in this calculation:

LT-474
LQ-474
L-474
LC-474
LC-474A
LM-474
LC-474B
LI-474
LM-474A
LM-474B
LM-474/R
LC-474/R
LC-474A/R

LT-475
LQ-475
L-475
LC-475
LC-475A
LM-475
LC-475B
LI-475
LM-475A
LM-475A/R
LC-475/R
LC-475A/R

LT-476
LQ-476
L-476
LC-476
LC-476A
LM-476
LI-476
FR-478
LM-476A
LM-476/R
LC-476/R
LC-476A/R

LT-484
LQ-484
L-484
LC-484
LC-484A
LM-484
LC-484B
LI-484
LM-484A
LM-484/R
LC-484/R
LC-484A/R

LT-485
LQ-485
L-485
LC-485
LC-485A
LM-485
LC-485B
LI-485
LM-485A
LM-485B
LM-485A/R
LC-485/R
LC-485A/R

LT-486
LQ-486
L-486
LC-486
LC-486A
LM-486
LI-486
FR-488
LM-486A
LM-486A/R
LC-486/R
LC-486A/R

LT-494
LQ-494
L-494
LC-494
LC-494A
LM-494
LC-494B
LI-494
LM-494A
LM-494/R
LC-494/R
LC-494A/R

LT-495
LQ-495
L-495
LC-495
LC-495A
LM-495
LC-495B
LI-495
LM-495A
LM-495/R
LC-495/R
LC-495A/R

LT-496
LQ-496
L-496
LC-496
LC-496A
LM-496
LI-496
FR-498
LM-496A
LM-496B
LM-496A/R
LC-496/R
LC-496A/R

2.0 FUNCTIONAL DESCRIPTION

The Steam Generator provides a heat sink for the Reactor Coolant System (RCS) during normal and accident plant operation. Feedwater occupies about half of the Steam Generator with steam filling the other half. Various events affect Steam Generator level during normal and accident operation. In the event that the normal control system is unable to maintain Steam Generator Level within the normal operating band, protective actions must be initiated to ensure that level remains within design limits during the transient. The instrument loop that is the subject of this calculation provide the following protective functions:

- Low Low Steam Generator Level Reactor Trip

2.1 Normal Function

During normal operation, the instrument loops addressed in this calculation provide Steam Generator Level indication (LI-474, 475, 476, 484, 485, 486, 494, 495 & 496), recording (FR-478), and input to the Emergency Response Facility Information System (ERFIS). These loops also provide Low Low, and High Steam Generator Level alarms, a High Steam Generator Level valve interlock, and provide input to AMSAC.

2.2 Accident Mitigating Function

The instrument loop addressed in this calculation provides a Reactor Trip on Low Low Steam Generator Level.

The Reactor Trip on Low Low Steam Generator Level also serves to protect against the loss of the Steam Generator as a heat sink for the RCS. A Reactor Trip and Auxiliary Feedwater System actuation occurs when two out of three Steam Generator Level signals fall below the Low Low Steam Generator Level setpoint. Per Reference 4.7.1, this trip is credited in the Safety Analysis for termination of the following events:

- Loss of non-emergency power to station auxiliaries
- Loss of normal feedwater
- Feedwater line break

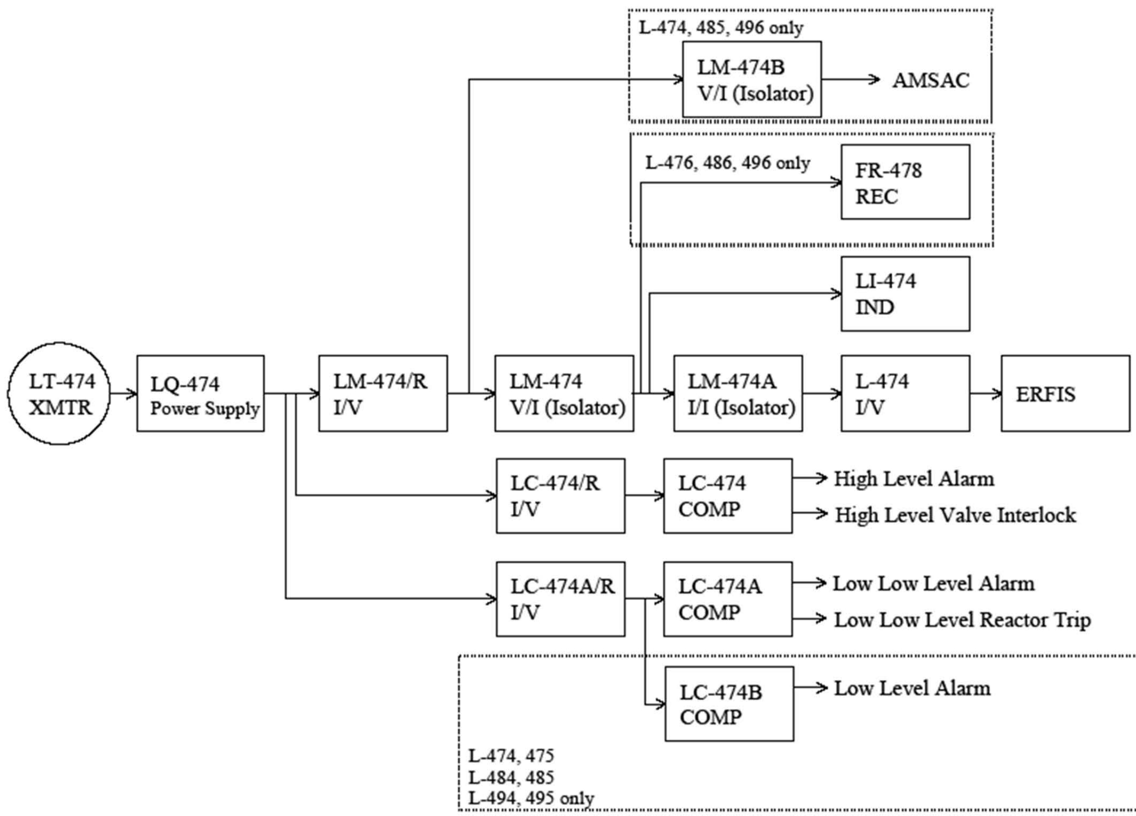
2.3 Post Accident Monitoring Function

Per TMM-026, these instrument loops are used for post accident monitoring.

2.4 Post Seismic Function

Per Reference 4.7.14, these instruments are seismically qualified to ensure that safety / protection functions remain operable following a seismic event.

3.0 LOOP DIAGRAM



Note: Same configuration for loops L-475, 476, 484, 485, 486, 494, 495, and 496 except where noted.

TAG NUMBER	FUNCTION	MAKE AND MODEL	LOCATION	REFERENCE
LT- 474, 475, 476 LT- 484, 485, 486 LT- 494, 495, 496	Transmitter	Rosemount 3154ND2R2F1E7	Containment	4.1.1-8, 4.7.4
LQ- 474, 475, 476 LQ- 484, 485, 486 LQ- 494, 495, 496	Power Supply	NUS SPS 800	Hagan Rack	4.1.1-8, 4.7.4
LM-474/R, LC-474/R, 474A/R LM-475A/R LC-475/R, 475A/R LM-476/R LC-476/R, 476A/R LM-484/R, LC-484/R, 484A/R LM-485A/R LC-485/R, 485A/R LM-486A/R LC-486/R, 486A/R LM-494/R, LC-494/R, 494A/R LM-495/R LC-495/R, 495A/R LM-496A/R LC-496/R, 496A/R	I/V	Hagan Model 3110554-000	Hagan Rack	4.1.1-8, 4.7.4
LM-474A, 475A LM-476A, 484A LM-485A, 486A LM-494A, 495A LM-496A	I/I Isolator	NUS EIP-E013DD-1	Hagan Rack	4.1.1-8, 4.7.4

TAG NUMBER	FUNCTION	MAKE AND MODEL	LOCATION	REFERENCE
LM-474, 475, 476 LM-484, 485, 486 LM-494, 495, 496	V/I Isolator	NUS OCA 800	Hagan Rack	4.1.1-8, 4.7.4
LM-474B, 485B LM-496B	V/I Isolator	NUS EIP-E013DD-37	Hagan Rack	4.1.1-8, 4.7.4
LC-474, 475, 476 LC-484, 485, 486 LC-494, 495, 496 LC-474A, 475A LC-476A, 484A LC-485A, 486A LC-494A, 495A LC-496A, 474B LC-475B, 484B LC-485B, 494B LC-495B	Comparator	Hagan Model 139-118 Or NUS SAM 800 Or NUS DAM 800	Hagan Rack	4.1.1-8, 4.7.4
LI- 474, 475, 476 LI- 484, 485, 486 LI- 494, 495, 496	Indicator	International Instruments 2520VB	RTGB	4.1.1-8, 4.7.4
FR-478, 488, 498	Recorder	Yokogawa DX1004N	RTGB	4.7.4, 4.7.15
L-474, 475, 476 L-484, 485, 486 L-494, 495, 496	I/V	Hagan Computer Signal Conditioner 3110552-000	Hagan Rack	4.1.1-8, 4.7.4

Instrument Identification

4.0 REFERENCES

4.1 Drawings

4.1.1 5379-03513, Hagan Wiring Diagram, Revision 23
4.1.2 5379-03514, Hagan Wiring Diagram, Revision 25
4.1.3 5379-03515, Hagan Wiring Diagram, Revision 24
4.1.4 5379-03516, Hagan Wiring Diagram, Revision 23
4.1.5 5379-03517, Hagan Wiring Diagram, Revision 25
4.1.6 5379-03518, Hagan Wiring Diagram, Revision 25
4.1.7 5379-03485, Hagan Wiring Diagram, Revision 23
4.1.8 5379-03486, Hagan Wiring Diagram, Revision 23
4.1.9 HBR2-11260, Zone Map For Environmental Parameters Reactor Building Elevation 228 ft, Sheet 5, Revision 6
4.1.10 HBR2-11260, Zone Map For Environmental Parameters, Sheet 8, Revision 15
4.1.11 HBR2-11135, RTGB Panel C - Annunciator Section, Sheet 2, Revision 1
4.1.12 HBR2-11135, RTGB Panel C - Vertical Section, Sheet 3, Revision 2
4.1.13 A-190299, Instrument Hook-Up Detail, Sheet 46, Revision 6
4.1.14 HBR2-10731, Steam Generator Model 44F Upper Steam Drum Field Modifications, Sheet 1, Revision 0
4.1.15 HBR2-10750, #44 Series Vertical Steam Generator Outline, Revision 1
4.1.16 5379-03487, Hagan Wiring Diagram, Revision 23
4.1.17 HBR2-10736, Rev. 0, Steam Generator - Mod. "44F" Feedwater Ring & J –Nozzle Assembly

4.2 Calculations

4.2.1 RNP-E-1.005, 120 VAC Instrument Bus Voltage Evaluation, Revision 4
4.2.2 RNP-I/EQ-1175, In-CV Rosemount Transmitter Loop Accuracy, Revision 3
4.2.3 RNP-M/MECH-1651, Containment Analysis Inputs, Revision 14
4.2.4 RNP-I/INST-1103, Steam Generator Level EOP Setpoint Parameters, Revision 5
4.2.5 RNP-I/INST-1109, Containment EOP Setpoint Parameters, Setpoint M.13, Rev. 7
4.2.6 RNP-M/HVAC-1078, Hagan Room Temperature, Revision 4
4.2.7 RNP-I/INST-1212, Rosemount 1154DP4 and 1154HP5 Pressurizer and Steam Generator Narrow Range Level Transmitters Instrument Drift Analysis, Revision 0
4.2.8 RNP-I/INST-1215, Drift Analysis for International Instruments Model 2520 Indicators, Revision 0
4.2.9 RNP-I/INST-1079, Steam Generator Level AOP Setpoint Parameters, Revision 3
4.2.10 RNP-F/NFSA-0356, Rev. 0, RNP UFSAR Section 15.1.2 – Increase in Feedwater Flow

4.3 Regulatory Documents

4.3.1 Regulatory Guide 1.97, Rev. 3, Instrumentation for Light Water-Cooled Nuclear Power Plants to Assess Plant and Environs Conditions During and Following an Accident

4.4 Technical Manuals

4.4.1 728-589-13, Vendor Manual Hagan, Revision 42
4.4.2 728-399-88, Auxiliary Indicating Meters Bulletin Model 2500 2520, Revision 3
4.4.3 728-012-10, Vendor Manual Rosemount, Revision 40
4.4.4 728-208-63. VERTICAL STEAM GENERATOR TECHNICAL MANUAL, Revision 22
4.4.5 DPM 1346.04-0002.001, Yokogawa Recorder Vendor Manual, Revision 0

4.5 Calibration And Maintenance Procedures

4.5.1 PIC-005, Steam Generator A Narrow Range Level Transmitter LT-474 Calibration, Revision 13
4.5.2 LP-027, Steam Generator #1 Narrow Range (N/R) Level Channel 476, Revision 16
4.5.3 LP-028, Steam Generator #2 Narrow Range (N/R) Level Channel 486, Revision 15
4.5.4 LP-029, Steam Generator #3 Narrow Range (N/R) Level Channel 496, Revision 19
4.5.5 LP-030, Steam Generator #1 Narrow Range (N/R) Level Channel 474, Revision 15
4.5.6 LP-031, Steam Generator #2 Narrow Range (N/R) Level Channel 484, Revision 15
4.5.7 LP-032, Steam Generator #3 Narrow Range (N/R) Level Channel 494, Revision 13
4.5.8 LP-033, Steam Generator #1 Narrow Range (N/R) Level Channel 475, Revision 13
4.5.9 LP-034, Steam Generator #2 Narrow Range (N/R) Level Channel 485, Revision 16
4.5.10 LP-035, Steam Generator #3 Narrow Range (N/R) Level Channel 495, Revision 13
4.5.11 MMM-006, Calibration Program, Revision 34
4.5.12 PIC-844, Yokogawa Recorders, Revision 13
4.5.13 MST-013, Steam Generator Water Level Protection Channel Testing, Revision 26
4.5.14 PIC-005-1, Steam Generator A Narrow Range Level Transmitter LT-475 Calibration, Revision 0
4.5.15 PIC-005-2, Steam Generator A Narrow Range Level Transmitter LT-476 Calibration, Revision 0
4.5.16 PIC-005-4, Steam Generator B Narrow Range Level Transmitter LT-484 Calibration, Revision 0
4.5.17 PIC-005-5, Steam Generator B Narrow Range Level Transmitter LT-485 Calibration, Revision 0
4.5.18 PIC-005-6, Steam Generator B Narrow Range Level Transmitter LT-486 Calibration, Revision 0
4.5.19 PIC-005-8, Steam Generator C Narrow Range Level Transmitter LT-494 Calibration, Revision 0
4.5.20 PIC-005-9, Steam Generator C Narrow Range Level Transmitter LT-495 Calibration, Revision 1
4.5.21 PIC-005-10, Steam Generator C Narrow Range Level Transmitter LT-96 Calibration, Revision 0

4.6 Procedures

4.6.1 EGR-NGGC-0153, Engineering Instrument Setpoints, Revision 12
4.6.2 TMM-026, List of Regulatory Guide 1.97 Components, Revision 32
4.6.3 MMM-006, Apprendix B-1, Calibration Program, Revision 51
4.6.4 OP-906, Heating, Ventilation, and Air Conditioning, Rev. 72
4.6.5 EOP-ECA-0.0, Loss of All AC Power, Revision 4
4.6.6 AD-EG-ALL-1153, Engineering Instrument Setpoint/Uncertainty Calculations, Revision 0.
FAD-EG-ALL-1153, DETAIL/EXAMPLE, Engineering Instrument Setpoint/Uncertainty Methodology and Discussion, Revision 0.

4.7 Other References

4.7.1 Updated Final Safety Analysis Report - Chapter 15, Revision 28.
4.7.2 Technical Specifications, Amendment 274. Rev. 16
4.7.3 SAIM RNP-000, Safety Analysis Inputs Manual Robinson Nuclear Plant
4.7.4 Equipment Data Base (EDB)
4.7.5 ASME Steam Tables, 5^{th} Edition (based on the 1967 IFC formulation)
4.7.6 Deleted
4.7.7 ASME Section II-A, Table TE-1
4.7.8 ASME Section II-A, SA-302/SA-302M
4.7.9 WNEP-8372, Model 44F Steam Generator Thermal and Hydraulic Design Data Report, Revision 3, April 1, 1985
4.7.10 Letter CQL-92-031, S/G Water Level PME Term Inaccuracies, June 18, 1992
4.7.11
a. WCAP-15304, Carolina Power and Light Company H. B. Robinson Steam Electric Plant, Unit No.2 LOCA Containment Integrity Analysis.
b. WCAP-15305, Carolina Power & Light Company H. B. Robinson Steam Electric Plant, Unit No.2 Steamline Break Containment Integrity Analysis
c. Calculation NAI-1664-005 “Containment Analysis with GOTHIC”
d. Letter to Progress Energy H.B Robinson Nuclear Plant, “LOCA M&E Reanalysis to Address Elevated RWST and Accumulator Temperature Engineering Report and FSAR Markups” with Attachment of Westinghouse LTR-CRA-12-19 “Engineering Report “Engineering Report for H.B. Robinson LOCA M&E Release Analysis,” Revision 6

4.7.12 Westinghouse Nuclear Safety Advisory Letters (NSALs)
a. NSAL-02-3 Revision 1, April 8, 2002
b. NSAL-02-4, February 19, 2002
c. NSAL-03-09, September 22, 2003
d. NSAL-11-5, “Westinghouse LOCA Mass and Energy Release Calculation

Issues," July 25, 2011

4.7.13 Westinghouse letter PGN-02-59 Rev. 1, dated August 7, 2002
4.7.14 DBD/R87038/SD06, DBD for the Reactor and Safeguards Protection System, Revision 12
4.7.15 EC 47208, Replacement of RTGB Recorders, Revision 16
4.7.16 EC 80767, "Correct LOCA Containment Analysis Errors", Rev. 0
4.7.17 EC 59047 Steam Generator Level Instrument Uncertainty, Revision 1
4.7.18 WCAP-16115-P, Steam Generator Level Uncertainties Program (See EC 59047 Attachment A)
4.7.19 SG-85-04-21, Westinghouse Steam Generator Thermal-Hydraulic Report
4.7.20 DBD/R87038/SD36, Rev. 15, Post-Accident HVAC Systems
4.7.21 UFSAR Section 7.5.2.1, Revision 26
4.7.22 EC 97661, Robinson Nuclear Plant Instrument Drift Analysis Methodology in Support of 24 Month Surveillance Interval, Revision 1
4.7.23 NUS Instruments Long Term Drift Test for NUS Modules, Final Report Executive Summary, dated October 26, 2001 (Attachment F)
4.7.24 Email form NUS Confirming Similarity of NUS Isolator Modules, dated, January 15, 2002 (Attachment G)
4.7.25 EC 415220 Revision 1, R2C33 Safety Analysis Site Implementation.
4.7.26 EC 420027, Implement SG High Level Feedwater Regulating Valve Interlock. Rev. 16

5.0 INPUTS AND ASSUMPTIONS

5.1 The accuracy of a typical test resistor is on the order of ± 0.01%. Therefore, the test resistors used during calibration are assumed to have a negligible impact on the overall uncertainty calculation. This is in accordance with the methodology described within Reference 4.6.6.

5.2 Per Reference 4.7.11 (a) and (b), the maximum Containment temperature following an accident is 280°F. Per Reference 4.7.16, the maximum Containment temperature by analysis following an accident is 340°F, which occurs within the first 60 seconds of the transient. The temperature then quickly falls below 280°F. Since the operator would not reach EOP steps that contain adverse setpoints is that short of time (i.e. less than 100 seconds), for EOP setpoint use only, the maximum containment temperature used to compute accident reference leg density effects is 280°F. Per Reference 4.1.9, the minimum Containment temperature during normal operation is 88°F and is assumed to be the minimum Containment temperature following an accident. Therefore, the maximum and minimum Containment temperatures used to compute accident reference leg density effects are 340°F and 88°F respectively for non-EOP applications and 280°F and 88°F respectively for EOP applications. In the event of a single feedwater line break, per WCAP-16115P, the maximum containment temperature is 225°F, which will be used to determine the accident reference leg effects.

5.3 Per Reference 4.1.13, the transmitter reference leg is connected to a condensate pot that is connected to the upper Steam Generator instrument tap. Due to the short piping run from the upper instrument tap to the condensate pot, the change in height from the instrument tap to the condensate pot is assumed to be negligible.

5.4 Per Reference 4.1.13, a portion of the transmitter reference leg is located inside the Steam Generator shield wall. The temperature inside the shield wall is greater than the ambient temperature inside Containment. Per Reference 4.2.3, a maximum Containment temperature of 130°F is used in the Containment analysis. For conservatism, the temperature inside the shield wall is assumed to be 140°F and is used to compute normal reference leg density effects. Per Reference 4.1.9, the minimum temperature inside Containment is 88°F. Therefore, a minimum temperature of 88°F is used to compute normal reference leg density effects.

5.5 Per Reference 4.6.6, reference accuracy typically includes the effects of linearity, hysteresis, and repeatability. The indicator reference accuracy is stated within Reference 4.2.2. The value is given as 2% full scale for a DC meter. Repeatability is listed separately and is stated as being in accordance with ANSI C39.1. Per C39.1 Plate 5 for a Direct Current Application, Edgewise instrument, repeatability is only applicable to the microammeter option. As this is not a microammeter application, the repeatability is taken to be included within the reference accuracy term. The reference accuracy will be taken to include the effects of linearity, hysteresis, and repeatability in accordance with Reference 4.6.6.

5.6 Per References 4.5.2 through 4.5.10, the I/V module is calibrated as part of a string. Per Reference 4.4.1, the I/V module is a resistor. Resistors typically experience negligible drift. Therefore, any resistor drift throughout the fuel cycle is negligible and is accounted for during the string calibration.

5.7 Per Reference 4.2.3, the maximum containment temperature assumed within the containment analysis is 130ºF. Technical Specification 3.6.5 limits containment average air temperature to less than or equal to 120ºF. For the purpose of this calculation, 130ºF will be used as the upper limit of containment temperature. Per review of OSI PI data for Tag CVT0001 Volume Weighted Ave CV Air Temp, it can be seen that the containment temperature trends greater than 60ºF. For the purpose of this calculation, 50ºF will be used as the lower limit for containment temperature.

5.8 The Hagan Room normal operating temperature is 50°F to 82ºF. The low limit of 50ºF is chosen as it is the more conservative value when comparing the 50ºF alarm setpoint [from Reference 4.6.3] for TS-A42 (HVA-2 Lo Temp Switch) and the 55ºF heater setpoint [from Reference 4.6.4] for TS-A40 (Temperature Switch for EDH-4). The basis for the 82ºF is the Hot Operations Log (TIN R0041). The hot operations log directs the installation of supplemental cooling when Hagan Room temperatures reach 78ºF, and the initiation of an NCR and an operability review when Hagan Room temperatures reach 82ºF. Per Reference 4.6.1 Section 9.4.3, the racks may experience an additional internal 10°F heat rise during operation. Therefore, a change in temperature of 42°F (23.33°C) is used to compute the normal temperature effect associated with rack components in setpoint and normal indication loops.

$$82°F + 10°F - 50°F = 42°F$$

The Hagan Room accident operating temperature is 50ºF to 120ºF. The low limit basis is as noted above. In order to bound a postulated loss of HVAC scenario (as can be induced by a Loss of Offsite Power), a Heatup analysis of the Hagan Room was completed by Reference 4.2.6. The maximum room temperature at the equipment elevation is 110ºF when the SPP-045 controls are applied. For conservatism, the high limit is taken to be 120ºF. As EOP-ECA-0.0 (Reference 4.6.5) requires opening all cabinet doors in the Hagan Room within 30 minutes, an internal cabinet heat rise is not specifically evaluated. Therefore, a change in temperature of 70°F (38.89°C) is used to compute the accident temperature effect associated with rack components in EOP indicator loops.

5.9 The Westinghouse 3110552-000 Computer Signal Conditioner is a high precision resistor. Based on the high accuracy of the resistor, the resistor has a negligible impact on the overall loop uncertainty computation.

5.10 Per Reference 4.7.3, Table 18, the lowest set pressure of the Main Steam Safety Valves is 1100 psia. Therefore, 1100 psia is the maximum pressure used to compute accident process measurement effects. Following a main steam line break, the Steam Generator will rapidly blow down to ambient Containment pressure. Therefore, a minimum Steam Generator pressure of 15 psia is used to compute accident process measurement effects. Note that Table 18 of Reference 4.7.3 provides the set pressure of the Main Steam Safety Valves in terms of psig.

5.11 Deleted

5.12 Per Reference 4.7.9, Steam Generator pressure is approximately 800 psia at 100% load and 1020 psia at 0% load. Therefore, the minimum and maximum pressure used to compute normal process measurement effects are 800 psia and 1020 psia respectively.

5.13 Per UFSAR Chapter 15, the High Steam Generator Level valve interlock is not credited in the safety analysis. This setpoint serves to protect against the Steam Generator becoming water solid and feedwater entering the main steam lines. NSAL-02-4 (Reference 4.7.12) identifies a previously unconsidered source of uncertainty. Due to the void content of the two-phase mixture above the mid-deck plate, the steam generator water level instrument channel(s) will not indicate water level as accurately as presumed when level is above the mid-deck plate. As a result, a high-high level trip (actuation) may not occur, even though the two-phase mixture level may actually be above the upper level tap. NSAL-02-4 provides a means of determining "maximum reliable indicated level (MRIL)" for steam generators and provides technical input that quantifies the void fraction above mid-deck plate for H. B. Robinson's steam generators at 11%.

Per NSAL-02-4, MRIL is determined as follows:

MRIL = 100% - (100% Level - Mid Deck Level) (Void Fraction)

100% Level Span = 143 inches (Reference 4.1.15)
100% Level Span with elongation correction = 143.5 inches (Section 9.1)
Distance from Tube Sheet to Lower Tap = 385.625 inches (Reference 4.7.9)
Distance from Tube Sheet to Mid Deck Plate = 500.0675 inches (Ref. 4.7.9)
Void Fraction = 11% (Reference 4.7.12)

Distance from Lower Tap to Mid Deck (MD) = (500.0675 – 385.625) inches
= 114.4425 inches

Thus, MD as a % of Narrow Range Span is:

$$MD = \left(\frac{114.4425}{143.5}\right) = 79.751\% \text{ of Span}$$

Therefore:

$$MRIL = 100\% - (100\% - MD)(11\%)$$
$$MRIL = 97.773\ \%\ \text{Level}$$

This MRIL is conservatively rounded to 97.77% Narrow Range Level. Since this is the upper limit for reliable level indication, the Analytic Limit for the High Level Valve Interlock addressed in this calculation is conservatively chosen at 97% span (Reference 4.2.10).

5.14 Per Reference 4.7.20, the Control Room normal operating temperature is 70ºF to 77ºF dry bulb, inclusive under all modes of operation. Per Reference 4.7.21, the normal ambient design temperature for Control Room located equipment is 75ºF (plus or minus 10ºF), which can also be stated as a temperature range of 65 ºF to 85 ºF. Per Reference 4.7.2, the Control Room Emergency Air Temperature Control (CREATC) maintains the Control Room temperature less than or equal to 85ºF. Therefore, a maximum change in temperature of 20ºF (11.1ºC) is used to compute the indicator and recorder temperature effect.

5.15 The High Steam Generator Level alarm serves to warn the operator that Steam Generator Level is approaching the High Steam Generator Level valve interlock setpoint. Therefore, the limit for this setpoint is set to the High Steam Generator Level valve interlock setpoint of 75% Span (References 4.5.2 through 4.5.10, and 4.7.3, Table 2).

5.16 The Low Steam Generator Level alarm serves to warn the operator that Steam Generator Level is approaching the Low Steam Generator Level Reactor Trip setpoint. Therefore, the limit for this setpoint is set to the Low Steam Generator Level Reactor Trip setpoint of 30% Span (Reference 4.7.2).

5.17 Deleted

5.18 Reference 4.7.12.a identifies a bias effect due to a differential pressure at the moisture separator mid-deck. For the purposes of this calculation, this bias shall be called mid-deck differential pressure bias, or MDDPb. Documented evaluations in Reference 4.7.12.a assert that this MDDPb would be negative (conservative) for a Feedwater Line Break accident and positive (non-conservative) for Loss of Offsite Power and Loss of Normal Feedwater Accidents. The steam flow to be considered in determining the $\triangle$P across the Moisture Separator Mid Deck Plate was increased from 100% to 112% by WCAP 16115P. Per Table 6.1 of WCAP 16115P the value of this $\triangle$P increased from 0.17 to 0.19psi This value can be converted to units of % Span using the specific gravity of water, 0.0160454 ft^3 / lbm, and the transmitter calibrated span of 108 inches (Section 6.4.1) as follows:

$$\text{MDDPb} = \left(\frac{0.19\,\text{pounds}}{\text{in}^2}\right)\left(\frac{0.0160454\,\text{ft}^3}{\text{pound}}\right)\left(\frac{144\,\text{in}^2}{\text{ft}^2}\right)\left(\frac{12\,\text{in}}{\text{ft}}\right) = 5.27\ \text{inches}$$

$$\text{MDDPb} = 5.27\,\text{inches}\left(\frac{100\%\,\text{Span}}{108\,\text{inches}}\right) = 4.88\%\ \text{Span}$$

For normal (non transient operational conditions, the Mid Deck Plate pressure drop remains as follows:

$$\text{MDDPb} = \left(\frac{0.17\,\text{pounds}}{\text{in}^2}\right)\left(\frac{0.0160454\,\text{ft}^3}{\text{pound}}\right)\left(\frac{144\,\text{in}^2}{\text{ft}^2}\right)\left(\frac{12\,\text{in}}{\text{ft}}\right) = 4.71\ \text{inches}$$

$$\text{MDDPb} = 4.71\,\text{inches}\left(\frac{100\%\,\text{Span}}{108\,\text{inches}}\right) = 4.36\%\ \text{Span}$$

5.19 Technical information included in Reference 4.4.5 shows the recorder manufacturer does not specify a time dependent drift uncertainty for these digital devices. It is therefore assumed that such drift is negligible and is included within the Reference Accuracy (RA) and Temperature Effect (TE) specification.

5.20 The resolution for a 6 Vdc range digital recorder is 1 mVdc per Reference 4.4.5. For conservatism, a 4 volt range will be used since the input to the recorder is 1 to 5 Vdc.

5.21 Feedwater Ring/Feedwater Ring Supports

A combination of recirculation flow and feedwater flows downward past the feedwater ring and the feedwater ring supports. This results in a $\triangle$P across these components. In the Westinghouse Model 44F Steam Generator, the Feedwater Ring and Feedwater Ring Supports are between the Narrow Range Level Taps. As a result of this location the $\triangle$P sensed by the narrow range level instrumentation is impacted.

The value for this effect given by WCAP 16115P is 0.006 psi. The instrumentation is calibrated to inches of water. The instrumentation system measures the level as inches of water and provides an output in % level as a % of the level indication span. For the narrow range level indication the span is 108 inches. The pressure may be converted to inches of H_2O (at 500°F, 900 psia) as follows:

1 inch water = 49.03889 lb/ft^3 X (1/12 ft/in)^3 X 1 in H_2O = .02838 psi

$$\left(\frac{1''_{\mathrm{WATER}}}{0.02838_{\mathrm{PSI}}}\right)\left(0.006_{\mathrm{PSI}}\right) = 0.211_{\mathrm{INCHES\_WATER}}$$

SPAN = 108 INCHES

$$\text{FEED RING}_{\%\text{SPAN}} = \left(\frac{0.211}{108}\right)100 = 0.195\,\%\ \text{Span}$$

In the case of the High functions, WCAP 16115P recommends an additional error for operation at less than 100% power. Per table 5-1 in WCAP 16115P, the additional error for the feedring ΔP is 0.007 psi (total) for 44F with three primary separators (Tech Manual 728-208-63, sect. 1.1). Using the above methodology, this results in the following:

(1”/0.02838) * (0.007) = 0.247” water
FEED RING$_{<100\%\ \text{SPAN}}$ = 0.23% Span

Based on the dimensions provided in HBR2-10750, HBR2-10731, and HBR2-10736, the Feedwater Nozzle is located at 24% span. Since the PMA effects are a result of a submerged feedring, only those alarms and control functions that occur at a level ≥24% narrow range indicated span will be impacted. The following are the alarm and trip location in % span.

Low-Low Level Reactor Trip; 16% span
Low-Low Level Alarm: 35% span
Low Level Alarm: 35% span
High Level Alarm: 60% span (increasing level setpoint)
High Level Valve Interlock: 75% span (increasing level setpoint)

When the actual level in the Steam Generator is below the feedwater ring and feedwater ring supports this PME = 0. When above the feedwater ring and feedwater ring supports the indicated level will be less than actual level. Therefore, this term results in a negative bias which will only be applied to increasing level setpoints above the feedring elevation of 24%.

5.22 Per Reference 4.2.5 for Setpoint M.13, normal containment EOP setpoint values are used up to an assumed containment temperature of 190°F. This impacts the normal containment transmitter temperature effect as well as the PME values. This impacts only EOP setpoint calculations and should not be used for RPS/EFSAS setpoints.

5.23 Setpoint values in the EOPs are always rounded in the conservative direction to a readable value. Therefore, the inclusion of a readability error in the instrument uncertainty calculations for the indicators and recorder are not necessary for EOP setpoint applications.

5.24 Per Reference 4.4.1 in Section 9.5.1, the Westinghouse 3110554-000 I/V is a high precision 250 Ω resistor with an accuracy of +/− 0.01%. Therefore, the Current to Voltage module is taken to have a negligible impact on the overall uncertainty calculation. This is in accordance with the methodology described within Reference 4.6.1.

5.25 For the Cases evaluated in Section 6.0, the Specific Gravity was calculated according to Procedure EGR-NGGC-0153 "Engineering Instrument Setpoints" Section 9.3.1.(Reference 4.6.1), using the specific volume from the ASME Steam Tables (Reference 4.7.5) in the following equation:

Specific Gravity = specific volume of water @ 68°F / specific volume of fluid
Specific Gravity = 0.016046 / V_f or V_g

where V_f = specific volume of fluid
V_g = specific volume of steam

5.26 As part of the 24 month fuel cycle project this project, a drift analysis was performed on most of the Technical Specification related transmitters to provide new drift values based on historical numbers. A drift analysis was not required to be performed on the portions of the loop that are tested by a quarterly (92 days) Channel Operability Test (COT) that verifies the rack tolerances. Rather than unnecessarily increase the value of component drift to reflect the longer calibration time, this calculation will take credit for the performance of the COT, which includes adjustments, as necessary, for the tested setpoints. The value for drift over an 18 month period is still conservative, and will not be changed.

5.27 An effect of the Drift Studies performed per EC 97661 (Reference 4.7.22) is that in addition to the component drift (DR), the Analyzed Drift (AD) value includes several sources of uncertainty, including the Reference Accuracy (RA) and Measuring and Test Equipment error (MTE). The As-Found/As-Left technique does not and cannot separate these factors that combine into the AD. Therefore, where the AD exceeds the DR, the results of the drift study may replace the RA, MTE, and DR factors as a single value for determination of the Total Device Uncertainty (TDU) and As-Found Tolerance (AFT). Where the DR exceeds the AD, and if desired to reduce conservatism, the AD may replace the RA, MTE, and DR factors in determination of the TDU and the AFT values. This is in accordance with Reference 4.6.6, which recommends the performance of a drift analysis, but does not specifically call out combining these terms.

5.28 As part of the 24 month fuel cycle project, the nominal calibration interval is being extended to 24 months with a maximum of 30 months (24 months + 25%).

6.0 CALCULATION OF UNCERTAINTY CONTRIBUTORS

6.1 ACCIDENT EFFECTS (AE)

Per Reference 4.6.2, the indication / recording functions provided by each loop are required post accident, so accident effects are computed for the indication / recording functions.

Per UFSAR Chapter 15, the Low Low Steam Generator Level Reactor Trip is credited in the safety analysis. Per Reference 4.7.2, this trip serves to prevent the loss of the Steam Generator as a heat sink as the result of a loss of power to the station auxiliaries, loss of normal feedwater, and a feedwater line break. A feedwater line break inside containment will create a harsh Containment environment, but not a high radiation environment. Therefore, accident temperature effects are included in the total loop uncertainties for this trip function, but accident radiation effects are not. Per EC 59047 additional effects are evaluated as applicable to the accident condition; Mid Deck Plate ΔP, and Downcomer Subcooling.

The Low Low, and High Steam Generator Level alarms serve to warn the operator that Steam Generator Level is outside the normal control band and are not used for accident mitigation. Therefore, only normal uncertainties are computed for the alarm.

The High Steam Generator Level valve interlock serves to close the feedwater control valves before the Steam Generator is completely full and feedwater enters the main steam lines. This function serves to prevent turbine damage. Since the main steam lines are not designed to contain water, this function also serves to prevent a possible main steam line break accident. The valve interlock serves as an equipment protection function not a safety function. Therefore, accident effects are not included in the total loop uncertainties for the valve interlock. Seismic uncertainties are included in the total loop uncertainties for this function.

The uncertainty at the input to AMSAC is computed for normal environmental conditions only. AMSAC is a non-safety system that is not required to mitigate a design basis event. Its function is to terminate anticipated transients where a loss of the Steam Generator as a heat sink is possible, and a Reactor Trip is not generated by Reactor Protection System.

6.1.1 Accident Temperature Effect (ATE)

Per EDB, the transmitter in each loop is a Rosemount 3154ND2R2F1E7. Per Reference 4.4.3, the transmitter Accident Temperature Effect (ATE_{xmtr}) is given as ± 1% Upper Range Limit plus 1% Span. The Upper Range Limit (URL) of a range code 2 transmitter is 250 inwc. Per Section 9.1, the span of each transmitter is 108 inwc. Therefore, the ATE_{xmtr} associated with each transmitter is computed as follows:

$ATE_{xmtr} = \pm \{(1.0\%)\left(\frac{250\ inwc}{108\ inwc}\right) + 1.0\%\ Span\}$

$ATE_{xmtr} = \pm$ 3.32% Span

6.1.2 Accident Pressure Effect (APE)

The transmitter in each loop is a differential pressure transmitter. Therefore, there are no Accident Pressure Effects.

6.1.3 Accident Radiation Effect (ARE)

Per EDB, the transmitter in each loop is a Rosemount 3154ND2R2F1E7. Per Reference 4.4.3, the transmitter Accident Radiation Effect (ARE_{xmtr}) is given as ± 0.3% Upper Range Limit plus 1.00% Span. The Upper Range limit (URL) of a range code 2 transmitter is 250 inwc. Per Section 9.1, the span of each transmitter is 108 inwc. Therefore, the ARE_{xmtr} associated with each transmitter is computed as follows:

$ARE_{xmtr} = \pm\{(0.3\%)\left(\frac{250\ inwc}{108\ inwc}\right) + 1.0\%\ Span\}$

$ARE_{xmtr} = \pm$ 1.69% Span

6.2 SEISMIC EFFECT (SE)

Per EDB, the transmitter in each loop is a Rosemount 3154ND2R2F1E7. Per Reference 4.4.3, the seismic effect associated with the transmitter is ± 0.50% Upper Range Limit (URL), and the URL of a range code 2 transmitter is 250 inwc. Per Section 9.1 of this calculation, the calibrated span of each loop is 108 inwc. Therefore,

$SE_{xmtr} = \pm\ 0.50\%\ URL\ (\frac{250\ inwc}{108\ inwc}) = \pm$ 1.16% Span

The SE is bounded by the ATE computed in Section 6.1.1. Therefore, the SE is not included in the uncertainty analysis for the indication, recording, alarm functions, or Low Low Steam Generator Level Trip function. Since the Low Steam Generator Reactor Trip and the High Level Valve Interlock do not include accident effects, the seismic effect is included in the uncertainties for this function.

6.3 INSULATION RESISTANCE ERROR (IR)

Per RNP-I/EQ-1175, the Insulation Resistance (IR) effect associated with the loop signal cabling inside Containment is a worst case bias of +2.2072% Span for LT-474. Therefore,

IR = +2.21% Span

6.4 PROCESS MEASUREMENT ERROR (PME)

6.4.1 Process Measurement Error - Normal Environment

Density Effects

Per EGR-NGGC-0153 (Reference 4.6.1), the following equation is used to compute the process measurement effects which result from changes in reference leg fill fluid density variations and process density variations from those assumed for scaling:

$$\text{PME(inwc)} = h\,SG_{WN} + (H - h)SG_{SN} - H\,SG_{RN} - \Delta P_C$$

where,

- h = height of fluid (inches)
- H = height of measured level span = 143.5 inches (Section 9.1)
- SG_{WN} = specific gravity of fluid during operation
- SG_{SN} = specific gravity of steam during operation
- SG_{RN} = specific gravity of reference leg fill fluid during operation
- ΔP_C = differential pressure associated with a particular level measurement at conditions assumed for scaling.
- ΔP Span = 108 inwc (Section 9.1)

Therefore,

$$\text{PME(\% Span)} = \left(\frac{\text{PME(inwc)}}{\Delta\text{P Span}}\right) 100\%\,\text{Span}$$

Per Section 9.1, the following conditions are assumed for loop scaling:

SG_{WC} = 0.787341 @ 900 psia, 500°F
SG_{SC} = 0.032034 @ 900 psia, saturated
SG_{RC} = 0.992946 @ 900 psia, 120°F, compressed

The differential pressure associated with a particular level measurement is computed with the following equation:

$$\Delta P_C = h\,SG_{WC} + (H-h)\,SG_{SC} - H\,SG_{RC}$$

Differential pressures are computed for the specific points of interest across the level span:

Fluid Height (% Span)	**Fluid Height (in)**	**Calibrated ΔP_C (inwc)**
0.00%	0.00	-138
16.00%	22.96	-121
30.00%	43.05	-105
50.00%	71.75	-84
75.00%	107.63	-57
100.00%	143.50	-30

The process measurement effect accounts for variations in process pressure and reference leg temperature. The following process conditions are obtained from Design Inputs 5.4 and 5.12.

Normal Conditions

800 psia to 1020 psia (Steam Generator pressure)
88°F to 140°F (Reference leg temperature)

A total of four possible conditions are considered for normal operation:

Case I	Reference Leg = 88°F, 1020 psia Process Pressure = 1020 psia, saturated
Case II	Reference Leg = 140°F, 1020 psia Process Pressure = 1020 psia, saturated
Case III	Reference Leg = 88°F, 800 psia Process Pressure = 800 psia, saturated
Case IV	Reference Leg = 140°F, 800 psia Process Pressure = 800 psia, saturated

Case I

SG_{RN} = 1.000125 @ 88°F, 1020 psia
SG_{SN} = 0.036786 @ 1020 psia saturated
SG_{WN} = 0.740813 @ 1020 psia saturated

The following equations are used to compute the values in the table below:

$$\text{Actual}\,\Delta P_N(\text{inwc}) = h\,SG_{WN} + (H - h)SG_{SN} - H\,SG_{RN}$$
$$\text{norPME}(\text{inwc}) = \text{Actual}\,\Delta P_N(\text{inwc}) - \text{Calibrated}\,\Delta P_C(\text{inwc})$$
$$\text{norPME}(\%\,\text{Span}) = \left(\frac{\text{norPME}(\text{inwc})}{\Delta P\,\text{Span}}\right)100\%\,\text{Span}$$

where,

ΔP Span = 108 inwc (Section 9.1)
Calibrated ΔP_C is computed above.
H = 143.5 inches (Section 9.1)

Fluid Height (% Span)	Fluid Height (in)	Actual ΔP_N (inwc)	Calibrated ΔP_C (inwc)	norPME (inwc)	norPME (% Span)
0.00%	0	-138.24	-138	-0.24	-0.22%
16.00%	22.96	-122.07	-121	-1.07	-1.00%
30.00%	43.05	-107.93	-105	-2.93	-2.71%
50.00%	71.75	-87.73	-84	-3.73	-3.45%
75.00%	107.63	-62.47	-57	-5.47	-5.06%
100.00%	143.50	-37.21	-30	-7.21	-6.68%

<u>Case II</u>

SG_{RN} = 0.988054 @ 140°F, 1020 psia
SG_{SN} = 0.036786 @ 1020 psia saturated
SG_{WN} = 0.740813 @ 1020 psia saturated

The following equations are used to compute the values in the table below:

$$\text{Actual}\,\Delta P_N(\text{inwc}) = h\,SG_{WN} + (H-h)SG_{SN} - H\,SG_{RN}$$
$$\text{norPME}(\text{inwc}) = \text{Actual}\,\Delta P_N(\text{inwc}) - \text{Calibrated}\,\Delta P_C(\text{inwc})$$
$$\text{norPME}(\%\,\text{Span}) = \left(\frac{\text{norPME}(\text{inwc})}{\Delta P\,\text{Span}}\right)100\%\,\text{Span}$$

where,

ΔP Span = 108 inwc (Section 9.1)
Calibrated ΔP_C is computed above.
H = 143.5 inches (Section 9.1)

Fluid Height (% Span)	Fluid Height (in)	Actual ΔP_N (inwc)	Calibrated ΔP_C (inwc)	norPME (inwc)	norPME (% Span)
0.00%	0.00	-136.51	-138	1.493	1.38%
16.00%	22.96	-120.34	-121	0.658	0.61%
30.00%	43.05	-106.20	-105	-1.199	-1.11%
50.00%	71.75	-85.99	-84	-1.993	-1.85%
75.00%	107.63	-60.74	-57	-3.736	-3.46%
100.00%	143.50	-35.48	-30	-5.479	-5.07%

<u>Case III</u>

SG_{RN} = 0.999502 @ 88°F, 800 psia
SG_{SN} = 0.028202 @ 800 psia saturated
SG_{WN} = 0.768855 @ 800 psia saturated

The following equations are used to compute the values in the table below:

$$\text{Actual } \Delta P_N(\text{inwc}) = h\,SG_{WN} + (H-h)SG_{SN} - H\,SG_{RN}$$
$$\text{norPME}(\text{inwc}) = \text{Actual } \Delta P_N(\text{inwc}) - \text{Calibrated } \Delta P_C(\text{inwc})$$
$$\text{norPME}(\%\,\text{Span}) = \left(\frac{\text{norPME}(\text{inwc})}{\Delta P\ \text{Span}}\right)100\%\,\text{Span}$$

where,

ΔP Span = 108 inwc (Section 9.1)
Calibrated ΔP_C is computed above.
H = 143.5 inches (Section 9.1)

Fluid Height (% Span)	Fluid Height (in)	Actual ΔP_N (inwc)	Calibrated ΔP_C (inwc)	norPME (inwc)	norPME (% Span)
0.00%	0.00	-139.38	-138	-1.38	-1.28%
16.00%	22.96	-122.38	-121	-1.38	-1.27%
30.00%	43.05	-107.50	-105	-2.50	-2.31%
50.00%	71.75	-86.24	-84	-2.24	-2.07%
75.00%	107.63	-59.67	-57	-2.67	-2.47%
100.00%	143.50	-33.10	-30	-3.10	-2.87%

Case IV

SG_{RN} = 0.987446 @ 140°F, 800 psia
SG_{SN} = 0.028202 @ 800 psia saturated
SG_{WN} = 0.768855 @ 800 psia saturated

The following equations are used to compute the values in the table below:

$$\text{Actual}\,\Delta P_N(\text{inwc}) = h\,SG_{WN} + (H - h)SG_{SN} - H\,SG_{RN}$$
$$\text{norPME}(\text{inwc}) = \text{Actual}\,\Delta P_N(\text{inwc}) - \text{Calibrated}\,\Delta P_C(\text{inwc})$$
$$\text{norPME}(\%\,\text{Span}) = \left(\frac{\text{norPME}(\text{inwc})}{\Delta P\,\text{Span}}\right)100\%\,\text{Span}$$

where,

ΔP Span = 108 inwc (Section 9.1)
Calibrated ΔP_C is computed above.
H = 143.5 inches (Section 9.1)

Fluid Height (% Span)	Fluid Height (in)	Actual ΔP_N (inwc)	Calibrated ΔP_C (inwc)	norPME (inwc)	norPME (% Span)
0.00%	0.00	-137.65	-138	0.35	0.32%
16.00%	22.96	-120.65	-121	0.35	0.33%
30.00%	43.05	-105.77	-105	-0.77	-0.71%
50.00%	71.75	-84.51	-84	-0.51	-0.47%
75.00%	107.63	-57.94	-57	-0.94	-0.87%
100.00%	143.50	-31.37	-30	-1.37	-1.27%

The following table presents the maximum positive and negative process measurement effects computed above for Cases I through IV.

Fluid Height (% Span)	Fluid Height (in)	Positive norPME (% Span)	Negative norPME (% Span)
0.00%	0.00	1.38%	-1.28%
16.00%	22.96	0.61%	-1.27%
30.00%	43.05	N/A	-2.71%
50.00%	71.75	N/A	-3.45%
75.00%	107.63	N/A	-5.06%
100.00%	143.50	N/A	-6.68%

<u>Fluid Velocity Effects</u>

Per Reference 4.7.9, the Steam Generators are model 44F. Per Reference 4.7.10, the fluid flow past the lower tap decreases the differential pressure across the transmitter. Reference 4.7.13 states that this bias uncertainty is bounded by –7.10% Span. Therefore, the following Fluid Velocity Effect (FVE) bias is introduced into the level measurement:

FVE = –7.10% Span

<u>Downcomer Subcooling Effects (Normal Conditions)</u>

Per Reference 4.7.9, the Steam Generators are model 44F. Per EC 59047, the subcooling of the fluid in the downcomer region in conjunction with a saturated mixture around the U-tubes introduces an additional bias into the level measurement. Therefore, the following Downcomer Subcooling Effect (DSE) bias is introduced into the level measurement:

DSE = 0.45% Span

This PME is only applicable for steam generator levels below a level where downcomer subcooling can occur. Water draining from the moisture seperators will be at saturation. Only water below the feedring can realistically be at a subcooled temperature. Since the feedring is located at 24% level, only the Steam Generator Low Low Trip (16%) is affected.

<u>Feedwater Ring)P (FRE) from section 5.21</u>

FRE = –0.23%

This error is only applicable above the level of the feed ring (~24%) for increasing level setpoints.

Steam Carryunder in the Downcomer

Per WCAP 16115P, Table 3.3.3-1, the calculated value of the effect caused by Steam Carryunder in the Downcomer region of the Steam Generator is small enough to be considered negligible. Therefore

$$U_{CARRYUNDER} = 0\% \text{ Span}$$

This effect deals with non-recoverable fluid pressure losses due to Steam Carryunder. This effect should not be confused with Downcomer Subcooling fluid temperature effects discussed above.

Summary

The following table presents the total positive and negative process measurement effects with the FVE, DSE, and FRE biases added as appropriate:

Normal PME

Fluid Height (% Span)	Fluid Height (in)	Positive norPME (% Span)	Negative norPME (% Span)
0.00%	0.00	1.83	-8.38
16.00%	22.96	1.06	-8.37
30.00%	43.05	NA	-9.81
50.00%	71.75	NA	-10.55
75.00%	107.63	NA	-12.39
100.00%	143.50	NA	-14.01

6.4.2 Process Measurement Error - Accident Environment

Density Effects

Per EGR-NGGC-0153 (Reference 4.6.1), the following equation is used to compute the process measurement effects which result from changes in reference leg fill fluid density variations and process density variations from those assumed for scaling:

$$\text{PME(inwc)} = \text{h}\,\text{SG}_{\text{WN}} + (\text{H} - \text{h})\text{SG}_{\text{SN}} - \text{H}\,\text{SG}_{\text{RN}} - \Delta\text{P}_{\text{C}}$$

where,

h = height of fluid (inches)
H = height of measured level span = 143.5 inches (Section 9.1)
SG_{WN} = specific gravity of fluid during operation
SG_{SN} = specific gravity of steam during operation
SG_{RN} = specific gravity of reference leg fill fluid during operation
ΔP_C = differential pressure associated with a particular level measurement at conditions assumed for scaling.
ΔP Span = 108 inwc (Section 9.1)

Therefore,

$$\text{PME(\% Span)} = \left(\frac{\text{PME(inwc)}}{\Delta\text{P Span}}\right) 100\%\,\text{Span}$$

Per Section 9.1, the following conditions are assumed for loop scaling:

SG_{WC} = 0.787341 @ 900 psia, 500°F
SG_{SC} = 0.032034 @ 900 psia, saturated
SG_{RC} = 0.992946 @ 900 psia, 120°F, compressed

The differential pressure associated with a particular level measurement is computed with the following equation:

$$\Delta P_C = h\,SG_{WC} + (H - h)SG_{SC} - H\,SG_{RC}$$

Differential pressures are computed for the specific points of interest across the level span:

Fluid Height (% Span)	Fluid Height (in)	Calibrated ΔP_C (inwc)
0.00%	0.00	-138
16.00%	22.96	-121
30.00%	43.05	-105
50.00%	71.75	-84
75.00%	107.63	-57
100.00%	143.50	-30

The process measurement effect accounts for variations in process pressure and reference leg temperature. The following process conditions are obtained from Design Inputs 5.2 and 5.10.

<u>Accident Conditions</u>

15 psia to 1100 psia (Steam Generator pressure)
88°F to 340°F (Reference leg temperature)

A total of four possible conditions are considered for accident operation:

Case I	Reference Leg = 88°F, 15 psia Process Pressure = 15 psia, saturated
Case II	Reference Leg = 15 psia, saturated Process Pressure = 15 psia, saturated
Case III	Reference Leg = 88°F, 1100 psia Process Pressure = 1100 psia, saturated
Case IV	Reference Leg = 340°F, 1100 psia Process Pressure = 1100 psia, saturated

Case I

SG_{RA} = 0.997018 @ 88°F, 15 psia
SG_{SA} = 0.000610 @ 15 psia saturated
SG_{WA} = 0.959345 @ 15 psia saturated

The following equations are used to compute the values in the table below:

$$\text{Actual}\,\Delta P_A(\text{inwc}) = h\,SG_{WA} + (H - h)SG_{SA} - H\,SG_{RA}$$
$$\text{accPME}(\text{inwc}) = \text{Actual}\,\Delta P_A(\text{inwc}) - \text{Calibrated}\,\Delta P_C(\text{inwc})$$
$$\text{accPME}(\%\,\text{Span}) = \left(\frac{\text{accPME}(\text{inwc})}{\Delta P\,\text{Span}}\right)100\%\,\text{Span}$$

where,

ΔP Span = 108 inwc (Section 9.1)
Calibrated ΔP_C is computed above.
H = 143.5 inches (Section 9.1)

Fluid Height (% Span)	Fluid Height (in)	Actual ΔP_A (inwc)	Calibrated ΔP_C (inwc)	accPME (inwc)	accPME (% Span)
0.00%	0.00	-142.98	-138	-4.98	-4.62%
16.00%	22.96	-120.97	-121	0.03	0.03%
30.00%	43.05	-101.71	-105	3.29	3.05%
50.00%	71.75	-74.20	-84	9.80	9.08%
75.00%	107.63	-39.80	-57	17.20	15.93%
100.00%	143.50	-5.41	-30	24.59	22.77%

Case II

SG_{RA} = 0.959345 @ 15 psia, saturated
SG_{SA} = 0.000610 @ 15 psia saturated
SG_{WA} = 0.959345 @ 15 psia saturated

The following equations are used to compute the values in the table below:

$$\text{Actual}\,\Delta P_A(\text{inwc}) = h\,SG_{WA} + (H - h)SG_{SA} - H\,SG_{RA}$$
$$\text{accPME}(\text{inwc}) = \text{Actual}\,\Delta P_A(\text{inwc}) - \text{Calibrated}\,\Delta P_C(\text{inwc})$$
$$\text{accPME}(\%\,\text{Span}) = \left(\frac{\text{accPME}(\text{inwc})}{\Delta P\ \text{Span}}\right)100\%\,\text{Span}$$

where,

ΔP Span = 108 inwc (Section 9.1)
Calibrated ΔP_C is computed above.
H = 143.5 inches (Section 9.1)

Fluid Height (% Span)	Fluid Height (in)	Actual ΔP_A (inwc)	Calibrated ΔP_C (inwc)	accPME (inwc)	accPME (% Span)
0.00%	0.00	-137.58	-138	0.42	0.39%
16.00%	22.96	-115.57	-121	5.43	5.03%
30.00%	43.05	-96.30	-105	8.70	8.05%
50.00%	71.75	-68.79	-84	15.21	14.08%
75.00%	107.63	-34.39	-57	22.61	20.93%
100.00%	143.50	0.00	-30	30.00	27.78%

<u>Case III</u>

SG_{RA} = 1.000125 @ 88°F, 1100 psia
SG_{SA} = 0.040057 @ 1100 psia saturated
SG_{WA} = 0.731025 @ 1100 psia saturated

The following equations are used to compute the values in the table below:

$$\text{Actual } \Delta P_A(\text{inwc}) = h\, SG_{WA} + (H - h) SG_{SA} \text{ - } H\, SG_{RA}$$
$$\text{accPME}(\text{inwc}) = \text{Actual } \Delta P_A(\text{inwc}) - \text{Calibrated } \Delta P_C(\text{inwc})$$
$$\text{accPME}(\%\,\text{Span}) = \left(\frac{\text{accPME}(\text{inwc})}{\Delta P\ \text{Span}}\right) 100\%\,\text{Span}$$

where,

ΔP Span = 108 inwc (Section 9.1)
Calibrated ΔP_C is computed above.
H = 143.5 inches (Section 9.1)

Fluid Height (% Span)	Fluid Height (in)	Actual ΔP_A (inwc)	Calibrated ΔP_C (inwc)	accPME (inwc)	accPME (% Span)
0.00%	0.00	-137.77	-138	0.23	0.21%
16.00%	22.96	-121.91	-121	-0.91	-0.84%
30.00%	43.05	-108.02	-105	-3.02	-2.80%
50.00%	71.75	-88.19	-84	-4.19	-3.88%
75.00%	107.63	-63.40	-57	-6.40	-5.93%
100.00%	143.50	-38.62	-30	-8.62	-7.98%

<u>Case IV</u>

SG_{RA} = 0.901967 @ 340°F, 1100 psia
SG_{SA} = 0.040057 @ 1100 psia saturated
SG_{WA} = 0.731025 @ 1100 psia saturated

The following equations are used to compute the values in the table below:

$$\text{Actual}\,\Delta P_A(\text{inwc}) = h\,SG_{WA} + (H-h)SG_{SA} - H\,SG_{RA}$$
$$\text{accPME}(\text{inwc}) = \text{Actual}\,\Delta P_A(\text{inwc}) - \text{Calibrated}\,\Delta P_C(\text{inwc})$$
$$\text{accPME}(\%\,\text{Span}) = \left(\frac{\text{accPME}(\text{inwc})}{\Delta P\,\text{Span}}\right)100\%\,\text{Span}$$

where,

ΔP Span = 108 inwc (Section 9.1)
Calibrated ΔP_C is computed above.
H = 143.5 inches (Section 9.1)

Fluid Height (% span)	Fluid Height h (in)	Actual ΔP_A (inwc)	Calibrated ΔP_C (inwc)	accPME (inwc)	accPME (% span)
0.00%	0.00	-123.68	-138	14.32	13.26
16.00%	22.96	-107.82	-121	13.18	12.20
30.00%	43.05	-93.94	-105	11.06	10.24
50.00%	71.75	-74.11	-84	9.89	9.16
75.00%	107.63	-49.32	-57	7.68	7.11
100.00%	143.50	-24.53	-30	5.47	5.06

The following table presents the maximum positive and negative process measurement effects computed above for Cases I through IV.

Fluid Height (% span)	Fluid Height h (in)	Positive accPME (% span)	CASE #	Negative accPME (% span)	CASE #
0.00%	0	13.26%	IV	-4.62%	I
16.00%	22.96	12.20%	IV	-0.84%	III
30.00%	43.05	10.24%	IV	-2.80%	III
50.00%	71.75	14.08%	II	-3.88%	III
75.00%	107.63	20.93%	II	-5.93%	III
100.00%	143.50	27.78%	II	-7.98%	III

Specific Conditions during a Feedwater Break Accident

In order to maintain adequate margin of the Low Low Trip Setpoint, the specific conditions of a feed water line break need to be addressed. Per WCAP-16115P, the maximum temperature that the reference legs will see is 225°F. Using the above methodology and the following values:

SG_{RA} = 0.958283 @ 225°F, 1020 psia
SG_{SA} = 0.036795 @ 1020 psia saturated
SG_{WA} = 0.740776 @ 1020 psia saturated

Then, the accPME at 0% level (condition of interest) is:

Fluid Height (% Span)	Fluid Height (in)	Actual ΔPa (inwc)	Calibrated ΔPc (inwc)	accPME (inwc)	accPME (% Span)
0.00	0	-132.23	-138	5.77	5.34

See EC 59047 for additional discussion.

Fluid Velocity Effects

Per Reference 4.7.9, the Steam Generators are model 44F. Per Reference 4.7.10, the fluid flow past the lower tap decreases the differential pressure across the transmitter. Reference 4.7.13 states that for HBR2, this fluid velocity effect is bounded by –7.10% Span. Therefore, the following Fluid Velocity Effect (FVE) bias is introduced into the level measurement:

FVE = -7.10% Span

Downcomer Subcooling Effects (Accident conditions)

Per Reference 4.7.9, the Steam Generators are model 44F. Per EC 59047, the subcooling of the fluid in the downcomer region in conjunction with a saturated mixture around the U-tubes introduces an additional bias into the level measurement. Therefore, the following Downcomer Subcooling Effect (DSE) bias is introduced into the level measurement. Downcomer Subcooling is unchanged under accident condition so:

DSE = 0.45% Span

Feedwater Ring ΔP (FRE) from section 5.21

Feedring Bias is unchanged for accident conditions, From section 5.21

FRE = -0.23% Span

Summary

The following table presents the total positive and negative process measurement effects with the FVE, FRE, and DSE biases added. Note that the Feedring bias only applies for levels greater than the feedring level of 24%, and that the DSE only applies for levels below the feedring level of 24%.

Fluid Height (% span)	Fluid Height h (in)	Positive accPME (% span)	Negative accPME (% span)
0.00%	0	13.71%	-11.72%
16.00%	22.96	12.65%	-7.94%
30.00%	43.05	10.24%	-10.13%
50.00%	71.75	14.08%	-11.21%
75.00%	107.63	20.93%	-13.26%
100.00%	143.50	27.78%	-15.31%

Accident PME

For a feed water line break, the Positive accPME at the % level of interest reduces to :

Fluid Height (% Span)	**Fluid Height (in)**	**Positive accPME (% Span)**	**Negative accPME (% Span)**

0.00%	0.00	5.79%	-11.72%

6.4.3 Process Measurement Error - Normal Environment for EOP Use

As discussed in Design Input 5.22, normal containment setpoint values are used in EOPs up to a containment temperature of 190°F. Therefore, the PME temperature effects are slightly different than the effect calculated in Section 6.4.1. In addition, the SG pressure may range from atmospheric pressure (15 psia) to the lowest SG safety valve setting (1085 psig) per Design Input 5.10.

Density Effects

Per EGR-NGGC-0153 (Reference 4.6.1), the following equation is used to compute the process measurement effects which result from changes in reference leg fill fluid density variations and process density variations from those assumed for scaling:

$$\text{PME(inwc)} = h\,SG_{WN} + (H - h)SG_{SN} - H\,SG_{RN} - \Delta P_C$$

where,

h = height of fluid (inches)
H = height of measured level span = 143.5 inches (Section 9.1)
SG_{WN} = specific gravity of fluid during operation
SG_{SN} = specific gravity of steam during operation
SG_{RN} = specific gravity of reference leg fill fluid during operation
ΔP_C = differential pressure associated with a particular level measurement at conditions assumed for scaling.
ΔP Span = 108 inwc (Section 9.1)

Therefore,

$$\text{PME(\% Span)} = \left(\frac{\text{PME(inwc)}}{\Delta\text{P Span}}\right)100\%\ \text{Span}$$

Per Section 9.1, the following conditions are assumed for loop scaling:

SG_{WC} = 0.787341 @ 900 psia, 500°F
SG_{SC} = 0.032034 @ 900 psia, saturated
SG_{RC} = 0.992946 @ 900 psia, 120°F, compressed

The differential pressure associated with a particular level measurement is computed with the following equation:

$$\Delta P_C = h\,SG_{WC} + (H - h)SG_{SC} - H\,SG_{RC}$$

Differential pressures are computed for the specific points of interest across the level span:

Fluid Height (% Span)	**Fluid Height (in)**	**Calibrated ΔP_C (inwc)**
0.00%	0.00	-138
16.00%	22.96	-121
30.00%	43.05	-105
50.00%	71.75	-84
75.00%	107.63	-57
100.00%	143.50	-30

The process measurement effect accounts for variations in process pressure and reference leg temperature. The following process conditions are obtained from Design Inputs 5.4 and 5.12.

<u>Normal Conditions</u>

15 psia to 1100 psia (Steam Generator pressure)
88°F to 190°F (Reference leg temperature)

A total of four possible conditions are considered for normal containment conditions in the EOP. Note the case numbers are consistent with section 6.4.1 with an "e" appended. The difference between the cases in Section 6.4.1 and here are the SG pressure assumed for each and the reference leg temperature assumed in cases IIIe and IVe.

Case Ie	Reference Leg = 88°F, 1100 psia Process Pressure = 1100 psia, saturated
Case IIe	Reference Leg = 190°F, 1100 psia Process Pressure = 1100 psia, saturated
Case IIIe	Reference Leg = 88°F, 15 psia Process Pressure = 15 psia, saturated
Case IVe	Reference Leg = 190°F, 15 psia Process Pressure = 15 psia, saturated

Case Ie

SG_{RA} = 1.000125 @ 88°F, 1100 psia
SG_{SA} = 0.040057 @ 1100 psia saturated
SG_{WA} = 0.731025 @ 1100 psia saturated

The following equations are used to compute the values in the table below:

$$\text{Actual}\,\Delta P_N(\text{inwc}) = h\,SG_{WN} + (H-h)SG_{SN} - H\,SG_{RN}$$
$$\text{norPME}(\text{inwc}) = \text{Actual}\,\Delta P_N(\text{inwc}) - \text{Calibrated}\,\Delta P_C(\text{inwc})$$
$$\text{norPME}(\%\,\text{Span}) = \left(\frac{\text{norPME}(\text{inwc})}{\Delta P\ \text{Span}}\right)100\%\,\text{Span}$$

where,

ΔP Span = 108 inwc (Section 9.1)
Calibrated ΔP_C is computed above.
H = 143.5 inches (Section 9.1)

Fluid Height (% span)	Fluid Height (in)	Actual dP (inwc)	Calibrated dP (inwc)	Calculated eopPME (inwc)	Calculated eopPME (% span)
0.00%	0.00	-137.77	-137.89	0.12	0.11%
16.00%	22.96	-121.91	-120.55	-1.36	-1.26%
30.00%	43.05	-108.02	-105.37	-2.65	-2.45%
50.00%	71.75	-88.19	-83.70	-4.49	-4.17%
75.00%	107.63	-63.40	-56.60	-6.80	-6.30%
100.00%	143.50	-38.62	-29.50	-9.12	-8.44%

Case IIe

SG_{RN} = 0.971896 @ 190°F, 1100 psia
SG_{SN} = 0.040057 @ 1100 psia saturated
SG_{WN} = 0.731025 @ 1100 psia saturated

The following equations are used to compute the values in the table below:

$$\text{Actual } \Delta P_N(\text{inwc}) = h\,SG_{WN} + (H - h)SG_{SN} - H\,SG_{RN}$$
$$\text{norPME}(\text{inwc}) = \text{Actual } \Delta P_N(\text{inwc}) - \text{Calibrated } \Delta P_C(\text{inwc})$$
$$\text{norPME}(\%\,\text{Span}) = \left(\frac{\text{norPME}(\text{inwc})}{\Delta P\ \text{Span}}\right)100\%\,\text{Span}$$

where,

ΔP Span = 108 inwc (Section 9.1)
Calibrated ΔP_C is computed above.
H = 143.5 inches (Section 9.1)

Fluid Height (% span)	Fluid Height (in)	Actual dP (inwc)	Calibrated dP (inwc)	Calculated eopPME (inwc)	Calculated eopPME (% span)
0.00%	0.00	-133.75	-137.89	4.15	3.84%
16.00%	22.96	-117.88	-120.55	2.67	2.47%
30.00%	43.05	-104.00	-105.37	1.38	1.27%
50.00%	71.75	-84.17	-83.70	-0.47	-0.44%
75.00%	107.63	-59.38	-56.60	-2.78	-2.57%
100.00%	143.50	-34.59	-29.50	-5.09	-4.71%

<u>Case IIIe</u>

SG_{RA} = 0.997018 @ 88°F, 15 psia
SG_{SA} = 0.000610 @ 15 psia saturated
SG_{WA} = 0.959345 @ 15 psia saturated

The following equations are used to compute the values in the table below:

$$\text{Actual } \Delta P_A(\text{inwc}) = h\,SG_{WA} + (H - h)SG_{SA} - H\,SG_{RA}$$
$$\text{accPME}(\text{inwc}) = \text{Actual } \Delta P_A(\text{inwc}) - \text{Calibrated } \Delta P_C(\text{inwc})$$
$$\text{accPME}(\%\ \text{Span}) = \left(\frac{\text{accPME}(\text{inwc})}{\Delta P\ \text{Span}}\right) 100\%\ \text{Span}$$

where,

ΔP Span = 108 inwc (Section 9.1)
Calibrated ΔP_C is computed above.
H = 143.5 inches (Section 9.1)

Fluid Height (% span)	Fluid Height (in)	Actual dP (inwc)	Calibrated dP (inwc)	Calculated eopPME (inwc)	Calculated eopPME (% span)
0.00%	0.00	-142.98	-137.89	-5.09	-4.71%
16.00%	22.96	-120.97	-120.55	-0.42	-0.39%
30.00%	43.05	-101.71	-105.37	3.66	3.39%
50.00%	71.75	-74.20	-83.70	9.50	8.80%
75.00%	107.63	-39.80	-56.60	16.80	15.56%
100.00%	143.50	-5.41	-29.50	24.09	22.31%

Case IVe

SG_{RN} = 0.968377 @ 190°F, 15 psia
SG_{SN} = 0.000610 @ 15 psia saturated
SG_{WN} = 0.959345 @ 15 psia saturated

The following equations are used to compute the values in the table below:

$$\text{Actual } \Delta P_N(\text{inwc}) = h\, SG_{WN} + (H - h) SG_{SN} - H\, SG_{RN}$$
$$\text{norPME}(\text{inwc}) = \text{Actual } \Delta P_N(\text{inwc}) - \text{Calibrated } \Delta P_C(\text{inwc})$$
$$\text{norPME}(\%\text{ Span}) = \left(\frac{\text{norPME}(\text{inwc})}{\Delta P \text{ Span}}\right) 100\% \text{ Span}$$

where,

ΔP Span = 108 inwc (Section 9.1)
Calibrated ΔP_C is computed above.
H = 143.5 inches (Section 9.1)

Fluid Height (% span)	Fluid Height (in)	Actual dP (inwc)	Calibrated dP (inwc)	Calculated eopPME (inwc)	Calculated eopPME (% span)
0.00%	0.00	-138.87	-137.89	-0.98	-0.91
16.00%	22.96	-116.86	-120.55	3.69	3.41
30.00%	43.05	-97.60	-105.37	7.77	7.20
50.00%	71.75	-70.09	-83.70	13.61	12.60
75.00%	107.63	-35.69	-56.60	20.91	19.36
100.00%	143.50	-1.30	-29.50	28.21	26.12

The following table presents the maximum positive and negative process measurement effects computed above for Cases I through IV.

Fluid Height (% span)	Fluid Height (in)	Positive eopPME (% span)	Negative eopPME (% span)
0.00%	0.00	3.84%	-4.71%
16.00%	22.96	3.41%	-1.26%
30.00%	43.05	7.20%	-2.45%
50.00%	71.75	12.60%	-4.16%
75.00%	107.63	19.36%	-6.30%
100.00%	143.50	26.12%	-8.44%

6.4.4 Process Measurement Error - Accident Environment for EOPs

Section 6.4.2 determined the accPME assuming maximum and minimum Containment temperatures of 340°F and 88°F respectively. For EOP applications the maximum and minimum Containment temperatures should be 280°F and 88°F respectively. See Section 5.2.

Only Case IV in Section 6.4.2 uses the maximum containment temperature. Thus Cases I, II, and III in Section 6.4.2 apply for EOP use. To avoid confusion with the cases presented in Section 6.4.2, the EOP Case IV will include an "e" after the case number.

Case IVe

SG_{RA} = 0.933450 @ 280°F, 1100 psia
SG_{SA} = 0.040057 @ 1100 psia saturated
SG_{WA} = 0.731025 @ 1100 psia saturated

The following equations are used to compute the values in the table below:

$$\text{Actual}\,\Delta P_A(\text{inwc}) = h\,SG_{WA} + (H-h)SG_{SA} - H\,SG_{RA}$$
$$\text{accPME}(\text{inwc}) = \text{Actual}\,\Delta P_A(\text{inwc}) - \text{Calibrated}\,\Delta P_C(\text{inwc})$$
$$\text{acceopPME}(\%\,\text{Span}) = \left(\frac{\text{acceopPME}(\text{inwc})}{\Delta P\ \text{Span}}\right)100\%\,\text{Span}$$

where,

ΔP Span = 108 inwc (Section 9.1)
Calibrated ΔP_C is computed above.
H = 143.5 inches (Section 9.1)

Fluid Height (% span)	Fluid Height h (in)	Actual ΔP_A (inwc)	Calibrated ΔP_C (inwc)	acceopPME (inwc)	acceopPME (% span)
0.00%	0.00	-128.20	-138	9.80	9.07
16.00%	22.96	-112.34	-121	8.66	8.02
30.00%	43.05	-98.46	-105	6.54	6.06
50.00%	71.75	-78.62	-84	5.38	4.98
75.00%	107.63	-53.84	-57	3.16	2.93
100.00%	143.50	-29.05	-30	0.95	0.88

The following table presents the maximum positive and negative process measurement effects computed above for Cases I through III in Section 6.4.2 and Case IVe in Section 6.4.4.

Fluid Height (% span)	Fluid Height h (in)	Positive acceopPME (% span)	CASE #	Negative acceopPME (% span)	CASE #
0.00%	0	9.07%	IVe	-4.62%	I
16.00%	22.96	8.02%	IVe	-0.84%	III
30.00%	43.05	8.05%	II	-2.80%	III
50.00%	71.75	14.08%	II	-3.88%	III
75.00%	107.63	20.93%	II	-5.93%	III
100.00%	143.50	27.78%	II	-7.98%	III

In addition to the process measurement effect (acceopPME) calculated above, there are three additional process measurement effects that must be considered during accident conditions. Section 6.4.2 determined the process measurement effects due to fluid velocity (FVE -7.10%), feedwater ring ΔP (FRE -0.23%), and downcomer subcooling (DSE +0.45%).

<u>Summary</u>

The following table presents the total positive and negative process measurement effects with the FVE (-7.10%), FRE (-0.23%), and DSE (+0.45%) biases determined in Section 6.4.2 added. Note that the Feedring bias (FRE) only applies for levels greater than the feedring level of 24%, and that the downcomer subcooling bias (DSE) only applies for levels below the feedring level of 24%.

Fluid Height (% span)	Fluid Height h (in)	Positive acceopPME (% span)	Negative acceopPME (% span)
0.00%	0	9.52%	-11.72%
16.00%	22.96	8.47%	-7.94%
30.00%	43.05	8.05%	-10.13%
50.00%	71.75	14.08%	-11.21%
75.00%	107.63	20.93%	-13.26%
100.00%	143.50	27.78%	-15.31%

Accident PME for EOP use only

6.5 PRIMARY ELEMENT ERROR (PE)

There is no primary element associated with the instrument loops addressed in this calculation.

6.6 Transmitter

6.6.1 Transmitter's Unverified Attributes of Reference Accuracy (RA_{xmtr})

Per Reference 4.4.3, the reference accuracy of the transmitter is ± 0.2% Span and includes the effects of linearity, hysteresis, and repeatability. Per References 4.5.1 and 4.5.11, the transmitter is calibrated to ± 0.50% Span at nine points (5 up and 4 down). Therefore, the calibration procedure verifies the attributes of linearity and hysteresis but not repeatability. Per Reference 4.6.6, the following equation is utilized to compute the repeatability portion of the transmitter reference accuracy:

$$\text{Repeatability} = \pm \frac{RA_{xmtr}}{\sqrt{3}} = \pm \frac{0.2\% Span}{\sqrt{3}} = \pm 0.12\% \text{ Span}$$

Therefore,

$RA_{xmtr} = \pm 0.12\%$ Span

6.6.2 Transmitter Calibration Tolerance (CAL_{xmtr})

Per Reference 4.5.11, the transmitter is calibrated to ± 0.50% Span. Therefore,

$CAL_{xmtr} = \pm 0.50\%$ Span

6.6.3 Transmitter Drift (DR_{xmtr})

Per Ref 4.4.3, the transmitter drift is given as ± 0.10% Upper Range Limit (URL) over a time period of thirty months. Per Reference 4.4.3, the URL for a range code 2 transmitter is 250 inwc. Per Section 9.1, the calibrated span of the transmitter is 108 inwc. Therefore,

$$DR_{xmtr} = \pm\left(\frac{0.1\%\ URL}{Span}\right) = \pm 0.10\%\left(\frac{250\ inwc}{108\ inwc}\right) = \pm\ 0.23\%\ \text{Span}$$

Based on historical As-Found/As-Left data from calibration records, RNP-I/INST-1212 (Reference 4.2.7) determined a bounding 30 month analyzed drift (AD) value composed of a random 2σ value term of ±1.044% Span, and a negative bias term of –0.227% Span. Since the current drift value of ±0.28% Span does not bound the random term of the AD value for the current calibration interval or the extended 30 month interval, the AD value will be used in this calculation, therefore,

$$AD_{xmtr} = \pm\ 1.044\%\ \text{Span}$$
$$AD_{xmtrBIAS} = -\ 0.227\%\ \text{Span}$$

6.6.4 Transmitter M&TE Effect (MTE_{xmtr})

A DMM, pressure gauge, and the instrument loop test point resistor are used to calibrate the transmitter. Per Reference 4.6.6, the combined (SRSS) accuracy of all the M&TE used to calibrate the transmitter is better than or equal to the calibration accuracy of the transmitter. For conservatism and flexibility in the choice of test equipment, the MTE term for the transmitter is set equal to the calibration tolerance of the transmitter.

$$MTE_{xmtr} = \pm\ 0.50\%\ \text{Span}$$

6.6.5 Transmitter Temperature Effect (TE_{xmtr})

Per Reference 4.4.3, the transmitter temperature effect is given as ± 0.15% Upper Range Limit + 0.60% Span for a change in temperature of 100°F from the temperature at which the transmitter was calibrated. Per Reference 4.4.3, the Upper Range Limit (URL) for a range code 2 transmitter is 250 inwc, and the calibrated span of each transmitter is 108 inwc (Section 9.1). Per TMM-026, the transmitters are located in Containment and the calibration and maximum Containment temperatures are 50°F and 130°F respectively (Design Input 5.7). Therefore, a maximum change in temperature of 80°F is used to calculate the transmitter temperature effect. Therefore,

$$TE_{xmtr} = \pm(\frac{0.15\%\ URL}{Span} + 0.60\%\ Span)(\frac{\Delta T}{100°F})$$
$$TE_{xmtr} = \pm(0.15\%(\frac{250\ inwc}{108\ inwc}) + 0.60\%\ Span)(\frac{80°F}{100°F}) = \pm\ 0.76\%\ Span$$

Per Design Input 5.22, the maximum containment temperature when using normal containment setpoint values is 190°F. As discussed above, the minimum containment temperature is 50°F. Therefore, a maximum change in temperature of 140°F is used to calculate the transmitter temperature effect. Therefore,

$$eopTE_{xmtr} = \pm(\frac{0.15\%\ URL}{Span} + 0.60\%\ Span)(\frac{\Delta T}{100°F})$$
$$eopTE_{xmtr} = \pm(0.15\%(\frac{250\ inwc}{108\ inwc}) + 0.60\%\ Span)(\frac{140°F}{100°F}) = = \pm 1.33\%\ Span$$

Note: The transmitter temperature effect computed above is for normal environmental conditions only. For accident environmental conditions, the accident temperature effect is included in the loop uncertainty computation.

6.6.6 Normal Transmitter Static Pressure Effect ($norSPE_{xmtr}$)

Per Reference 4.4.3, a static pressure span correction is not required on the transmitter. Per Reference 4.4.3, the static pressure span effect correction uncertainty is ± $(0.1\%\ URL + 0.1\%\ Span)$ per 1000 psi. Per Reference 4.7.9, the maximum normal operating pressure of the Steam Generator is 1020 psia (0% Load). Per Section 9.1, the maximum reading for the transmitter is approximately 138 inwc and the span of each transmitter is 108 inwc.

Per Reference 4.4.3, the static pressure zero effect is ± 0.10% Upper Range Limit per 1000 psi, and the Upper Range Limit of a range code 2 transmitter is 250 inwc.

Therefore, the normal static pressure effect for each transmitter is calculated with the following equation:

$$norSPE_{xmtr} = \pm\left(0.1\%\left(\frac{250\ inwc}{108\ inwc}\right) + 0.1\%\ Span + 0.1\%\left(\frac{250\ inwc}{108\ inwc}\right)\right)\left(\frac{1020\ psia}{1000\ psia}\right)$$

$$norSPE_{xmtr} = \pm\ 0.57\%\ Span$$

6.6.7 Accident Transmitter Static Pressure Effect ($accSPE_{xmtr}$)

Per Section 9.1, a static pressure span correction is performed on the transmitter. Per Reference 4.4.3, the static pressure span effect correction uncertainty is $\pm\ (0.1\%\ URL + 0.1\%\ Span)$ per 1000 psi. Per Design Input 5.10, the lowest set pressure of the Steam Generator safety relief valves (1100 psia) is taken as the maximum pressure of the Steam Generator. Per Section 9.1, the maximum reading for the transmitter is approximately 138 inwc and the span of each transmitter is 108 inwc.

Per Reference 4.4.3, the static pressure zero effect is ± 0.10% Upper Range Limit per 1000 psi, and the Upper Range Limit of a range code 2 transmitter is 250 inwc.

Therefore, the accident static pressure effect for each transmitter is calculated with the following equation:

$$accSPE_{xmtr} = \pm\ \left(0.1\%\left(\frac{250\ inwc}{108\ inwc}\right) + 0.1\%\ Span + 0.1\%\left(\frac{250\ inwc}{108\ inwc}\right)\right)\left(\frac{1100\ psia}{1000\ psia}\right)$$

$$accSPE_{xmtr} = \pm\ 0.62\%\ \text{Span}$$

Note that due to the pressure range of interest in the EOPs, the $accSPE_{xmtr}$ value is also applicable during normal containment conditions when in the EOPs. Thus,

$$eopSPE_{xmtr} = accSPE_{xmtr} = \pm\ 0.62\%\ \text{Span}$$

6.6.8 Transmitter Power Supply Effect (PSE_{xmtr})

Per Reference 4.4.3, the power supply effect associated with the transmitters is given as ± 0.005% Span per volt variation in power supplied to the transmitter from the power supplied at the time of calibration. Per EDB (Reference 4.7.4), each instrument loop is powered by an NUS SPS 800 power supply. The power supply is powered by regulated instrument buses per Reference 4.2.1. Therefore, the power supply effect is negligible.

$$PSE_{xmtr} = \text{N/A}$$

6.6.9 Normal Transmitter Total Device Uncertainty (norTDU$_{xmtr}$)

Per Reference 4.6.6, the Total Device Uncertainty for normal environmental conditions is computed using the following equation:

$$norTDU_{xmtr} = \pm \sqrt{(CAL_{xmtr}^2 + MTE_{xmtr}^2) + RA_{xmtr}^2 + DR_{xmtr}^2 + norTE_{xmtr}^2 + norSPE_{xmtr}^2} + DR_{xmtrBIAS}$$

Per Design Input 5.27, AD may replace RA, MTE, and DR as a single value when calculating the TDU, therefore,

$$norTDU_{xmtr} = \pm \sqrt{CAL_{xmtr}^2 + AD_{xmtr}^2 + norTE_{xmtr}^2 + norSPE_{xmtr}^2} + AD_{xmtrBIAS}$$

$$norTDU_{xmtr} = \pm\sqrt{0.50^2 + 1.044^2 + 0.76^2 + 0.57^2} - 0.227$$

$$norTDU_{xmtr} = \pm\ 1.50\%\ \text{Span},\ -\ 0.23\%\ \text{Span}$$

6.6.10 Normal Transmitter Total Device Uncertainty (eopTDU$_{xmtr}$) for EOPs

Per Reference 4.6.6, the Total Device Uncertainty for normal environmental conditions for EOPs is computed using the following equation:

$$eopTDU_{xmtr} = \pm \sqrt{(CAL_{xmtr}^2 + MTE_{xmtr}^2) + RA_{xmtr}^2 + DR_{xmtr}^2 + eopTE_{xmtr}^2 + eopSPE_{xmtr}^2} + DR_{xmtrBIAS}$$

Per Design Input 5.27, AD may replace RA, MTE, and DR as a single value when calculating the TDU, therefore,

$$eopTDU_{xmtr} = \pm \sqrt{CAL^2 + AD_{xmtr}^2 + eopTE_{xmtr}^2 + eopSPE_{xmtr}^2} + AD_{xmtrBIAS}$$

$$eopTDU_{xmtr} = \pm\sqrt{0.50^2 + 1.044^2 + 1.33^2 + 0.62^2} - 0.227$$

$$eopTDU_{xmtr} = \pm\ 1.87\%\ \text{Span},\ -\ 0.23\%\ \text{Span}$$

6.6.11 Accident Transmitter Total Device Uncertainty (accTDU$_{xmtr}$)

Per Reference 4.6.6, the Total Device Uncertainty for accident conditions is computed using the following equation:

$$accTDU_{xmtr} = \pm \sqrt{(CAL_{xmtr}{}^2 + MTE_{xmtr}{}^2) + RA_{xmtr}{}^2 + DR_{xmtr}{}^2 + accSPE_{xmtr}{}^2} + DR_{xmtrBIAS}$$

Per Design Input 5.27, AD may replace RA, MTE, and DR as a single value when calculating the TDU, therefore,

$$accTDU_{xmtr} = \pm \sqrt{CAL^2 + AD_{xmtr}{}^2 + accSPE_{xmtr}{}^2} + AD_{xmtrBIAS}$$
$$accTDU_{xmtr} = \pm \sqrt{0.50^2 + 1.044^2 + 0.62^2} - 0.23$$
$$accTDU_{xmtr} = \pm 1.31\% \text{ Span}, - 0.23\% \text{ Span}$$

6.6.12 Transmitter As Found Tolerance (AFT_{xmtr})

Per Reference 4.6.6, the As Found Tolerance (AFT) is computed using the following equation:

$$AFT_{xmtr} = \pm \sqrt{CAL_{xmtr}{}^2 + DR_{xmtr}{}^2 + MTE_{xmtr}{}^2}$$
$$AFT_{xmtr} = \pm \sqrt{0.50^2 + 0.23^2 + 0.50^2}$$
$$AFT_{xmtr} = \pm 0.74\% \text{ Span}$$

Per Design Input 5.27, AD may replace RA, MTE, and DR as a single value when calculating the AFT, therefore,

$$AFT_{xmtr} = \pm \sqrt{CAL_{xmtr}{}^2 + AD_{xmtr}{}^2}$$
$$AFT_{xmtr} = \pm \sqrt{0.50^2 + 1.044^2}$$
$$AFT_{xmtr} = \pm 1.16\% \text{ Span}$$

Note: The bias portion of the analyzed drift will be captured in the Total Device Uncertainty, the Total Loop Uncertainty, and ultimately included, if appropriate, in the setpoint margin. For conservatism, it will not be included in the AFT.

The current AFT_{xmtr} value of ± 0.74% Span is less than, i.e., more conservative than, the above calculated AFT_{xmtr} value of ± 1.16% Span. For conservatism, AFT_{xmtr} = ± 0.74% Span will be retained.

6.6.13 Transmitter As Left Tolerance (ALT_{xmtr})

Per Reference 4.6.6, the As Left Tolerance (ALT) is computed using the following equation:

$ALT_{xmtr} = CAL_{xmtr}$
$ALT_{xmtr} = \pm 0.50\%$ Span

Error Contributor	Value	Type	Section
RA	± 0.12% Span	Random	6.6.1
CAL	± 0.50% Span	Random	6.6.2
DR	± 0.23% Span	Random	6.6.3
AD	± 1.044% Span	Random	6.6.3
	− 0.227% Span	Bias	
MTE	± 0.50% Span	Random	6.6.4
ATE	± 3.32% Span	Random	6.1.1
ARE	±1.69% Span	Random	6.1.3
SE	± 1.16% Span	Random	6.2
eopTE	± 1.33% Span	Random	6.6.5
norTE	± 0.76% Span	Random	6.6.5
norSPE	± 0.57% Span	Random	6.6.6
accSPE	± 0.62% Span	Random	6.6.7
As Left Tolerance (ALT)	± 0.50% Span	Random	6.6.13
As Found Tolerance (AFT)	± 0.74% Span	Random	6.6.12
Total Device Uncertainty (EOP)	± 1.87% Span	Random	6.6.10
	− 0.23% Span	Bias	
Total Device Uncertainty (non-accident)	± 1.50 %Span	Random	6.6.9
	− 0.23% Span	Bias	
Total Device Uncertainty (accident)	± 1.31% Span	Random	6.6.11
	− 0.23% Span	Bias	

Transmitter Uncertainty Summary

6.7 COMPARATOR MODULE

6.7.1 Comparator's Unverified Attributes of Reference Accuracy (RA_{comp})

Per Reference 4.4.1, the comparator reference accuracy is ± 0.50% Span. Per References 4.5.2 through 4.5.11, the comparator is calibrated to ± 0.50% Span, and the calibration procedure verifies the attributes of linearity and hysteresis but not repeatability. Per Reference 4.6.6, the following equation is utilized to compute the repeatability portion of the comparator reference accuracy:

$$\text{Repeatability} = \pm \frac{RA_{comp}}{\sqrt{3}} = \pm \frac{0.50\%\ \text{Span}}{\sqrt{3}} = \pm\ 0.29\%\ \text{Span}$$

Therefore,

$RA_{comp} = \pm\ 0.29\%$ Span

6.7.2 Comparator Calibration Tolerance (CAL_{comp})

Per Reference 4.5.11, the comparator is calibrated to ± 0.50% Span. Therefore,

$CAL_{comp} = \pm\ 0.50\%$ Span

6.7.3 Comparator Drift (DR_{comp})

Per Reference 4.4.1, no drift is specified for the Hagan or NUS comparator. Per Reference 4.6.6, if no drift is specified for a device, a default value of ± 1.00% Span may be used. Based on historical data, Hagan comparator drift is ± 0.25% Span (Attachment B). If the default value bounds the value obtained through a review of the historical data, the default value of ± 1.00% Span may be used for comparator drift (Reference 4.6.6). Therefore, the default value of ± 1.00% Span is used for comparator drift for the NUS and Hagan comparators.

$DR_{comp} = \pm\ 1.00\%$ Span

The comparator is subject to a quarterly COT per MST-013 (Reference 4.5.13). Therefore, per Design Input 5.26, the above drift value is conservative and will be used.

6.7.4 Comparator M&TE Effect (MTE_{comp})

Per References 4.5.2-10, one DMM with an accuracy of ± 0.25% Reading is used to calibrate the comparator. For conservatism, a maximum reading of 5 Vdc is used to compute the accuracy of the DMM as follows:

$$MTE_{comp} = \pm(0.25\%\ \text{Reading})\left(\frac{5\ \text{Vdc}}{4\ \text{Vdc}}\right) = \pm\ 0.31\%\ \text{Span}$$

6.7.5 Comparator Temperature Effect (TE_{comp})

Per Reference 4.4.1, the NUS comparator temperature effect is given as ± 0.04% Span per 1°C change in temperature from the temperature at the time of calibration, and no temperature effect is specified for the Hagan comparator. Per EGR-NGGC-0153 (Reference 4.6.1), if no temperature effect is specified for a device, a default value of ± 0.50% Span may be used for the temperature effect. Per Design Input 5.8, a change in temperature of 42°F (23.33°C) is used to compute the comparator temperature effect. Therefore,

$$TE_{comp} = \pm\ 0.04\%\ \text{Span}\left(\frac{23.33°C}{1°C}\right)$$

$$TE_{comp} = \pm\ 0.93\%\ \text{Span}$$

Since either Westinghouse Hagan or NUS comparator may be used, the most restrictive temperature effect (NUS comparator) is used in this calculation.

6.7.6 Comparator Power Supply Effect (PSE_{comp})

Per Reference 4.4.1, no uncertainty for the comparator power supply effect is specified. Since the comparators are powered by regulated instrument buses, the comparator power supply effect is considered to be negligible. Therefore,

$$PSE_{comp} = N/A$$

6.7.7 Comparator Total Device Uncertainty (TDU_{comp})

Total Device Uncertainty is computed using the following equation:

$$TDU_{comp} = \pm\sqrt{(CAL_{comp} + MTE_{comp})^2 + RA_{comp}{}^2 + DR_{comp}{}^2 + TE_{comp}{}^2}$$

$$TDU_{comp} = \pm\ 1.61\%\ \text{Span}$$

6.7.8 Comparator As Found Tolerance (AFT_{comp})

Per Reference 4.6.6, the As Found Tolerance (AFT) is computed using the following equation:

$$AFT_{comp} = \pm\sqrt{CAL_{comp}^{\ 2} + DR_{comp}^{\ 2} + MTE_{comp}^{\ 2}}$$

$$AFT_{comp} = \pm\ 1.16\%\ \text{Span}$$

6.7.9 Comparator As Left Tolerance (ALT_{comp})

Per Reference 4.6.6, the As Left Tolerance (ALT) is computed using the following equation:

$$ALT_{comp} = CAL_{comp}$$

$$ALT_{comp} = \pm\ 0.50\%\ \text{Span}$$

Error Contributor	Value	Type	Section
RA	± 0.29% Span	Random	6.7.1
CAL	± 0.50% Span	Random	6.7.2
DR	± 1.00% Span	Random	6.7.3
MTE	± 0.31% Span	Random	6.7.4
TE	± 0.93% Span	Random	6.7.5
As Left Tolerance (ALT)	± 0.50% Span	Random	6.7.9
As Found Tolerance (AFT)	± 1.16% Span	Random	6.7.8
Total Device Uncertainty (non-accident)	± 1.61% Span	Random	6.7.7

Comparator Module Uncertainty Summary

6.8 ISOLATOR MODULE

6.8.1 Isolator's Unverified Attributes of Reference Accuracy (RA_{isol})

Per Hagan vendor manual 728-589-13 (Reference 4.4.1), the reference accuracy of the NUS 800 isolator is ±0.1% of output full scale, repeatable to ± 0.05%, with a linearity better than ±0.05% of output full scale.

Per Hagan vendor manual 728-589-13 (Reference 4.4.1), the reference accuracy of the NUS EIP isolator is ±0.1% of full scale, with a linearity better than ±0.1% of full scale output.

Per LP-027 through LP-035 and MMM-06 (References 4.5.2 through 4.5.11), the isolator is calibrated to ± 0.50% Span, and the calibration procedure verifies the attributes of linearity but not hysteresis or repeatability. Per Reference 4.6.6, the following equation is used to compute the repeatability portion of the NUS EIP isolator reference accuracy:

$$\text{Repeatability} = \pm\frac{RA_{isol}}{\sqrt{3}} = \pm\frac{0.10\%\ \text{Span}}{\sqrt{3}} = \pm\ 0.06\%\ \text{Span}$$

For conservatism, Repeatability = ± 0.06% ΔP Span will be assigned to both the NUS 800 and NUS EIP isolators.

Per Reference 4.6.6, the following equation is used to compute the hysteresis portion of both the NUS 800 and NUS EIP isolator reference accuracy:

$$\text{Hysteresis} = \pm\frac{RA_{isol}}{\sqrt{3}} = \pm\frac{0.10\%\ \text{Span}}{\sqrt{3}} = \pm\ 0.06\%\ \text{Span}$$

The NUS 800 and NUS EIP isolator reference accuracy is now determined by combining the attributes of the hysteresis and repeatability calculated above, using the SRSS method.

$$RA_{isol} = \pm\sqrt{0.06^2 + 0.06^2}$$

$$RA_{isol} = \pm 0.08\%\ \text{Span}$$

6.8.2 Isolator Calibration Tolerance (CAL_{isol})

Per Reference 4.5.11, the isolator is calibrated to ± 0.50% Span. Therefore,

$$CAL_{isol} = \pm\ 0.50\%\ \text{Span}$$

6.8.3 Isolator Drift (DR_{isol})

Per Reference 4.4.1, no uncertainty for isolator drift is specified. The default value of ± 1.00% Span is used to represent isolator drift [Reference 4.6.6]. Therefore,

$$DR_{isol} = \pm\ 1.00\%\ \text{Span}$$

NUS 800 Isolator Drift ($DR_{800isol}$)

Per Attachments F (Reference 4.7.23) and G (Reference 4.7.24), the NUS 800 isolator drift has been tested to be less than ±0.20% Span for calibration intervals of up to 36 months, which bounds the 30 month requirement for these isolators. For conservatism, $DR_{800isol}$ = ± 1.00% Span will be retained.

NUS EIP Isolator Drift ($DR_{EIPisol}$)

Per Hagan vendor manual 728-589-13 (Reference 4.4.1), no drift uncertainty for the NUS EIP isolator is specified. Per Reference 4.6.6, the default value of
± 1.00% Span/18 months is used to represent the isolator drift.

Per Design Input 5.28, as part of the 24 month fuel cycle project, the nominal calibration interval is being extended to 24 months with a maximum of 30 months (24 months + 25%).

Per EGR-NGGC-0153 (Reference 4.6.1), when the calibration interval exceeds the vendor specified drift interval (default value in this instance), treatment of the drift as random and independent with respect to the multiple time intervals is the preferred methodology. Accordingly, the SRSS method will be used to combine the ± 1.0% Span/18 month drift intervals.

The number of drift intervals = 30 months/18 months = 1.67.

Calculating $DR_{EIPisol}$,

$$DR_{EIPisol} = \pm\sqrt{1.67(1.0)^2}$$

$$DR_{EIPisol} = \pm\ 1.29\%\ \text{Span}$$

6.8.4 Isolator M&TE Effect (MTE_{isol})

Per References 4.5.2-10, two DMMs are used to calibrate the isolator. Each DMM has an accuracy of ± 0.25% Reading. The total MTE term is the SRSS of the individual DMM accuracy terms. For conservatism, a maximum reading of 5 Vdc is used to compute the accuracy of the DMMs as follows:

$$MTE_{isol} = \pm\sqrt{\left((2)\left[(0.25\%\ \text{Reading})\left(\frac{5\ \text{Vdc}}{4\ \text{Vdc}}\right)\right]^2\right)}$$

$$MTE_{isol} = \pm\ 0.44\%\ \text{Span}$$

6.8.5 Isolator Temperature Effect (TE_{isol})

Per Hagan vendor manual 728-589-13 (Reference 4.4.1), the NUS EIP isolator temperature effect is ± 0.01% full scale/°C. Per Reference 4.4.1, the NUS 800 isolator temperature effect is less than ± 0.50% of output full scale per 50°F for module gains less than 1.7.

Per Design Input 5.8, a change in temperature of 42°F (23.33°C) is used to compute the isolator temperature effect for normal conditions, and a change in temperature of 70°F.

NUS EIP Isolator Temperature Effect for Normal Conditions ($norTE_{EIPisol}$)

For a temperature change of 42°F (23.33°C), $norTE_{EIPisol}$ is computed as follows:

$$norTE_{EIPisol} = \pm\ 0.01\%\ \text{Full Scale}\left(\frac{5\ \text{Vdc}}{100\%\ \text{Full Scale}}\right)\left(\frac{100\%\ \text{Span}}{4\ \text{Vdc}}\right)\left(\frac{23.33°\text{C}}{1°\text{C}}\right)$$

$$norTE_{EIPisol} = \pm\ 0.29\%\ \text{Span}$$

NUS 800 Isolator Temperature Effect for Normal Conditions ($norTE_{800isol}$)

For a temperature change of 42°F, $norTE_{800isol}$ is computed as follows:

$$norTE_{800isol} = \pm\ 0.50\%\ \text{Full Scale}\left(\frac{5\ \text{Vdc}}{100\%\ \text{Full Scale}}\right)\left(\frac{100\%\ \text{Span}}{4\ \text{Vdc}}\right)\left(\frac{42°\text{F}}{50°\text{F}}\right)$$

$$norTE_{800isol} = \pm\ 0.53\%\ \text{Span}$$

NUS EIP Isolator Temperature Effect for Accident Conditions ($accTE_{EIPisol}$)

For a temperature change of 70°F (38.89°C), $accTE_{EIPisol}$ is computed as follows:

$$accTE_{EIPisol} = \pm 0.01\%\ \text{Full Scale}\left(\frac{5\ \text{Vdc}}{100\%\ \text{Full Scale}}\right)\left(\frac{100\%\ \text{Span}}{4\ \text{Vdc}}\right)\left(\frac{38.89°\text{C}}{1°\text{C}}\right)$$

$$accTE_{EIPisol} = \pm 0.49\%\ \text{Span}$$

NUS 800 Isolator Temperature Effect for Accident Conditions ($accTE_{800isol}$)

For a temperature change of 70°F, $accTE_{800isol}$ is computed as follows:

$$accTE_{800isol} = \pm 0.50\%\ \text{Full Scale}\left(\frac{5\ \text{Vdc}}{100\%\ \text{Full Scale}}\right)\left(\frac{100\%\ \text{Span}}{4\ \text{Vdc}}\right)\left(\frac{70°\text{F}}{50°\text{F}}\right)$$

$$accTE_{800isol} = \pm 0.88\%\ \text{Span}$$

6.8.6 Isolator Power Supply Effect (PSE_{isol})

Per Reference 4.4.1, no uncertainty for the isolator power supply effect is specified. Since the isolators are powered by regulated instrument buses, the isolator power supply effect is considered to be negligible. Therefore,

PSE_{isol} = N/A

6.8.7 Isolator Total Device Uncertainty (TDU_{isol})

NUS EIP Isolator TDU for Normal conditions ($norTDU_{EIPisol}$)

Per Reference 4.6.6, the Total Device Uncertainty is computed using the following equation:

$$norTDU_{EIPisol} = \pm\sqrt{(CAL_{isol} + MTE_{isol})^2 + RA_{isol}^{\ 2} + DR_{EIPisol}^{\ 2} + norTE_{EIPisol}^{\ 2}}$$
$$norTDU_{EIPisol} = \pm\sqrt{(0.50 + 0.44)^2 + 0.08^2 + 1.29^2 + 0.29^2}$$
$$norTDU_{EIPisol} = \pm\ 1.62\%\ \text{Span}$$

NUS 800 Isolator TDU for Normal Conditions ($norTDU_{800isol}$)

Per Reference 4.6.6, the Total Device Uncertainty is computed using the following equation:

$$norTDU_{800isol} = \pm\sqrt{(CAL_{isol} + MTE_{isol})^2 + RA_{isol}^{\ 2} + DR_{800isol}^{\ 2} + norTE_{800isol}^{\ 2}}$$
$$norTDU_{800isol} = \pm\sqrt{(0.50 + 0.44)^2 + 0.08^2 + 1.00^2 + 0.53^2}$$
$$norTDU_{800isol} = \pm\ 1.47\%\ \text{Span}$$

NUS EIP Isolator TDU for Accident Conditions ($accTDU_{EIPisol}$)

Per Reference 4.6.6, the Total Device Uncertainty is computed using the following equation:

$$accTDU_{EIPisol} = \pm\sqrt{(CAL_{isol} + MTE_{isol})^2 + RA_{isol}^{\ 2} + DR_{EIPisol}^{\ 2} + accTE_{EIPisol}^{\ 2}}$$
$$accTDU_{EIPisol} = \pm\sqrt{(0.50 + 0.44)^2 + 0.08^2 + 1.29^2 + 0.49^2}$$
$$accTDU_{EIPisol} = \pm\ 1.67\%\ \text{Span}$$

NUS 800 Isolator TDU for Accident Conditions ($accTDU_{800isol}$)

Per Reference 4.6.6, the Total Device Uncertainty is computed using the following equation:

$$accTDU_{800isol} = \pm\sqrt{(CAL_{isol} + MTE_{isol})^2 + RA_{isol}{}^2 + DR_{800isol}{}^2 + accTE_{800isol}{}^2}$$
$$accTDU_{800isol} = \pm\sqrt{(0.50 + 0.44)^2 + 0.08^2 + 1.00^2 + 0.88^2}$$
$$accTDU_{800isol} = \pm\ 1.63\%\ \text{Span}$$

For conservatism, $norTDU_{EIPisol}$, $norTDU_{800isol}$, and $accTDU_{800isol}$ will be assigned the $accTDU_{EIPisol}$ uncertainty value of ± 1.67% Span for both accident and non-accident (normal) conditions.

6.8.8 Isolator As Found Tolerance (AFT_{isol})

NUS 800 Isolator As Found Tolerance ($AFT_{800isol}$)

Per EGR-NGGC-0153, the As Found Tolerance (AFT) is computed using the following equation:

$$AFT_{800isol} = \pm\sqrt{CAL_{isol}{}^2 + DR_{800isol}{}^2 + MTE_{isol}{}^2}$$
$$AFT_{800isol} = \pm\sqrt{0.50^2 + 1.00^2 + 0.44^2}$$
$$AFT_{800isol} = \pm\ 1.20\%\ \text{Span}$$

NUS EIP Isolator As Found Tolerance ($AFT_{800isol}$)

Per Reference 4.6.6, the As Found Tolerance is computed using the following equation:

$$AFT_{EIPisol} = \pm\sqrt{CAL_{isol}{}^2 + DR_{EIPisol}{}^2 + MTE_{isol}{}^2}$$
$$AFT_{EIPisol} = \pm\sqrt{0.50^2 + 1.29^2 + 0.44^2}$$
$$AFT_{EIPisol} = \pm\ 1.45\%\ \text{Span}$$

The current $AFT_{EIPisol}$ value of ± 1.20% Span is less than, i.e., more conservative than, the above calculated $AFT_{EIPisol}$ value of ± 1.45% Span. For conservatism, $AFT_{EIPisol}$ = ± 1.20% Span will be retained.

6.8.9 Isolator As Left Tolerance (ALT_{isol})

Per Reference 4.6.6, the As Left Tolerance (ALT) is computed using the following equation:

$$ALT_{800isol} = CAL_{isol} = \pm\ 0.50\%\ \text{Span}$$

$ALT_{EIPisol} = CAL_{isol} = \pm 0.50\%$ Span

Error Contributor	Value	Type	Section
RA	± 0.08% Span	Random	6.8.1
CAL	± 0.50% Span	Random	6.8.2
DR	± 1.00% Span	Random	6.8.3
$DR_{800isol}$	± 1.00% Span	Random	6.8.3
$DR_{EIPisol}$	± 1.29% Span	Random	6.8.3
MTE	± 0.44% Span	Random	6.8.4
$norTE_{800isol}$	± 0.53% Span	Random	6.8.5
$norTE_{EIPisol}$	± 0.29% Span	Random	6.8.5
$accTE_{800isol}$	± 0.88% Span	Random	6.8.5
$accTE_{EIPisol}$	±0.49% Span	Random	6.8.5
As Left Tolerance (ALT)	± 0.50% Span	Random	6.8.9
As Found Tolerance (AFT)	± 1.20% Span	Random	6.8.8
Total Device Uncertainty (accident)	± 1.67% Span	Random	6.8.7
Total Device Uncertainty (non-accident)	±1.67% Span	Random	6.8.7

Isolator Module Uncertainty Summary

Note: RA, CAL, MTE, ALT, and AFT values are equalvalent for both isolators.

6.9 INDICATOR

6.9.1 Indicator's Unverified Attributes of Reference Accuracy (RA_{ind})

Per Reference 4.4.2, the reference accuracy of the indicator is ± 2.00% Span and includes the effects of linearity, hysteresis, and repeatability (Design Input 5.5). Per References 4.5.2 through 4.5.11, the indicator is calibrated to ± 2.00% Span at nine points (5 up and 4 down). Therefore, the calibration procedure verifies the attributes of linearity and hysteresis but not repeatability. Per Reference 4.6.6, the following equation is utilized to compute the repeatability portion of the indicator reference accuracy:

$$\text{Repeatability} = \pm \frac{RA_{ind}}{\sqrt{3}} = \pm \frac{2.00\%\ \text{Span}}{\sqrt{3}} = \pm\ 1.15\%\ \text{Span}$$

Therefore,

$$RA_{ind} = \pm\ 1.15\%\ \text{Span}$$

6.9.2 Indicator Calibration Tolerance (CAL_{ind})

Per Reference 4.5.11, the indicator is calibrated to ± 2.00% Span. Therefore,

$$CAL_{ind} = \pm\ 2.00\%\ \text{Span}$$

6.9.3 Indicator Drift (DR_{ind})

Per Attachment D, indicator drift is specified as ± 1.00% Span per year. Per Reference 4.6.6, the time interval between calibrations is 22.5 month (18 months + 25%), and the following equation is used to compute the indicator drift:

$$DR_{ind} = \pm \sqrt{1.00\%\ \text{Span}\left(\frac{22.5\ \text{months}}{12\ \text{months}}\right)}$$

$$DR_{ind} = \pm\ 1.37\%\ \text{Span}$$

Based on historical As-Found/As-Left data from calibration records, RNP-I/INST-1215 (Reference 4.2.8) determined a bounding 30 month analyzed drift (AD) value of ±1.792% Span, which is to be treated as a random 2σ value term with no significant bias term. Since the current drift value of ±1.37% Span does not bound the AD value for the current calibration interval or the extended 30 month interval, the AD value will be used in this calculation, therefore,

$$AD_{ind} = \pm\ 1.792\%\ \text{Span}$$

6.9.4 Indicator M&TE Effect (MTE_{ind})

Per Reference 4.5.2-10, one DMM with an accuracy of ± 0.25% Reading is used to calibrate the indicator. The calibration points are cardinal points on the indicator scale (Reference 4.5.2-10). Therefore, the indicator resolution is not included in the MTE term. For conservatism, a maximum reading of 5 Vdc is used to compute the accuracy of the DMM as follows:

$$MTE_{ind} = \pm(0.25\%\ \text{Reading})\left(\frac{5\ \text{Vdc}}{4\ \text{Vdc}}\right) = \pm\ 0.31\%\ \text{Span}$$

6.9.5 Indicator Temperature Effect (TE_{ind})

Per Attachment D, the indicator temperature effect is specified as ±0.10% Span per 1°C change from the temperature at the time of calibration. Per Design Input 5.14, a change in temperature of 11.1°C is used to compute the indicator temperature effect.

$$TE_{ind} = \pm\ 0.10\%\ \text{Span}\left(\frac{11.1°\text{C}}{1°\text{C}}\right)$$

$$TE_{ind} = \pm\ 1.11\%\ \text{Span}$$

6.9.6 Indicator Power Supply Effect (PSE_{ind})

Per References 4.1.1 through 4.1.8, the indicators are not powered by an external source. Therefore, there is no indicator power supply effect.

$$PSE_{ind} = \text{N/A}$$

6.9.7 Indicator Readability (RD_{ind})

Per Reference 4.6.6, the indicator readability term is ½ of the smallest indicator scale demarcation. Per References 4.1.11 and 4.1.12, the indicator has a scale of 0 to 100% with minor demarcations of 2%. Therefore,

$$RD_{ind} = \pm\left(\frac{2\%}{2}\right)\left(\frac{100\%\ \text{Span}}{100\%}\right) = \pm\ 1.00\%\ \text{Span}$$

6.9.8 Indicator Total Device Uncertainty (TDU_{ind})

Per Reference 4.6.6, the Total Device Uncertainty is computed using the following equation:

$$TDU_{ind} = \pm\sqrt{(CAL_{ind} + MTE_{ind})^2 + RA_{ind}^2 + DR_{ind}^2 + TE_{ind}^2 + RD_{ind}^2}$$
$$TDU_{ind} = \pm\sqrt{(2.00 + 0.31)^2 + 1.15^2 + 1.37^2 + 1.11^2 + 1.00^2}$$
$$TDU_{ind} = \pm\ 3.28\%\ \text{Span}$$

Per Design Input 5.27, AD may replace RA, MTE, and DR as a single value when calculating the TDU, therefore,

$$TDU_{ind} = \pm\sqrt{CAL_{ind}^2 + AD_{ind}^2 + TE_{ind}^2 + RD_{ind}^2}$$
$$TDU_{ind} = \pm\sqrt{2.00^2 + 1.792^2 + 1.11^2 + 1.00^2}$$
$$TDU_{ind} = \pm\ 3.07\%\ \text{Span}$$

6.9.9 Indicator Total Device Uncertainty for EOP Setpoints ($eopTDU_{ind}$)

Per Input 5.20, indicator readability is not required for EOP setpoint applications. Per Reference 4.6.6, the Total Device Uncertainty for EOP setpoints is computed using the following equation:

$$eopTDU_{ind} = \pm\sqrt{(CAL_{ind} + MTE_{ind})^2 + RA_{ind}^2 + DR_{ind}^2 + TE_{ind}^2}$$
$$eopTDU_{ind} = \pm\sqrt{(2.00 + 0.31)^2 + 1.15^2 + 1.37^2 + 1.11^2}$$
$$eopTDU_{ind} = \pm\ 3.13\%\ \text{Span}$$

Per Design Input 5.27, AD may replace RA, MTE, and DR as a single value when calculating the TDU, therefore,

$$eopTDU_{ind} = \pm\sqrt{CAL_{ind}^2 + AD_{ind}^2 + TE_{ind}^2}$$
$$eopTDU_{ind} = \pm\sqrt{2.00^2 + 1.792^2 + 1.11^2}$$
$$eopTDU_{ind} = \pm\ 2.91\%\ \text{Span}$$

6.9.10 Indicator As Found Tolerance (AFT_{ind})

Per Reference 4.6.6, the As Found Tolerance (AFT) is computed using the following equation:

$$AFT_{ind} = \pm\sqrt{CAL_{ind}^{2} + DR_{ind}^{2} + MTE_{ind}^{2}}$$
$$AFT_{ind} = \pm\sqrt{2.00^2 + 1.37^2 + 0.31^2}$$
$$AFT_{ind} = \pm 2.44\% \text{ Span}$$

Per Design Input 5.27, AD may replace RA, MTE, and DR as a single value when calculating the AFT, therefore,

$$AFT_{ind} = \pm\sqrt{CAL_{ind}^{2} + AD_{ind}^{2}}$$
$$AFT_{ind} = \pm\sqrt{2.00^2 + 1.792^2}$$
$$AFT_{ind} = \pm 2.69\% \text{ Span}$$

The current AFT_{ind} value of ± 2.44% Span is less than, i.e., more conservative than, the above calculated AFT_{ind} value of ± 2.69% Span. Therefore, for conservatism, AFT_{ind} = ± 2.44% Span will be retained.

6.9.11 Indicator As Left Tolerance (ALT_{ind})

Per Reference 4.6.6, the As Left Tolerance (ALT) is computed using the following equation:

$ALT_{ind} = CAL_{ind}$
$ALT_{ind} = \pm 2.00\%$ Span

Error Contributor	Value	Type	Section
RA	± 1.15% Span	Random	6.9.1
CAL	± 2.00% Span	Random	6.9.2
DR	± 1.37% Span	Random	6.9.3
AD	± 1.792% Span	Random	6.9.3
MTE	± 0.31% Span	Random	6.9.4
TE	± 1.11% Span	Random	6.9.5
RD	± 1.00% Span	Random	6.9.7
As Left Tolerance (ALT)	± 2.00% Span	Random	6.9.11
As Found Tolerance (AFT)	± 2.44% Span	Random	6.9.10
Total Device Uncertainty (EOP)	± 2.91% Span	Random	6.9.9
Total Device Uncertainty (non-accident)	± 3.07% Span	Random	6.9.8

Indicator Uncertainty Summary

6.10 RECORDER

6.10.1 Recorder's Unverified Attributes of Reference Accuracy (RA_{rec})

Per References 4.1.7, 4.1.8 and 4.1.16, the recorder input span is 1 to 5 Vdc. Therefore, the specifications for a 6 Vdc input range are used to compute the recorder Reference Accuracy. Per Reference 4.4.5, for a 6 Vdc input range, the maximum resolution of the input is 1 mVdc (0.001 Vdc) and the Measurement Accuracy for the recorder is given as ± (0.05% of reading + 3 digits). Therefore, the recorder Reference Accuracy (RA_{rec}) is calculated as follows:

$$RA_{rec} = \pm (0.05\%\ \text{Reading} + 3\ \text{digits})$$

$$RA_{rec} = \pm (0.05\%\ \text{x}\ 5\ \text{Vdc} + 3\ \text{digits})$$

$$RA_{rec} = \pm (0.0025\ \text{Vdc} + 0.003\ \text{Vdc}) = \pm 0.0055\ \text{Vdc}$$

$$RA_{rec} = \pm \left(\frac{0.0055\ Vdc}{4\ Vdc}\right)100\%\ \text{Span}$$

$$RA_{rec} = \pm 0.14\%\ \text{Span}$$

6.10.2 Recorder Calibration Tolerance (CAL_{rec})

Per Reference 4.5.11, the recorder is calibrated to ± 0.50% Span. Therefore,

$$CAL_{rec} = \pm 0.50\%\ \text{Span}$$

6.10.3 Recorder Drift (DR_{rec})

Per Section 5.19, no recorder drift is specified and recorder drift is assumed to be included in the Reference Accuracy and Temperature Effect specifications. Therefore,

DR_{rec} = N/A

6.10.4 Recorder M&TE Effect (MTE_{rec})

Per References 4.5.2 through 4.5.4, one DMM with an accuracy of ± 0.25% Reading is used to calibrate the recorder. For conservatism, a maximum reading of 5 Vdc is used to compute the accuracy of the DMM as follows:

$$MTE_{rec} = \pm\left(0.25\%\text{ Reading}\right)\left(\frac{5\text{ Vdc}}{4\text{ Vdc}}\right) = \pm\, 0.31\%\text{ Span}$$

6.10.5 Recorder Temperature Effect (TE_{rec})

Per Reference 4.4.5, the Recorder Ambient Temperature Effect is given as ± (0.1% of reading + 0.05% range) for ambient temperature variation of 10°C (18°F). Per EDB, the recorder is located in the Control Room. Per References 4.1.7, 4.1.8 and 4.1.16, the input range of the recorder is 1 to 5 Vdc. Per Section 5.14, a maximum Control Room temperature variation of 20°F is bounding for this application. Therefore, the Recorder Temperature Effect (TE_{rec}) is calculated as follows:

$$TE_{rec} = \pm\,(0.1\%\text{ Reading} + 0.05\%\text{ range})\,(20°F/18°F)$$

$$TE_{rec} = \pm\,(0.1\% \times 5\text{ Vdc} + 0.05\%\text{ range})\,(20°F/18°F)$$

$$TE_{rec} = \pm\,(0.005\text{ Vdc} + 0.003\text{ Vdc})\,(20°F/18°F) = \pm\, 0.0089\text{ Vdc}$$

$$TE_{rec} = \pm\,\left(\frac{0.0089\ Vdc}{4\ Vdc}\right)100\%\text{ Span}$$

$$TE_{rec} = \pm\, 0.22\%\text{ Span}$$

6.10.6 Recorder Power Supply Effect (PSE_{rec})

Per Reference 4.4.5, the power supply effect for a variation within 90 to 132 Vac is within measurement accuracy. Per Reference 4.2.1, power variation will remain within this band. Therefore,

PSE_{rec} = N/A

<u>6.10.7 Recorder Readability (RD_{rec})</u>

Per Reference 4.4.5, for a 6 Vdc Volt Range recorder minimum recorder resolution is 0.001 Vdc. The recorders have an input span of 4 Vdc (1 to 5 Vdc). Therefore,

$$RD_{rec} = \pm \left(\frac{0.001\,\text{Vdc}}{4.0\,\text{Vdc}} \right) 100\%\ \text{Span} = \pm\ 0.03\%\ \text{Span}$$

Per EGR-NGGC-0153 (Reference 4.6.1), uncertainties less than or equal to 0.05% Span have a negligible effect on the calculation results and may be omitted from the calculation. Therefore,

RD_{rec} = N/A

<u>6.10.8 Recorder Total Device Uncertainty (TDU_{rec})</u>

Total Device Uncertainty is computed using the following equation:

$$TDU_{rec} = \pm\sqrt{(CAL_{rec} + MTE_{rec})^2 + RA_{rec}{}^2 + TE_{rec}{}^2}$$
$$TDU_{rec} = \pm\sqrt{(0.50 + 0.31)^2 + 0.14^2 + 0.22^2}$$
$$TDU_{rec} = \pm\ 0.85\%\ \text{Span}$$

<u>6.10.9 Recorder As-Found Tolerance (AFT_{rec})</u>

Per Reference 4.6.6, the As Found Tolerance (AFT) is computed using the following equation:

$$AFT_{rec} = \pm\sqrt{CAL_{rec}{}^2 + MTE_{rec}{}^2}$$
$$AFT_{rec} = \pm\ 0.59\%\ \text{Span}$$

6.10.10 Recorder As Left Tolerance (ALT_{rec})

Per Reference 4.6.6, the As Left Tolerance (ALT) is computed using the following equation:

$ALT_{rec} = CAL_{rec}$
$ALT_{rec} = \pm 0.50\%$ Span

Error Contributor	Value	Type	Section
RA	± 0.14% Span	Random	6.10.1
CAL	± 0.50% Span	Random	6.10.2
DR	N/A	Random	6.10.3
MTE	± 0.31% Span	Random	6.10.4
TE	± 0.22% Span	Random	6.10.5
RD	N/A	Random	6.10.7
As Left Tolerance (ALT)	± 0.50% Span	Random	6.10.10
As Found Tolerance (AFT)	± 0.59% Span	Random	6.10.9
Total Device Uncertainty (non-accident)	± 0.85% Span	Random	6.10.8

Recorder Uncertainty Summary

7.0 TOTAL LOOP UNCERTAINTY (TLU)

7.1 TOTAL LOOP UNCERTAINTY - PLANT NORMAL

7.1.1 Total Loop Uncertainty - Indicator LI-474, 475, 476, 484, 485, 486, 494, 495, AND 496

Per Reference 4.6.6, the total loop uncertainty associated with the indicator is computed with the following equation:

$$TLU_{ind} = \pm\sqrt{norTDU_{xmtr}^{2} + TDU_{isol}^{2} + TDU_{ind}^{2}} + norPME + AD_{xmtrBIAS}$$

$$TLU_{ind} = \pm\sqrt{1.50^2 + 1.67^2 + 3.07^2} + norPME - 0.23$$

$$TLU_{ind} = \pm 3.80\%\ Span + norPME\%\ Span - 0.23\%\ Span$$

Fluid Height (% Span)	Fluid Height (in.)	Random Uncertainty (% Span)	$AD_{xmtrBIAS}$ Uncertainty (% Span)	Positive norPME (% Span)	Negative norPME (% Span)
0.00	0.00	±3.80	−0.23	1.83	−8.38
16.00	22.96	±3.80	−0.23	1.06	−8.37
30.00	43.05	±3.80	−0.23	NA	−9.81
50.00	71.75	±3.80	−0.23	NA	−10.55
75.00	107.63	±3.80	−0.23	NA	−12.39
100.00	143.50	±3.80	−0.23	NA	−14.01

Combined Uncertainties

Fluid Height (% Span)	Fluid Height (in.)	Positive TLU (% Span)	Negative TLU (% Span)
0.00	0.00	5.63	−12.41
16.00	22.96	4.86	−12.40
30.00	43.05	3.80	−13.84
50.00	71.75	3.80	−14.58
75.00	107.63	3.80	−16.42
100.00	143.50	3.80	−18.04

7.1.2 Total Loop Uncertainty - Input to ERFIS

Per Reference 4.6.6, the total loop uncertainty at the input to ERFIS is computed with the following equation:

$$TLU_{ERFIS} = \pm\sqrt{norTDU_{xmtr}^{2} + TDU_{isol}^{2} + TDU_{isol}^{2}} + norPME + AD_{xmtrBIAS}$$

$$TLU_{ERFIS} = \pm\sqrt{1.50^2 + 1.67^2 + 1.67^2} + norPME - 0.23$$

$$TLU_{ERFIS} = \pm\ 2.80\%\ Span + norPME\%\ Span - 0.23\%\ Span$$

Fluid Height (% Span)	Fluid Height (in.)	Random Uncertainty (% Span)	$AD_{xmtrBIAS}$ Uncertainty (% Span)	Positive norPME (% Span)	Negative norPME (% Span)
0.00	0.00	±2.80	–0.23	1.83	–8.38
16.00	22.96	±2.80	–0.23	1.06	–8.37
30.00	43.05	±2.80	–0.23	NA	–9.81
50.00	71.75	±2.80	–0.23	NA	–10.55
75.00	107.63	±2.80	–0.23	NA	–12.39
100.00	143.50	±2.80	–0.23	NA	–14.01

Combined Uncertainties

Fluid Height (% Span)	Fluid Height (in.)	Positive TLU (% Span)	Negative TLU (% Span)
0.00	0.00	4.63	–11.41
16.00	22.96	3.86	–11.40
30.00	43.05	2.80	–12.84
50.00	71.75	2.80	–13.58
75.00	107.63	2.80	–15.42
100.00	143.50	2.80	–17.04

7.1.3 Total Loop Uncertainty - Recorder

FR-478, 488, & 498

Per Reference 4.6.6, the total loop uncertainty associated with the recorder is computed with the following equation:

$$TLU_{rec} = \pm\sqrt{norTDU_{xmtr}^{2} + TDU_{isol}^{2} + TDU_{rec}^{2}} + norPME + AD_{xmtrBIAS}$$

$$TLU_{rec} = \pm\sqrt{1.50^2 + 1.67^2 + 0.85^2} + norPME - 0.23$$

$$TLU_{rec} = \pm\ 2.40\%\ Span + norPME\%\ Span - 0.23\%\ Span$$

Fluid Height (% Span)	Fluid Height (in)	Random Uncertainty (% Span)	$AD_{xmtrBIAS}$ Uncertainty (% Span)	Positive norPME (% Span)	Negative norPME (% Span)
0.00	0.00	±2.40	–0.23	1.83	–8.38
16.00	22.96	±2.40	–0.23	1.06	–8.37
30.00	43.05	±2.40	–0.23	NA	–9.81
50.00	71.75	±2.40	–0.23	NA	–10.55
75.00	107.63	±2.40	–0.23	NA	–12.39
100.00	143.50	±2.40	–0.23	NA	–14.01

Combined Uncertainties

Fluid Height (% Span)	Fluid Height (in)	Positive TLU (% Span)	Negative TLU (% Span)
0.00	0.00	4.23	–11.01
16.00	22.96	3.46	–11.00
30.00	43.05	2.40	–12.44
50.00	71.75	2.40	–13.18
75.00	107.63	2.40	–15.02
100.00	143.50	2.40	–16.64

7.1.4 Total Loop Uncertainty - High Level Alarm

LC-474, 475, 476, 484, 485, 486, 494, 495, & 496 (switch 2)

Per Reference 4.6.6, the total loop uncertainty associated with the comparators which provide the High Steam Generator Level alarm is computed with the following equation:

$$TLU_{comp} = \pm\sqrt{norTDU_{xmtr}^{2} + TDU_{comp}^{2}} + norPME\ @\ 75\%\ Level + AD_{xmtrBIAS}$$
$$TLU_{comp} = \pm\sqrt{1.50^2 + 1.61^2} - 12.39 - 0.23$$
$$TLU_{comp} = \pm\ 2.20\%\ Span - 12.62\%\ Span$$
$$TLU_{comp} = +\ 2.20\%\ Span, -14.82\%\ Span$$

7.1.5 Total Loop Uncertainty - Low Low Level Alarm

LC-474A, 475A, 476A, 484A, 485A, 486A, 494A, 495A, & 496A (switch 2)

Per Reference 4.6.6, the total loop uncertainty associated with the comparators which provide the Low Low Steam Generator Level alarm is computed with the following equation:

$$TLU_{comp} = \pm\sqrt{norTDU_{xmtr}^{2} + TDU_{comp}^{2}} + norPME\ @16\%\ Level + AD_{xmtrBIAS}$$
$$TLU_{comp} = \pm\sqrt{1.50^2 + 1.61^2} + 1.06 - 8.37 - 0.23$$
$$TLU_{comp} = \pm\ 2.20\%\ Span + 1.06\%\ Span - 8.60\%\ Span$$
$$TLU_{comp} = +3.26\%\ Span, -10.80\%\ Span$$

7.1.6 Total Loop Uncertainty - Low Level Alarm

LC-474B, 475B, 484B, 485B, 494B, 495B

Per Reference 4.6.6, the total loop uncertainty associated with the comparators which provide the Low Steam Generator Level alarm are computed with the following equation:

$$TLU_{comp} = \pm\sqrt{norTDU_{xmtr}^{2} + TDU_{comp}^{2}} + norPME\ @\ 30\% + AD_{xmtrBIAS}$$
$$TLU_{comp} = \pm\sqrt{1.50^2 + 1.61^2} - 9.81 - 0.23$$
$$TLU_{comp} = \pm\ 2.20\%\ Span - 10.04\%\ Span$$
$$TLU_{comp} = +2.20\%\ Span, -12.24\%\ Span$$

7.1.7 Total Loop Uncertainty - Input to AMSAC

Per Reference 4.6.6, the total loop uncertainty associated with the input to AMSAC are computed with the following equation:

$$TLU_{AMSAC} = \pm\sqrt{norTDU_{xmtr}{}^{2} + TDU_{isol}{}^{2}} + norPME + AD_{xmtrBIAS}$$

$$TLU_{AMSAC} = \pm\sqrt{1.50^2 + 1.67^2} + norPME - 0.23$$

$$TLU_{AMSAC} = \pm\ 2.24\%\ Span + norPME\%\ Span - 0.23\%\ Span$$

Fluid Height (% Span)	Fluid Height (in.)	Random Uncertainty (% Span)	$AD_{xmtrBIAS}$ Uncertainty (% Span)	Positive norPME (% Span)	Negative norPME (% Span)
0.00	0.00	±2.24	–0.23	1.83	–8.38
16.00	22.96	±2.24	–0.23	1.06	–8.37
30.00	43.05	±2.24	–0.23	NA	–9.81
50.00	71.75	±2.24	–0.23	NA	–10.55
75.00	107.63	±2.24	–0.23	NA	–12.39
100.00	143.50	±2.24	–0.23	NA	–14.01

Combined Uncertainties

Fluid Height (% Span)	Fluid Height (in.)	Positive TLU (% Span)	Negative TLU (% Span)
0.00	0.00	4.07	–10.85
16.00	22.96	3.30	–10.84
30.00	43.05	2.24	–12.28
50.00	71.75	2.24	–13.02
75.00	107.63	2.24	–14.86
100.00	143.50	2.24	–16.48

7.1.8 Total Loop Uncertainty for use in the EOPs - Indicator LI-474, 475, 476, 484, 485, 486, 494, 495, AND 496

Per Reference 4.6.6, the total loop uncertainty associated with the indicator, for normal conditions (15 psia to 1100 psia SG pressure) and 88°F to 190°F (Ref Leg temp), is computed with the following equation:

$$TLU_{ind} = \pm\sqrt{eopTDU_{xmtr}^{2} + TDU_{isol}^{2} + eopTDU_{ind}^{2}} + eopPME + AD_{xmtrBIAS}$$

$$TLU_{ind} = \pm\sqrt{1.87^2 + 1.67^2 + 2.91^2} + eopPME - 0.23$$

$$TLU_{ind} = \pm\ 3.84\%\ Span + eopPME\%\ Span - 0.23\%\ Span$$

Note: The eopPME values were determined in Section 6.4.3.

Fluid Height (% Span)	Fluid Height (in.)	Random Uncertainty (% Span)	$AD_{xmtrBIAS}$ Uncertainty (% Span)	Positive eopPME (% Span)	Negative eopPME (% Span)
0.00	0.00	± 3.84	–0.23	3.84	–4.71
16.00	22.96	± 3.84	–0.23	3.41	–1.26
30.00	43.05	± 3.84	–0.23	7.20	–2.45
50.00	71.75	± 3.84	–0.23	12.60	–4.16
75.00	107.63	± 3.84	–0.23	19.36	–6.30
100.00	143.50	± 3.84	–0.23	26.12	–8.44

Combined Uncertainties

Fluid Height (% Span)	Fluid Height (in)	Positive TLU (% Span)	Negative TLU (% Span)
0.00	0.00	7.68	–8.78
16.00	22.96	7.25	–5.33
30.00	43.05	11.04	–6.52
50.00	71.75	16.44	–8.23
75.00	107.63	23.20	–10.37
100.00	143.50	29.96	–12.51

7.2 TOTAL LOOP UNCERTAINTY - ACCIDENT

7.2.1 Total Loop Uncertainty - Indicator LI-474, 475, 476, 484, 485, 486, 494, 495, & 496

Per Reference 4.6.6, the total loop uncertainty associated with the indicator is computed with the following equation:

$$TLU_{ind} = \pm\sqrt{accTDU_{xmtr}^{2} + TDU_{isol}^{2} + TDU_{ind}^{2} + ATE_{xmtr}^{2} + ARE_{xmtr}^{2}} + IR + accPME + AD_{xmtrBIAS}$$

$$TLU_{ind} = \pm\sqrt{1.31^2 + 1.67^2 + 3.07^2 + 3.32^2 + 1.69^2} + IR + accPME - 0.23$$

$$TLU_{ind} = \pm\ 5.27\%\ Span + IR\%\ Span + accPME\%\ Span - 0.23\%\ Span$$

Note: The IR value was determined in Section 6.3 and the accPME values were determined in Section 6.4.2, and include FVE, DSE and FRE. Also note the IR effects are a positive bias and thus, not included in the negative TLU calculation.

Fluid Height (% Span)	Fluid Height (in.)	Random Uncertainty (% Span)	$AD_{xmtrBIAS}$ Uncertainty (% Span)	IR (% Span)	Posititve accPME (% Span)	Negative accPME (% Span)
0.00	0.00	±5.27	–0.23	2.21	13.71	–11.72
16.00	22.96	±5.27	–0.23	2.21	12.65	–7.94
30.00	43.05	±5.27	–0.23	2.21	10.24	–10.13
50.00	71.05	±5.27	–0.23	2.21	14.08	–11.21
75.00	107.63	±5.27	–0.23	2.21	20.93	–13.26
100.00	143.5	±5.27	–0.23	2.21	27.78	–15.31

Combined Uncertainties

Fluid Height (% Span)	Fluid Height (in.)	Posititve TLU (% Span)	Negative TLU (% Span)
0.00	0.00	21.19	–17.22
16.00	22.96	20.13	–13.44
30.00	43.05	17.72	–15.63
50.00	71.05	21.56	–16.71
75.00	107.63	28.41	–18.76
100.00	143.5	35.26	–20.81

7.2.2 Total Loop Uncertainty - Recorder

FR-478, 488, & 498

Per Reference 4.6.6, the total loop uncertainty associated with the recorder is computed with the following equation:

$$TLU_{rec} = \pm\sqrt{accTDU_{xmtr}^{2} + TDU_{isol}^{2} + TDU_{rec}^{2} + ATE_{xmtr}^{2} + ARE_{xmtr}^{2}} + IR + accPME + AD_{xmtrBIAS}$$

$$TLU_{rec} = \pm\sqrt{1.31^2 + 1.67^2 + 0.85^2 + 3.32^2 + 1.69^2} + IR + accPME - 0.23$$

$$TLU_{rec} = \pm\ 4.37\%\ Span + IR\%\ Span + accPME\%\ Span - 0.23\%\ Span$$

Note: The IR value was determined in Section 6.3 and the accPME values were determined in Section 6.4.2, and include FVE, DSE and FRE. Also note the IR effects are a positive bias and thus, not included in the negative TLU calculation.

Fluid Height (% Span)	Fluid Height (in.)	Random Uncertainty (% Span)	$AD_{xmtrBIAS}$ Uncertainty (% Span)	IR (% Span)	Positive accPME (% Span)	Negative accPME (% Span)
0.00	0.00	±4.37	–0.23	2.21	13.71	–11.72
16.00	22.96	±4.37	–0.23	2.21	12.65	–7.94
30.00	43.05	±4.37	–0.23	2.21	10.24	–10.13
50.00	71.75	±4.37	–0.23	2.21	14.08	–11.21
75.00	107.63	±4.37	–0.23	2.21	20.93	–13.26
100.00	143.50	±4.37	–0.23	2.21	27.78	–15.31

Combined Uncertainties

Fluid Height (% Span)	Fluid Height (in.)	Positive TLU (% Span)	Negative TLU (% Span)
0.00	0.00	20.29	–16.32
16.00	22.96	19.23	–12.54
30.00	43.05	16.82	–14.73
50.00	71.75	20.66	–15.81
75.00	107.63	27.51	–17.86
100.00	143.50	34.36	–19.91

7.2.3 Total Loop Uncertainty - Input to ERFIS

Per Reference 4.6.6, the total loop uncertainty at the input to ERFIS is computed with the following equation:

$$TLU_{ERFIS} = \pm\sqrt{accTDU_{xmtr}^{\ 2} + TDU_{isol}^{\ 2} + TDU_{isol}^{\ 2} + ATE_{xmtr}^{\ 2} + ARE_{xmtr}^{\ 2}} + IR + accPME + AD_{xmtrBIAS}$$

$$TLU_{ERFIS} = \pm\sqrt{1.31^2 + 1.67^2 + 1.67^2 + 3.32^2 + 1.69^2} + IR + accPME - 0.23$$

$$TLU_{ERFIS} = \pm\ 4.60\%\ Span + IR\%\ Span + accPME\%\ Span - 0.23\%\ Span$$

Note: The IR value was determined in Section 6.3 and the accPME values were determined in Section 6.4.2, and include FVE, DSE and FRE. Also note the IR effects are a positive bias and thus, not included in the negative TLU calculation.

Fluid Height (% Span)	Fluid Height (in.)	Random Uncertainty (% Span)	$AD_{xmtrBIAS}$ Uncertainty (% Span)	IR (% Span)	Positive accPME (% Span)	Negative accPME (% Span)
0.00	0.00	± 4.60	−0.23	2.21	13.71	−11.72
16.00	22.96	± 4.60	−0.23	2.21	12.65	−7.94
30.00	43.05	± 4.60	−0.23	2.21	10.24	− 10.13
50.00	71.75	± 4.60	−0.23	2.21	14.08	−11.21
75.00	107.63	± 4.60	−0.23	2.21	20.93	−13.26
100.00	143.50	± 4.60	−0.23	2.21	27.78	− 15.31

Combined Uncertainties

Fluid Height (% Span)	Fluid Height (in.)	Positive Uncertainty (% Span)	Negative Uncertainty (% Span)
0.00	0.00	20.52	−16.55
16.00	22.96	19.46	−12.77
30.00	43.05	17.05	−14.96
50.00	71.75	20.89	−16.04
75.00	107.63	27.74	−18.09
100.00	143.50	34.59	−20.14

7.2.4 Total Loop Uncertainty - Low Low Level Reactor Trip

Although the Low Low Level Reactor Trip occurs at 16% level, the PME values for 0% level are used below. This is conservative and allows for additional margin.
LC-474, 475, 476, 484, 485, 486, 494, 495, & 496 (switch 1)

Uncertainties for Feedwater Line Break Accident

Per Reference 4.6.6, the total loop uncertainty associated with the comparators that provide the Low Low Steam Generator Level Reactor Trip is computed with the following equation:

$$TLU_{comp} = \pm\sqrt{accTDU_{xmtr}^2 + TDU_{comp}^2 + ATE_{xmtr}^2} + IR + accPME\ @\ 0\%\ Level + AD_{xmtrBIAS}$$

$$TLU_{comp} = \pm\sqrt{1.31^2 + 1.61^2 + 3.32^2} + 2.21 + 5.79 - 11.72 - 0.23$$

$$TLU_{comp} = \pm\ 3.92\%\ Span + 8.00\%\ Span - 11.95\%\ Span$$

$$TLU_{comp} = +11.92\%\ Span\ ,\ -15.87\%\ Span$$

The accPME in this case is taken from the specific case for a Feedwater Line Break Accident. This is acceptable as the conditions that result from a Main Steam Line Break (MSLB) are overly conservative and the Low Low Steam Generator Trip is not credited in an MSLB accident.

Uncertainties for Loss of Offsite Power and for Loss of Normal Feedwater Accidents

For these accidents, no harsh conditions exist at the transmitter location, so the limiting accident scenario is the post-seismic condition. Per Reference 4.6.6, the total loop uncertainty associated with the comparators that provide the Low Low Steam Generator Level Reactor Trip is computed with the following equation:

$$TLU_{comp} = \pm\sqrt{norTDU_{xmtr}^2 + TDU_{comp}^2 + SE_{xmtr}^2} + norPME\ @\ 0\%\ Level + MDDPb + AD_{xmtrBIAS}$$

From Section 5.18, MDDPb = +4.88% Span for accident conditions.

$$TLU_{comp} = \pm\sqrt{1.50^2 + 1.61^2 + 1.16^2} + 1.83 - 8.38 + 4.88 - 0.23$$

$$TLU_{comp} = \pm\ 2.49\%\ Span + 6.71\%\ Span\ - 8.61\%\ Span$$

$$TLU_{comp} = +\ 9.20\%\ Span,\ -11.10\%\ Span$$

This section shows that the bounding scenario is for the feedwater line break resulting in a harsh environment at the transmitter(s).

7.2.5 Total Loop Uncertainty for use in the EOPs - Indicator LI-474, 475, 476, 484, 485, 486, 494, 495, AND 496

Per Reference 4.6.6, the total loop uncertainty associated with the indicator is computed with the following equation. The individual error components, $acceopTDU_{xmtr}$, TDU_{isol}, TDU_{ind}, ATE_{xmtr}, and ARE_{xmtr} were determined in Sections 6.6.11, 6.8.7, 6.9.9, 6.1.1, and 6.1.3, respectively.

$$TLU_{ind} = \pm\sqrt{accTDU_{xmtr}^{2} + TDU_{isol}^{2} + TDU_{ind}^{2} + ATE_{xmtr}^{2} + ARE_{xmtr}^{2}} + IR + acceopPME + AD_{xmtrBIAS}$$

$$TLU_{ind} = \pm\sqrt{1.31^2 + 1.67^2 + 2.91^2 + 3.32^2 + 1.69^2} + IR + acceopPME - 0.23$$

$$TLU_{ind} = \pm\ 5.18\%\ Span + IR\%\ Span + acceopPME\%\ Span - 0.23\%\ Span$$

Note: The IR value was determined in Section 6.3 and the acceopPME values were determined in Section 6.4.4, and include FVE, DSE and FRE. Also note the IR effects are a positive bias and thus, not included in the negative TLU calculation.

Fluid Height (% Span)	Fluid Height (in.)	Random Uncertainty (% Span)	$AD_{xmtrBIAS}$ Uncertainty (% Span)	IR (% Span)	Posititve acceopPME (% Span)	Negative acceopPME (% Span)
0.00	0.00	± 5.18	–0.23	2.21	9.52	–11.72
16.00	22.96	± 5.18	–0.23	2.21	8.47	–7.94
30.00	43.05	± 5.18	–0.23	2.21	8.05	–9.90
50.00	71.05	± 5.18	–0.23	2.21	14.08	–10.98
75.00	107.63	± 5.18	–0.23	2.21	20.93	–13.26
100.00	143.5	± 5.18	–0.23	2.21	27.78	–15.31

Combined Uncertainties

Fluid Height (% Span)	Fluid Height (in.)	Posititve TLU (% Span)	Negative TLU (% Span)
0.00	0.00	16.91	–17.13
16.00	22.96	15.86	–13.35
30.00	43.05	15.44	–15.31
50.00	71.05	21.47	–16.39
75.00	107.63	28.32	–18.67
100.00	143.5	35.17	–20.72

7.3 TOTAL LOOP UNCERTAINTY – POST SEISMIC

7.3.1 Total Loop Uncertainty - High Level Valve Interlock

LC-474, 475, 476, 484, 485, 486, 494, 495, & 496 (switch 1)

Per Reference 4.6.6, the total loop uncertainty associated with the comparators which provide the High Steam Generator Level Valve interlock is computed with the following equation:

$$TLU_{comp} = \pm\sqrt{norTDU_{xmtr}^{\;2} + TDU_{comp}^{\;2} + SE_{xmtr}^{\;2}} + norPME \text{ @ } 100\% \text{ Level} + AD_{xmtrBIAS}$$
$$TLU_{comp} = \pm\sqrt{1.50^2 + 1.61^2 + 1.16^2} + 0.00 - 14.01 - 0.23$$
$$TLU_{comp} = \pm 2.49\% \text{ Span} - 14.24\% \text{ Span}$$
$$TLU_{comp} = +2.49\% \text{ Span}, -16.73\% \text{ Span}$$

7.4 LOOP AS FOUND TOLERANCE

7.4.1 Loop As Found Tolerance - Indicator LI-474, 475, 476, 484, 485, 486, 494, 495, & 496

Per Reference 4.6.6, the following equation is used to calculate the indicator Loop As Found Tolerance ($LAFT_{ind}$):

$$LAFT_{ind} = \pm\sqrt{AFT_{xmtr}^{\;2} + AFT_{isol}^{\;2} + AFT_{ind}^{\;2}}$$
$$LAFT_{ind} = \pm\sqrt{0.74^2 + 1.20^2 + 2.44^2}$$
$$LAFT_{ind} = \pm 2.82\% \text{ Span}$$

7.4.2 Loop As Found Tolerance - Input to ERFIS

Per Reference 4.6.6, the following equation is used to calculate the ERFIS Loop As Found Tolerance ($LAFT_{ERFIS}$):

$$LAFT_{ERFIS} = \pm\sqrt{AFT_{xmtr}^{\;2} + AFT_{isol}^{\;2} + AFT_{isol}^{\;2}}$$
$$LAFT_{ERFIS} = \pm\sqrt{0.74^2 + 1.20^2 + 1.20^2}$$
$$LAFT_{ERFIS} = \pm 1.85\% \text{ Span}$$

7.4.3 Loop As Found Tolerance - Comparators

LC-474, 475, 476, 484, 485, 486, 494, 495, & 496
LC-474A, 475A, 476A, 484A, 485A, 486A, 494A, 495A, & 496A
LC-474B, 475B, 484B, 485B, 494B, & 495B

Per Reference 4.6.6, the following equation is used to calculate the comparator Loop As Found Tolerance ($LAFT_{comp}$):

$$LAFT_{comp} = \pm\sqrt{AFT_{xmtr}{}^2 + AFT_{comp}{}^2}$$
$$LAFT_{comp} = \pm\sqrt{0.74^2 + 1.16^2}$$
$$LAFT_{comp} = \pm\ 1.38\%\ \text{Span}$$

7.4.4 Loop As Found Tolerance - Recorder

FR-478, 488, & 498

Per Reference 4.6.6, the following equation is used to calculate the recorder Loop As Found Tolerance ($LAFT_{rec}$):

$$LAFT_{rec} = \pm\sqrt{AFT_{xmtr}{}^2 + AFT_{isol}{}^2 + AFT_{rec}{}^2}$$
$$LAFT_{rec} = \pm\sqrt{0.74^2 + 1.20^2 + 0.59^2}$$
$$LAFT_{rec} = \pm\ 1.53\%\ \text{Span}$$

7.4.5 Loop As Found Tolerance - Input to AMSAC

Per Reference 4.6.6, the following equation is used to calculate the Loop As Found Tolerance for AMSAC ($LAFT_{AMSAC}$):

$$LAFT_{AMSAC} = \pm\sqrt{AFT_{xmtr}{}^2 + AFT_{isol}{}^2}$$
$$LAFT_{AMSAC} = \pm\sqrt{0.74^2 + 1.20^2}$$
$$LAFT_{AMSAC} = \pm\ 1.41\%\ \text{Span}$$

7.5 GROUP AS FOUND TOLERANCE

7.5.1 Group As Found Tolerance - Indicator LI-474, 475, 476, 484, 485, 486, 494, 495, & 496

Per Reference 4.6.6, the following equation is used to calculate the indicator Group As Found Tolerance ($GAFT_{ind}$):

$$GAFT_{ind} = \pm\sqrt{AFT_{isol}{}^2 + AFT_{ind}{}^2}$$
$$GAFT_{ind} = \pm\sqrt{1.20^2 + 2.44^2}$$
$$GAFT_{ind} = \pm\ 2.72\%\ \text{Span}$$

7.5.2 Group As Found Tolerance - Input to ERFIS

Per Reference 4.6.6, the following equation is used to calculate the ERFIS Group As Found Tolerance ($GAFT_{ERFIS}$):

$$GAFT_{ERFIS} = \pm\sqrt{AFT_{isol}{}^2 + AFT_{isol}{}^2}$$
$$GAFT_{ERFIS} = \pm\sqrt{1.20^2 + 1.20^2}$$
$$GAFT_{ERFIS} = \pm\ 1.70\%\ \text{Span}$$

7.5.3 Group As Found Tolerance - Recorder

FR-478, 488, & 498

Per Reference 4.6.6, the following equation is used to calculate the recorder Group As Found Tolerance ($GAFT_{rec}$):

$$GAFT_{rec} = \pm\sqrt{AFT_{isol}^{2} + AFT_{rec}^{2}}$$
$$GAFT_{rec} = \pm\sqrt{1.20^{2} + 0.59^{2}}$$
$$GAFT_{rec} = \pm\ 1.34\%\ \text{Span}$$

7.5.4 Group As Found Tolerance - Comparators

LC-474, 475, 476, 484, 485, 486, 494, 495, & 496
LC-474A, 475A, 476A, 484A, 485A, 486A, 494A, 495A, & 496A
LC-474B, 475B, 484B, 485B, 494B, & 495B

Per Reference 4.6.6, the following equation is used to calculate the comparator Group As Found Tolerance ($GAFT_{comp}$):

$$GAFT_{comp} = \pm\ AFT_{comp}$$
$$GAFT_{comp} = \pm\ 1.16\%\ \text{Span}$$

7.5.5 Group As Found Tolerance - Input to AMSAC

Per Reference 4.6.6, the following equation is used to calculate the AMSAC Group As Found Tolerance ($GAFT_{AMSAC}$):

$$GAFT_{AMSAC} = \pm\ AFT_{isol}$$
$$GAFT_{AMSAC} = \pm\ 1.20\%\ \text{Span}$$

8.0 DISCUSSION OF RESULTS

High Steam Generator Level Valve Interlock Setpoint - LC-474, 475, 476, 484, 485, 486, 494, 495, & 496 (dual comparator switch 1)

The function of this setpoint is to close the main feedwater control valve before the Steam Generator is full of water. Therefore, the High Steam Generator Level interlock setpoint is an increasing setpoint and is computed using negative total loop uncertainties. Per Reference 4.6.6, the following equation is used to calculate the maximum value for this setpoint:

$SP_{limit} \leq AL - TLU$

where,

SP_{limit} = calculated setpoint limit
AL = Analytical Limit
TLU = Total Loop Uncertainty

Per Section 7.3.1 of this calculation, the negative Total Loop Uncertainty associated with this setpoint is −16.73% Span. Per Section 7.3.1, ± 2.49% Span of this is the random component. Per Reference 4.6.6, the random uncertainty may be reduced by applying the single side of interest. Therefore, the random loop uncertainty for this setpoint is ± 2.05% span (0.8225 · 2.49% Span). This results in a negative uncertainty of −16.29% Span (−2.05% Span − 14.24% Span). Per Design Input 5.13, the High Steam Generator Level valve interlock analytical limit is 97% Span. Therefore, Rev. 16

$SP_{limit} \leq 97\%\ Span - 16.29\%\ Span$
$SP_{limit} \leq 80.71\%\ Span$

Per References 4.5.2 through 4.5.10, the High Steam Generator valve interlock setpoint is currently set to 75% Span increasing. The Margin (M) associated with this setpoint is computed as follows:

$M = SP_{limit} - \text{Calibrated Setpoint}$
$M = 80.71\%\ Span - 75\%\ Span$
$M = 5.71\%\ Span$

Therefore, the current High Steam Generator Level valve interlock setpoint is conservative.

For a rising setpoint, the Allowable Value (AV) is determined using the following equation:

AV = SP + GAFT **(Eq. 29 - Ref. 4.6.6 // FAD-EG-ALL-1153, Section 5.3.2.4)**

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Where: SP = Hi SG Level Valve Interlock calibrated setpoint (= 75% span).*
GAFT = Calculated Group As Found Tolerance (= 1.16 % - Section 7.5.4 of this calc).*

Thus, AV = 75% span + 1.16% span
AV*** = 76.16% span

Therefore, to ensure channel operability and protection of the analytical limit (AL) assumed in the safety analysis, the surveillance measured setpoint should be ≤ 76.16% span.

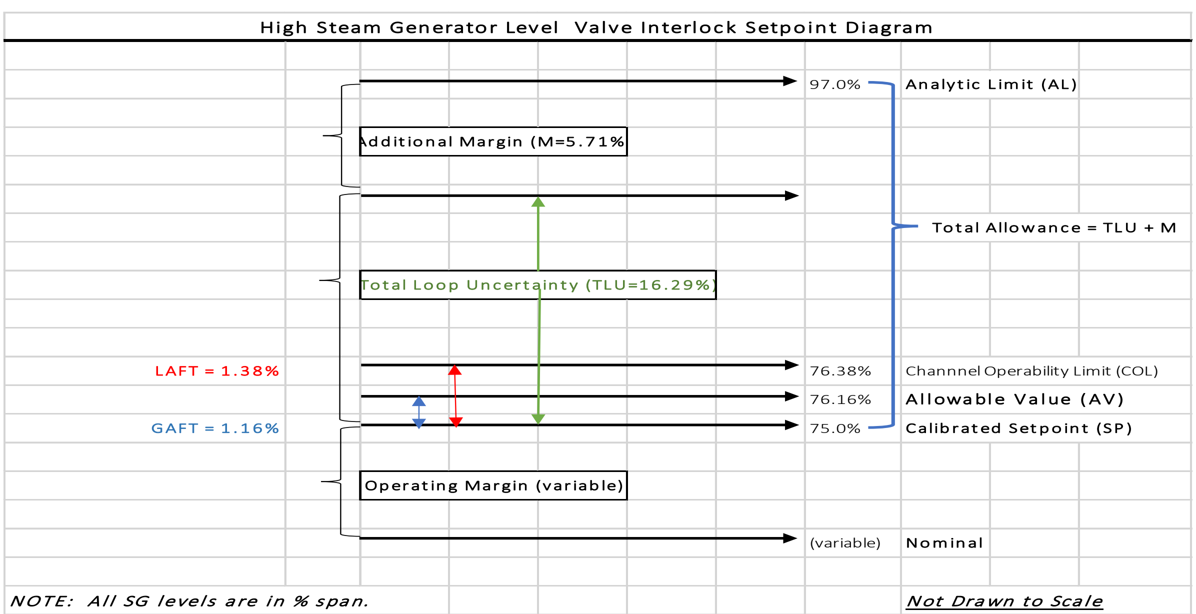
*Note: * SP is the actual setpoint at which the trip action occurs and, for increasing setpoints, can be conservatively set at a lower value than SP_{lim} = AL + TLU.*

*** The GAFT is determined using vendor specification/bounding values of calibration tolerance, device dift and test equipment measurement uncertainty.*

**** AV by definition is a limit (acceptance criterion), which the surveillance measured setpoint should be maintained within to ensure operability of the channel.*

The Loop As Found Tolerance (LAFT) of 1.38% Span is computed in Section 7.4.3. Per Reference 4.6.6, the Channel Operability Limit (COL) is computed with the following equation:

COL = SP + LAFT, where SP = calibrated setpoint
COL = 75% Span + 1.38% Span
COL = 76.38% Span



<u>High Steam Generator Level Alarm Setpoint - LC-474, 475, 476, 484, 485, 486, 494, 495, & 496 (switch 2)</u>

The function of this setpoint is to warn the operator that Steam Generator Level is approaching the valve interlock setpoint which closes the feedwater control valves. Therefore, the High Steam Generator Level alarm setpoint is an increasing setpoint and is computed using negative total loop uncertainties. Per Reference 4.6.6, the following equation is used to calculate the maximum value for this setpoint:

$SP_{limit} \leq AL - TLU$

where,

SP_{limit} = calculated setpoint limit
AL = Analytical Limit
TLU = Total Loop Uncertainty

The function of this alarm is to warn the operator before the feedwater control valves are closed by the High Steam Generator Level valve interlock, and this alarm is provided by the same dual bistable module that provides the valve interlock. Any uncertainty at the input of the bistable module will offset both the interlock and alarm setpoints in the same direction. Therefore, the only uncertainties which need to be considered for this setpoint are those associated with the bistable which provides the valve interlock and the bistable which provides the alarm. Therefore, the total uncertainty associated with this setpoint is the square root sum of squares of two bistable uncertainty terms. Per Section 6.7.7, the uncertainty associated with one bistable is ± 1.61% Span. Therefore, the total uncertainty associated with this setpoint is −2.28% Span (negative portion of the SRSS of two ± 1.61% Span terms). Per Design Input 5.15, the High Steam Generator Level alarm setpoint limit is 75% Span. Therefore,

$SP_{limit} \leq 75\% \text{ Span} - 2.28\% \text{ Span}$
$SP_{limit} \leq 72.72\% \text{ Span}$

Per References 4.5.2 through 4.510, the High Steam Generator valve interlock setpoint is currently set to 60% Span increasing. The Margin (M) associated with this setpoint is computed as follows:

$M = SP_{limit} - \text{Calibrated Setpoint}$
$M = 72.72\% \text{ Span} - 60\% \text{ Span}$
$M = 12.72\% \text{ Span}$

Therefore, the current High Steam Generator Level alarm setpoint is conservative.

Low Steam Generator Level Alarm Setpoint - LC-474B, 475B, 484B, 485B, 494B, & 495B

The function of this setpoint is to provide an alarm when Steam Generator level is approaching the Low Steam Generator Level Reactor Trip setpoint. Therefore, the Low Steam Generator level alarm is a decreasing setpoint and is computed using positive total loop uncertainties. Per Reference 4.6.6, the following equation is used to calculate the minimum value for this setpoint:

$$SP_{limit} \geq AL + TLU$$

where,

SP_{limit} = calculated setpoint limit
AL = Analytical Limit
TLU = Total Loop Uncertainty

Per Section 7.1.6 of this calculation, the positive Total Loop Uncertainty associated with this setpoint is 2.20% Span. Per Design Input 5.16, the Low Steam Generator Level alarm setpoint limit is 30% Span. Therefore,

$$SP_{limit} \geq 30\%\ Span + 2.20\%\ Span$$
$$SP_{limit} \geq 32.20\%\ Span$$

Per References 4.5.2 through 4.5.10, the Low Steam Generator Level alarm setpoint is currently set to 35% Span decreasing. The Margin (M) associated with this setpoint is computed as follows:

$$M = \text{Calibrated Setpoint} - SP_{limit}$$
$$M = 35\%\ Span - 32.20\%\ Span$$
$$M = 2.80\%\ Span$$

Therefore, the current alarm setpoint is conservative.

Per Section 7.5.4 of this calculation, the Group As Found Tolerance (GAFT) is 1.16% Span. Per Reference 4.6.6, the Allowable Value (AV) associated with this setpoint is computed as follows:

AV ≥ SP − GAFT, where SP = calibrated setpoint
AV ≥ 30% Span − 1.16% Span
AV ≥ 28.84% Span

The Loop As Found Tolerance (LAFT) of 1.38% Span is computed in Section 7.4.3. Per Reference 4.6.6, the Channel Operability Limit (COL) is computed with the following equation:

COL = SP − LAFT, where SP = calibrated setpoint
COL = 30% Span − 1.38% Span
COL = 28.62% Span

<u>Low Low Steam Generator Level Alarm Setpoint - LC-474A, 475A, 476A, 484A, 485A, 486A, 494A, 495A, & 496A (dual comparator switch 2)</u>

The function of this setpoint is to provide an alarm when Steam Generator level is approaching the Low Low Steam Generator Level Reactor Trip setpoint. Therefore, the Low Low Steam Generator level alarm is a decreasing setpoint and is computed using positive total loop uncertainties. Per Reference 4.6.6, the following equation is used to calculate the minimum value for this setpoint:

$SP_{limit} \geq AL + TLU$

where,

SP_{limit} = calculated setpoint limit
AL = Analytical Limit
TLU = Total Loop Uncertainty

Per Section 7.1.5 of this calculation, the positive Total Loop Uncertainty associated with this setpoint is 3.26% Span. Per Design Input 5.17, Low Low Steam Generator Level alarm setpoint limit is 16% Span. Therefore,

$SP_{limit} \geq 16\%\ Span + 3.26\%\ Span$
$SP_{limit} \geq 19.26\%\ Span$

Per Reference 4.5.2-10, the Low Low Steam Generator Level Alarm setpoint is currently set to 35% Span decreasing. The Margin (M) associated with this setpoint is computed as follows:

$M = \text{Calibrated Setpoint} - SP_{limit}$
$M = 35\%\ Span - 19.26\%\ Span$
$M = 15.74\%\ Span$

Therefore, the current alarm setpoint is conservative.

Low Low Steam Generator Level Reactor Trip Setpoint - LC-474, 475, 476, 484, 485, 486, 494, 495, & 496

The function of this setpoint is to provide a Reactor Trip before Steam Generator level falls below the Low Low Steam Generator analytical limit. Therefore, the Low Low Steam Generator Reactor Trip setpoint is a decreasing setpoint and is computed using positive total loop uncertainties. Per Reference 4.6.6, the following equation is used to calculate the minimum value for this setpoint:

$SP_{limit} \geq AL + TLU$

where,

SP_{limit} = calculated setpoint limit
AL = Analytical Limit
TLU = Total Loop Uncertainty

Per Section 7.2.4 of this calculation, the random portion of the Total Loop Uncertainty associated with this setpoint is ±3.92% Span, and the positive bias portion under accident conditions is +8.00% Span. Per Reference 4.6.6, the random loop uncertainty may be reduced by applying the single side of interest. Therefore, the random loop uncertainty for this setpoint is ±3.22% Span (3.92% Span · 0.8225). Therefore, the positive total loop uncertainty associated with this setpoint is 11.22% Span .

Per Reference 4.7.3, Table 2, the Low Low Steam Generator Level Reactor Trip setpoint analytical limit is 0% Span. Therefore,

$SP_{limit} \geq 0\%$ Span + 11.22% Span
$SP_{limit} \geq 11.22\%$ Span

Per Reference 4.7.2, Table 3.3.1-1, Item 13, the Low Low Steam Generator Level Reactor Trip setpoint is currently set to 16% Span decreasing. The Margin (M) associated with this setpoint is computed as follows: Rev. 16

M = Calibrated Setpoint – SP_{limit}
M = 16% Span – 11.22% Span
M = 4.78% Span

Per Reference 4.6.6, the Allowable Value (AV) associated with Low-Low Steam Generator Level Reactor Trip Setpoint (falling setpoint) is computed as follows:

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AV = SP – GAFT (Eq. 30 - Ref. 4.6.6 // FAD-EG-ALL-1153, Section 5.3.2.4)

Where SP = Low-Low SG Level Calibrated Trip Setpoint (= 16% span//Ref. 4.7.2, Table 3.3.1-1, Item 13)
GAFT = Calculated Group As Found Tolerance (= 1.16% span - Section 7.5.4 of calc).

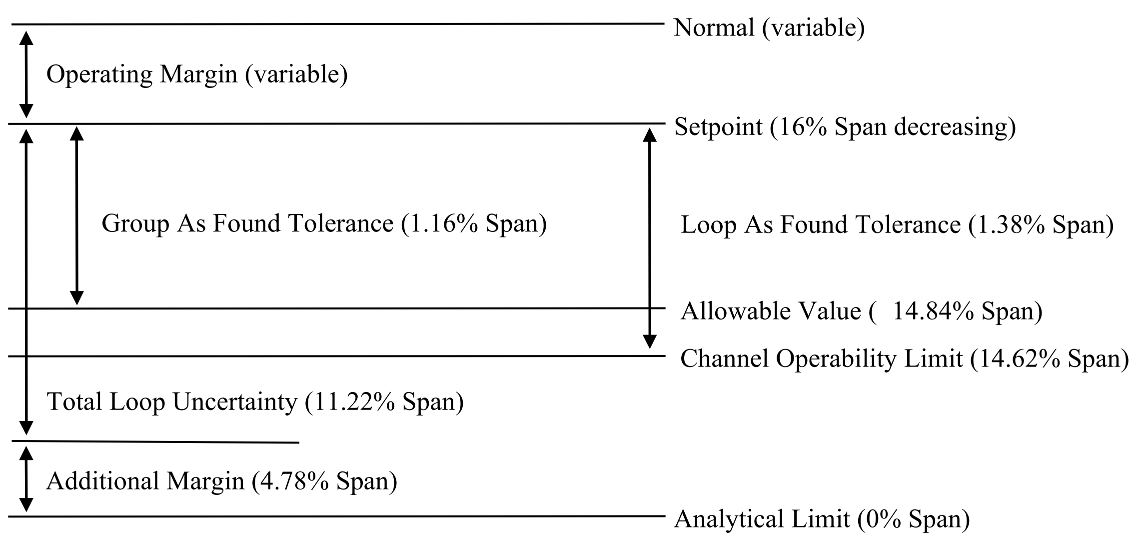
Thus, AV = 16% Span – 1.16% Span
*AV = 14.84% Span

Therefore, to ensure channel operability and protection of the analytical limit (AL) assumed in the safety analysis, the surveillance measured setpoint should be $\geq$ 14.84% span.

* Note: The plant, however, has conservatively implemented AV = 15.36% span (Reference 4.7.2, RPS Instrumentation, Table 3.3.1-1, Item 13).

The Loop As Found Tolerance (LAFT) of 1.38% Span is computed in Section 7.4.3. Per Reference 4.6.6, the Channel Operability Limit (COL) is computed with the following equation:

COL = SP – LAFT, where SP = calibrated setpoint
COL = 16% Span – 1.38% Span
COL = 14.62% Span



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Low Low Steam Generator Level Reactor Trip Setpoint Diagram

8.1 Impact On Improved Technical Specifications

Based on the results of this calculation, there is no impact to the Technical Specifications.

8.2 Impact On Ufsar

Revision 13 of RNP-I/INST-1070 does not impact the UFSAR.

8.3 Impact On Design Basis Documents

This calculation impacts no design basis documents.

8.4 Impact On Other Calculations

Revision 13 of this calculation does not impact other calculations.

This calculation, revision 12, impacts the following calculations:

1. RNP-I/INST-1103
   - The instrument uncertainty values used in RNP-I/INST-1103 Rev. 6 (Reference 4.2.4) references this calculation. Due to changes in total loop uncertainties and the revised IR value, calculations for various EOP setpoints within RNP-I/INST-1103 Rev. 6 require change.

2. RNP-I/INST-1079
   - RNP-I/INST-1079 Rev. 4 (Reference 4.2.9) references this calculation but no AOP setpoints are affected by this revision.

3. RNP-M/MECH-1651
   - RNP-M/MECH-1651 Rev. 16 (Reference 4.2.3) references this calculation. Due to changes in steam generator water level uncertainty, parameter 14 in Table I of RNP-M/MECH-1651 requires update to revise the TLU from 3.99% to 3.80%.

In addition, calculations RNP-I/INST-1132 and RNP-I/INST-1071 reference this calculation, but are not impacted by the changes made in this revision. Note that RNP-I/INST-1071 is identified as an impacted document by EC 413069, but this is due to the replacement of recorder LR-477. The changes made to RNP-I/INST-1070 under this revision for the replacement of recorders FR-478, FR-488 and FR-498 do not impact RNP-I/INST-1071.

8.5 Impact On Plant Procedures

The following procedures reference this calculation, although none are directly affected by this revision:

PIC-005, Steam Generator A Narrow Range Level Transmitter LT-474 Calibration, Revision 13 (Reference 4.5.1)
PIC-005-1, Steam Generator A Narrow Range Level Transmitter LT-475 Calibration, Revision 0 (Reference 4.5.14)
PIC-005-2, Steam Generator A Narrow Range Level Transmitter LT-476 Calibration, Revision 0 (Reference 4.5.15)
PIC-005-4, Steam Generator B Narrow Range Level Transmitter LT-484 Calibration, Revision 0 (Reference 4.5.16)
PIC-005-5, Steam Generator B Narrow Range Level Transmitter LT-485 Calibration, Revision 0 (Reference 4.5.17)
PIC-005-6, Steam Generator B Narrow Range Level Transmitter LT-486 Calibration, Revision 0 (Reference 4.5.18)
PIC-005-8, Steam Generator C Narrow Range Level Transmitter LT-494 Calibration, Revision 0 (Reference 4.5.19)
PIC-005-9, Steam Generator C Narrow Range Level Transmitter LT-495 Calibration, Revision 1 (Reference 4.5.20)
PIC-005-10, Steam Generator C Narrow Range Level Transmitter LT-96 Calibration, Revision 0 (Reference 4.5.21)
LP-027, Steam Generator #1 Narrow Range (N/R) Level Channel 476, Revision 16 (Reference 4.5.2)
LP-028, Steam Generator #2 Narrow Range (N/R) Level Channel 486, Revision 15 (Reference 4.5.3)
LP-029, Steam Generator #3 Narrow Range (N/R) Level Channel 496, Revision 19 (Reference 4.5.4)
LP-030, Steam Generator #1 Narrow Range (N/R) Level Channel 474, Revision 15 (Reference 4.5.5)
LP-031, Steam Generator #2 Narrow Range (N/R) Level Channel 484, Revision 15 (Reference 4.5.6)
LP-032, Steam Generator #3 Narrow Range (N/R) Level Channel 494, Revision 13 (Reference 4.5.7)
LP-033, Steam Generator #1 Narrow Range (N/R) Level Channel 475, Revision 13 (Reference 4.5.8)
LP-034, Steam Generator #2 Narrow Range (N/R) Level Channel 485, Revision 16 (Reference 4.5.9)
LP-035, Steam Generator #3 Narrow Range (N/R) Level Channel 495, Revision 13 (Reference 4.5.10)
PIC-844, Yokogawa Recorders, Revision 13 (Reference 4.5.12)

9.0 SCALING CALCULATIONS

9.1 Level Transmitter (LT-474, 475, 476, 484, 485, 486, 494, 495, and 496)

Per EDB, each transmitter is a Rosemount model 3154ND2R2F1E7 differential pressure transmitter. Per Reference 4.4.3, a range code 2 transmitter has the following differential pressure ranges 0-25 to 0-250 inwc.

Per Reference 4.7.9, the Steam Generator pressure at 100% load is approximately 800 psia, and the pressure at 0% load is approximately 1020 psia. Per Reference 4.7.5, the Steam Generator temperature at 800 psia is 518°F, and the temperature at 1020 psia is 547°F. Per Reference 4.1.15, the distance between the upper and lower instrument taps is 143 inches. Per Reference 4.1.14, the Steam Generator is constructed from SA-302 Grade B Plate. This material is defined in Reference 4.7.8 as manganese-molybdenum. Per Reference 4.7.7, the average coefficient of thermal expansion for this material between 500°F and 550°F is 7.73×10^{-6} in / in / °F. The following equation is used to compute the thermal expansion of the Steam Generator during normal operation (100% load):

$$H_{operating} = H_{cold} \left[1 + \alpha(T_{operating} - T_{cold}) \right]$$
$$H_{operating} = 143 \text{ inches} \left[1 + 7.73 \times 10^{-6}(518\ °F - 70\ °F) \right]$$
$$H_{operating} = 143.5 \text{ inches}$$

As stated above, the normal operating pressure range of the Steam Generator is 800 psia (100% load) and 1020 psia (0% load). Therefore, the transmitters are scaled for a process fluid of compressed water at 900 psia @500°F and saturated steam at 900 psia. The reference leg contains compressed water at a nominal temperature of 120°F. The following equation is used to obtain the calibration values for the transmitter:

$$\Delta P_C = h\, SG_{WC} + (H - h) SG_{SC} - H\, SG_{RC}$$

where,

h	=	height of fluid (inches)
H	=	height of measured level span = 143.5 inches
SG_{WC}	=	specific gravity of fluid = 0.787341 @ 900 psia, 500°F
SG_{SC}	=	specific gravity of steam = 0.032034 @ 900 psia, saturated
SG_{RC}	=	specific gravity of reference leg fill fluid = 0.992946 @ 900 psia, 120°F, compressed

Therefore,

Fluid Height (% Span)	Fluid Height (in)	Calibrated ΔP_C (inwc)
0.00%	0.00	-138
16.00%	22.96	-121
30.00%	43.05	-105
50.00%	71.75	-84
75.00%	107.63	-57
100.00%	143.50	-30

Transmitter Calibration Points

Per Reference 4.4.3, a static pressure span effect of 0.75% of input per 1000 psi is specified. This effect is calibrated out by adjusting the calibrated range of the transmitter as follows:

$$0.75\%\text{ of input}\left(\frac{900\text{ psi}}{1000\text{ psi}}\right) = 0.675\%\text{ of input}$$

For zero percent level,

0.675% (-138 inwc / 100%) = -0.932 inwc
-0.932 inwc (100% Span / 108 inwc) = -0.863% Span
-0.863% Span (16 mA / 100% Span) = -0.138 mA
4.000 mA - 0.138 mA = 3.862 mA

For 100 percent level,

0.675% (-30 inwc / 100%) = -0.203 inwc
-0.203 inwc (100% Span / 108 inwc) = -0.188% Span
-0.188% Span (16 mA / 100% Span) = -0.030 mA
20.000 mA - 0.030 mA = 19.970 mA

Therefore, the transmitters are calibrated from -138 to -30 inwc (3.862 mA to 19.970 mA) which corresponds to -137.1 to -29.8 inwc (4 to 20 mA) at zero pressure. At the operating pressure, the span of each loop is 108 inwc.

The following equation is used to compute the required transmitter output for a given differential pressure input:

$$E_O = \left(\frac{4\ \text{Vdc}}{107.3\ \text{inwc}}\right)(137.1\ \text{inwc} - P) + 1.000\ \text{Vdc}$$

Per Section 6.6.12 of this calculation, the As Found Tolerance (AFT) of the transmitter is ± 0.76% Span. Per Section 6.6.13 of this calculation, the As Left Tolerance (ALT) of the transmitter is ± 0.50% Span. The AFT and ALT are converted to voltage units with the following equations:

$$\text{AFT(Vdc)} = \pm 4\ \text{Vdc}\left(\frac{\text{AFT(\% Span)}}{100}\right) = \pm 4\ \text{Vdc}\left(\frac{0.74\%\ Span}{100}\right) = \pm\ 0.030\ \text{Vdc}$$

$$\text{ALT(Vdc)} = \pm 4\ \text{Vdc}\left(\frac{\text{ALT(\% Span)}}{100}\right) = \pm 4\ \text{Vdc}\left(\frac{0.50\%\ \text{Span}}{100}\right) = \pm\ 0.020\ \text{Vdc}$$

The calibration table for the transmitter is as follows:

Required Input (inwc)	Desired Output (Vdc)	As Found Tolerance (Vdc)	As Left Tolerance (Vdc)
137.1	1.000	0.970 to 1.030	0.980 to 1.020
110.3	2.000	1.970 to 2.030	1.980 to 2.020
83.5	3.000	2.970 to 3.030	2.980 to 3.020
56.6	4.000	3.970 to 4.030	3.980 to 4.020
29.8	5.000	4.970 to 5.030	4.980 to 5.020

Transmitter Calibration Table

9.2 Isolator Module (LM-474, 474A, 474B, 475, 475A, 476, 476A, 484, 484A, 485, 485A, 485B, 486, 486A, 494, 494A, 494B, 495, 495A, 496, 496A, And 496B)

The isolator transfer function is as follows:

$E_O = E_I$

Per Section 6.8.8 of this calculation, the As Found Tolerance (AFT) of the isolator is ± 1.20% Span. Per Section 6.8.9 of this calculation, the As Left Tolerance (ALT) of the isolator is ± 0.50% Span. The AFT and ALT are converted to voltage units with the following equations:

$$\mathrm{AFT(Vdc)} = \pm 4\ \mathrm{Vdc}\left(\frac{\mathrm{AFT(\%\,Span)}}{100}\right) = \pm 4\ \mathrm{Vdc}\left(\frac{1.20\%\ \mathrm{Span}}{100}\right) = \pm\ 0.048\ \mathrm{Vdc}$$

$$\mathrm{ALT(Vdc)} = \pm 4\ \mathrm{Vdc}\left(\frac{\mathrm{ALT(\%\,Span)}}{100}\right) = \pm 4\ \mathrm{Vdc}\left(\frac{0.50\%\ \mathrm{Span}}{100}\right) = \pm\ 0.020\ \mathrm{Vdc}$$

The calibration table for the isolator is as follows:

Required Input (Vdc)	Desired Output (Vdc)	As Found Tolerance (Vdc)	As Left Tolerance (Vdc)
1.000	1.000	0.952 to 1.048	0.980 to 1.020
2.000	2.000	1.952 to 2.048	1.980 to 2.020
3.000	3.000	2.952 to 3.048	2.980 to 3.020
4.000	4.000	3.952 to 4.048	3.980 to 4.020
5.000	5.000	4.952 to 5.048	4.980 to 5.020

Isolator Calibration Table

9.3 Comparator Module (LC-474, 475, 476, 484, 485, 486, 494, 495, And 496)

Each comparator provides a High Steam Generator Level alarm (switch 2), and a High Steam Generator Level interlock (switch 1). The following equation is used to compute the voltage representation of the comparator setpoints:

$$\text{Setpoint(Vdc)} = 4\ \text{Vdc}\left(\frac{\text{Setpoint(\%)}}{100\%}\right) + 1.000\ \text{Vdc}$$

Per Section 8.0 of this calculation, the High Steam Generator Level alarm setpoint is 60% increasing, and the High Steam Generator Level valve interlock setpoint is 75% increasing. Therefore, the setpoints expressed in voltage units are 3.400 Vdc (60%) and 4.000 Vdc (75%).

Per Section 6.7.8 of this calculation, the As Found Tolerance (AFT) of the comparator is ± 1.16% Span. Per Section 6.7.9 of this calculation, the As Left Tolerance (ALT) of the comparator is ± 0.50% Span. The AFT and ALT are converted to voltage units with the following equations:

$$\text{AFT(Vdc)} = \pm 4\ \text{Vdc}\left(\frac{\text{AFT(\% Span)}}{100}\right) = \pm 4\ \text{Vdc}\left(\frac{1.16\%\ \text{Span}}{100}\right) = \pm\ 0.046\ \text{Vdc}$$

$$\text{ALT(Vdc)} = \pm 4\ \text{Vdc}\left(\frac{\text{ALT(\% Span)}}{100}\right) = \pm 4\ \text{Vdc}\left(\frac{0.50\%\ \text{Span}}{100}\right) = \pm\ 0.020\ \text{Vdc}$$

The following table provides calibration values for the comparators:

Setpoint (%)	**Setpoint (Vdc)**	**As Found Tolerance (Vdc)**	**As Left Tolerance (Vdc)**
75	4.000	3.954 to 4.046	3.980 to 4.020
60	3.400	3.354 to 3.446	3.380 to 3.420

Comparator Calibration Table

9.4 Comparator Module (LC-474A, 475A, 476A, 484A, 485A, 486A, 494A, 495A, and 496A)

Each comparator provides a Low Low Steam Generator Level alarm (switch 2), and a Low Low Steam Generator Level Reactor Trip (switch 1). The following equation is used to compute the voltage representation of the comparator setpoints:

$$\text{Setpoint(Vdc)} = 4\ \text{Vdc}\left(\frac{\text{Setpoint(\%)}}{100\%}\right) + 1.000\ \text{Vdc}$$

Per Section 8.0 of this calculation, the Low Low Steam Generator Level Reactor Trip setpoint is 16% decreasing, and the Low Low Steam Generator Level alarm setpoint is 35% decreasing. Therefore, the setpoints expressed in voltage units are 1.64 Vdc (16%) and 2.400 Vdc (35%).

Per Section 6.7.8 of this calculation, the As Found Tolerance (AFT) of the comparator is ± 1.16% Span. Per Section 6.7.9 of this calculation, the As Left Tolerance (ALT) of the comparator is ± 0.50% Span. The AFT and ALT are converted to voltage units with the following equations:

$$\text{AFT(Vdc)} = \pm 4\ \text{Vdc}\left(\frac{\text{AFT(\% Span)}}{100}\right) = \pm 4\ \text{Vdc}\left(\frac{1.16\%\ \text{Span}}{100}\right) = \pm\ 0.046\ \text{Vdc}$$

$$\text{ALT(Vdc)} = \pm 4\ \text{Vdc}\left(\frac{\text{ALT(\% Span)}}{100}\right) = \pm 4\ \text{Vdc}\left(\frac{0.50\%\ \text{Span}}{100}\right) = \pm\ 0.020\ \text{Vdc}$$

The following table provides calibration values for the comparators:

Setpoint (%)	Setpoint (Vdc)	As Found Tolerance (Vdc)	As Left Tolerance (Vdc)
35	2.400	2.354 to 2.446	2.380 to 2.420
16	1.640	1.594 to 1.686	1.620 to 1.660

Comparator Calibration Table

9.5 Comparator Module (LC-474B, 475B, 484B, 485B, 494B, And 495B)

Each comparator provides a Low Steam Generator Level alarm. The following equation is used to compute the voltage representation of the comparator setpoints:

$$\text{Setpoint(Vdc)} = 4\ \text{Vdc}\left(\frac{\text{Setpoint(\%)}}{100\%}\right) + 1.000\ \text{Vdc}$$

Per Section 8.0 of this calculation, the Low Steam Generator Level alarm setpoint is 35% decreasing. Therefore, the setpoint expressed in voltage units is 2.400 Vdc (35%).

Per Section 6.7.8 of this calculation, the As Found Tolerance (AFT) of the comparator is ± 1.16% Span. Per Section 6.7.9 of this calculation, the As Left Tolerance (ALT) of the comparator is ± 0.50% Span. The AFT and ALT are converted to voltage units with the following equations:

$$\text{AFT(Vdc)} = \pm 4\ \text{Vdc}\left(\frac{\text{AFT(\% Span)}}{100}\right) = \pm 4\ \text{Vdc}\left(\frac{1.16\%\ \text{Span}}{100}\right) = \pm\ 0.046\ \text{Vdc}$$

$$\text{ALT(Vdc)} = \pm 4\ \text{Vdc}\left(\frac{\text{ALT(\% Span)}}{100}\right) = \pm 4\ \text{Vdc}\left(\frac{0.50\%\ \text{Span}}{100}\right) = \pm\ 0.020\ \text{Vdc}$$

The following table provides calibration values for the comparators:

Setpoint (%)	Setpoint (Vdc)	As Found Tolerance (Vdc)	As Left Tolerance (Vdc)
35	2.400	2.354 to 2.446	2.380 to 2.420

Comparator Calibration Table

9.6 Indicator (LI-474, 475, 476, 484, 485, 486, 494, 495, And 496)

The indicators are scaled to provide an output of 0 to 100% for a 1 to 5 Vdc input. Therefore, the transfer function for the indicator is as follows:

$$I_O = \left(\frac{100\%}{4\text{ Vdc}}\right)\left(E_I - 1.000\text{ Vdc}\right)$$

Per Section 6.9.10 of this calculation, the As Found Tolerance (AFT) of the indicator is ± 2.44% Span. Per Section 6.9.11 of this calculation, the As Left Tolerance (ALT) of the indicator is ± 2.00% Span. The AFT and ALT are converted to voltage units with the following equations:

$$\text{AFT(Vdc)} = \pm 4\text{ Vdc}\left(\frac{\text{AFT(\% Span)}}{100}\right) = \pm 4\text{ Vdc}\left(\frac{2.44\%\text{ Span}}{100}\right) = \pm\ 0.098\text{ Vdc}$$

$$\text{ALT(Vdc)} = \pm 4\text{ Vdc}\left(\frac{\text{ALT(\% Span)}}{100}\right) = \pm 4\text{ Vdc}\left(\frac{2.00\%\text{ Span}}{100}\right) = \pm\ 0.080\text{ Vdc}$$

The following table provides calibration values for the indicators:

Desired Input (Vdc)	Required Output (%)	As Found Tolerance (Vdc)	As Left Tolerance (Vdc)
1.000	0	0.902 to 1.098	0.920 to 1.080
2.000	25	1.902 to 2.098	1.920 to 2.080
3.000	50	2.902 to 3.098	2.920 to 3.080
4.000	75	3.902 to 4.098	3.920 to 4.080
5.000	100	4.902 to 5.098	4.920 to 5.080

Indicator Calibration Table

9.7 Recorder (FR-478, 488, & 498)

The recorders are scaled to provide an output of 0 to 100% for a 1 to 5 Vdc input. Therefore, the transfer function for the recorder is as follows:

$$R_O = \left(\frac{100\%}{4\ \text{Vdc}}\right)\left(E_I - 1.000\ \text{Vdc}\right)$$

Per Section 6.10.9 of this calculation, the As Found Tolerance (AFT) of the recorder is ± 0.59% Span. Per Section 6.10.10 of this calculation, the As Left Tolerance (ALT) of the recorder is ± 0.50% Span. The AFT and ALT are converted to voltage units with the following equations:

$$\text{AFT(Vdc)} = \pm\ 4\ \text{Vdc}\left(\frac{\text{AFT(\% Span)}}{100}\right) = \pm\ 4\ \text{Vdc}\left(\frac{0.59\%\ \text{Span}}{100}\right) = \pm\ 0.024\ \text{Vdc}$$

$$\text{ALT(Vdc)} = \pm\ 4\ \text{Vdc}\left(\frac{\text{ALT(\% Span)}}{100}\right) = \pm\ 4\ \text{Vdc}\left(\frac{0.50\%\ \text{Span}}{100}\right) = \pm\ 0.020\ \text{Vdc}$$

The following table provides calibration values for the recorder:

Desired Input (Vdc)	Required Output (%)	As Found Tolerance (Vdc)	As Left Tolerance (Vdc)
1.000	0	0.976 to 1.024	0.980 to 1.020
2.000	25	1.976 to 2.024	1.980 to 2.020
3.000	50	2.976 to 3.024	2.980 to 3.020
4.000	75	3.976 to 4.024	3.980 to 4.020
5.000	100	4.976 to 5.024	4.980 to 5.020

Recorder Calibration Table

ATTACHMENT B

COMPARATOR DRIFT

CALIBRATION DATA SHEET REVIEW SUMMARY

HAGAN MODEL 118 SINGLE COMPARATOR							
TC-141		LC-949		PC-145A		TC-143	
Cal. Dt.	Devia.	Cal. Dt.	Devia.	Cal. Dt.	Devia.	Cal. Dt.	Devia.
7/14/84		9/26/84		5/29/84			
			.001				
	.001	9/25/85			.000	6/26/85	
			.001				.008
6/04/86		9/24/86		2/23/86		2/02/86	
	.001		.002		.004		.001
5/15/87		9/28/87		4/30/87		1/27/87	
	.003		.002		.009		.003
6/13/88		9/30/88		12/29/88		2/5/88	
	.003						.004
11/20/89			.001		.009	7/4/89	
		2/26/90		9/22/90			

HAGAN MODEL 118 DUAL COMPARATOR								
	LC-106A		LC-106B		LC-108A		LC-108B	
Cal.Dt.	Devia.	Devia.	Devia.	Devia.	Devia.	Devia.	Devia.	Devia.
6/14/84								
	.000	.000	.001	.004	.000	.000	.000	.000
4/01/85								
	.001	.000	.001	.001	.001	.000	N/A	N/A
4/18/86								
	.001	.001	.001	.000	.001	.000	N/A	N/A
3/03/87								
	.001	.003	.001	.001	.000	.001	N/A	N/A
4/06/88								
	.000	.001	.002	.000	.002	.001	N/A	N/A
4/04/89								
	.000	.000	*	*	*	*	.003	.003
4/04/90								

* Instrument Malfunction
N/A Not Available

Maximum deviation noted between the as-found and as-left values recorded on the available calibration data sheets was .009 vdc.

This value is approximately equal to 0.25%.

ATTACHMENT C

ROSEMOUNT DRIFT

ROSEMOUNT
Measurement
Control
Analytical
Valves

Rosemount Inc.
12001 Technology Drive
Eden Prairie, MN 55344
Tel (612) 941-5560
Telex 4310012
Fax (612) 828-3088

September 20, 1990

Entergy Operations
Grand Gulf Nuclear Plant
ESC Building
P.O. Box 429
Port Gibson, MS 39150

Attention: Bob McCain

Dear Mr. McCain:

Rosemount has developed a new drift specification for the Model 1152, 1153 and 1154 pressure transmitters. The specification is ±.2% URL over a 30 month period.

In addition, all normal performance specs (i.e. accuracy) can be considered 3 sigma specs. The nuclear specs such as LOCA/HELB, radiation, and seismic were developed based on type testing. Due to the small sample size of test units, it is difficult to apply statistical methodology to these type of specs.

If you have any further questions please feel free to call me at (612) 828-3100.

Sincerely,

Neil P. Lien
Marketing Engineer

NPL:lbc

Enc: PDS 2302, 2388, 2514, 2235
Report D8600063

c: Les Callender #2

ATTACHMENT D

INTERNATIONAL INSTRUMENTS INDICATOR DATA

operating companies
General Resistance
International Instruments
Transducers & Systems
Shunts Meters
E.I. & S.

PRIME TECHNOLOGY

PRIME TECHNOLOGY, INC. • Twin Lakes Road • P.O. Box 185 • North Branford, CT 06471
Tel. (203) 481-5721
TWX: 710-452-3082
FAX: (203) 481-8937

June 24, 1991

CAROLINA POWER & LIGHT
P.O. Box 1551
Raleigh, NC 27602-1551

Attn: Robert Mann OHS 6th Floor

Dear Robert,

Per our conversation the drift and T.C. for International Instruments model 2520 are 1% of span per year and .1% of span per degree C respectively. The accuracy following a seismic event are per Mil Standards for shock and vibration and are quoted as 5% of span. Understand that the assumption is made that the seismic event reflects both shock and vibration.

Should you have any further information, please do not hesitate to contact me.

Best Regards,

James L. Jamieson
Executive Vice President

cc: Keith Macdowall

NUS Instruments Long Term Drift Test for NUS Modules – Final Report, Executive

NUS
Instruments

440 West Broadway , Idaho Falls, ID 83402 , Phone: 208-529-1000 , Fax: 208-524-9238

October 26, 2001

Pat Hartig
FirstEnergy Nuclear Operating Company
Beaver Valley Power Station
P.O.Box 4
Shippingport, Pa 15077

Subject: Long Term Drift Test (LTDT) Results for NUS modules – Final Report, Executive Summary

Dear Mr. Pat Hartig:

NUS Instruments (NUSI), undertook a research and development project in 1996 to re-engineer instrumentation for use as replacements for the obsolete Hagan line of nuclear plant instrumentation. The NUSI replacement modules were designed originally using specifications written by Public Service Electric and Gas (PSE&G). The final specifications incorporated both original Hagan published specifications and new or additional plant-specific requirements. The final agreed upon specification formed the design basis for the NUS Instruments 800 Series product line that has been sold to many nuclear plants including Salem, H.B. Robinson, Turkey Point and Diablo Canyon.

NUSI has been requested by FENOC to supply instrumentation drift specifications for the 800 Series modules. We understand that these numbers are to be used to determine requirements for plant calibration cycles for these modules. The calibration cycle may be extended if it can be shown that the drift of the replacement modules is below specified criteria. This change would result in a significant savings in plant maintenance costs.

NUSI was contracted by PSE&G to conduct a 36-month Long Term Drift Test (LTDT). This test was conducted on four classes of modules with four units of each type for a total of sixteen modules undergoing the test. The four classes of modules consisted of four Dual Alarm Modules (DAM), four One-channel Analog Isolators (OCA), four RTD Amplifiers (RTD), and four Four-Channel Summing Modules (SUM). A loop of instruments was also tested to determine overall loop drift.

ATTACHMENT F
Page 2 of 2

Drift was specified as a percentage of the upper range limit (URL) over an 18-month period. After 36 months of testing, NUSI can proudly state that all modules performed better than the stated specification. The specification and summary results are given below.

	SPECIFICATION		TEST RESULTS	
MODULE CLASS	**ACCURACY**	**DRIFT**	**DRIFT (%URL)**	**2 sigma DRIFT**
RTD	0.5%	0.4%	0.240 %	0.365 %
OCA	0.5%	0.2%	0.048 %	0.074 %
DAM	0.5%	0.3%	0.083 %	0.127 %
SUM	0.5%	0.6%	0.135 %	0.214 %
LOOP	0.5%	Not specified	0.115 %	0.186 %

NUSI is currently in the process of preparing the final test report which will provide greater details about the test modules and fixture, test procedure and processes, data and sampling intervals, analysis and plots showing the data trends. This data represents over 26,000 hours of testing and over 24,000 individual data measurements. NUSI can make available upon request the Excel 97 workbook that provides the data, analysis, and necessary graphing tools. This report will be available October 31, 2001.

It is also worth noting that several utilities have been conducting their own independent long term drift tests of a instruments installed in their loops. They can independently support that the NUSI 800 Series instruments meet or exceed the long term drift specification.

Please contact NUS Instruments for additional information.

SCIENTECH, Inc., NUS Instruments
440 West Broadway
Idaho Falls, Idaho 83402
(208) 529-1000 (LaWanda Wold or Heath Buckland)

Respectfully,

LaWanda Wold
Facility Manager, NUS Instruments

Office Address:
SCIENTECH - Broadway
440 West Broadway
Idaho Falls, Idaho 83402-3638
208.524.9200 Front Desk
208.524.9282 Fax

Work Phone: 208.524.9236
Facsimile: 208.524.9238
E-mail: LWold@scientech.com

Email from NUS Confirming Similarity of NUS Isolator Modules, dated 01/15/02

From: James Siedelmann@scientech.com
Sent: Tuesday, January 15,2002 11:54 AM
To:bobh@hursttech.com
Subj.: Series SC993 and Series 800 Isolators

Series SC993 isolators were manufactured by us under the names of Energy Incorporated, EI Electronics, EI Systems and EI International. They are an early version of stand alone isolator intended for electrical isolation of the inputs from the outputs. They were encapsulated and had terminal blocks for connection of power, inputs and outputs. They were single channel devices. The power supply used was an early type of switching power supply that is no longer manufactured. The isolation circuitry was basically the same as is currently used in all NUSI isolators and many of our other instrumentation devices. The actual isolation element, the Burr-Brown 3656 is identical to that used today. All devices manufactured then underwent dielectric withstand testing of 3000 Vdc and at 2500 Vac to ensure their readiness to isolate a potential fault. They also were 100% functional tested. The units were encapsulated with an epoxy and aluminum oxide based compound that made them impervious to virtually all environmental concerns and seismically were considered a "brick". They were qualified simply by their mounting constraints. Internal heating was not a concern as the potting compound used had a very high thermal conductivity. Outputs and power were fused on the top surface of the aluminum chassis. Span and zero adjustments were also mounted there. The device is simple internally and externally. It has many years of reliable performance at several nuclear plants with little or no undue maintenance issues. The only know life issue is the power supplies used (then and now) have aluminum electrolytic capacitors with know life characteristics of about twenty years. Pots should not be adjusted unless the unit is out of tolerance to reduce the wear and tear on them. If a typical maintenance cycle is used, the devices will easily achieve their twenty year life expectancy with no problems. The limited life characteristics will not affect their isolation specifications in any way. These devices had only limited surge protection circuitry (on the inputs) included. Outputs and power ports may be susceptible to damage from surges but will not pass this to the inputs.

NUS Instruments currently manufactures devices that are form, fit and function replacements for the SC993 series. These are the SCA101 devices in the SCA100 series of isolators. These devices differ from the SC993 in the power supply used and that the chassis is 1/16" deeper than the older versions. These devices have surge suppression circuitry and have been surge tested on all ports. Fault testing and other isolation parameter testing has been completed on these devices. All other parameters, including the circuitry and elements used do not differ from the SC993 series.

ATTACHMENT G

Series 800 devices were manufactured by us under the names Haliburton NUS, Haliburton NUS Environmental Corp., NUS Corp. and NUS Instruments. They are still in production. These devices include FCA, OCA and FIA versions with series designations 800 and 801. The only differences are the number of channels loaded, test jack size and LED power indicator colors. These devices all use modern switching power supplies in varying numbers dependent upon the output ranges and isolator types. FIA isolators have a separate power supply for each channel to give the outputs isolated commons. The circuit is operationally the same as earlier types and the actual isolation element is still the Burr-Brown 3656. These devices have undergone complete isolation type testing for dielectric withstand of 3000 Vdc and 1000 Vac, and most production units are tested to these values. The devices under went fault type testing to 480 Vac and 140 Vdc applied to all ports in the FIA800 series. Shorts, opens and inter-channel effects have also all been type tested. The devices have also been tested for surge withstand using the waveform specified in IEEE 472. All production units are 100% functionally tested prior to shipment. The chassis and electronics have been seismically proof tested for operation before, during and after the defined DBE with no anomalies. These devices use an aluminum chassis that is intended for rack mounting. The internals are accessible and passive air flow through the chassis removes internally generated heat. Outputs are fused on the rear and power is fused on the front of the devices. Span and zero adjustments are located on the front plate of the devices. These devices have the same life characteristics in the power supplies used but since they are not potted, the power supplies may be replaced allowing for the isolators to have 40 year life expectancies.

All devices are manufactured using a 10CFR50 appendix B quality assurance program and are provided with 10CFR part 21 traceability as basic components.

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J.E. Siedelmann, P.E.
Sr. Design Engineer
NUS Instruments, Inc.
Phone: (208) 524-9246
Fax: (208) 524-9238
jsiedelmann@scientech.com
440 W. Broadway, Idaho Falls
Idaho 83402-3638

ATTACHMENT H

Document: __RNP_I/INST-1070________________________________ Revision: __16__________

The signature of the Design Verification reviewer confirms:

- The type of verification method performed
- Technical errors have been resolved and the records have been included, if applicable

_Yes__ Reviewer or ___ Concurrent Reviewer (Type "Yes" to indicate Reviewer type)

Design Verification Review Method (Type "Yes" beside selection to indicate Review Method used) __Yes_ Design Review ___ Alternate Calculation ___ Qualification Testing	(Type "Yes" to indicate if Records attached) Other Records: ___ Attached

Note:
This Record of Review form may be used to document other reviews, but is only required for Design Verification reviews.

Reviewer (print/sign): Christy Ray	Discipline:	Date:
(Electronically Approved)	Safety Analysis Models	(see Fusion)

Item No.	Technical Error	Resolution
	None	