Enclosure 14

Calculation SC-BB-0525, "Hope Creek Heat Balance Uncertainty Calculation", Revision 5

CC-AA-309-1001-F1 Revision 0 Page 1 of 1

Design Analysis (Major Re Analysis No.: ¹ SC-BB Title: ³ Hope C DCP No(s)./ 801160 Revision: ⁴ R0 Station(s): ⁷ Unit No.: ⁸ Discipline: ⁹ Safety/QA Class: ¹¹ System Code: ¹² Structure: ¹³	~0525 Dreek Heat Balance		Revision: ² 5 alculation AD No(s)./ 150 Revision: ⁶ R0	p. ⁶ Attachment 8 pa	ge 1			
Title: 3Hope CDCP No(s)./ Revision: 4801163Revision: 4R0Station(s): 7Unit No.: 8Discipline: 9Safety/QA Class: 11System Code: 12	Creek Heat Balance 312 Hope Creek 1 I Important to		AD No(s)./ I50 Revision: ⁶ R0	ompon <mark>ent(s):</mark> ¹⁴				
DCP No(s)./ 801163 Revision: ⁴ R0 Station(s): ⁷ Unit No.: ⁸ Discipline: ⁹ Safety/QA Class: ¹¹ System Code: ¹²	Hope Creek 1 I Important to		AD No(s)./ 150 Revision: ⁶ R0	omponent(s): ¹⁴				
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Revision: 4R0Station(s): 7Unit No.: 8Discipline: 9Safety/QA Class: 11System Code: 12	Hope Creek 1 I Important to	Safety	Revision: ⁶ R0	pmponent(s): ¹⁴				
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Document No.:		From/To	Document No.:		From/To			
SC-AE-0540		From	SC-AE-0541		From			
SC-BB-0355		From	SC-BG-0516		From			
SC-BF-0511		From	SC-BB-0526		From			
SC-BG-0515		From	432792 Sheet 001		From			
Is this Design Analysis Saf	eguards Informat	ion? ¹⁶	Yes 🗍 No 🛛	If yes, see SY-A	A-101-106			
Does this Design Analysis	contain Unverifie	d Assumption	s? ¹⁷ Yes 🗌 No 🖾	If yes, Order#:				
This Design Analysis SUP	ERCEDES: 18	4		in i	its entirety.			
Description of Revision (Ilst affected pages for partials): ¹⁹ This revision is to increase the thermal power level from 3840 to 3902 in response to the MUR uprate per Appendix K. Attachments have been added for the various mode of operation of the LEFM. The attachments have been reordered as follows: Attachment 1 is now the Heat Balance Calculation with a Normally Operating LEFM Attachment 2 is the Heat Balance Calculation with a LEFM in Maintenance Mode (new attachment) Attachment 3 is the Heat Balance Calculation with a Normally Operating LEFM Attachment 4 is the FFWTR Heat Balance Calculation with a Normally Operating LEFM (new attachment) Attachment 5 is the FFWTR Heat Balance Calculation with a Normally Operating LEFM (new attachment) Attachment 6 is the FFWTR Heat Balance Calculation with a LEFM in Maintenance Mode (new attachment) Attachment 7 is the General Electric Reactor Heat Balance Power Uprate (previously attachment 2) Attachment 8 is the General Electric Reactor Heat Balance For Final Feedwater Temperature Reduction Operation (previously attachment 5) Note that the revision bars in the attachments identify the content change from the previous attachment and does not identify the formatting changes with the rearrangement of the calculation. Preparer: ²⁰ Michael Miller (S&L) Print Name Sign Name Bign Name 3/16/17 Data Data Method of Review: ²¹ Detailed Review Alerenew Peer review								
(For External Analyses Only) External Approver: 24	R. MASTEL	<u></u>	K Mark		3 /16 /17 Date			
PSEG Reviewer: 20	3. Brahm	10	Sign Na	ma	3/17/17			
Independent 3 rd Party Re PSEG Approver: ²⁷	eview Reqd? 28 Shawn Ma	Yes []	No X Man	Molih	3/17/17 Date			

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Salem and Hope Creek Common

LEVEL 3 - INFORMATIONAL USE

11

Rev:

CC-AA-309

CONTROL OF DESIGN ANALYSES

DESI	Attachment 1, General Review Questions IGN ANALYSIS NO. SC-BB-0525 REV: 5	ж.		
1.	Does the Design Analysis conform to design requirements?	Yes	No	N/A
2.	Does the Design Analysis conform to applicable codes, standards, and regulatory requirements?			
3.	Have applicable design and safety limits been identified?	\boxtimes		
4.	Is the analysis method appropriate?	\boxtimes		
5.	Are the methods used and recommendations given conservative relative to the desi and safety limits?	ign 🛛		
6.	Are assumptions/Engineering Judgments explained and appropriate?			
7.	Have appropriately verified Computer Program and versions been identified, when applicable?	n 🗌		\boxtimes
8.	Does the Computer Program conform with the NRC SER or similar document whe applicable?	en 🗌		\boxtimes
9.	Has the input been correctly incorporated into the Design Analysis?	\boxtimes		
10.	Has the input been reviewed by all cognizant design authorities?	\boxtimes		
11.	Are the analysis outputs and conclusions reasonable compared to the inputs and assumptions?	\boxtimes		
12.	Are the recommendations/results/conclusions reasonable based on previous experience?	\boxtimes		
13.	Has a verification of the Design Analysis been performed by alternate methods?			
14.	Has all input data been used correctly and is it traceable?	\boxtimes		
15.	Has the effect on plant drawings, procedures, databases, and/or plant simulator bee addressed?	en 🖂		
16.	Has the effect on other systems been addressed?	\boxtimes		
17.	Have any changes in other controlled documents (e.g. UFSAR, Technical Specifications, Core Operating Limits Report (COLR), etc.) been identified and tracked?			
18.	When applicable, are the analysis results consistent with the proposed license amendment?	\boxtimes	a 🔲 s	
19.	Have other documents that have used the calculation as input been reviewed and revised as appropriate?			
2 0.	Have all affected design analyses been documented on the Affected Documents Li (ADL) for the associated Configuration Change?	ist 🖂		
21.	Do the sources of inputs and analysis methodology used meet current technical requirements and regulatory commitments? (If the input sources or analysis methodology are based on an out-of-date methodology or code, additional reconciliation may be required if the site has since committed to a more recent cod	le)		L L
22.	Have supporting technical documents and references been reviewed when necessar	ry?		

PSEG Nuclear LLC	Salem and Hope Creek Common	LEVEL 3 - INFORMATIONAL USE	Page 19 of 19		
 CC-AA-309					
	CONTRO	L OF DESIGN ANALYSES			

Attachment 2, Owners Acceptance Review Checklist for External Design Analysis SAP Standard Text Key "NDAEXT"

DESIGN ANALYSIS NO. SC-BB-0525 REV: 5

1.	Do assumptions have sufficient rationale?	Yes 🖾		N/A
2.	Are assumptions compatible with the way the plant is operated and with the licensing basis?	\bowtie		
3.	Do the design inputs have sufficient rationale?	\ge		
4.	Are design inputs correct and reasonable?	X		
5.	Are design inputs compatible with the way the plant is operated and with the licensing basis?	X		
6.	Are Engineering Judgments clearly documented and justified?			X
7.	Are Engineering Judgments compatible with the way the plant is operated and with the licensing basis?			Ø
8.	Do the results and conclusions satisfy the purpose and objective of the Design Analysis?	\boxtimes		
9.	Are the results and conclusions compatible with the way the plant is operated and with the licensing basis?	\boxtimes		
10.	Does the Design Analysis include the applicable design basis documentation?	\bowtie		
11.	Have any limitations on the use of the results been identified and transmitted to the appropriate organizations?	X		
12.	Are there any unverified assumptions?		\bowtie	
13.	Do all unverified assumptions have a tracking and closure mechanism in place?			\boxtimes
14.	Have all affected design analyses been documented on the Affected Documents List (ADL) for the associated Configuration Change?	X		
15.	Do the sources of inputs and analysis methodology used meet current technical requirements and regulatory commitments? (If the input sources or analysis methodology are based on an out-of-date methodology or code, additional reconciliation may be required if the site has since committed to a more recent code)	X		
16.	Have vendor supporting technical documents and references (including GE DRFs) been reviewed when necessary?	X		
17.	Has the Vendor supplied the native electronic file(s)?			\boxtimes
PSEG	REVIEWER: S. Brahma DATE: 3/	17/1		

PSEG	CALCULATION CONTINUATION/ REVISION HISTORY SHEET			SHEET: 4 of 10
CALC. No.: SC-BB-052	25		REFERENCE:	
ORIGINATOR, DATE:	REV	MTM 02/14/17	5	
REVIEWER/VERIFIE	R, DATE	JW 02/28/17		

LIST OF EFFECTIVE PAGES

Page No.	Revision	Page No. Revision
Cover Sheet Attachment 1 Attachment 2	5 5 5	
2 3 4 5 6 7 8 9 10	5 5 5 5 5 5 5 5 5 5	
Attachment 1 Attachment 2 Attachment 3 Attachment 4 Attachment 5 Attachment 6 Attachment 7 Attachment 8	5 5 5 5 5 5 5 5 5 5	

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CALCULATION CONTINUATION/ REVISION HISTORY SHEET

CALC. No.: SC-BB-0525			REF	ERENCE:		
ORIGINATOR, DATE:	REV	MTM 02/14/17	5			
REVIEWER/VERIFIER	, DATE	JW 02/28/17				

1.0	PURPOSE	6
2.0	FUNCTIONAL DESCRIPTION/ DESIGN BASIS	6
3.0	REFERENCES	7
3.1	Updated Final Safety Analysis Report	7
3.2	Technical Specifications	7
3.3	Drawings	7
3.4	Support Documents	7
3.5	Procedures	8
3.6	Computer Programs	8
4.0	Loop Diagram	9
5.0	Design Inputs	9
6.0	Assumptions	10
7.0	Calculations See attachments 1 thought 6	
8.0	Summary See attachments 1 through 6	10
9.0	Results	10

ATTACHMENTS	Number of Pages
Attachment 1 –Heat Balance Calculation with a Normally Operating LEFM	29
Attachment 2- Heat Balance Calculation with a LEFM in Maintenance Mode	29
Attachment 3- Heat Balance Calculation without Taking Credit for the Operation	ı of
the LEFM	31
Attachment 4 -FFWTR Heat Balance Calculation with a Normally Operating LE	FM 29
Attachment 5-FFWTR Heat Balance Calculation with a LEFM in Maintenance I	Mode 29
Attachment 6- FFWTR Heat Balance Calculation without Taking Credit for the	
Operation of the LEFM	31
Attachment 7– General Electric Reactor Heat Balance Power Uprate	1
Attachment 8- General Electric Reactor Heat Balance For Final Feedwater	
Temperature Reduction Operation	1 .

PSEG		CULATION CONT CVISION HISTOR		SHEE	E T: 6 of 10
CALC. No.: SC-BB-05	25		REFERENCE:		
ORIGINATOR, DATE	REV	MTM 02/14/17	5		
REVIEWER/VERIFIE	R, DATE	JW 02/28/17			

1.0 PURPOSE

The purpose of this calculation is to determine the uncertainty in the heat balance calculation performed by the plant computer taking credit for the operation of the LEFM Check Plus in Attachment 1. The calculation without the LEFM Check Plus is provided in Attachment 3 and the calculation with the LEFM in maintenance mode is provided in Attachment 2. In each mode of operation, this calculation shows that margin exists for the calculated measurement uncertainty between the power levels defined in the Operating License and the accident analyses performed at 2% above the pre-MUR uprate power. This calculation also provides the basis for the Maintenance mode power level, which is set at the highest whole MWt power level which produces positive margin.

2.0 FUNCTIONAL DESCRIPTION/ DESIGN BASIS

2.1 Functional Description

The Core Thermal Power is determined by a heat balance calculation performed in the secondary system. The heat balance accounts for heat added and lost into the "system" as depicted in the loop diagram in Section 4.0. The calculated power by the secondary heat balance is utilized to calibrate the Neutron Monitoring System.

2.2 Design Basis

Hope Creek current design basis, for the most part, is based on reactor power greater than or equal to 102% of the licensed reactor thermal power for the Nuclear Steam Supply System (NSSS) and Emergency Core Cooling System (ECCS) design and 105% steam flow for the Balance of Plant (BOP) design (UFSAR Chapter 1.1, 5.4, 6.2, 6.3, 10 and 15). The plant has been licensed to operate at less than 2% total uncertainty based on installation of an LEFM CheckPlus ultrasonic flow meter. Two uprated power levels are defined; one is based on a fully functional flow meter with two operable measurement planes, the second is based on the LEFM flow meter operating with one plane out of service (maintenance mode). In the event of a failure of both LEFM measurement planes or other system-level failure, the plant will operate using venturi measurements for flow with an allowance for 2% total uncertainty.

CALCULATION CONTINUATION/ REVISION HISTORY SHEET SHEET: 7 of 10 CALC. No.: SC-BB-0525 REFERENCE: ORIGINATOR, DATE: REV MTM 02/14/17 5 REVIEWER/VERIFIER, DATE JW 02/28/17

3.0 **REFERENCES**

3.1 Updated Final Safety Analysis Report

- 3.1.1 Figure 1.1-1, UFSAR Rev. 10 September 30, 1999, Heat Balance at Rated Power
- 3.1.2 Table 4.4-1, UFSAR Rev. 0 April 11, 1988, Thermal Hydraulic Design Characteristics of the Reactor Core
- 3.1.3 Section 5.1.11, Reactor Water Cleanup System
- 3.1.4 Section 5.4.8, Reactor Water Cleanup System
- 3.1.5 Section 4.1.1, Information for the CRD System
- 3.1.6 Section 7.5.1.3.3, Plant Computer System
- 3.1.7 Section 7.7.13, Feedwater Control System
- 3.1.8 Section 7.7.1.6, Reactor Water Cleanup System
- 3.1.9 Section 10.4.7, Condensate and Feedwater

3.2 Technical Specifications

- 3.2.1 Section 2.1, Safety Limits
- 3.2.2 Section 2.2, Limiting Safety Limits Settings
- 3.2.3 Technical Specifications Amendment 131
- 3.2.4 Technical Specifications Amendment for EPU
- 3.2.5 Hope Creek Generating Station Renewed Facility Operating License No. NPF-57

3.3 Drawings

- 3.3.1 M-44-1, Rev. 27, Reactor Water Clean-up P&ID
- 3.3.2 M-41-1, Sht. 1, Rev. 29, Nuclear Boiler P&ID
- 3.3.3 M-42-1, Sht. 1, Rev. 38, Nuclear Boiler Vessel Instrumentation P&ID
- 3.3.4 M-43-1, Sht. 1, Rev. 26, Reactor Recirculation System P&ID
- 3.3.5 M-46-1, Rev. 21, Control Rod Drive Hydraulic Part A

3.4 Support Documents

- 3.4.1 H-1-RJ-ECS-0190(07), Rev. 1, Software Design Specification NSSS Process Computer Replacement Heat Balance Program
- 3.4.2 PN0-A41-5050-0009, Rev. 3, GE Reactor System Heat Balance Rated
- 3.4.3 HC.RE-RA.ZZ-0001, Core Thermal Power Evaluation Application Results 11/22/99
- 3.4.4 SC-BB-0355, Rev. 2, Reactor Vessel Pressure 1BBPT-N005-C32
- 3.4.5 SC-BF-0511, Rev. 1, Control Rod Drive 1BFFT-N004-C11
- 3.4.6 SC-BG-0515, Rev. 1, Reactor Water Cleanup Temperature
- 3.4.7 SC-AE-0540, Rev 5, Feedwater Line A&B Flow
- 3.4.8 SC-AE-0541, Rev. 3, Feedwater Temperature 1AETT-N602A-D-C32

CALCULATION CONTINUATION/ REVISION HISTORY SHEET

KEVISION HISTORY SHEET						
CALC. No.: SC-BB-052	25		RE	FERENCE:		γ
ORIGINATOR, DATE	REV	MTM 02/14/17	5		[]	
REVIEWER/VERIFIE	R, DATE	JW 02/28/17				

- 3.4.9 Fluid Meters their Theory and Application, Sixth Edition (ASME)
- 3.4.10 SC-BG-0516, Rev. 0, Reactor Water Cleanup System Inlet Flow 1BGFT-N036A-G33
- 3.4.11 SC-BB-0526, Rev. 0, Reactor Recirculation Pump Motor Power
- 3.4.12 ISA-RP67.04, Par II, Methodologies for the Determination of Setpoints for Nuclear Safety-Related Instrumentation, September 1994
- 3.4.13 Regulatory Guide 1.105, Rev. 3, Setpoints for Safety-Related Instrumentation
- 3.4.14 NEDC-31336, Class III, October 1986, General Electric Instrument Setpoint Methodology
- 3.4.15 ASME Steam Tables, Sixth Edition
- 3.4.16 Deleted

DSEC

- 3.4.17 VTD 430003 (002), GE Nuclear Energy Project Task Report for Task T0100: Reactor Heat Balance
- 3.4.18 Deleted
- 3.4.19 DCP 80100455 FFWTR
- 3.4.20 LEFM Bounding Uncertainty Analysis VTD 432792

3.5 Procedures

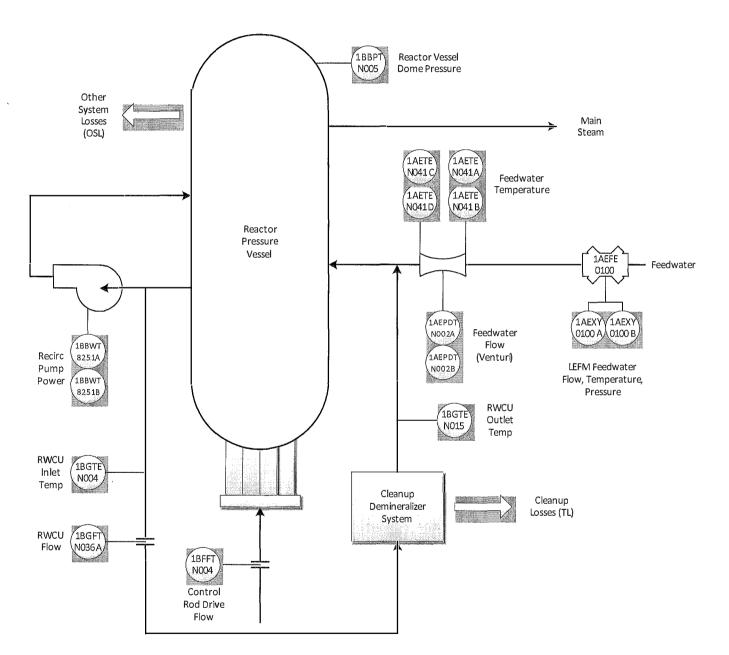
3.5.1 HC.RE-RA.ZZ-0001, Rev. 10 -Core Thermal Power Evaluation

3.6 Computer Programs

3.6.1 STMFUNC v2.0, Steam Table Function Dynamic Link Library, S&L Program Number STM 03.7.598 - 2.0 was used as an Excel add-in. This program uses the 1967 ASME Steam Tables.

PSEG	CALCULATION CONTINUATION/ REVISION HISTORY SHEET			SHEET	: 9 of 10		
CALC. No.: SC-BB-052	25		RE	FERENCE:			
ORIGINATOR, DATE:	REV	MTM 02/14/17	5				
REVIEWER/VERIFIE	R, DATE	JW 02/28/17					

4.0 Loop Diagram



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5.0 Design Inputs

See attachments 1 through 6

PSEG		CULATION CON EVISION HISTOR			SHEET: 10 of 10				
CALC. No.: SC-BB-052	25		REFERI	ENCE:		•			
ORIGINATOR, DATE:	REV	MTM 02/14/17	5				1. S.		
REVIEWER/VERIFIE	R, DATE	JW 02/28/17			· · ·				
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6.0 Assumptions

See attachments 1 through 6

7.0 Calculations

See attachments 1 thought 6

8.0 Summary

See attachments 1 through 6

9.0 Results

Summary of results

The total uncertainty is the calculated uncertainty contained within attachments 1 through 6. The margin is defined by the following:

Margin= 3840 * 102% – Rated Thermal Power – Total uncertainty

There remains a positive margin between the 2% design basis and the combined rated thermal power and total uncertainty for each operating condition; therefore, the results are acceptable.

Plant	LEFM Status	Rated	Total	Total	Margin	Margin
Condition		Thermal	Uncertainty	Uncertainty	(%)	(MWt)
	3	Power	^(%)	(MWt)	н. Т	
Normal	Normal	3902	0.374%	14.59	0.005%	0.21
Feedwater	(Attachment 1)				8 a T	7
Temperature	Maintenance	3889*	0.694%	26.99	0.021%	0.81
	(Attachment 2)				and the second	
	Fail	3840	0.919%	35.29	1.081%	41.51
	(Attachment 3)				1. A.	
Feedwater	Normal	3902	0.373%	14.55	0.006%	0.25
Temperature	(Attachment 4)				-	
Reduction	Maintenance	3889*	0.693%	26.95	0.022%	0.85
(102 Deg F)	(Attachment 5)					
	Fail	3840	1.095%	42.05	0.905%	34.75
	(Attachment 6)			· .		

*Note that the Thermal Power in Maintenance Mode operation is calculated as described in section 1 by attachments 2 and 5. This power level is not identified in Reference 3.2.5

(NC.[DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCULATION CONTINUATION SHEET SHEET			
CALC NO.: SC-BB-0525 Attachment 1		REV:	5	REF:	CONT'D ON SHEE	: <u>2</u>
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A	N/A

Sections 1 through 4 have been replaced with the main body of the calculation

5.0 DESIGN INPUTS

5.1 Rated Power Conditions

100% rated Power Conditions are listed below. Actual 100% operation values might be used in lieu of rated nominal values, for other than Rated MWt, Feedwater Flow and Main Steam parameters as deemed appropriate. This is found acceptable, since for the purpose of error determination to rated MWt "heat differential errors", actual heat contribution deviation from measured/calculated heat to rated MWt due to instrumentation uncertainties, is required not the actual deviation value.

Rated MWt = <u>3902MW</u>	(Ref. 3.4.17, 3.2.5)	Rev 5
Rated FW flow = <u>1.7054E+07lbm/hr</u>	(Ref. 3.4.17)	
Rated FW temperature = <u>433.5 F</u>	(Ref. 3.4.17)	
Rated MS flow = <u>17086000</u>	(Ref. 3.4.17)	
Rated MS pressure = <u>1020 psia</u>	(Ref. 3.4.17)	
Rated MS quality = <u>100.000</u>	(Ref. 3.4.1)	•
Rated RWCU flow = <u>148000.0 lb/hr</u>	(Ref. 3.4.17)	Rev 5
Rated RWCU temperature = <u>530.7 F</u>	(Ref. 3.4.17)	
Rated RWCU return temperature = <u>433.8 F</u>	(Ref. 3.4.17)	
Rated CRD flow = <u>32000.0 lb/hr</u>	(Ref. 3,4.3)	
CRD Calibration pressure = <u>1474.0 psia</u>	(Ref. 3.4.5)	•
Rated CRD temperature = <u>77 F</u>	(Ref. 3.4.17)	Rev 5
Radiation Loses = <u>1.10MW</u>	(Ref. 3.4.2, 3.4.17)	•
Other System Loses = <u>1.18MW</u>	(Ref. 3.4.2, 3.4.17) These loses are not included in UFSAR Heat Balance, Ref. 3.1.1	Rev 5
MWt/BTU/hr = <u>2.9300E-07</u>	(Ref. 3.4.1)	•
Power = MFW(MSh-FWh)-CRDF(hi	n-hout)+RWCU(hout-hin)-RRP+HL+Miscellaneous	

Notes:

1) This calculation uses rated MS quality of 100.0%, which will produce a more conservative number with respect to the actual plant MS quality. This parameter may be revised when the actual MS quality is measured after the implementation of EPU.

2) This calculation specifies radiation loses as 1.10 MW and other loses as 0.84 MW for the total lose of 1.94 MW. Reference 3.4.17 stated "other system loses" as 1.9 MW without specifically accounting for Radiation loses. Since the two total numbers are almost identical and the difference would have negligible affect on the Power Error, radiation loses of 1.10 MW and the other loses of 0.84 MW will be maintained.

6.0 ASSUMPTIONS

See sections 7.2.3, 7.2.4, 7.2.6 and 7.2.7 for specific assumptions.

	(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)			CALCULATION C	T SHEET	2	
CALC NO .:	SC-BB-0525 Attachn	nent 1	REV:	5	REF:	CONT'D ON SHEET	3
ORIGINATOR:	ر D	ATE:	REVIEWER:		DATE:	VERIFIER:	DATE:
Michael Mill	ler 2	/14/2017	John Wilkens		3/13/2017	N/A	N/A

7.0 CALCULATIONS

7.1 Methodology

The methodology used to combine the uncertainties for the different contributors to the heat balance calculation is the square root of the sum of the squares of those uncertainties which are statistically independent. Then algebraically combined with the those errors that are systematic, or bias. The uncertainties are considered to be random, two sided distributions. This methodology has been utilized before, and has been endorsed by the NRC and various industry standards (Ref. 3.4.12-3.4.14).

The uncertainty calculation combines the different errors from the different parameters contributing to the heat balance in accordance to the heat balance equation. The contributing parameters errors are taken from the specific system uncertainty calculation.

These errors are generally classified in two groups:

a) Instrument loop(s) uncertainty

b) Process effects

The individual uncertainties affecting the heat balance calculation are determined by the application of the corresponding process algorithm, as described below:

a) the appropriate algorithm for the specific process parameter is set in the form to its specific contribution to the heat balance at specified rated conditions,
 b) subsequently, the instrumentation loop error is factored in the process algorithm to calculate the corresponding process parameter with the error built-in,

c) the difference of the calculated contributed process parameter heat, with error, to the rated process rated heat is then calculated,

d) the resultant heat error contribution is then divided by the rated 100% power thermal megawatts. The result is the error contribution by the specific process to the total heat balance uncertainty,

e) finally, all the calculated heat errors are combined in accordance to their parameter function in the heat balance equation. The resultant combination of all contributing errors is the Heat Balance Uncertainty.

(NC.E	(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)			CALCULATION CONTINUATION SHEET				3
CALC NO.:	SC-BB-0525 Attach	nment 1	REV:	5	REF:	CONT'D ON SHEET	:	4
ORIGINATOR:		DATE:	REVIEWER:		DATE:	VERIFIER:	DATE:	
Michael Miller 2/		2/14/2017	John Wilkens		3/13/2017	N/A		

Rev 5

7.2 Uncertainties Calculation

7.2.1 Main Feedwater Uncertainty(ies)

The Main Feedwater uncertainties are included in the total thermal power uncertainty provided by the LEFM is 0.34% per Reference 3.4.20. This includes the Main Feedwater mass flow error, main feedwater heat enthalpy error, and the Main Steam mass flow error

7.2.1.1 Main Feedwater Mass Flow Heat Error due to Flow Element Uncertainty (FWm)

Deleted

7.2.1.2 Main Feedwater Heat Enthalpy Error due to Pressure Loop Uncertainty (FWhp)

Deleted

7.2.1.3 Main Feedwater Heat Enthalpy Error due to Temperature Loop Uncertainty (FWht)

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(NC	DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCULATION CONTINUATION SHEET				
CALC NO .:	SC-BB-0525 Attachment 1	REV:	5	REF:	CONT'D ON SH	EET: 5	
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	DATE:	
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A	N/A	

7.2.2 Main Steam Flow Uncertainty(ies)

Referring to the schematic drawing in section 4.0, It can be seen that the Main Steam heat contribution is affected by the following parameters:

a) Main Steam Enthalpy determination is affected by the pressure instrumentation loop error, documented in calculation:

Rev 5

Ref. 3.4.4

7.2.2.1 Main Steam Mass Flow Heat Error due to Main Feedwater Flow Uncertainty (MSm)

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(NC.	DE-AP.ZZ-0002(Q), Rev. 12, Form 2)	CALCULATION CONTINUATION SHEET				SHEET:	5
CALC NO.: SC-BB-0525 Attachment 1		REV:	5	REF:	REF:		6
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	DATE:	
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A	N/A	

7.2.2.2 Main Steam Heat Enthalpy Error due to Pressure Loop Uncertainty (MShp)

This Section calculates the Main Heat Steam enthalpy error due to the loop pressure uncertainty, documented in:

Ref.: 3.4.4

The heat error is the difference in the Main Steam flow heat content at rated flow and enthalpy conditions minus the heat content at rated flow with enthalpy at rated pressure plus pressure induced error:

MShp = [Flow (hrated - hrated+err)] x 2.93E-07 / 3902 x 100%

P Rtd	P+err	Moist Rtd	Moist+err	h rated	h+err	Flow	
1020	1026.1	100	100.000	1192.19	1191.96	17,086,000	Rev 5
Error (psi) =	6.1		0				
	•						
-							
		TTL MS Heat					
		20,365,884,863	BTU/hr				Rev 5
		20,369,812,105	BTU/hr at rated cor	nditions			Rev 5
		_					
		Error			-		
		3,927,242	BIU/hr error at rat	ted main feedwater	flow		Rev 5
		Error in Rated MWt	0.0005%				ID
		MShp =	0.0295%				Rev 5

(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)			1	CALCULATION CONTINUATION SHEET SHEET				
CALC NO.: SC-BB-0525 Attachment 1		REV:	5	REF:		CONT'D ON SHEET: 7		
ORIGINATOR:		DATE:	REVIEWER:		DATE:	VERIFIER:	<u>ا</u> ر	DATE:
Michael Miller	· ·	2/14/2017	John Wilkens		3/13/2017	N/A		N/A

7.2.2.3. Main Steam Moisture Heat Enthalpy Error due to Steam Moisture Uncertainty (MSmoist)

This section calculates the Main Steam enthalpy error due to MS moisture uncertainty. The uncertainty is conservatively set to 50% of rated moisture content of 0.0%.

The heat error is the difference in the Main Steam flow heat content at rated flow and moisture conditions minus the heat content at rated moisture conditions plus moisture error:

MSmoist = [Flowrated hrated (hmoist-rated - hmoist-rated+err)] x 2.93E-07 / 3902 x 100%

Rev 5

P Rtd	P+err Moist	Rtd	Moist+err	h rated	h+err	Flow	
1020	1020	100	100.0000	1192.19	1192.19	17,086,000	Rev 5
	0.00000	0.00%	<u>‡ 0</u>			· · · · ·	·
-							
	TTL M	S Heat]				

20,369,812,105	BTU/hr	Rev 5
·····		
20,369,812,105	BTU/hr at rated conditions	Rev 5

Error

BTU/hr error at rated main feedwater flow

Error in Rated MWt

MSmoist = 0.0000%

(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)			CALCULATION CONTINUATION SHEET				7
CALC NO .:	SC-BB-0525 Attachment 1	REV:	5	REF:		CONT'D ON SHEET:	8
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	DA	ATE:
Michael Miller	2/14/2017	John Wilker	ns	3/13/2017	N/A	N	I/A

7.2.3 Control Rod Drive Flow

Referring to the schematic drawing in section 4.0, it can be seen that CRD flow is not monitored for pressure or temperature.

The CRD calculated heat is affected by the following effects:

a) Mass Flow Measurement affected by: 1) flow, instrumentation loop effect and 2) temperature, and 3) pressure deviation from calibration values

b) The CRD Enthalpy determination is affected by: 1) temperature, from applied constants, and 2) pressure, from reactor pressure loop error

The CRD flow loop errors are documented in calculation:

Ref. 3.4.5

The flow formula is derived from the ASME (Ref. 3.4.9) as follows:

Flow = C*Fa*K*(DP*r)^0.5

where K is calculated below:

K = Calib Flow/(Calib inWC * Calib r)^0.5

CALC NO.: SC	-BB-0525 Attachment 1		REF:		CONT'D ON SHEET: 9
ORIGINATOR:	DATE:	REVIEWER:	DATE:	VERIFIER:	DATE:
Michael Miller	2/14/2017	John Wilkens	3/13/2017	N/A	N/A
	ve Flow Heat Error due to Flow Ele	ment and Fluid Specific Weight I	Jncertainty due to Temperatu	e Error (CRDt)	
Fa = FE	Thermal Expansion	r = Fluid S	Specific Weight		
	ulates the CRD flow with a constan d 77F, and this impacts the Fa and				
CRDt = [(hs rated - CRI	Dh rated) (Flowrated - Flowrated+	err)] x 2.93E-07 / 3902 x 100%			Rev 5
Ref.: 3.4.5		K = 448.48	3		
		Calib Flow = 50154			
Fa Error		Calib inWC = <u>200</u>			
Rated 77F	1.0003	Calib Temp = $\underline{77}$	_		
@140 F	1.0013	Calib Press = <u>1474.</u>			
@40 F Fa/F	0.9995	r = 62.529			
га/г	1.8E-05	Assumed Rated Flow = <u>32000</u> Rated Press = 1020 p			
· · · ·		Rated Press = 1020 p Rated Temp = 77 F	JSIA		
		Rated remp = $\frac{1}{11}$ Rated h = 47.83	btu/ib		
CRtd	C+err DP Rtd		Fa Rtd Fa+err	T Rtd	T+err
1.0000		.3694 81.3694		.0011	77 120
0.00%	00	0.00%	<u>.</u>		4 3
	· · · · ·			alib Temp - Min Temp	
P Rtd	r h Rtd		hs Rtd		
1020	61.9029	47.83 31,863.902	1192.19		
	TTL CRD Heat	2 926 DTU//	. <u>.</u>		
		3,826 BTU/hr			
	36 610	9,571 BTU/hratrated conditions			
1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 -					
	Error		·		
	(15	5,745) BTU/hr error at rated CR	D flow		
	Error in Rated M	Wt			
			rror is a bias, not a random ins	trument induced uncerta	ainty.
	• • • • • • • • • • • • • • • • • • •				
and the second		and a second			
				· · ·	
			 A state of the sta		· · ·
		- All All All All All All All All All Al			

(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)			CALCULATION CONTINUATION SHEET			
CALC NO.:	SC-BB-0525 Attachment 1	REV:	5	REF:	CONT'D ON SHEET:	10
ORIGINATOR:	DATE:	REVIEWER:		DATE: VERIFIE	R:	DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017 N/A		N/A

7.2.3.2 Control Rod Drive Flow Heat Error due to Flow Element Uncertainty (CRDc)

The CRD contributed heat is affected by the FE error that is assigned to the flow element expansion coefficient.

С

The FE uncertainty is determined based in calculation:

Ref.: 3.4.5

The heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error:

CRDc = [(hs rated - CRDh rated) (Flowrated - Flowrated+err)] x 2.93E-07 / 3902 x 100%

Fa Error Rated 77F @140 F @60 F Fa/F	1.0003 1.0013 0.9995 1.8E-05	Assu	K = 4 Calib Flow = 5 Calib inWC = 2 med Calib Temp = 7 med Calib Press = 1 r = 6 med Rated Flow = 3 Rated Press = 1 Rated Temp = 7 Rated h = 4	0154 00.00 7.00 474.00 2.529 2000.0 lb/hr 020 psia 7 F	100.00 0.0159925			
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	T+err	
1.0000	1.0200	81.3694	81.3694	1.0003	1.0003	77	7 77	
2.00%		0.00%			· · · · ·		; 0	
P Rtd	r	h Rtd	Flow	hs Rtd				
1020.00	62.4433	47.83	32,617.500	1192.19			Re	ev 5
	TTL	- MFW Heat 37,326,215 36,619,571	BTU/hr BTU/hr at rated cond	litions			R	ev 5
	Erro	Error 706,644 or in Rated MWt CRDc =	BTU/hr error at rate	d CRD flow			•	ev 5 ev 5

(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)			CALCULATION CONTINUATION SHEET				10
CALC NO .:	SC-BB-0525 Attachment 1	REV:	5	REF:		CONT'D ON SHEET:	11
ORIGINATOR:	DATE:	REVIEWER	- <u> </u>	DATE:	VERIFIER:	D	ATE:
Michael Miller	2/14/2017	John W	ilkens	3/13/2017	N/A	N	I/A

7.2.3.3 Control Rod Drive Heat Error due to Differential Pressure (DP) Loop Uncertainty (CRDdp)

This error is calculated in calculation.

Ref.: 3.4.5

The loop is comprised of 1) flow transmitter, FT, 2) resistor, REST, 3) computer analog to digital card, A/D. The uncertainties are in % DP span:

Accuracy:		Loop Drift:	
CRD_AFT	CRD_AREST	CRD AA/D CRD_VDFT	CRD_VDA/D
1.154%	0.100%	0.188% 1.450%	0.000%
1		the second se	

Loop Calibration:

CRD_CEFT	CRD_CEA/D	ŀ
0.140%	0.188%	

The uncertainties are random and independent and combined by the SRSS method:

1.88% span DP

(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)			CALCULATION CONTINUATION SHEET				11
CALC NO.:	SC-BB-0525 Attachment 1	REV:	5	REF:		CONT'D ON SHEET:	12
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	DA	TE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A)N	/A

The heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error:

CRDdp = [(hs rated - CRDh rated) (Flowrated - Flowrated+err)] x 2.93E-07 / 3902 x 100%

Fa Error		K= 448.51	
Rated 77F	1.0003	Calib Flow = 50157.2 lb/hr	100 GPM
@140 F	1.0013	Calib inWC = 200	
@60 F	0.9995	Assumed Calib Temp = 77	
Fa/F	1.8E-05	Assumed Calib Press = 1474	
		r = 62.529	
		Assumed Rated Flow = 32000.0 lb/hr	
		Rated Press = 1020.0 lb/hr	
		Rated Temp = 77 F	
		CRDh rated = 47.83 btu/lb	

C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	T+err
1.0000	1.0000	81.3584	85.1183	1.0003	1.0003	77	77
0.00%	2 0	1.88%	÷				\$ 0

P Rtd r		CRDh rated	Flowrated+err	hs Rtd
1020	62.4433	47.83	32,708.537	1192.19

TTL MFW Heat 37,430,393 BTU/hr

36,619,571 BTU/hr at rated conditions

Error

810,822 BTU/hr at rated CRD flow

Error in Rated MWt CRDdp = 0.0061%

Rev 5

(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCULATION CONTINUATION SHEET				SHEET:	12		
CALC NO.:	SC-BB-0525 Attach	nment 1	REV:	5	REF:	<u> </u>	CONT'D ON SHEET:	13	
ORIGINATOR:		DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:	
Michael Miller		2/14/2017	John Wilkens		3/13/2017	N/A		N/A	

7.2.3.4 Control Rod Drive Flow Enthalpy Heat Error due to Temperature Calibration Deviation (CRDht)

The plant computer calculates the CRD fluid enthalpy at a constant 77F and reactor pressure. However, the actual temperature varies and it is assumed to vary as much as 43F from the expected 77F; therefore, the effect due to this temperature deviation in the calculated enthalpy is:

Ref. 3.4.5

The heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error.

CRDht = [Flow (hs rated - CRDh rated) - Flow (hs rated - CRDh rated+err)] x 2.93E-07 / 3902 x 100%

TRtd	T Max/Min	T+err	P Rtd	h rated	h+err	hs rated	Flow
77	40	37	1020	47.83	8.05	1192.19	32,000

TTL RWCU Heat 37,892,585 BTU/hr

36,619,571 BTU/hr at rated conditions

Error

(1,273,014) BTU/hr at rated CRD flow

Uncertainty in Rated MWt CRDht = -0.0096%

This error is a bias, not a random instrument induced uncertainty.

Rev 5

(NC	.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALC	CULATION CONTINUATION	SHEET	SHEET:	13
CALC NO.:	SC-BB-0525 Attachment 1	REV:	5	REF:		CONT'D ON SHEET:	14
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	D	ATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A	N	I/A

7.2.3.5 Control Rod Drive Flow Enthalpy Heat Error due to Pressure Loop Uncertainty (CRDhp)

The plant computer calculates the CRD fluid enthalpy at a constant 77Fand reactor loop pressure, that is affected by the loop uncertainty. The pressure loop uncertainty is documented in:

Ref.: 3.4.4

The heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error:

CRDhp = [Flow (hs rated - CRDh rated) - Flow (hs rated+err - CRDh rated)] x 2.93E-07 / 3902 x 100%

P Rtd	P+err	TRtd	CRDh rated	hs rated	hs rated+err	Flow	
1020	1026.1	77	47.83	1192.19	1191.96	32,000	Rev 5
Error (psi) =	<u>6.1</u>						
		TTL MFW Heat 36,612,216	RTU/br				Rev 5
	1	30,012,210	D i O/III				litero
		36,619,571	BTU/hr at rated cor	nditions			Rev 5
		Error (7,355)	BTU/hr at rated CI	RD flow			Rev 5
		Uncertainty in Rated CRDhp =	MWt -0.00006%				Rev 5

(N	IC.DE-AP.ZZ-0002(Q), Rev. 12	2, Form 2)		CALCULATION	CONTINUATION SHEE	T	SHE T	14
CALC NO.:	SC-BB-0525 Attach	ment 1	REV:	5	REF:	·	CONT'DONSHE T	15
ORIGINATOR:		DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller		2/14/2017	John Wilkens		3/13/2017	N/A		N/A

7.2.4 Reactor Water Cleanup Uncertainty(ies)

Referring to the schematic drawing in section 4.0, it can be seen that RWCU flow is measured and mass calculated by a "NUMAC" process unit. Differential pressure, temperature, by dedicated thermocouples, and reactor pressure are an input to the instrument. Therefore, the RWCU contributed heat is affected by the following parameters:

a) Mass Flow Measurement affected by: 1) flow, 2) temperature, and 3) pressure induced factors/instrumentation loops errors

b) The RWCU Enthalpy determination is affected by: 1) temperature instrumentation loop error (see discussion for pressure)

The flow formula is derived from the ASME (Ref. 3.4.9) as follows:

Flow = C*K*(DP)^0.5

where K is:

K = Calib Flow / [C*(Calib inWC)^0.5]

	NC.DE-AP.ZZ-0002(Q), Rev. 12, F	form 2)		CALCULATION C	ONTINUATION	SHEET	SHEET:	15
CALC NO.:	SC-BB-0525 Attachm	ent 1 RE	EV:	5 1	REF:		CONT'D ON SHEET:	16
RIGINATOR:		TE: RE	EVIEWER:		DATE:	VERIFIËR:	<u> </u>	DATE:
Michael Miller	21-	14/2017 J	ohn Wilkens		3/13/2017	N/A	I	N/A
7.2.4.1 RWCU	Inlet/Outlet Flow Heat Error	due to Flow Element Ex	xpansion deviatio	n from Calibration (R	WCUFa)			
	nputer calculating the mass							
	533F. This induces a bias er					cific weight of 47.0 lbm/cuft		
pressure and te	mperature conditions, back	calculated below; theref	ore, the rated co	nditions are set at 53	0.7F.			Rev 5
Pressure Densi	ty Compensated to :	47.19 lb/cuft	530.7 F	908 psia				Rev 5
	the calculation is fixed to:		1.0045					
The correct Fa	at rated 533 F is:		1.0087					
Based on the F	a differences the induced flo	w error is calculated be	IOW:					
	Fa = FE Thermal Expansion	ı						
	•							
Ref.: 3.4.10								
$Flow+err = C \times F$	Fa+err / Fa x K x (DP)^0.5		К =	9449.90				Rev 5
					500 GPM	(Note)	I	
Fa Error			Calib inWC =					
Rated 533F	<u>1.0087</u>		ned Calib Temp =					Rev 5
Calibrated	<u>1.0045</u>	Assum	ed Calib Press =	Sound Street Str				
		A	r = = ed Rated Flow	47.332	389 GPM			Rev 5
		Assuit		524.83 btu/lb	<u>369 GP M</u>			
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	T+err	
	1.0000	245.3520	245.3520	1.0087	1	.0045 530.		
0.	00%	0.00%	;0	J			; 0	
P Rtd	P+err	r i	h Rtd	Flow+err				
	14.7 1114.7	47.3324	524.83				ſ	Rev 5
· · · ·	÷0		02 1100	,,				
	kuunnin 1999 –							
	Г	Uncertainty RWCUFa -6				d Heat is Higher than indica		Rev 5

and a second second

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Note: This value is slightly different to the 189,197 lb/hr calculated in the reference due to rounding

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(NC.	.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCULATION O	CONTINUATION SHEE	T	SHEET:	16
CALC NO.:	SC-BB-0525 Attachment 1	REV:	5	REF:		CONT'D ON SHEET:	17
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A

7.2.4.2 RWCU Inlet/Outlet Flow Heat Error due to Fluid Specific Weight deviation (RWCUPMA)

This error is the combination of several uncertainties calculated below:

7.2.4.2.1 RWCU Inlet/Outlet Flow Error due to Fluid Specific Weight Numac Lookup Tables Error (RWCUPMA1)

The Numac performs the fluid specific weight determination with an error of 0.1 specific weight, this effect in the flow is calculated below.

r = Fluid Specific Weight

Ref.: 3.4.10

Flow+err = $C \times K \times (DP \times r+err / r)^{A}0.5$

The flow error is the difference between the rated flow at rated specific weight minus the flow at specific weight plus error:

RWCUPMA1 = Flowrated - Flowrated+error

			К =	9449.90			Rev 5
			Calib Flow =	189823.1 lb/hr 50	00 GPM (No	te)	r
Fa Error			Calib inWC =	403.5			
Rated 533F	1.0087	Ass	umed Calib Temp =	530.7	•		Rev 5
Calibrated	1.0045	Ass	umed Calib Press =	1114.7			•
			· r=	47.332			Rev 5
		Ass	umed Rated Flow =	148021 lb/hr 38	38.8 GPM		
			Rated hout =	524.83 btu/lb			
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	•
1.000	0 1.0000	245.3520	245.3520	1.0087	1.0087	530.7	Rev 5
0.00%	6 0	0.00%	: 0				•
		· · · · ·	· · · · ·				
P Rtd	P+err	r	Numac err	r+perr+Numac	h Rtd	Flow	
1114.7	1114.7 psi	47.332	0.1	47.432	524.83	148,177	Rev 5
4	0 psi					· · · · · · · · · · · · · · · · · · ·	
		and the second second		• "			
	and a second of the second	Uncertainty					
		RWCUPMA1 =	156.3 lb/hr				
Note: This value is	slightly different to the 18	9 197 lh/hr calculate	d in the reference du	le to rounding			
	onging anioronic to the ro	o, ior iorni oulouluto		io to i ounaling			

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CALC NO.:	SC-BB-0525 Attach	nment 1	REV:	5	REF:			CONT'D ON SHEET:	18
ORIGINATOR:		DATE:	REVIEWER:		DATE		VERIFIER:		DATE:
Michael Miller		2/14/2017	John Wilkens		3/13	/2017	N/A		N/A

7.2.4.2.2 RWCU Inlet/Outlet Flow Error due to Fluid Specific Weight Numac 0.75 Factor Pressure Correction Factor Error (RWCUPMA2)

The Numac computer introduces a 0.75 factor to the input pressure raw value and calculates the specific weight for saturated conditions, which bias the actual flow.

Ref.: 3.4.10

Flow+err = $C \times K \times (DP \times r+err / r)^{0.5}$

The flow error is the difference between the rated flow at rated specific weight minus the flow at specific weight plus error:

RWCUPMA2 = Flowrated - Flowrated+error

r = Fluid Specific Weight

			K =	9449.90			Rev 5
			Calib Flow =	189823.1 lb/hr	500 GPM	(Note)	
Fa Error			Calib inWC =	403.5			
Rated 533F	1.0087	Assum	ned Calib Temp =	530.7			Rev 5
Calibrated	1.0045	Assum	ned Calib Press =	1114.7			
			r = -	47.332			Rev 5
		Assum	ned Rated Flow =	148021 lb/hr	388.8 GPM		
			Rated =	524.83 btu/lb			
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	
1.0000	1.0000	245.3520	245.3520	1.0087	1.0087	530.7	Rev 5
0.00%	<u> </u>	0.00%	: 0				

	P Rtd	P+err	T Sat	r+perr	Numac rerr	r+perr+Numac	h Rtdout	h Rtd return	Flow
- {	1114.7	840 psi	523.8	47.5905	0	47.5905	524.83	412.64	148,424
-		75%	<u>75</u>						

Uncertainty RWCUPMA2 = -403 lb/hr_____This a bias and the actual contributed Heat is Higher than indicated Rev 5

Note: This value is slightly different to the 189,197 lb/hr calculated in the reference due to rounding

- (NC.DE	-AP.ZZ-0002(Q), Rev. 12, F	form 2)		CALCULATION	ONTINUATION SHEE	T	SHEET	r: 1 8
	SC-BB-0525 Attachm		EV:		REF:		CONT'D ON SHEET	
ORIGINATOR:	DAT	TE:	EVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/1	14/2017 J	ohn Wilkens			N/A		N/A
Pressure is utilized a	t/Outlet Flow Heat Erro s an input to the Numao I with the Numac comp	c to determine the spec	cific weight of the flu	uid. The pressure l	оор			
The loop error is com	prised of 1) pressure lo	pop, PT, 2) NUMAC co	mputer uncertaintie	s. The combined ι	incertainties are:			
RWCUpress error=	21 psi							
		ta €gi sa s						
Ref.: 3.4.10			•	÷				
Flow+err = C x K x (D	P x r+err / r)^0.5	en e				·		÷ .
The flow error is the	difference between the	rated flow at rated spa	cific weight minus t	he flow at specific y	veight plus error:	-		
		Taleu now al Taleu spe		ne now at specific i	weight plus end.	and a second		
RWCUp_SW = [Flow	/rated (h_in - h_out) - F	lowrated+error (h_in -	h_out)]x 2.93E-0	7 / 3902 x 100%				Rev 5
r =	Fluid Specific Weight		К = с	9449.90				Rev 5
			Calib Flow = 1		500 GPM	(Note)		
F a Error Rated 533F	1.0087	A	Calib inWC = 4					
Calibrated	1.0045		ned Calib Temp = 5 ned Calib Press = 1					Rev 5
		_		17.332				Rev 5
		Assur	ned Rated Flow = 1 Rated b = F	148021 lb/hr 524.83 btu/lb	388.8 GPM			{
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd in	T Rtd out	-j
1.0000	1.0000	245.3520	245.3520	1.0087	1.0087	530.7	433.8	3
0.00%	0	0.00%	<u> </u>	•			-	
P Rtd	P+err		lumac rerr	r+perr+Numac	h Rtd in	h Rtd out	Flow]
1020	1041 psi	47.2821	0	47.2821	524.96	412.64	147,942	Rev 5
		TTL MFW Heat				ан Ал		
	Ĺ	16,616,340 E	STU/hr					Rev 5
		16,625,169 B	TU/hr at rated cond	ditions				Rev 5
	- 1	Error						
	· .	8,829	· • .					Rev 5
	Un	certainty in Rated M RWCUp_sw = 0						

(NC.	DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALC	ULATION CO	ONTINUATION	SHEET	SHEET:	19
CALC NO.:	SC-BB-0525 Attachment 1	REV:	5	R	REF:		CONT'D ON SHEET:	20
ORIGINATOR:	DATE:	REVIEWER:		D	DATE:	VERIFIER:		DATE:
Michael Miller	2/14/2017	John Wilkens		3	3/13/2017	N/A		N/A

7.2.4.3 Reactor Water Cleanup Flow Error due to Flow Element Uncertainty (RWCUc)

The RWCU flow is affected by the FE error that is assigned to the flow element expansion coefficient.

С

The FE uncertainty is determined based in calculation:

Ref.: 3.4.10

Flow+err = C+err x K x (DP)^0.5

The flow error is the difference between the rated flow minus the flow with the C coefficient error:

RWCUc = Flowrated - Flowrated+error

Fa Error Rated 533F	1.0087		K = 94 Calib Flow = 18		500 GPM	(Note)	F	Rev 5
Calibrated	1.0045		Calib inWC = 40	3.50			· ·	
4		Assu	med Calib Temp = 53				R	Rev 5
			med Calib Press = 11					
			r = 47	.332			R	Rev 5
		Assu	med Rated Flow = 14	8021 lb/hr	389 GPM			
			Rated h = 52	24.83 btu/lb				
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	T+err	
1.0000	1.0150	245.3520	245.3520	1.0087	1.0087	530.7	530.7	
1.50%	<u>‡ 150</u>	0.00%	÷0				2 0	

P Rtd	r	h	Flow					
1114.7	47.3324	524.8	150,241				R	Rev 5
		Uncertainty RWCUc = 2	2220.3 lb/hr				ק	Rev 5
							•	

Note: This value is slightly different to the 189,197 lb/hr calculated in the reference due to rounding

· · · · ·							
(NC	DE-AP.ZZ-0002(Q), Rev. 12, F	Form 2)	· · ·	CALCULATION	CONTINUATION SHE	ET	SHEET: 20
CALC NO .:	SC-BB-0525 Attachm		REV:	5	REF:		CONT'D ON SHEET: 21
ORIGINATOR:	DA	NTE:	REVIEWER:		DATE:	VERIFIER:	DATE:
Michael Miller	2/	14/2017	John Wilkens		3/13/2017	N/A	N/A
7.2.4.4 Reactor W	ater Cleanup Flow Error	due to Differential P	ressure (DP) Loop	Uncertainty (RWCU	lp)	-	
This error is introd	uced by the differential pr	ressure instrument lo	oop. The uncertaint	ies in the loop are fo	ound in:	Ref.: 3.4.10	
The loop is compr	ised of 1) flow transmitter	ET 2) NUMAC cor	mouter The uncert	ainties are in % DP s	nan.		· · · ·
			11 · · ·		, parin		
The flow error is the	ne difference between the	rated flow minus the	e flow with the C co	efficient error:			
RWCUdp = Flowra	ted - Flowrated+error						
A		· · · · ·	Loop Drift.				
Accuracy: RWCU_AFT	RWCU_ANU_IE	RWCU_ANU_A/D	Loop Drift:	RWCU VDNU IE	RWCU_VDNU_A/D	7	
0.503%	0.100%	0.233%	0.900%	0.127%	0.127%		
Leen Calibration	,	an a			· ·		
Loop Calibration	RWCU_CENU_A/D				· ·		
0.139%	0.02%						
	are random and independ	lent and combined b	by the SRSS metho	d:			
	% span DP	lent and combined b	by the SRSS method	d:			
1.09	% span DP	lent and combined b		d: = 9449.90			Rev 5
Flow+err = C x K x Fa Error Rated 533F	% span DP (DP+err)^0.5 1.0087	lent and combined b	K Calib Flow	= 9449.90 = 189823.1 LB/HR	500 GPM	(Note)	Rev 5
Flow+err = C x K x	% span DP (DP+err)^0.5		K Calib Flow Calib inWC	= 9449.90 = 189823.1 LB/HR = 403.50	500 GPM	(Note)	
Flow+err = C x K x Fa Error Rated 533F	% span DP (DP+err)^0.5 1.0087	As	K Calib Flow	= 9449.90 = 189823.1 LB/HR = 403.50 = 530.70	500 GPM	(Note)	Rev 5 Rev 5
Flow+err = C x K x Fa Error Rated 533F	% span DP (DP+err)^0.5 1.0087	As As	K Calib Flow Calib inWC sumed Calib Temp sumed Calib Press r	= 9449.90 = 189823.1 LB/HR = 403.50 = 530.70 = 1114.70 = 47.332		(Note)	
Flow+err = C x K x Fa Error Rated 533F	% span DP (DP+err)^0.5 1.0087	As As	K Calib Flow Calib inWC sumed Calib Temp sumed Calib Press r sumed Rated Flow	= 9449.90 = 189823.1 LB/HR = 403.50 = 530.70 = 1114.70 = 47.332 = 148021 LB/HR	500 GPM 389 GPM	(Note)	Rev 5
Flow+err = C x K x Fa Error Rated 533F Calibrated	%(span DP (DP+err)^0.5 1.0087 1.0045	As As As DP Rtd	K Calib Flow Calib inWC sumed Calib Temp sumed Calib Press r sumed Rated Flow Rated h DP+err	= 9449.90 = 189823.1 LB/HR = 403.50 = 530.70 = 1114.70 = 47.332 = 148021 LB/HR = 524.83 btu/lb Fa Rtd	389 GPM	T Rtd	Rev 5
Flow+err = C x K x Fa Error Rated 533F Calibrated C Rtd 1.000	%(span DP (DP+err)^0.5 1.0087 1.0045 00 C+err	As As As	K Calib Flow Calib inWC sumed Calib Temp sumed Calib Press r sumed Rated Flow Rated h DP+err	= 9449.90 = 189823.1 LB/HR = 403.50 = 530.70 = 1114.70 = 47.332 = 148021 LB/HR = 524.83 btu/lb Fa Rtd	389 GPM	T Rtd	Rev 5 Rev 5 1 T+err 1.7 530.7
1.09 Flow+err = C x K x Fa Error Rated 533F Calibrated Calibrated 1.000 0.000	%(span DP (DP+err)^0.5 1.0087 1.0045	As As As DP Rtd	K Calib Flow Calib inWC sumed Calib Temp sumed Calib Press r sumed Rated Flow Rated h DP+err 0 249.733	= 9449.90 = 189823.1 LB/HR = 403.50 = 530.70 = 1114.70 = 47.332 = 148021 LB/HR = 524.83 btu/lb Fa Rtd	389 GPM	T Rtd	Rev 5
1.09 Flow+err = C x K x Fa Error Rated 533F Calibrated C Rtd 1.000 0.000 P Rtd	% span DP (DP+err)^0.5 1.0087 1.0045 1.0045 00 1.0000 % ○ 0	As As DP Rtd 245.352 h	K Calib Flow Calib inWC sumed Calib Temp sumed Calib Press r sumed Rated Flow Rated h DP+err 0 249.733	= 9449.90 = 189823.1 LB/HR = 403.50 = 530.70 = 1114.70 = 47.332 = 148021 LB/HR = 524.83 btu/lb Fa Rtd 8 1.008	389 GPM	T Rtd	Rev 5
1.09 Flow+err = C x K x Fa Error Rated 533F Calibrated Calibrated 1.000 0.000	% span DP (DP+err)^0.5 1.0087 1.0045 1.0045 00 1.0000 % ○ 0	As As DP Rtd 245.352	K Calib Flow Calib inWC sumed Calib Temp sumed Calib Press r sumed Rated Flow Rated h DP+err 0 249.733	= 9449.90 = 189823.1 LB/HR = 403.50 = 530.70 = 1114.70 = 47.332 = 148021 LB/HR = 524.83 btu/lb Fa Rtd 8 1.008	389 GPM	T Rtd	Rev 5 Rev 5 1 T+err 1.7 530.7
1.09 Flow+err = C x K x Fa Error Rated 533F Calibrated C Rtd 1.000 0.000 P Rtd	% span DP (DP+err)^0.5 1.0087 1.0045 1.0045 00 1.0000 % ○ 0	As As DP Rtd 245.352 h 524.8 Uncertainty	K Calib Flow Calib inWC sumed Calib Temp sumed Calib Press r sumed Rated Flow Rated h DP+err 0 249.733 Flow 3 149,336	= 9449.90 = 189823.1 LB/HR = 403.50 = 530.70 = 1114.70 = 47.332 = 148021 LB/HR = 524.83 btu/lb Fa Rtd 8 1.008	389 GPM	T Rtd	Rev 5
1.09 Flow+err = C x K x Fa Error Rated 533F Calibrated C Rtd 1.000 0.000 P Rtd	% span DP (DP+err)^0.5 1.0087 1.0045 1.0045 00 1.0000 % ○ 0	As As DP Rtd 245.352 h 524.8 Uncertainty	K Calib Flow Calib inWC sumed Calib Temp sumed Calib Press r sumed Rated Flow Rated h DP+err 0 249.733 Flow 3 149,336	= 9449.90 = 189823.1 LB/HR = 403.50 = 530.70 = 1114.70 = 47.332 = 148021 LB/HR = 524.83 btu/lb Fa Rtd 8 1.008	389 GPM	T Rtd	Rev 5
1.09 Flow+err = C x K x Fa Error Rated 533F Calibrated C Rtd 1.000 0.00 P Rtd 1114	% span DP (DP+err)^0.5 1.0087 1.0045 1.0045 00 1.0000 % ○ 0	As As DP Rtd 245.352 h 524.8 Uncertainty RWCUdp	K Calib Flow Calib inWC sumed Calib Temp sumed Calib Press r sumed Rated Flow Rated h DP+err 0 249.733 Flow 3 149,330 y = 1315.9 lb/hr	= 9449.90 = 189823.1 LB/HR = 403.50 = 530.70 = 1114.70 = 47.332 = 148021 LB/HR = 524.83 btu/lb Fa Rtd 8 1.008	389 GPM	T Rtd	Rev 5

(NC	.DE-AP.ZZ-0002(Q), Rev. 12,	, Form 2)		CALCULATION	CONTINUATION SHEE	ET SHI	ET:	21
CALC NO.:	SC-BB-0525 Attach	ment 1	REV:	5	REF:	CONT'D ON SHE	ET:	22
ORIGINATOR:	D	DATE:	REVIEWER:		DATE:	VERIFIER:	DATE:	
Michael Miller	2	2/14/2017	John Wilkens		3/13/2017	N/A	N/A	ľ

7.2.4.5 Reactor Water Cleanup Flow Error due to Signal Conditioning/NSSS Computer Loop Uncertainty (RWCUNSSS_cptr)

The differential pressure is converted to flow by the Numac computer and retransmitted as flow signal to the plant computer for heat balance calculations.

This portion of the loop is comprised of 1) NUMAC computer output, 2) NSSS computer uncertainty. The uncertainties are in % flow span:

	Accuracy:		Loop Drift:		
ĺ	RWCU_ANU_D/A	RWCU_AA/D	RWCU_VDNU_D/	A RWCU_VNA/D	Rev 5
	0.233%	0.188%	0.13%	0.000%]

Loop Calibration:	
RWCU_CENU_D/A	RWCU_CEA/D
0.02%	0.188%

The uncertainties are random and independent and combined by the SRSS method:

0.38% span FLOW

The flow error is the difference between the rated flow at without loop error minus the flow plus loop error:

RWCUNSSS_cptr = Flowrated - Flowrated+error

Fa Error Rated 533F	1.0087			9449.90 189823.1 lb/hr	500 GPM	(Note)		Rev 5
Calibrated	1.0045		Calib inWC =			(NOLE)		l
Calibrated	1.0043		ned Calib Temp =	530.70				Rev 5
		Assun	ned Calib Press = r = r	47.332				Rev 5
		Assun	ned Rated Flow =		389 GPM			
			Rated h =	524.83 btu/ l b				
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	T+err	Ì
1.0000	1.0000	245.3520	245.3520	1.0087	1.0087	530.7	530.7	Ì
0.00%	0						\$ 0	Ì

P Rtd	r	h	Flowrated+err
1114.7	47.3324	524.83	148,733.9

Uncertainty RWCUNSSS_cptr= 713.3 lb/hr

Note: This value is slightly different to the 189,197 lb/hr calculated in the reference due to rounding

Rev 5

Rev 5

(NC	C.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALC	JLATION CONTINUATION SHE	ET	SHEET:	22
CALCNO .:	SC-BB-0525 Attachment 1	REV:	5	REF:		CONT'D ON SHEET:	23
ORIGINATOR:		REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A

7.2.4.6 Reactor Water Cleanup Total Flow due to Flow Loop Uncertainties (RWCUf)

RWCU inlet h - Outlet h.

The total RWCU Flow Uncertainty is calculated below:

RWCUfu =+/-SQRT(RWCUPMA1^2+RWCUc^2+RWCUdp^2+RWCUNSSS cptr^2)-RWCUFa-RWCUPMA2

Notice that the bias PMAs are factored with both signs, since the negative uncertainty is the one that has impact in the heat balance calculations, that is, that (-) less indication means that power is higher; however, it will be factored in both directions for simplicity.

RWCUfu = 3710 lb/hr

Then, the heat error contribution is the calculated inlet flow heat error minus the outlet flow heat error:

RWCUh_in = 524.96 btu/lb RWCUh_out = 412.64 btu/lb

And the RWCU heat error contribution is calculated by the following expression:

RWCU = [RWCUfu (RWCUh_in - RWCUh_out) x MWt_BTU_hr (conversion factor)] / Rated MWt 100%

RWCUf = 0.0031%

This total error will be treated as bias in the total heat balance error

Rev 5

(NC	.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCI	JLATION CONTINUATION SI	HEET	SHEET:	23
CALC NO.:	SC-BB-0525 Attachment 1	REV:	5	REF:		CONT'D ON SHEET:	24
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A

7.2.4.7 Reactor Water Cleanup Flow Enthalpy Heat Error due to Temperature Uncertainty (RWCUht)

This error is the error resultant of temperature measurement errors by the inlet/outlet RWCU thermocouple loops factored into the fluid enthalpy determination. The thermocouples are instruments with good repeatability and stability. However, fabrication errors can amount to several farenheit degrees. The fabrication errors can be calibrated out, since essentially it is a bias, systematic error. The temperature loops for RWCU are not calibrated out. Finally, since most of the thermocouples loop error is a bias, the conservative and safe way to apply the error, is for the two temperature error to be set in the same direction; therefore, the effect is additive, bias. The temperature loops error is found in:

<u>Ref. 3.4.6</u>

The heat error is the difference between the inlet flow heat error minus the outlet flow heat error:

In flow heat

Inneumeat					
TRtd	T+err	P Rtd	h rated	h+err	Flow
530.7	541.6	1020	524.96	538.69	148,021
Error (F)	<u>10.9</u>				

Out flow heat

outhen heat					
TRtd	T+err	P Rto	d h rated	h+err	Flow
433.8	444.7	1020) 412.64	424.67	148,021
Error (F)	10.9				

Error
3,813,151 BTU/hr error at rated reactor water cleanup flow
Rev 5

Uncertainty in Rated MWt RWCUht = 0.0286%

This error is a bias

Rev 5

(N0	C.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCULATION	CONTINUATION SHEE	T	SHEET:	24
CALCNO.:	SC-BB-0525 Attachment 1	REV:	5	REF:		CONT'D ON SHEET:	25
ORIGINATOR:	DATE:	REVIEWER.		DATE:	VERIFIER:	1	DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/À

7.2.4.8 Reactor Water Cleanup Flow Enthalpy Heat Error due to Pressure Loop Uncertainty (RWCUhp)

The reactor water cleanup enthalpy determination is affected by the loop pressure error. The pressure has a very small effect in the water enthalpy, however, it is determined in this calculation. The loop uncertainty is documented in:

Ref.: 3.4.4

The heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error:

RWCUhp = [Flow [(hin - hin+error) - (hout - hout+error)]] x 2.93E-07 / 3902 x 100%

In flow heat				1			
P Rtd		P+err	ľ	TRtd	h rated	h+err	Flow
1020	-	1040.2	- -	530.7	524.96	524.93	148,000
Error (psi)		20.2					

Out flow heat

P Rtd	1	P+err		TRtd	h rated	h+err	Flow
1020	1.	1040.2	}	433.8	412.64	412.66	148,000
Error (psi)		20.2	1				· ·

Error

Uncertainty in Rated MWt

RWCUhp = 0.00005%

6,672 BTU/hr at rated reactor water cleanup flow

Rev 5

Rev 5

(NC.	.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALC	ULATION CONTINUATION SH	EET	SHEET:	25
CALC NO.:	SC-BB-0525 Attachment 1	REV:	5	REF:		CONT'D ON SHEET:	26
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A]	N/A

7.2.5 Recirculation Pumps Heat Error due to Watts Loop Uncertainty (RRPw)

This section calculates the uncertainty due to RRP watts loop error, calculated in:

Ref.: 3.4.11

The rated power for the pump-motor and the motor efficiency (0.93) is from reference:

(Ref. 3.4.3)

.

There are two recirculation pumps, the calculated error below is per pump. The actual total MW for the 2 pumps is taken from above reference.

W 2 pump = 7.33

The Watt error contribution is calculated as follows:

RRPw = [(W Rtd/pump + MW Loop Span x Span err) x Mottor eff] - W Rtd/pump x Motor eff] / 3902 x 100%

Rev 5

W Rtd/pmp+err	Motor Eff	W+err
3.823	0.93	3.55
	Error =	1.50 % span
	Span =	10.5 Mwatt

TTL Mwatt _____3.41 Mwatt

Error

0.1465 Mwatt

Uncertainty	in Rated MWT
	RRPw = 0.0038%

	(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CAL	CULATION CONTINUATION S	SHEET	SHEET:	26
CALC NO.:	SC-BB-0525 Attachment 1	REV:	5	REF:		CONT'D ON SHEET:	27
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	1	DATE:
Michael Mille	r 2/14/2017	John Wilkens	6	3/13/2017	N/A		N/A

7.2.6 Thermal Loses (TL)

This section calculates the uncertainty due to TL error. This error will be treated as a bias error since the estimated value is larger or smaller than assumed, i.e. it is a fixed error not a random error.

An assumed error equal to 20% of the specified loses is used.

The rated Heat Loss is from reference:

(Ref. 3.4.2)

W Rtd	W+err
1.1	1.32
Error =	20.00%

TL Mwatt Heat	_
1.32	MW
	· · ·

1.10 MWat rated conditions

Error

0.2200 MW error at rated radiated loses

Uncertainty in Rated MWT	This error is treated as bias.	
TL = 0.0056%	l f	Rev 5

Note: The computer utilizes this value combined with Other System Loses (Section 7.2.7) as Radiative power loses, QRAD = 1.94

(NC	.DE-AP.ZZ-0002(Q), Rev. 12,	Form 2)		CALCULATION C	ONTINUATION SHEE	Т	SHEET:	27
CALC NO.:	SC-BB-0525 Attach	ment 1	REV:	5	REF:		CONT'D ON SHEET:	28
ORIGINATOR:	E	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2	2/14/2017	John Wilkens		3/13/2017	N/A		N/A

7.2.7 Other System Loses (OSL)

The rated value includes Rod Drive seal purge flow to recirculation pumps. An assumed error equal to 20% of the specified loses is used. This error will be treated as a bias error since if the estimated value is larger or smaller than assumed, i.e. it is a fixed error not a random error.

The rated Losses figure is from reference:

(Ref. 3.4.2)

	W Rtd	W+err
1	1.18	1.416
	Error =	20%

TTL Mwatt Heat 1.42	MW	Rev 5
1.18	MW at rated conditions	Rev 5
Error 0.2360	MW error at rated radiated loses	Rev 5
Uncertainty in Rated OSL :	MWT This error is treated as bias. = 0.0060%	Rev 5

Note: The computer utilizes this value combined with Thermal Loses (Section 7.2.6) as Radiative power loses, QRAD = 1.94

(NC.	DE-AP.ZZ-0002(Q), Rev. 12, Form	2)	CALCU	LATION CONTINUATION	SHEET	SHEET:	28
CALC NO.:	SC-BB-0525 Attachment	1	5	REF:		CONT'D ON SHEET:	29
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	1	DATE:
Michael Miller	2/14/2	017 John Wilke	ens	3/13/2017	N/A		N/A

7.2.8 Heat Balance Calculation Power Uncertainty (Power U)

The calculated heat balance uncertainty is the algebraic combination of the bias errors with the independent/random errors statistically combined, that contribute into the heat balance calculation, in accordance with the heat balance formula:

Power = MFW(MSh-FWh)-CRDF(hin-hout)+RWCU(hout-hin)-RRP+HL+Miscellaneous

Summary of Heat Balance Calculation Contributing Errors:

$CRDc = 0.0053\%$ $CRDdp = 0.0061\%$ $RRPw = 0.0038\%$ $RWCUp sw = 0.0001\%$ Pependent Errors: Errors FWhp = ** FWht = ** MSm = ** FWht = ** MSm = ** CRDht = -0.0006% RWCUhp = 0.00006% RWCUhp = 0.00006% CRDht = -0.0012\% CRDht = -0.0012\% CRDht = -0.0096% RWCUf = 0.0031% RWCUf = 0.0031% RWCUf = 0.0031% RWCUf = 0.0036% TL = 0.0066% OSL = 0.0066% * Note that these terms are combined in reference 3.4.20 for an over all uncertainty of 0.34% for FWm, FWht and FWhp teat Balance Calculation Power Error (U): Power Error = SQRT[((0.0034)^2+(MShp+CRDhp+RWCUhp)^2+MSmoist^2+CRDc^2+CRDdp^2+ +RWCUp_sw^2+RRPw^2x2]+CRDt+CRDht+RWCUht+TL+OSL	
RRPw = 0.0038% RWCUp sw = 0.0001% Dependent Errors: Errors FWhp = ** FWm = ** FWm = ** MSm = ** MSm = ** MShp = 0.0295% CRDhp = -0.0006% RWCUhp = 0.00005% Dias Errors: CRDt = -0.0012% CRDht = -0.0096% RWCUht = 0.0031% RWCUht = 0.0036% TL = 0.0056% OSL = 0.0060% * Note that these terms are combined in reference 3.4.20 for an over all uncertainty of 0.34% for FWm, FWht and FWhp teat Balance Calculation Power Error (U): Power Error = SQRT[((0.0034)^2+(MShp+CRDhp+RWCUhp)^2+MSmoist^2+CRDc^2+CRDdp^2+	
RWCUp sw = 0.0001% Dependent Errors: Errors FWhp = ** FWm = ** FWht = ** MSm = ** MSnp = 0.0295% CRDhp = -0.0006% RWCUfp = 0.00006% RWCUfp = 0.00005% Bias Errors: CRDt = -0.0012% CRDht = -0.0012% CRDht = 0.0086% TL = 0.0058% OSL = 0.0060% * Note that these terms are combined in reference 3.4.20 for an over all uncertainty of 0.34% for FWm, FWht and FWhp teat Balance Calculation Power Error (U): Power Error = SQRT[((0.0034)^2+(MShp+CRDhp+RWCUhp)^2+MSmoist^2+CRDc^2+CRDdp^2+	
Dependent Errors:ErrorsVariableFWhp = **FWm = **FWmt = **FWht = **MSm = **MSmp = 0.0295%CRDhp = -0.00006%CRDhp = -0.00005%Bias Errors:CRDt = -0.0012%CRDht = -0.0096%CRDt = 0.0031%RWCUfh = 0.0286%TL = 0.0056%TL = 0.0056%OSL = 0.0060%* Note that these terms are combined in reference 3.4.20 for an over all uncertainty of 0.34% for FWm, FWht and FWhpPower Error = SQRT[((0.0034)^2+(MShp+CRDhp+RWCUhp)^2+MSmoist^2+CRDc^2+CRDdp^2+	
Dependent Errors:ErrorsVariableFWhp = **FWm = **FWmt = **FWht = **MSm = **MSmp = 0.0295%CRDhp = -0.00006%CRDhp = -0.00005%Bias Errors:CRDt = -0.0012%CRDht = -0.0096%CRDt = 0.0031%RWCUfh = 0.0286%TL = 0.0056%TL = 0.0056%OSL = 0.0060%* Note that these terms are combined in reference 3.4.20 for an over all uncertainty of 0.34% for FWm, FWht and FWhpPower Error = SQRT[((0.0034)^2+(MShp+CRDhp+RWCUhp)^2+MSmoist^2+CRDc^2+CRDdp^2+	
$FWm = ** FWht = ** FWht = ** MSm = ** MSm = 0.0295%CRDhp = -0.00006%RWCUhp = 0.00005%Bias Errors: CRDt = -0.0012%CRDht = -0.0096%RWCUf = 0.0031%RWCUf = 0.0031%RWCUht = 0.0286%TL = 0.0056%OSL = 0.0060%* Note that these terms are combined in reference 3.4.20 for an over all uncertainty of 0.34% for FWm, FWht and FWhpleat Balance Calculation Power Error (U):Power Error = SQRT[((0.0034)^2+(MShp+CRDhp+RWCUhp)^2+MSmoist^2+CRDc^2+CRDdp^2+$	
$FWm = ** FWht = ** MSm = ** MSm = ** MSm = 0.0295%CRDhp = -0.00006%RWCUhp = 0.00005%Sias Errors: CRDt = -0.0012%CRDht = -0.0096%RWCUf = 0.0031%RWCUf = 0.0031%RWCUht = 0.0286%TL = 0.0056%OSL = 0.0060%* Note that these terms are combined in reference 3.4.20 for an over all uncertainty of 0.34% for FWm, FWht and FWhpleat Balance Calculation Power Error (U):Power Error = SQRT[((0.0034)^2+(MShp+CRDhp+RWCUhp)^2+MSmoist^2+CRDc^2+CRDdp^2+$	
MSm = ** MShp = 0.0295% CRDhp = -0.00006% <u>RWCUhp = 0.00005%</u> bias Errors: CRDt = -0.012% CRDht = -0.0096% RWCUf = 0.0031% RWCUht = 0.0286% TL = 0.0056% OSL = 0.0060% * Note that these terms are combined in reference 3.4.20 for an over all uncertainty of 0.34% for FWm, FWht and FWhp leat Balance Calculation Power Error (U): Power Error = SQRT[((0.0034)^2+(MShp+CRDhp+RWCUhp)^2+MSmoist^2+CRDc^2+CRDdp^2+	
MShp = 0.0295% CRDhp = -0.00006% RWCUhp = 0.00005% tias Errors: CRDt = -0.0012% CRDht = -0.0096% RWCUf = 0.0031% RWCUht = 0.0286% TL = 0.0056% OSL = 0.0060% * Note that these terms are combined in reference 3.4.20 for an over all uncertainty of 0.34% for FWm, FWht and FWhp leat Balance Calculation Power Error (U): Power Error = SQRT[((0.0034)^2+(MShp+CRDhp+RWCUhp)^2+MSmoist^2+CRDc^2+CRDdp^2+	
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CRDht = -0.0096% RWCUf = 0.0031% RWCUht = 0.0286% TL = 0.0056% OSL = 0.0060% * Note that these terms are combined in reference 3.4.20 for an over all uncertainty of 0.34% for FWm, FWht and FWhp leat Balance Calculation Power Error (U): Power Error = SQRT[((0.0034)^2+(MShp+CRDhp+RWCUhp)^2+MSmoist^2+CRDc^2+CRDdp^2+	
RWCUf = 0.0031% RWCUht = 0.0286% TL = 0.0056% OSL = 0.0060% * Note that these terms are combined in reference 3.4.20 for an over all uncertainty of 0.34% for FWm, FWht and FWhp leat Balance Calculation Power Error (U): Power Error = SQRT[((0.0034)^2+(MShp+CRDhp+RWCUhp)^2+MSmoist^2+CRDc^2+CRDdp^2+	
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* Note that these terms are combined in reference 3.4.20 for an over all uncertainty of 0.34% for FWm, FWht and FWhp leat Balance Calculation Power Error (U): Power Error = SQRT[((0.0034)^2+(MShp+CRDhp+RWCUhp)^2+MSmoist^2+CRDc^2+CRDdp^2+	
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Power Error = SQRT[((0.0034)^2+(MShp+CRDhp+RWCUhp)^2+MSmoist^2+CRDc^2+CRDdp^2+	
	•
+RWCUp_sw^2+RRPw^2x2]+CRDt+CRDht+RWCUf+RWCUht+TL+OSL	Rev 5
Power Error = 0.374%	Rev 5
o ensure operation margin exist, due to possible instrumentation loops miss-calibration, actual drift (to be determined by history), etc., a margin is added:	
Power U = Power Error + Margin	
here margin is defined as 3840 * 102% –Rated Thermal Power – Power Error	
Margin = 3916.8 - 3902 - Power Error	
Margin = 0.005% and Power U = 0.379%	Rev 5

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CALC NO.:	SC-BB-0525 Attachment 1	REV:	5	REF:		CONT'D ON SHEET:	N/A
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
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8.0 SUMMARY

The calculated Heat Balance Error performed in this calculation is applicable to fully operational LEFM. The Power Uncertainty is the	Rev 5
difference between the 2% design basis and the rated termal power for the current LEFM mode of operation. Positive margin is	1
maintained between the Power Uncertainty and the Power Error. The Heat Balance calculation error (Section 7.0) is:	1

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<u>Power U = 0.379%</u>

(NC.E	DE-AP.ZZ-0002(Q), Rev.	12, Form 2)		CALCULATION	CONTINUATION SHEE	Т	SHEET:	1
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Sections 1 through 4 have been replaced with the main body of the calculation

5.0 DESIGN INPUTS

5.1 Rated Power Conditions

100% rated Power Conditions are listed below. Actual 100% operation values might be used in lieu of rated nominal values, for other than Rated MWt, Feedwater Flow and Main Steam parameters as deemed appropriate. This is found acceptable, since for the purpose of error determination to rated MWt "heat differential errors", actual heat contribution deviation from measured/calculated heat to rated MWt due to instrumentation uncertainties, is required not the actual deviation value.

Rated MWt = <u>3889MW</u>	This power level is set at the highest whole MWt power level which produces positive margin	Rev 5
Rated FW flow = <u>1.7054E+07lbm/hr</u>	(Ref. 3.4.17)	
Rated FW temperature = <u>433.5 F</u>	(Ref. 3.4.17)	
Rated MS flow = <u>17086000</u>	(Ref. 3.4.17)	
Rated MS pressure = <u>1020 psia</u>	(Ref. 3.4.17)	
Rated MS quality = <u>100.000</u>	(Ref. 3.4.1)	
Rated RWCU flow = <u>148000.0 lb/hr</u>	(Ref. 3.4.17)	Rev 5
Rated RWCU temperature = <u>530.7 F</u>	(Ref. 3.4.17)	
Rated RWCU return temperature = <u>433.8 F</u>	(Ref. 3.4.17)	
Rated CRD flow = <u>32000.0 lb/hr</u>	(Ref. 3.4.3)	
CRD Calibration pressure = <u>1474.0 psia</u>	(Ref. 3.4.5)	
Rated CRD temperature = <u>77 F</u>	(Ref. 3.4.17)	Rev 5
Radiation Loses = <u>1.10MW</u>	(Ref. 3.4.2, 3.4.17)	
Other System Loses = <u>1.18MW</u>	(Ref. 3.4.2, 3.4.17) These loses are not included in UFSAR Heat Balance, Ref. 3.1.1	Rev 5
MWt/BTU/hr = <u>2.9300E-07</u>	(Ref. 3.4.1)	

Power = MFW(MSh-FWh)-CRDF(hin-hout)+RWCU(hout-hin)-RRP+HL+Miscellaneous

Notes:

1) This calculation uses rated MS quality of 100.0%, which will produce a more conservative number with respect to the actual plant MS quality. This parameter may be revised when the actual MS quality is measured after the implementation of EPU.

2) This calculation specifies radiation loses as 1.10 MW and other loses as 0.84 MW for the total lose of 1.94 MW. Reference 3.4.17 stated "other system loses" as 1.9 MW without specifically accounting for Radiation loses. Since the two total numbers are almost identical and the difference would have negligible affect on the Power Error, radiation loses of 1.10 MW and the other loses of 0.84 MW will be maintained.

6.0 ASSUMPTIONS

The Main Feedwater uncertainties is included in the total termal power uncertainty provided by the LEFM while in mantenance mode is 0.66% per Reference 3.4.20 is provided based on a power level of 3902MWt. This is not interpolated based on a 3889MWt since the uncertainty provided by Reference 4.1.20 is only provided in two significant digits and the impact is neglible.

The design inputs from reference 3.4.17 are used as bounding design inputs and a 3889MWt heat balance is not included in reference 3.4.17. The difference between the operating region of the steam tables between the inputs of 3902MWt and 3889MWt are considered to be minimal and the impact is neglible.

Rev 5

See sections 7.2.3, 7.2.4, 7.2.6 and 7.2.7 for specific assumptions.

(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)			CALCULATION CONTINUATION SHEET				T: 2	2
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7.0 CALCULATIONS

7.1 Methodology

The methodology used to combine the uncertainties for the different contributors to the heat balance calculation is the square root of the sum of the squares of those uncertainties which are statistically independent. Then algebraically combined with the those errors that are systematic, or bias. The uncertainties are considered to be random, two sided distributions. This methodology has been utilized before, and has been endorsed by the NRC and various industry standards (Ref. 3.4.12-3.4.14).

The uncertainty calculation combines the different errors from the different parameters contributing to the heat balance in accordance to the heat balance equation. The contributing parameters errors are taken from the specific system uncertainty calculation.

These errors are generally classified in two groups:

a) Instrument loop(s) uncertainty

b) Process effects

The individual uncertainties affecting the heat balance calculation are determined by the application of the corresponding process algorithm, as described below:

- a) the appropriate algorithm for the specific process parameter is set in the form to its specific contribution to the heat balance at specified rated conditions,
- b) subsequently, the instrumentation loop error is factored in the process algorithm to calculate the corresponding process parameter with the error built-in,
- c) the difference of the calculated contributed process parameter heat, with error, to the rated process rated heat is then calculated,
- d) the resultant heat error contribution is then divided by the rated 100% power thermal megawatts. The result is the error contribution by the specific process to the total heat balance uncertainty,
- e) finally, all the calculated heat errors are combined in accordance to their parameter function in the heat balance equation. The resultant combination of all contributing errors is the Heat Balance Uncertainty.

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7.2.2 Main Steam Flow Uncertainty(ies)

Referring to the schematic drawing in section 4.0, It can be seen that the Main Steam heat contribution is affected by the following parameters:

a) Main Steam Enthalpy determination is affected by the pressure instrumentation loop error, documented in calculation:

Ref. 3.4.4

7.2.2.1 Main Steam Mass Flow Heat Error due to Main Feedwater Flow Uncertainty (MSm)

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Rev 5

7.2.2.2 Main Steam Heat Enthalpy Error due to Pressure Loop Uncertainty (MShp)

This Section calculates the Main Heat Steam enthalpy error due to the loop pressure uncertainty, documented in:

Ref.: 3.4.4

The heat error is the difference in the Main Steam flow heat content at rated flow and enthalpy conditions minus the heat content at rated flow with enthalpy at rated pressure plus pressure induced error:

MShp = [Flow (hrated - hrated+err)] x 2.93E-07 / 3889 x 100%

P Rtd P+err Moist Rtd Moist+err h rated h+err Flow 1192.19 1191.96 17,086,000 Rev 5 1020 1026.1 100 100.000 Error (psi) = 6.1 0 • TTL MS Heat Rev 5 20,365,884,863 BTU/hr Rev 5 20,369,812,105 BTU/hr at rated conditions Error Rev 5 3,927,242 BTU/hr error at rated main feedwater flow Error in Rated MWt Rev 5 MShp = 0.0296%

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7.2.2.3. Main Steam Moisture Heat Enthalpy Error due to Steam Moisture Uncertainty (MSmoist)

This section calculates the Main Steam enthalpy error due to MS moisture uncertainty. The uncertainty is conservatively set to 50% of rated moisture content of 0.0%.

The heat error is the difference in the Main Steam flow heat content at rated flow and moisture conditions minus the heat content at rated moisture conditions plus moisture error:

P Rtd	P+err	Moist Rtd	Moist+err	h rated	h+err	Flow	
1020	1020	100	100.0000	1192.19	1192.19	17,086,000	-
	0.00000	0.00%	÷				

TTL MS Heat 20,369,812,105 BTU/hr

20,369,812,105 BTU/hr at rated conditions

Rev 5

Rev 5

Error

- BTU/hr error at rated main feedwater flow

Error in Rated MWt MSmoist = 0.0000%

(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)				CALCULATION CONTINUATION SHEET				7
CALC NO .:	SC-BB-0525 Attacl	hment 2	REV:	5	REF:	C	ONT'D ON SHEET:	8
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7.2.3 Control Rod Drive Flow

Referring to the schematic drawing in section 4.0, it can be seen that CRD flow is not monitored for pressure or temperature.

The CRD calculated heat is affected by the following effects:

a) Mass Flow Measurement affected by: 1) flow, instrumentation loop effect and 2) temperature, and 3) pressure deviation from calibration values

b) The CRD Enthalpy determination is affected by: 1) temperature, from applied constants, and 2) pressure, from reactor pressure loop error

The CRD flow loop errors are documented in calculation:

<u>Ref. 3.4.5</u>

The flow formula is derived from the ASME (Ref. 3.4.9) as follows:

Flow = C*Fa*K*(DP*r)^0.5

where K is calculated below:

K = Calib Flow/(Calib inWC * Calib r)^0.5

(NC	C.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCULATION CONTINUATION SHEET				8
CALC NO.:	SC-BB-0525 Attachment 2	REV:	5	REF:	<u> </u>	CONT'D ON SHEET:	9
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7.2.3.1 Control Rod Drive Flow Heat Error due to Flow Element and Fluid Specific Weight Uncertainty due to Temperature Error (CRDt)

The uncertainty is dependent for the following variables:

Fa = FE Thermal Expansion

r = Fluid Specific Weight

The plant computer calculates the CRD flow with a constant flow K factor. However, the actual temperature could vary as much as 43F from the expected 77F, and this impacts the Fa and r impacting the calculated flow; therefore, the effect due to this temperature deviation is:

CRDt = [(hs rated - CRDh rated) (Flowrated - Flowrated+err)] x 2.93E-07 / 3889 x 100%

Ref.: 3.4.5				48.48						
			Calib Flow = 5		100 GPM					
Fa Error			Calib inWC = 2							
Rated 77F	1.0003		Calib Temp = <u>7</u>	<u>7</u>						
@140 F	1.0013		Calib Press = 1	474.7						
@40 F	0.9995		r = 6	52.529						
Fa/F	1.8E-05	Assu	Assumed Rated Flow = <u>32000.0 lb/hr</u>							
			- Rated Press = 1							
			Rated Temp = 7							
			Rated $h = 4$							
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	T+err			
1.0000	1.0000	81.3694	81.3694	1.0003	1.0011	77	120			
0.00%	• 0	0.00%			•		<u>. 43</u>			
		•			Temp error = Calib Ter					
P Rtd	r	h Rtd	Flow	hs Rtd						
1020	61.9029	47.83	31,863.902	1192.19						
		!								
	ITTL	CRD Heat								
		36,463,826	BTU/hr							
		36 619 571	BTU/hr at rated cond	litions						

Error

(155,745) BTU/hr error at rated CRD flow

Error in Rated MWt CRDt = -0.0012%

This error is a bias, not a random instrument induced uncertainty.

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CALC NO.:	SC-BB-0525 Attachment 2	REV:	5	REF:	· <u> </u>	CONT'D ON SHEET:	10
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Rev 5

7.2.3.2 Control Rod Drive Flow Heat Error due to Flow Element Uncertainty (CRDc)

The CRD contributed heat is affected by the FE error that is assigned to the flow element expansion coefficient.

С

The FE uncertainty is determined based in calculation:

Ref.: 3.4.5

The heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error:

CRDc = [(hs rated - CRDh rated) (Flowrated - Flowrated+err)] x 2.93E-07 / 3889 x 100%

		· · · · · ·						
Fa Error			K = 4	48.48	.*			
Rated 77F	1.0003		Calib Flow = 5	0154	100.00			
@140 F	1.0013		Calib inWC = 2	00.00				
@60 F	0.9995	Assu	med Calib Temp = 7	7.00				
Fa/F	1.8E-05	Assu	med Calib Press = 1	474.00				
				2.529	0.0159925			
		Assu	med Rated Flow = 3	2000.0 lb/hr				
			Rated Press = 1					
			Rated Temp = 7					
<u> </u>			Rated h = 4					
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	T+err	
1.0000	1.0200	81.3694		1.0003	1.0003			77
2.00%	200	0.00%	0				÷	0
	· · · · · ·				ī			
P Rtd	r	h Rtd	Flow	hs Rtd				
1020.00	62.4433	47.83	32,617.500	1192.19				Rev 5
		Addition of						
	·	MFW Heat		1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 -				Rev 5
		37,326,215	DIU/II					IKev 5
	· · ·	26 610 571	BTU/hr at rated cond	litiona				
		30,019,3711						
		Error				,		
			BTU/hr error at rate	d CPD flow				
		700,044						Rev 5
	Erro	r in Rated MWt						1.000
		CRDc = (0 0053%		×			Rev 5
· · · · · · · · · · · · · · · · · · ·	.	ONDE -						11000

(NC	.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)	CALCULATION CONTINUATION SHEET				SHEET:	10
CALC NO.: SC-BB-0525 Attachment 2		REV:	5	REF:	REF:		11
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A

7.2.3.3 Control Rod Drive Heat Error due to Differential Pressure (DP) Loop Uncertainty (CRDdp)

This error is calculated in calculation:

Ref.: 3.4.5

The loop is comprised of 1) flow transmitter, FT, 2) resistor, REST, 3) computer analog to digital card, A/D. The uncertainties are in % DP span:

Accuracy:		Loop Drift:			
CRD_AFT	CRD_AREST	CRD_AA/D	CRD_VDFT	CRD_VDA/D	
1.154%	0.100%	0.188%	1.450%	0.000%	

Loop Calibration:

CRD_CEFT	CRD_CEA/D
0.140%	0.188%

The uncertainties are random and independent and combined by the SRSS method:

1.88% span DP

(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)				CALCULATION CONTINUATION SHEET				11
CALC NO .:	SC-BB-0525 Attac	hment 2	REV:	5	REF:		CONT'D ON SHEET:	12
ORIGINATOR:		DATE:	REVIEWER:		DATE:	VERIFIER:	1	DATE:
Michael Miller		2/14/2017	John Wilkens		3/13/2017	Ń/Á		N/A

The heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error:

CRDdp = [(hs rated - CRDh rated) (Flowrated - Flowrated+err)] x 2.93E-07 / 3889 x 100%

C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	T+e
			CRDh rated =	47.83 btu/lb	· · ·		
			Rated Temp =	77 F			
			Rated Press =	1020.0 lb/hr			
		A	ssumed Rated Flow =	32000.0 lb/hr			
			r =	62.529			
Fa/F	1.8E-05	A	ssumed Calib Press =	1474			
@60 F	0.9995	A	ssumed Calib Temp =	77			
@140 F	1.0013		Calib inWC =	200			
Rated 77F	1.0003		Calib Flow =	50157.2 lb/hr	100 GPM		
Fa Error			κ=	448.51			

ļ	C Rtd	C+err	DP Rtd (DP+err	Fa Rtd	Fa+err	T Rtd	T+err
	1.0000	1.0000	81.3584	85.1183	1.0003	1.0003	77	77
	0.00%	÷0	1.88%			· · · ·		: 0

P Rtd	r	CRDh rated	Flowrated+err	hs Rtd
1020	62.4433	47.83	32,708.537	1192.19

TTL MFW Heat 37,430,393 BTU/hr

36,619,571 BTU/hr at rated conditions

Error

810,822 BTU/hr at rated CRD flow

Error in Rated MWt CRDdp = 0.0061%

Rev 5

(NC		CALCULATION CONTINUATION SHEET SHEET				
CALC NO.: SC-BB-0525 Attachment 2		REV:	5	REF:	CONT'D O N SHEET:	13
ORIGINATOR:	DATE:	REVIEWER:		DATE: VERIFIER:		DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017 N/A		N/A

7.2.3.4 Control Rod Drive Flow Enthalpy Heat Error due to Temperature Calibration Deviation (CRDht)

The plant computer calculates the CRD fluid enthalpy at a constant 77F and reactor pressure. However, the actual temperature varies and it is assumed to vary as much as 43F from the expected 77F; therefore, the effect due to this temperature deviation in the calculated enthalpy is:

Ref. 3.4.5

The heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error:

CRDht = [Flow (hs rated - CRDh rated) - Flow (hs rated - CRDh rated+err)] x 2.93E-07 / 3889 x 100%

TRtd	T Max/Min	T+err	P Rtd	h rated	h+err	hs rated	Flow
77	<u>40</u>	37	1020	47.83	8.05	1192.19	32,000

TTL RWCU Heat 37,892,585 BTU/hr

36,619,571 BTU/hr at rated conditions

Error

(1,273,014) BTU/hr at rated CRD flow

 Uncertainty
 in Rated MWt

 CRDht = -0.0096%
 This error is a bias, not a random instrument induced uncertainty.
 Rev 5

(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)			e	CALCULATION CONTINUATION SHEET			SHEET:	13
CALC NO.:	SC-BB-0525 Attack	nment 2	REV:	5	REF:		CONT'D ON SHEET:	14
ORIGINATOR:		DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller		2/14/2017	John Wilkens		3/13/2017	N/A	i i	N/A

7.2.3.5 Control Rod Drive Flow Enthalpy Heat Error due to Pressure Loop Uncertainty (CRDhp)

The plant computer calculates the CRD fluid enthalpy at a constant 77F and reactor loop pressure, that is affected by the loop uncertainty. The pressure loop uncertainty is documented in:

Ref.: 3.4.4

The heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error:

CRDhp = [Flow (hs rated - CRDh rated) - Flow (hs rated+err - CRDh rated)] x 2.93E-07 / 3889 x 100%

P Rtd	P+err	TRtd	CRDh rated	hs rated	hs rated+err	Flow	
1020	1026.1	77	47.83	1192.19	1191.96	32,000	Rev 5
Error (psi) =	= <u>6.1</u>		· · · · · ·	,			I
• •		TTL MFW Heat 36,612,216	BTU/hr				Rev 5
•	- -	36,619,571	BTU/hr at rated co	nditions			Rev 5
		Err or (7,355)	BTU/hr at rated C	RD flow			Rev 5
		Uncertainty in Rated I CRDhp =					Rev 5

(NC		CALC	SHEET:	14				
CALC NO.:	SC-BB-0525 Attachment 2	REV:	5	REF:	<u></u>	CONT'D ON SHEET:	15	
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:	
Michae Miller	2/14/2017	John Wilke	ens	3/13/2017	N/A		N/A	

7.2.4 Reactor Water Cleanup Uncertainty(ies)

Referring to the schematic drawing in section 4.0, it can be seen that RWCU flow is measured and mass calculated by a "NUMAC" process unit. Differential pressure, temperature, by dedicated thermocouples, and reactor pressure are an input to the instrument. Therefore, the RWCU contributed heat is affected by the following parameters:

a) Mass Flow Measurement affected by: 1) flow, 2) temperature, and 3) pressure induced factors/instrumentation loops errors

b) The RWCU Enthalpy determination is affected by: 1) temperature instrumentation loop error (see discussion for pressure)

The flow formula is derived from the ASME (Ref. 3.4.9) as follows:

Flow = C*K*(DP)^0.5

where K is:

K = Calib Flow / [C*(Calib inWC)^0.5]

(NC	C.DE-AP.ZZ-0002(Q), Rev. 1	2, Form 2)		HEET	SHEET:	15		
CALC NO .:	SC-BB-0525 Attac	hment 2	REV:	5	REF:	· <u> </u>	CONT'D ON SHEET:	16
RIGINATOR:		DATE:	REVIEWER:		DATE:	VERIFIER:	DA	TE:
Michael Miller		2/14/2017	John Wilkens		3/13/2017	N/A	Ň	/A
The Numac comp temperature of 53	outer calculating the mas 33F. This induces a bias	ror due to Flow Element ss flow has a built-in Fa s error. Furthermore, the	constant different t plant NUMAC nor	han the flow eleme malizes the flow m	nt Fa provided at the ass signal to a specif			
pressure and tem	perature conditions, bac	ck calculated below; the	refore, the rated co	nditions are set at	530.7F.		R	ev 5
	Compensated to : e calculation is fixed to: rated 533 F is:	47.19 lb/cuft	530.7 F 1.0045 1.0087	<u>908 psia</u>			R	ev 5
Based on the Fa	differences the induced	flow error is calculated	below:					
Fa	a = FE Thermal Expans	sion						
Ref.: 3.4.10								
Flow+err = C x Fa	+err / Fa x K x (DP)^0.5							
				= 9449.90			R	ev 5
Fa Error				= 189823.1 lb/hr	<u>500 GPM</u>	(Note)	I	
Rated 533F	1.0087	Δεσ	Calib inWC = umed Calib Temp =				le	ev 5
Calibrated	1.0045		umed Calib Press =				I Y	600
Calibratoa		7,66		= 47.332			R	ev 5
		Ass	umed Rated Flow =		389 GPM	8		
				= 524.83 btu/lb				
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	T+err	
1.00				1.008	37 1.0	045 5	530.7 530.7	
0.00	0%	0.00%		<u></u>			٥ (
				-				
P Rtd	P+err	r	h Rtd	Flow+err				
111/	4.7 1114.7		524.83	3 147,40	4		R	ev 5
, ili") 🗯 🔰 O							
. 411"								
	L		· · · · · · · · · · · · · · · · · · ·	-				
		Uncertainty	-616.3 lb/hr			Heat is Higher than in		ev 5

ан Алтана. Алтана (1996)

Note: This value is slightly different to the 189,197 lb/hr calculated in the reference due to rounding

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(NC.D	DE-AP.ZZ-0002(Q), Rev. 12, Form 2)	CALCULATION CONTINUATION SHEET					16
CALC NO.:	SC-BB-0525 Attachment 2	REV:	5	REF:	<u> </u>	CONT'D O N SHEET:	17
ORIGINATOR:	DATE:	REVIEWER:	_	DATE:	VERIFIER:	D	ATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A	N	/A

7.2.4.2 RWCU Inlet/Outlet Flow Heat Error due to Fluid Specific Weight deviation (RWCUPMA)

This error is the combination of several uncertainties calculated below:

7.2.4.2.1 RWCU Inlet/Outlet Flow Error due to Fluid Specific Weight Numac Lookup Tables Error (RWCUPMA1)

The Numac performs the fluid specific weight determination with an error of 0.1 specific weight, this effect in the flow is calculated below.

r = Fluid Specific Weight

Ref.: 3.4.10

Flow+err = $C \times K \times (DP \times r+err / r)^{0.5}$

The flow error is the difference between the rated flow at rated specific weight minus the flow at specific weight plus error:

RWCUPMA1 = Flowrated - Flowrated+error

			К=	9449.90			Re
			Calib Flow =	189823.1 lb/hr	500 GPM	(Note)	
Fa Error			Calib inWC =	403.5			
Rated 533F	1.0087	Assı	umed Calib Temp =	530.7			Re
Calibrated	1.0045	Assi	umed Calib Press =	1114.7			
			r =	47.332			Re
		Assu	umed Rated Flow =	148021 lb/hr	388.8 GPM		
			Rated hout =	524.83 btu/lb			
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	
1.0000	1.0000	245.3520	245.3520	1.0087	1.0087	530.7	Re
0.00%	0	0.00%	: 0				
						<u>. </u>	
P Rtd	P+err		Numac err	r+perr+Numac	h Rtd	Flow	
1114.7	1114.7 psi	47.332	<u>0.1</u>	47.432	524.83	148,177	Re
	0 psi						
	_						
		Uncertainty					
		RWCUPMA1 =	150 2 16/64				

(NC	.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALO	CULATION CONTINUATION SHEE	Т	SHEET	17
CALC NO .:	SC-BB-0525 Attachment 2	REV:	5	REF:		CONT'D ON SHEET:	18
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A

7.2.4.2.2 RWCU Inlet/Outlet Flow Error due to Fluid Specific Weight Numac 0.75 Factor Pressure Correction Factor Error (RWCUPMA2)

The Numac computer introduces a 0.75 factor to the input pressure raw value and calculates the specific weight for saturated conditions, which bias the actual flow.

Ref.: 3.4.10

Flow+err = $C \times K \times (DP \times r+err / r)^{0.5}$

The flow error is the difference between the rated flow at rated specific weight minus the flow at specific weight plus error:

RWCUPMA2 = Flowrated - Flowrated+error

r = Fluid Specific Weight

• ·				x = 9449.90				R	ev 5
			Calib Flov	v = 189823.1 lb/hr	500	GPM (N	lote)		
a Error			Calib inWC	c = 403.5					
Rated 533F	1.0087	Assun	ed Calib Tem	o = 530.7				R	ev 5
Calibrated	1.0045	Assum	ed Calib Pres	s = 1114.7				•	
				r = 47.332				R	ev 5
		Assun	ed Rated Flov	v = 148021 lb/hr	388	.8 GPM			
			Rated	= 524.83 btu/lb					
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd		Fa+err	T Rtd		
1.0000	1.0000	245.3520	245.35	20 1.00	87	1.0087	530.7	i Ir	ev 5
0.00%	;0	0.00%	÷	0				•	
P Rtd	P+err	T Sat	r+perr	Numac rerr	1	+perr+Numac	h Rtdout	h Rtd return	Flow
1114.7	.840 psi	523.8	47.59		ol	47.5905	524.83		148,42
i		: 75		- r					
		Uncertainty							
		RWCUPMA2 = -4	03 lb/hr	This a bias and	the act	ual contributed Heat i	s Higher than indica	ited IR	ev 5
								I	

(NC.I	DE-AP.ZZ-0002(Q), Rev. 12, Form 2)	CALCULATION CONTINUATION SHEET					18
CALC NO.:	SC-BB-0525 Attachment 2	REV:	5	REF:		CONT'D ON SHEET:	19
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	Ľ	ATE:
Michael Miller	2/14/2017	John Wilkens	8	3/13/2017	N/A	1	N/A

7.2.4.2.3 RWCU Inlet/Outlet Flow Heat Error due to Fluid Specific Weight Pressure Loop Uncertainty (RWCUP_SW)

Pressure is utilized as an input to the Numac to determine the specific weight of the fluid. The pressure loop uncertainty combined with the Numac computer uncertainty introduces an error in the calculated specific weight.

The loop error is comprised of 1) pressure loop, PT, 2) NUMAC computer uncertainties. The combined uncertainties are:

RWCUpress error= 21 psi

Ref.: 3.4.10

Flow+err = $C \times K \times (DP \times r+err / r)^{0.5}$

The flow error is the difference between the rated flow at rated specific weight minus the flow at specific weight plus error:

RWCUp SW = [Flowrated	(h in - h out) - Flowrated+error ((h in - h out)] x 2.93E-07 / 3889 x 100%

r =	Fluid Specific Weight		К=	9449.90			[Rev 5
			Calib Flow =	189823.1 lb/hr	500 GPM	(Note)		
Fa Error			Calib inWC =	403.5				
Rated 533F	1.0087	Assum	ed Calib Temp =	530.7				Rev 5
Calibrated	1.0045	Assum	ed Calib Press =	1114.7			•	
			r =	47.332				Rev 5
		Assum	ned Rated Flow =	148021 lb/hr	388.8 GPM			
			Rated h =	524.83 btu/lb				
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd in	T Rtd out	
1.0000	1100001	245.3520	245.3520	1.0087	1.0087	530.7	433.8	
0.00%	0	0.00%	2 0					

Rev 5

	0.00%	0	0.00%

P Rtd	P+err	r+perr	Numac rerr	r+perr+Numac	h Rtd in	h Rtd out	Flow
1020	1041 psi	47.2821		0 47.282	524.96	412.64	147,942 Rev 5
		TTL MFW Heat 16,616,340	BTU/hr				Rev 5
		16,625,169	BTU/hr at rated o	conditions			Rev 5
		Error 8,829					Rev 5
		Uncertainty in Rated RWCUp_sw =					

(NC.D	DE-AP.ZZ-0002(Q), Rev. 12, Form 2)	CALCULATION CONTINUATION SHEET					19
CALC NO .:	SC-BB-0525 Attachment 2	REV:	5	REF:		CONT'D ON SHEET:	20
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A

7.2.4.3 Reactor Water Cleanup Flow Error due to Flow Element Uncertainty (RWCUc)

The RWCU flow is affected by the FE error that is assigned to the flow element expansion coefficient.

С

The FE uncertainty is determined based in calculation:

Ref.: 3.4.10

Flow+err = C+err x K x (DP)^0.5

The flow error is the difference between the rated flow minus the flow with the C coefficient error:

RWCUc = Flowrated - Flowrated+error

Fa Error				К=	9449.90				Rev 5	5
Rated 533F	-	1.0087		Calib Flow =	189823.1 LB/HR	500 GPM	(Note)			
Calibrated		1.0045		Calib inWC =	403.50				•	
			A	ssumed Calib Temp =	530.70				Rev 5	5
			A	ssumed Calib Press =	1114.70				•	
				r =	47.332				Rev 5	5
			A	ssumed Rated Flow =	148021 lb/hr	389 GPM				
				Dotod h -	E04 00 http://h					
				Rateu n –	524.83 btu/lb	· ·				
C Rt	td	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	1 -	Γ+err	
C Rt	t d	C+err 1.0150	DP Rtd 245.35	DP+err	Fa Rtd			530.7	F+err 530.7	
C Rt	1.0000		245.35	DP+err 520 245.3520	Fa Rtd			530.7	530.7	
C Rt	1.0000	1.0150	245.35	DP+err	Fa Rtd				530.7	
C Rt	1.0000	1.0150	245.35	DP+err 520 245.3520	Fa Rtd			530.7	530.7	
C Rt	1.0000 1.50%	1.0150	245.35	DP+err 520 245.3520	Fa Rtd			530.7	530.7	

Uncertainty RWCUc = 2220.3 lb/hr

Note: This value is slightly different to the 189,197 lb/hr calculated in the reference due to rounding

(NC.D	E-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCUI	SHEET:	20		
CALC NO .:	SC-BB-0525 Attachment 2	REV:	5	REF:		CONT'D ON SHEET:	21
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	DA	ATE:
Michael Miller	2/14/2017	John Wilker	is	3/13/2017	N/A	N	/A

7.2.4.4 Reactor Water Cleanup Flow Error due to Differential Pressure (DP) Loop Uncertainty (RWCUdp)

This error is introduced by the differential pressure instrument loop. The uncertainties in the loop are found in: Ref.: 3.4.10

The loop is comprised of 1) flow transmitter, FT, 2) NUMAC computer. The uncertainties are in % DP span:

The flow error is the difference between the rated flow minus the flow with the C coefficient error:

RWCUdp = Flowrated - Flowrated+error

Accuracy:			Loop Drift:		
RWCU_AFT	_RWCU_ANU_IE_	RWCU_ANU_A/D	RWCU_VDFT	RWCU_VDNU_IE	RWCU_VDNU_A/D
0.503%	0.100%	0.233%	0.900%	0.127%	0.127%

Loop Calibration:

RWCU_CEFT	RWCU_CENU_A/D
0.139%	0.02%

The uncertainties are random and independent and combined by the SRSS method:

1.09% span DP

Flow+err = $C \times K \times (DP+err)^{0.5}$

Fa Error		K = 9	9449.90			R	lev 5
Rated 533F	1.0087	Calib Flow =	189823.1 LB/HR	500 GPM	(Note)		
Calibrated	1.0045	Calib inWC = 4	403.50				
	A	ssumed Calib Temp =	530.70			R	lev 5
	A	ssumed Calib Press = '	1114.70				
		r = 4	47.332			R	lev 5
	4	ssumed Rated Flow = '	148021 LB/HR	389 GPM			
		Rated h = {	524.83 btu/lb				
C Rtd C+e	rr DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	T+err	
1.0000	1.0000 245.35	20 249.7338	1.0087	1.0087	530.7	530.7	
0.00%	0					0	
P Rtd r	h	Flow					
	47.3324 524					R	lev 5
	Uncertain	ty o = 1315.9 lb/hr				Iр	lev 5

(N	NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCULATION	CONTINUATION SHEE	T	SHEET:	21
CALC NO.:	SC-BB-0525 Attachment 2	REV:	5	REF:	·	CONT'D ON SHEET:	22
ORIGINATOR:	DATE:	REVIEWER:	1	DATE:	VERIFIER:	. D.	ATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A	N	I/A

7.2.4.5 Reactor Water Cleanup Flow Error due to Signal Conditioning/NSSS Computer Loop Uncertainty (RWCUNSSS_cptr)

The differential pressure is converted to flow by the Numac computer and retransmitted as flow signal to the plant computer for heat balance calculations.

This portion of the loop is comprised of 1) NUMAC computer output, 2) NSSS computer uncertainty. The uncertainties are in % flow span:

Accuracy:			Loop Drift:	
_RWCU_ANU_D/A	RWCU_AA/D		RWCU_VDNU_D/A	RWCU_VNA/D
0.233%	0.188%		0.13%	0.000%
		-		

Loop	Calibration:	

RWCU_CENU_D/A	RWCU_CEA/D
0.02%	0.188%

The uncertainties are random and independent and combined by the SRSS method:

0.38% span FLOW

The flow error is the difference between the rated flow at without loop error minus the flow plus loop error:

RWCUNSSS_cptr = Flowrated - Flowrated+error

Fa Error			K = 94	49.90			Rev	5
Rated 533F	1.0087		Calib Flow = 18	9823.1 lb/hr 50	DO GPM	(Note)		
Calibrated	1.0045		Calib inWC = 40	3.50			•	
		Assum	ed Calib Temp = 53	0.70			Rev	5
		Assum	ed Calib Press = 11	14.70				
			r = 47	.332			Rev	5
		Assum	ed Rated Flow = 14	8021 lb/hr 38	39 GPM			
			Rated h = 52	4.83 btu/lb				
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	T+err	
1.000	1.0000	245.3520	245.3520	1.0087	1.0087	530.7	7 530.7	
0.00	% 0						÷0	

P Rtd	r	h	Flowrated+err
1114.7	47.3324	524.83	148,733.9
		Uncertainty	713 3 lb/br

Rev 5

Note: This value is slightly different to the 189,197 lb/hr calculated in the reference due to rounding

(NC.	DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCULATION CONTINUATION SHEET				
CALC NO.:	SC-BB-0525 Attachment 2	REV:	5	REF:	<u></u>	CONT'D ON SHEET:	23
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A

7.2.4.6 Reactor Water Cleanup Total Flow due to Flow Loop Uncertainties (RWCUf)

RWCU Inlet h - Outlet h.

The total RWCU Flow Uncertainty is calculated below:

RWCUfu =+/-SQRT(RWCUPMA1^2+RWCUc^2+RWCUdp^2+RWCUNSSS_cptr^2)-RWCUFa-RWCUPMA2

Notice that the bias PMAs are factored with both signs, since the negative uncertainty is the one that has impact in the heat balance calculations, that is, that (-) less indication means that power is higher; however, it will be factored in both directions for simplicity.

RWCUfu = 3710 lb/hr

Then, the heat error contribution is the calculated inlet flow heat error minus the outlet flow heat error:

RWCUh_in = 524.96 btu/lb RWCUh_out = 412.64 btu/lb	Rev 5
And the RWCU heat error contribution is calculated by the following expression:	
RWCU = [RWCUfu (RWCUh_in - RWCUh_out) x MWt_BTU_hr (conversion factor)] / Rated MWt 100%	
RWCUf = 0.0031% This total error will be treated as bias in the total heat balance error	Rev 5

(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)			CALC	ULATION CONTINUATION SH	IEET	SHEET:	23
CALC NO.:	SC-BB-0525 Attachment 2	REV:	5	REF:	·	CONT'D ON SHEET:	24
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A

7.2.4.7 Reactor Water Cleanup Flow Enthalpy Heat Error due to Temperature Uncertainty (RWCUht)

This error is the error resultant of temperature measurement errors by the inlet/outlet RWCU thermocouple loops factored into the fluid enthalpy determination. The thermocouples are instruments with good repeatability and stability. However, fabrication errors can amount to several farenheit degrees. The fabrication errors can be calibrated out, since essentially it is a bias, systematic error. The temperature loops for RWCU are not calibrated out. Finally, since most of the thermocouples loop error is a bias, the conservative and safe way to apply the error, is for the two temperature error to be set in the same direction; therefore, the effect is additive, bias. The temperature loops error is found in:

Ref. 3.4.6

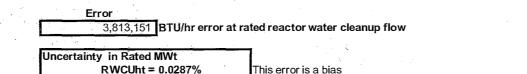
The heat error is the difference between the inlet flow heat error minus the outlet flow heat error:

RWCUht = [Flow [(hin - hin+error) + (hout - hout+error)]] x 2.93E-07 / 3889 x 100%

In flow heat		· · · ·		,	
TRtd	T+err	P Rtd	h rated	h+err	Flow
530.7	541.6	1020	524.96	538.69	148,021
Error (F)	<u>10.9</u>				

Out flow heat

TRtd	T+err	1	P Rtd	h rated	h+err	Flow
433.8	444.7		1020	412.64	424.67	148,021
Error (F)	10.9					



Rev 5

Rev 5

Rev 5

(NC.I	CALCULATION CONTINUATION SHEET SHEET:				24			
CALC NO .:	SC-BB-0525 Attachment 2	REV:	5	REF:		CONT'D ON SHEET:	25	
ORIGINATOR:	DATE:	REVIEWER:	:	DATE:	VERIFIER:	· · · · · · · · · · · · · · · · · · ·	DATE:	
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A	

7.2.4.8 Reactor Water Cleanup Flow Enthalpy Heat Error due to Pressure Loop Uncertainty (RWCUhp)

The reactor water cleanup enthalpy determination is affected by the loop pressure error. The pressure has a very small effect in the water enthalpy, however, it is determined in this calculation. The loop uncertainty is documented in:

Ref.: 3.4.4

The heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error:

RWCUhp = [Flow [(hin - hin+error) - (hout - hout+error)]] x 2.93E-07 / 3889 x 100%

In flow heat

P Rtd	P+err	TRtd	h rated	h+err	Flow
1020	1040.2	530.7	524.96	524.93	148,000
Error (psi)	20.2	1			

Out flow heat

P Rtd	P+err	TRtd	h rated	h+err	Flow
1020	1040.2	433.8	412.64	412.66	148,000
Error (psi)	20.2				

Error

6,672 BTU/hr at rated reactor water cleanup flow

Rev 5

Rev 5

Uncertainty in Rated MWt RWCUhp = 0.00005%

(N0	C.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCULA	TION CONTINUATION S	HEET	SHEET:	25
CALC NO .:	SC-BB-0525 Attachment 2	REV:	5	REF:		CONT'D ON SHEET:	26
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	1	DATE:
Michael Miller	2/14/2017	John Wilkens	۰.	3/13/2017	N/A	· ·	N/A

7.2.5 Recirculation Pumps Heat Error due to Watts Loop Uncertainty (RRPw)

This section calculates the uncertainty due to RRP watts loop error, calculated in:

Ref.: 3.4.11

The rated power for the pump-motor and the motor efficiency (0.93) is from reference:

(Ref. 3.4.3)

There are two recirculation pumps, the calculated error below is per pump. The actual total MW for the 2 pumps is taken from above reference.

W 2 pump = 7.33

The Watt error contribution is calculated as follows:

RRPw = [(W Rtd/pump + MW Loop Span x Span err) x Mottor eff] - W Rtd/pump x Motor eff] / 3889 x 100%

Rev 5

W Rtd/pmp+err			Motor Eff	W+err		
		3.823	0.93	3.55		
	: .	- F	Error =	1.50 % span		
		t E	Span=	10.5 Mwatt		

TTL Mwatt	· · · · ·	
	3.41	Mwatt
		-

Error 0.1465 Mwatt

0.1403 101

Uncertainty in Rated MWT RRPw = 0.0038%

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CALC NO .:	SC-BB-0525 Attachment 2	REV:	5	REF:	<u> </u>	CONT'D ON SHEET:	27
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Michael Miller	2/14/2017	John Wilkens	5	3/13/2017	N/A	N	/A

7.2.6 Thermal Loses (TL)

This section calculates the uncertainty due to TL error. This error will be treated as a bias error since the estimated value is larger or smaller than assumed, i.e. it is a fixed error not a random error.

An assumed error equal to 20% of the specified loses is used.

The rated Heat Loss is from reference:

(Ref. 3.4.2)

W Rto	1	W+err
	1.1	1.32
	Error =	20.00%

TTL Mwatt Heat	
1.32	MW

1.10 MW at rated conditions

Error

0.2200 MW error at rated radiated loses

Uncertainty in Rated MWT	This error is treated as bias.	
TL = 0.0057%	R	Rev 5

Note: The computer utilizes this value combined with Other System Loses (Section 7.2.7) as Radiative power loses, QRAD = 1.94

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ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A	N/A

7.2.7 Other System Loses (OSL)

The rated value includes Rod Dr ve seal purge flow to recirculation pumps. An assumed error equal to 20% of the specified loses is used. This error will be treated as a bias error since if the estimated value is larger or smaller than assumed, i.e. it is a fixed error not a random error.

The rated Losses figure is from reference:

(Ref. 3.4.2)

W Rtd	W+err			
1.18				Rev 5
Error =	20%	- 		
		TTL Mwatt Heat 1.42	MW	Rev 5
•		1.18	MW at rated conditions	Rev 5
		Error 0.2360	MW error at rated radiated loses	Rev 5
		Uncertainty in Rated OSL =	MWT This error is treated as bias. 0.0061%	Rev 5

Note: The computer utilizes this value combined with Thermal Loses (Section 7.2.6) as Radiative power loses, QRAD = 1.94

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Michael Miller		2/14/2017	John Wilkens		3/13/2017	N/A	N/A	

7.2.8 Heat Balance Calculation Power Uncertainty (Power U)

The calculated heat balance uncertainty is the algebraic combination of the bias errors with the independent/random errors statistically combined, that contribute into the heat balance calculation, in accordance with the heat balance formula:

Power = MFW(MSh-FWh)-CRDF(hin-hout)+RWCU(hout-hin)-RRP+HL+Miscellaneous

Summary of Heat Balance Calculation Contributing Errors:

Random Errors:	MSmoist	t = 0.0000%			Rev 5
	CRDo	;= 0.0053%			
	CRDdp	o = 0.0061%			
	RRPw	<i>i</i> = 0.0038%			
	RWCUp sw	r = 0.0001%			
Dependent Errors:	Errors		Variable		
	FWhp) = **	Rated MS pressu	ure = 1020 psia	
	FWm				
	FWht	= **			
	MSm	= **			
	MShp	= 0.0296%			
	CRDhp	= -0.00006%			
	RWCUhp	= 0.00005%			
Bias Errors:	CRD	t = -0.0012%			
	CRDh	t = -0.0096%			
	RWCUf	= 0.0031%			
	RWCUht	= 0.0287%			
	TL	. = 0.0057%			
	OSL	= 0.0061%			
** Note that these terms	s are combined	in reference 3.4.20 for	n over all uncertainty of 0.66% for FV	Vm, FWht and FWhp	
Heat Balance Calculat			-		I
Power Error = SC	RT[((0.0066)^2	+(MShp+CRDhp+RW	lhp) ^x 2+MSmoist^2+CRDc^2+CRDdp	o^2+	Rev 5
	+RWCUp_	sw^2+RRPw^2x2]+CR	+CRDht+RWCUf+RWCUht+TL+OSL	-	
Power Error = 0.	694%				Rev 5
To ensure operation ma	argin exist, due	to possible instrument	on loops miss-calibration, actual drift	(to be determined by history), etc., a margin is a	dded:
Power U = Powe	er Error + Margi	n			
where margin is define	d as 3840 * 102	% – Rated Thermal Po	er – Power Error		
0	916.8 - 3889 - P	ower Error			
Margin = 0.	021%	and	Power U = 0.715%		Rev 5

(NC.I	DE-AP.ZZ-0002(Q), Rev. 1	2, Form 2)		CALC	ULATION CONTINUATION	SHEET	SHEET:	29
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Michael Miller	·	2/14/2017	John Wilkens		3/13/2017	N/A	N	/A

8.0 SUMMARY

The calculated Heat Balance Error performed in this calculation is applicable to fully operational LEFM. The Power Uncertainty is the	Rev 5
difference between the 2% design basis and the rated termal power for the current LEFM mode of operation. Positive margin is	
maintained between the Power Uncertainty and the Power Error. The Heat Balance calculation error (Section 7.0) is:	

Power U = 0.715%

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CALC NO.:	SC-BB-0525 Attachment 3	REV:	5	REF:		CONT'D ON SHEET:	2
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	DA	TE:
Michael Miller	2/14/2017	John Wilkens	•	3/13/2017	N/A	N	/A

Sections 1 through 4 have been replaced with the main body of the calculation

5.0 DESIGN INPUTS

5.1 Rated Power Conditions

100% rated Power Conditions are listed below. Actual 100% operation values might be used in lieu of rated nominal values, for other than Rated MWt, Feedwater Flow and Main Steam parameters as deemed appropriate. This is found acceptable, since for the purpose of error determination to rated MWt "heat differential errors", actual heat contribution deviation from measured/calculated heat to rated MWt due to instrumentation uncertainties, is required not the actual deviation value.

Rated MWt = <u>3840M</u>	₩ (Ref. 3.4.17, 3.2.4)		Rev 5
Rated FW flow = <u>1.6741</u>	E+07lbm/hr (Ref. 3.4.17)		
Rated FW temperature = 431.6 F	(Ref. 3.4.17)		
Rated MS flow = <u>167730</u>	00 (Ref. 3.4.17)		
Rated MS pressure = <u>1020 p</u>	sia (Ref. 3.4.17)		
Rated MS quality = <u>100.000</u>	<u>0</u> (Ref. 3.4.1)		•
Rated RWCU flow = <u>148000</u>	<u>.0 lb/hr</u> (Ref. 3.4.17)		Rev 5
Rated RWCU temperature = <u>530.8 F</u>	(Ref. 3.4.17)		
Rated RWCU return temperature = <u>433.9 F</u>	(Ref. 3.4.17)		
Rated CRD flow = <u>32000.0</u>	<u>) lb/hr</u> (Ref. 3.4.3, 3.4.17)		
CRD Calibration pressure = <u>1474.0</u>	psia (Ref. 3.4.5)		
Rated CRD temperature = <u>77 F</u>	(Ref. 3.4.5)		
Radiation Loses = <u>1.10MV</u>	<u>V</u> (Ref. 3.4.2, 3.4.17)		Rev 5
Other System Loses = <u>1.18MV</u>	V (Ref. 3.4.2, 3.4.17) No	ote: These loses are not included in UFSAR Heat Balance, Ref. 3.1.1	
MWt/BTU/hr = <u>2.9300</u>	<u>-07</u> (Ref. 3.4.1)		•
Power = MFW(MSh-H	Wh)-CRDF(hin-hout)+RWCU(hout-hin	n)-RRP+HL+Miscellaneous	

Notes:

1) This calculation uses rated MS quality of 100.00%, which will produce a more conservative number with respect to the actual plant MS quality. This parameter may be revised when the actual MS quality is measured after the implementation of EPU.

2) This calculation specifies radiation loses as 1.10 MW and other loses as 0.84 MW for the total lose of 1.94 MW. Reference 3.4.17 stated "other system loses" as 1.9 MW without specifically accounting for Radiation loses. Since the two total numbers are almost identical and the difference would have negligible affect on the Power Error, radiation loses of 1.10 MW and the other loses of 0.84 MW will be maintained.

6.0 ASSUMPTIONS

See sections 7.2.3, 7.2.4, 7.2.6 and 7.2.7 for specific assumptions.

(NC.	DE-AP.70002(Q), Rev. 12	, Form 2)		CALCULATION O	CONTINUATION SHEE	ŕ ,	SHEET:	2
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Michael Miller		2/14/2017	John Wilkens		3/13 <i>1</i> 2017	N/A		N/A

7.0 CALCULATIONS

7.1 Methodology

The methodology used to combine the uncertainties for the different contributors to the heat balance calculation is the square root of the sum of the squares of those uncertainties which are statistically independent. Then algebraically combined with the those errors that are systematic, or bias. The uncertainties are considered to be random, two sided distributions. This methodology has been utilized before, and has been endorsed by the NRC and various industry standards (Ref. 3.4.12-3.4.14).

The uncertainty calculation combines the different errors from the different parameters contributing to the heat balance in accordance to the heat balance equation. The contributing parameters errors are taken from the specific system uncertainty calculation.

These errors are generally classified in two groups:

a) Instrument loop(s) uncertainty

b) Process effects

The individual uncertainties affecting the heat balance calculation are determined by the application of the corresponding process algorithm, as described below:

a) the appropriate algorithm for the specific process parameter is set in the form to its specific contribution to the heat balance at specified rated conditions,

b) subsequently, the instrumentation loop error is factored in the process algorithm to calculate the corresponding process parameter with the error built-in,

c) the difference of the calculated contributed process parameter heat, with error, to the rated process rated heat is then calculated,

d) the resultant heat error contribution is then divided by the rated 100% power thermal megawatts. The result is the error contribution by the specific process to the total heat balance uncertainty,

e) finally, all the calculated heat errors are combined in accordance to their parameter function in the heat balance equation. The resultant combination of all contributing errors is the Heat Balance Uncertainty.

(NC.I	DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCU	LATION CONTINUATION	SHEET	SHEET:	3
CALC NO.:	SC-BB-0525 Attachment 3	REV:	5	REF:		CONT'D ON SHEET:	4
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	1	DATE:
Michael Miller	2/14/2017	John Wilker	าร	3/13/2017	N/A		N/A

7.2 Uncertainties Calculation

7.2.1 Main Feedwater Uncertainty(ies)

Referring to the schematic drawing in section 4.0, it can be seen that the Main Feedwater heat contribution is affected by the following parameters:

a) Mass Flow Measurement affected by: 1) flow, 2) temperature, and 3) pressure instrumentation loops error.

The error provided by the vendor for the ultrasonic flow meter already factors the corresponding temperature and pressure loops effect.

b) Feedwater Enthalpy determination affected by: 1) temperature, and 2) pressure, instrumentation loops error.

The main feedwater enthalpy is calculated using the following signals:

- Main Steam Pressure and Main Feedwater Temperature

The main feedwater mass error is provided as percentage of span at 100% rated power at span of 20,000,000 lbm/hr as documented in Ref.: 3.4.7 Section 7.12.3. The number to be used for 100% flow is positive error of +0.72% flow span at 20,000,000 lbm/hr span or 144,000 lbm/hr.

(Note: Ref.: 3.4.7 Section 7.12.1 NSSS Computer-Feedwater Flow took credit for constant correction of feedwater flow by crossflow. For this calculation where crossflow correction is not credited, the number in Section 7.12.1 cannot be used. Instead the error calculated in Section 7.12.3: GETARS Total Flow 3840 MWt should be used. The propagation of feedwater flow error is identical between NSSS computer and GETARS computer, i.e. both their loops consist of feedwater nozzles, flow transmitters, DFCS Foxboro interface modules, and computers.)

The heat error is the difference in the MFW heat content at rated flow conditions minus the heat error content at rated conditions plus flow error:

FWm = [hrated (Flowrated - Flowrated+err)] x 2.93E-07/3840 x100%

	F Rtd	F+err	P Rtd	TRtd	h rated
	16,741,000	16,885,000	1020	431.6	410.23
_	0/ 11			· · · · · · · · · · · · · · · · · · ·	

Error % reading 0.7200%

TTL MFW Heat 6,926,704,606 BTU/hr

6,867,631,732 BTU/hr at rated conditions

Error

59,072,873 BTU/hr at rated main feedwater flow

Uncertainty in Rated MWT FWm = 0.4507%

(N	(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)				CALCULATION CONTINUATION SHEET					4	
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Michael Miller		2/14/2017		John Wilkens		· · · · ·	3/13/2017	N/A		N/A	

7.2.1.2 Main Feedwater Heat Enthalpy Error due to Pressure Loop Uncertainty (FWhp)

The main feedwater enthalpy is determined from reactor loop pressure, that is affected by the loop uncertainty. The pressure loop uncertainty is documented in:

Ref.: 3.4.4

The heat error is the difference in the MFW heat content at rated flow and enthalpy conditions minus the heat content at rated flow with enthalpy at rated pressure plus pressure induced error:

FWhp = [Flow (hrated - hrated+err)] x 2.93E-07 / 3840 x 100%

÷.

P Rtd	P+err	TRtd	h rated	h+err	Flow	
1020	1026.1	431.6	410.23	410.23	16,741,000	Rev 5
Error (psi) =	6.1			·		
		TTL MFW Heat 6,867,717,889	BTU/hr			Rev 5
		6,867,631,732	BTU/hr at rated co	nditions		Rev 5
		Error 86,156	BTU/hr at rated m	ain feedwater flow		Rev 5
	l	Incertainty in Rated I FWhp =	MWt 0.0007%			Rev 5

(NC.I	DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCULATION CONTINUATION SHEET				
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ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/14/2017	John Wilkens	5	3/13/2017	N/A		N/A

7.2.1.3 Main Feedwater Heat Enthalpy Error due to Temperature Loop Uncertainty (FWht)

The main feedwater enthalpy determination is affected by the loop temperature error, documented in:

Ref.: 3.4.8

The heat error is the difference in the MFW heat content at rated flow and enthalpy conditions minus the heat content at rated flow conditions with enthalpy at rated temperature plus temperature induced error:

FWht = [Flow (hrated - hrated+err)] x 2.93E-07 / 3840 x 100%

TRtd	T+err	P Rtd	h rated	h+err	Flow
431.6	433	1020	410.23	411.91	16,741,000

Error (F) = 1.53 This error is subject to change depending in performance history

TTL MFW Heat 6,895,730,240 BTU/hr

6,867,631,732 BTU/hr at rated conditions

Error

28,098,508 BTU/hr error at rated main feedwater flow

Uncertainty in Rated MWt FWht = 0.2144%

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ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A	N/A

7.2.2 Main Steam Flow Uncertainty(ies)

Referring to the schematic drawing in section 4.0, It can be seen that the Main Steam heat contribution is affected by the following parameters:

a) The calculated Main Steam Heat is affected by the mass flow measurement error (see section 7.2.1.1 Main Feedwater Mass Error).

b) Main Steam Enthalpy determination is affected by the pressure instrumentation loop error, documented in calculation:

Ref. 3.4.4

7.2.2.1 Main Steam Mass Flow Heat Error due to Main Feedwater Flow Uncertainty (MSm)

The main feedwater mass error is provided from Section 7.2.1.1:

The heat error is the difference in the Main Steam flow heat content at rated flow conditions minus the heat content at rated conditions plus flow error:

MSm = [hs rated (Flowrated - Flowrated+err)] x 2.93E-07 / 3840 x 100%

FWFEerr = 0.7200%

Span Mass Flow

F Rtd	F+err	P Rtd	Moist Rtd	hs rated
16,773,000	16,917,000	1020	100	1192.19

TTL MFW Heat 20,168,331,463 BTU/hr

19,996,655,650 BTU/hr at rated conditions

Error

171,675,813 BTU/hr at rated main feedwater flow

Uncertainty in Rated MWT MSm = 1.3099%

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CALC NO.:	SC-BB-0525 Attachment 3	REV:	5	REF:		CONT'D ON SHEET:	8	
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:	
Michael Miller	2/14/2017	John Wilkens	5	3/13/2017	N/A		N/A	

7.2.2.2 Main Steam Heat Enthalpy Error due to Pressure Loop Uncertainty (MShp)

This Section calculates the Main Heat Steam enthalpy error due to the loop pressure uncertainty, documented in:

Ref.: 3.4.4

The heat error is the difference in the Main Steam flow heat content at rated flow and enthalpy conditions minus the heat content at rated flow with enthalpy at rated pressure plus pressure induced error:

MShp = [Flow (hrated - hrated+err)] x 2.93E-07 / 3840 x 100%

P Rtd	P+err	Moist Rtd	Moist+err	h rated	h+err	Flow	
1020	1026.1	100	100.000	1192.19	1191.96	16,773,000	Rev 5
Error (psi) =	6.1		0				
	÷.						
		TTL MS Heat					· · ·
		19,992,800,352	BTU/hr				Rev 5
		19,996,655,650	BTU/hr at rated con	ditions			Rev 5
		F amor					
		Error	57110				
		3,855,299	BIU/hr error at rate	ed main feedwater f	low		Rev 5
		Error in Rated MWt	0.000.00/				1
		I MSnp =	0.0294%				Rev 5

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ORIGINATOR:		DATE:	REVIEWER:		DATE:	VERIFIER:	E	ATE:
Michael Miller	· · · ·	2/14/2017	John Wilker	ns	3/13/2017	N/A	<u> </u>	N/A

7.2.2.3. Main Steam Moisture Heat Enthalpy Error due to Steam Moisture Uncertainty (MSmoist)

This section calculates the Main Steam enthalpy error due to MS moisture uncertainty. The uncertainty is conservatively set to 50% of rated moisture content of 0.0%.

The heat error is the difference in the Main Steam flow heat content at rated flow and moisture conditions minus the heat content at rated moisture conditions plus moisture error:

MSmoist = [Flowrated hrated (hmoist-rated - hmoist-rated+err)] x 2.93E-07 / 3840 x 100%

P Rtd	P+err M	oist Rtd	Moist+err	h rated	h+err	Flow
1020	1020	100	100.0000	1192.19	1192.19	16,773,000
	0.00000	0.00%	÷ 0			

TTL MS Heat 19,996,655,650 BTU/hr

19,996,655,650 BTU/hr at rated conditions

Error

- BTU/hr error at rated main feedwater flow

Error in Rated MWt

MSmoist = 0.0000%

(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)				Т	SHEET:	9		
CALC NO.:	SC-BB-0525 Attach	ment 3	REV:	5	REF:	CON	T'D ON SHEET:	10
ORIGINATOR:		DATE:	REVIEWER:		DATE:	VERIFIER:	1	DATE:
Michael Miller		2/14/2017	John Wilkens		3/13/2017	N/A		N/A

7.2.3 Control Rod Drive Flow

Referring to the schematic drawing in section 4.0, it can be seen that CRD flow is not monitored for pressure or temperature.

The CRD calculated heat is affected by the following effects:

a) Mass Flow Measurement affected by: 1) flow, instrumentation loop effect and 2) temperature, and 3) pressure deviation from calibration values

b) The CRD Enthalpy determination is affected by: 1) temperature, from applied constants, and 2) pressure, from reactor pressure loop error

The CRD flow loop errors are documented in calculation:

<u>Ref. 3.4.5</u>

The flow formula is derived from the ASME (Ref. 3.4.9) as follows:

Flow = C*Fa*K*(DP*r)^0.5

where K is calculated below:

K = Calib Flow/(Calib inWC * Calib r)^0.5

(N	C.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)	CALCULATION	SHEET	10			
CALC NO .:	SC-BB-0525 Attachment 3	REV:	5	REF:		CONT'DONSHEET	: 11
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	· · ·	DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A

7.2.3.1 Control Rod Drive Flow Heat Error due to Flow Element and Fluid Specific Weight Uncertainty due to Temperature Error (CRDt)

The uncertainty is dependent for the following variables:

Fa = FE Thermal Expansion

r = Fluid Specific Weight

The plant computer calculates the CRD flow with a constant flow K factor. However, the actual temperature could vary as much as 43F from the expected 77F, and this impacts the Fa and r impacting the calculated flow; therefore, the effect due to this temperature deviation is:

CRDt = [(hs rated - CRDh rated) (Flowrated - Flowrated+err)] x 2.93E-07 / 3840 x 100%

Ref.: 3.4.5			K = 4	148.48			
			Calib Flow = \$	50154 lb/hr	100 GPM		
Fa Error	•		Calib inWC =	200			
Rated 77F	1.0003		Calib Temp =	77			
@140 F	1.0013		Calib Press =	1474.7			
@40 F	0.9995			62.529			
Fa/F	1.8E-05	Assu	med Rated Flow =	<u>32000.0 lb/hr</u>			
			Rated Press =	1020 psia			
			Rated Temp =	77 F			· · · ·
			Rated h =	47.83 btu/lb			
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	T+err
1.0000	1.0000	81.3694	81.3694	1.0003	1.0011	7	
0.00%	: 0	0.00%	\$ O				43
· · · · · · · · · · · · · · · · · · ·					Temp error = Calib Tem	p - Min Temp	
P Rtd	r	h Rtd	Flow	hs Rtd	•		
1020	61.9029	47.83	31,863.902	1192.19			
	ŢŢ	L CRD Heat		· · · ·	- · · · · ·		
2		36,463,826	BTU/hr				
				• · · · · · ·		4	
	· •	36,619,571 E	BTU/hr at rated cond	ditions			
· · · · · · · · · · · · · · · · · · ·		Error					

(155,745) BTU/hr error at rated CRD flow

Error in Rated MWt CRDt = -0.0012%

This error is a bias, not a random instrument induced uncertainty.

(NC	C.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCULATION CONTI	NUATION SHEET	SHEET:	
CALC NO.:	SC-BB-0525 Attachment 3	REV:	5REF:		CONT'D ON SHEET:	12
ORIGINATOR:	DATE:	REVIEWER:	DATE:	VERIFIER:		DATE:
Michael Miller	2/14/2017	John Wilkens	3/13/2	2017 N/A	1	N/A

7.2.3.2 Control Rod Drive Flow Heat Error due to Flow Element Uncertainty (CRDc)

The CRD contributed heat is affected by the FE error that is assigned to the flow element expansion coefficient.

С

The FE uncertainty is determined based in calculation:

Ref.: 3.4.5

The heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error:

CRDc = [(hs rated - CRDh rated) (Flowrated - Flowrated+err)] x 2.93E-07 / 3840 x 100%

Fa Error Rated 77F @140 F @60 F Fa/F	1.0003 1.0013 0.9995 1.8E-05	Assu	Calib Flow = Calib inWC = med Calib Temp = med Calib Press =	200.00 77.00 1474.00 62.529 32000.0 lb/hr 1020 psia	0.0159925		
				47.83 btu/lb			
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	T+err
1.0000	1.0200	81.3694	81.3694	1.0003	1.0003	•	77 77
2.00%	<u>200</u>	0.00%	• 0				<u> </u>

P Rtd	r	h Rtd	Flow	hs Rtd
1020.00	62.4433	47.83	32,017.500	1192.19

TTL MFW Heat 37,326,215 BTU/hr

36,619,571 BTU/hr at rated conditions

Error

706,644 BTU/hr error at rated CRD flow

Error in Rated MWt CRDc = 0.0054%

	(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)	*	с С.	ALCULATION O	CONTINUATION SH	EET	SHEET:	12	
CALC NO .:	SC-BB-0525 Attachment 3	RE	v: <u>5</u>	,	REF:		CONT'D ON SHEET:	13	
ORIGINATOR:	DATE:	RE	VIEWER:		DATE:	VERIFIER:	······································	DATE:	
Michael Miller	2/14/2017	Jo	ohn Wilkens		3/13/2017	N/A		N/A	

7.2.3.3 Control Rod Drive Heat Error due to Differential Pressure (DP) Loop Uncertainty (CRDdp)

This error is calculated in calculation:

Ref.: 3.4.5

The loop is comprised of 1) flow transmitter, FT, 2) resistor, REST, 3) computer analog to digital card, A/D. The uncertainties are in % DP span:

Accuracy:

Loop Drift: CRD AREST CRD_VDFT CRD AFT CRD VDA/D CRD AA/D 1.154% 0.188% 1.450% 0.100% 0.000%

Loop Calibration:

.

CRD_CEFT	CRD_CEA/D
0.140%	0.188%

The uncertainties are random and independent and combined by the SRSS method:

1.88% span DP

(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)				CALCULATION CONTINUATION SHEET SHEET:				13
CALC NO.:	SC-BB-0525 Attach	nment 3	REV:	5	REF:		CONT'D ON SHEET:	14
ORIGINATOR:		DATE:	REVIEWER:		DATE:	VERIFIER:	D	ATE:
Michael Miller		2/14/2017	John Wilkens		3/13/2017	N/A	N	VA

The heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error:

CRDdp = [(hs rated - CRDh rated) (Flowrated - Flowrated+err)] x 2.93E-07 / 3840 x 100%

Fa Error		K = 448.51	
Rated 77F	1.0003	Calib Flow = 50157.2 lb/hr	100 GPM
@140 F	1.0013	Calib inWC = 200	
@60 F	0.9995	Assumed Calib Temp = 77	
Fa/F	1.8E-05	Assumed Calib Press = 1474	
		r = 62.529	
		Assumed Rated Flow = 32000.0 lb/hr	
		Rated Press = 1020.0 lb/hr	
		Rated Temp = 77 F	
		CRDh rated = 47.83 btu/lb	

C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	T+err
1.0000		81.3584	85.1183	1.0003	1.0003	77	77
0.00%	• 0	1.88%	*				0

. بالداد ..

P Rtd	r	CRDh rated	Flowrated+err	hs Rtd
1020	62.4433	47.83	32,708.537	1192.19

TTL MFW Heat 37,430,393 BTU/hr

36,619,571 BTU/hr at rated conditions

Error

810,822 BTU/hr at rated CRD flow

Error in Rated MWt CRDdp = 0.0062%

(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)			CALCULATION CONTINUATION SHEET SHEET:				14	
CALC NO .:	SC-BB-0525 Attachment 3		REV:	5	REF:	<u> </u>	CONT'D ON SHEET	15
ORIGINATOR:	DATE:		REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/14/2017		John Wilkens		3/13/2017	N/A		N/A

7.2.3.4 Control Rod Drive Flow Enthalpy Heat Error due to Temperature Calibration Deviation (CRDht)

The plant computer calculates the CRD fluid enthalpy at a constant 77F and reactor pressure. However, the actual temperature varies and it is assumed to vary as much as 43F from the expected 77F; therefore, the effect due to this temperature deviation in the calculated enthalpy is:

<u>Ref. 3.4.5</u>

The heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error:

CRDht = [Flow (hs rated - CRDh rated) - Flow (hs rated - CRDh rated+err)] x 2.93E-07 / 3840 x 100%

TRtd	T Max/Min	T+err	P Rtd	h rated	h+err	hs rated	Flow
77	40	37	1020	47.83	8.05	1192,19	32,000

TTL RWCU Heat 37,892,585 BTU/hr

36,619,571 BTU/hr at rated conditions

Error (1,273,014) BTU/hr at rated CRD flow

Uncertainty in Rated MWt CRDht = -0.0097%

This error is a bias, not a random instrument induced uncertainty.

(NC		CALCULATION CONTINUATION SHEET					
CALC NO.:	SC-BB-0525 Attachment 3		5	REF:	REF:		16
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A

7.2.3.5 Control Rod Drive Flow Enthalpy Heat Error due to Pressure Loop Uncertainty (CRDhp)

The plant computer calculates the CRD fluid enthalpy at a constant 77F and reactor loop pressure, that is affected by the loop uncertainty. The pressure loop uncertainty is documented in:

Ref.: 3.4.4

The heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error:

CRDhp = [Flow (hs rated - CRDh rated) - Flow (hs rated+err - CRDh rated)] x 2.93E-07 / 3840 x 100%

P Rtd	P+err	TRtd	CRDh rated	hs rated	hs rated+err	Flow	
1020	1026.1	77	47.83	1192.19	1191.96	32,000	Rev 5
Error(psi) =	= <u>6.1</u>		-				
		TTL MFW Heat	1				
		36,612,216	BTU/hr				Rev 5
		36,619,571	BTU/hr at rated con	ditions			Rev 5
		Error					,
			BTU/hr at rated CF	2D flow			Rev 5
		(1,000)					
	I	Uncertainty in Rated	MWt				
		CRDhp =	-0.00006%				Rev 5
	-		-				

(NC	C.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)	CALCULATION CONTINUATION SHEET SHE					16
CALC NO.:	SC-BB-0525 Attachment 3	RE :	5	REF:		CONT'D ON SHEET:	17
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	DATE:	
Michael Miller	2/14/2017	John Wilkens	5	3/13/2017	N/A	N/A	

7.2.4 Reactor Water Cleanup Uncertainty(ies)

Referring to the schematic drawing in section 4.0, it can be seen that RWCU flow is measured and mass calculated by a "NUMAC" process unit. Differential pressure, temperature, by dedicated thermocouples, and reactor pressure are an input to the instrument. Therefore, the RWCU contributed heat is affected by the following parameters:

a) Mass Flow Measurement affected by: 1) flow, 2) temperature, and 3) pressure induced factors/instrumentation loops errors

b) The RWCU Enthalpy determination is affected by: 1) temperature instrumentation loop error (see discussion for pressure)

The flow formula is derived from the ASME (Ref. 3.4.9) as follows:

Flow = C*K*(DP)^0.5

where K is:

K = Calib Flow / [C*(Calib inWC)^0.5]

(NC.	(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)			CALCULATION CONTINUATION SHEET SHEET				
CALC NO.:	SC-BB-0525 Attachment 3	REV:	5	REF:		CONT'D ON SHEET:	18	
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:	
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A	

7.2.4.1 RWCU Inlet/Outlet Flow Heat Error due to Flow Element Expansion deviation from Calibration (RWCUFa)

The Numac computer calculating the mass flow has a built-in Fa constant different than the flow element Fa provided at the calculated venturi rated temperature of 533F. This induces a bias error. Furthermore, the plant NUMAC normalizes the flow mass signal to a specific weight of 47.0 lbm/cuft for pressure and temperature conditions, back calculated below; therefore, the rated conditions are set at 530.8F.

Pressure Density Compensated to :	47.18 lb/cuft	530.8 F	<u>908 psia</u>
The Fa used in the calculation is fixed to:		1.0045	
The correct Fa at rated 533 F is:		1.0087	

Based on the Fa differences the induced flow error is calculated below:

Fa = FE Thermal Expansion

Ref.: 3.4.10

Flow+err = C x Fa+err / Fa x K x (DP)^0.5

			K =	9448.61				
			Calib Flow =	189797.2 lb/hr	500 GPM	(Note)		
Fa Error			Calib inWC =	<u>403.5</u>		. ,		
Rated 533F	1.0087	Ass	umed Calib Temp =	530.8				
Calibrated	1.0045	Ass	umed Calib Press =	1114.7				
		r = 47.326						
		Ass	umed Rated Flow =	148000 lb/hr	<u>389 GPM</u>			
			Rated h =	524.95 btu/lb		Sum.		
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	T+err	
1.0000		245.3519	245.3519	1.0087	1.0045	530.8	53	
0.00%	• 0	0.00%	÷ 0				<u>.</u>	
P Rtd	P+err	r	h Rtd	Flow+err				
1114.7	1114.7	47.3259	524.95	147,384				
	0							
		Uncertainty						
		RWCUFa	-616.2 lb/hr	This a bias and the	actual contributed Heat	is Higher than indicate	d	

<u>30.8</u> 0

(NC.	(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)			CALCULATION CONTINUATION SHEET				
CALC NO.:	SC-BB-0525 Attachment 3	REV:	5	REF:		CONT'D ON SHEET:	19	
ORIGINATOR:	DATE	REVIEWER:		DATE:	VERIFIER:		DATE:	
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A	

7.2.4.2 RWCU Inlet/Outlet Flow Heat Error due to Fluid Specific Weight deviation (RWCUPMA)

This error is the combination of several uncertainties calculated below:

7.2.4.2.1 RWCU Inlet/Outlet Flow Error due to Fluid Specific Weight Numac Lookup Tables Error (RWCUPMA1)

The Numac performs the fluid specific weight determination with an error of 0.1 specific weight, this effect in the flow is calculated below.

r = Fluid Specific Weight

Ref.: 3.4.10

Flow+err = $C \times K \times (DP \times r + err / r)^{0.5}$

The flow error is the difference between the rated flow at rated specific weight minus the flow at specific weight plus error:

RWCUPMA1 = Flowrated - Flowrated+error

			K = 9	9448.61		
	· · · ·		Calib Flow =	189797.2 lb/hr	500 GPM	(Note)
Fa Error			Calib inWC = 4	403.5		
Rated 533F	1.0087	Assur	ned Calib Temp = {	530.8		
Calibrated	1.0045	Assur	ned Calib Press = ·	1114.7		
		2. C	r = 4	47.326		
		Assu	med Rated Flow = "	148000 lb/hr	388.8 GPM	
	2		Rated hout = :	524.95 btu/lb		
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd
1.0000	1.0000	245.3519	245.3519	1.0087	1.0087	530.8
0.00%	: 0	0.00%	\$ 0			
		· · · · ·				
P Rtd	P+err	r N	lumac err	r+perr+Numac	h Rtd	Flow
1114.7	1114.7 psi	47.326	0.1	47.426	524.95	148,157

0 psi

Uncertainty	
RWCUPMA1 = 156.3 lb/hr	

(NC	(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)			CALCULATION CONTINUATION SHEET				
CALC NO.: SC-BB-0525 Attachment 3		REV:	5	REF:	REF:		CONT'D ON SHEET: 20	
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:	
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A	

7.2.4.2.2 RWCU Inlet/Outlet Flow Error due to Fluid Specific Weight Numac 0.75 Factor Pressure Correction Factor Error (RWCUPMA2)

The Numac computer introduces a 0.75 factor to the input pressure raw value and calculates the specific weight for saturated conditions, which bias the actual flow.

Ref.: 3.4.10

Flow+err = $C \times K \times (DP \times r+err / r)^{0.5}$

The flow error is the difference between the rated flow at rated specific weight minus the flow at specific weight plus error:

RWCUPMA2 = Flowrated - Flowrated+error

r = Fluid Specific Weight

P Rtd	P+orr	T Sat	r+perr	Numac rerr	r+perr+Numac	h Rtdout	l h
0.00%	: 0	0.00%	* 0				
1.0000	1.0000	245.3519	245.3519	1.0087	1.0087	530.8	
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	l
	-		Rated =	524.95 btu/lb			_
		Ass	umed Rated Flow =	148000 lb/hr	388.8 GPM		
			r =				
Calibrated	1.0045	Ass	umed Calib Press =	1114.7			
Rated 533F	1.0087		umed Calib Temp =				
Fa Error			Calib inWC =	403.5			
			Calib Flow =	189797.2 lb/hr	500 GPM	(Note)	
			К =	9448.61			

1	P Rtd	P+err	T Sat	r+perr	Numac rerr	r+perr+Numac	h Rtdout	h Rtd return	Flow	
	1114.7	840 psi	523.8	47.5895	0	47.5895	524.95	412.75	148,412	
		75%	<u>75</u>							

Uncertainty RWCUPMA2 = -412 lb/hr This a bias and the actual contributed Heat is Higher than indicated

(N	C.DE-AP.ZZ-0002(Q), Rev. 1	2, Form 2)	· .	CALCULATION CONTINUATION SHEET SHEET				
CALC NO .:	SC-BB-0525 Attac	hment 3	REV:	5	REF:	· · · · · · · · · · · · · · · · · · ·	CONT'D ON SHEET:	21
ORIGINATOR:		DATE:	REVIEWER:	······	DATE:	VERIFIER:		DATE:
Michael Miller	•	2/14/2017	John Wilkens		3/13/2017	N/A		N/A

7.2.4.2.3 RWCU Inlet/Outlet Flow Heat Error due to Fluid Specific Weight Pressure Loop Uncertainty (RWCUP_SW)

Pressure is utilized as an input to the Numac to determine the specific weight of the fluid. The pressure loop uncertainty combined with the Numac computer uncertainty introduces an error in the calculated specific weight.

The loop error is comprised of 1) pressure loop, PT, 2) NUMAC computer uncertainties. The combined uncertainties are:

RWCUpress error= 21 psi

Ref.: 3.4.10

Flow+err = $C \times K \times (DP \times r+err / r)^{0.5}$

The flow error is the difference between the rated flow at rated specific weight minus the flow at specific weight plus error:

RWCUp_SW = [Flowrated (h_in - h_out) - Flowrated+error (h_in - h_out)] x 2.93E-07 / 3840 x 100%

C Rtd		C+err	1	DP Rtd		DP+err	Fa Rtd	Fa+	err	T Rtd in	T Rtd out
	· · ·	•	· ·			Rated h =	524.95 btu/lb	1			
					Assur	ned Rated Flow =	148000 lb/hr	388.8 GPM			
						, r=	47.326				
Calibrated		1.00	045		Assun	ned Calib Press =	1114.7				
Rated 533F		1.00	087		Assur	ned Calib Temp =	530.8				
Fa Error					- * - * * * *	Calib inWC =	403.5				
		· · · ·			-	Calib Flow =	189797.2 lb/hr	500 GPM		(Note)	
	r = Flui	d Specific W	eight			К =	9448.61	· · · ·			

			DITEN	Turtu	Tu . Chi	I ICUM HI	T KLU OUL
1.0000	1.0000	245.3519	245.3519	1.0087	1.0087	530.8	433.9
0.00%	0	0.00%	÷0				
				an an ga	and the second second		

P Rtd P+err	r+perr Numac rerr	r+perr+Numac h Rtd in	h Rtd out	Flow
1020 1041 psi	47.2756	0 47.2756 525.08	412.75	147,922

Ť	TL MFW Heat	
	16,616,239	BTU/hr

16,625,077 BTU/hr at rated conditions

Error

8,837

Uncertainty in Rated MWt RWCUp_sw = 0.0001%

(NC.I	DE-AP.ZZ-0002(Q), Rev. 12, Form 2)	CALCULATION CONTINUATION SHEET				SHEET:	21
CALC NO.: SC-BB-0525 Attachment 3		REV:	5	REF:	REF:		22
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A

7.2.4.3 Reactor Water Cleanup Flow Error due to Flow Element Uncertainty (RWCUc)

The RWCU flow is affected by the FE error that is assigned to the flow element expansion coefficient.

С

The FE uncertainty is determined based in calculation:

Ref.: 3.4.10

 $Flow+err = C+err \times K \times (DP)^{0.5}$

The flow error is the difference between the rated flow minus the flow with the C coefficient error:

RWCUc = Flowrated - Flowrated+error

C Dtd	Ctorr		DDtorr	Eo Did	Enterr	TDtd
			Rated h =	524.95 btu/lb		
		Assur	med Rated Flow =	148000 lb/hr	389 GPM	
			r =	47.33		
		Assur	ned Calib Press =	1114.70		
		Assun	ned Calib Temp =	530.80		
Calibrated	1.0045		Calib inWC =	403.50		
Rated 533F	1.0087		Calib Flow =	189797.2 LB/HR	500 GPM	(Note)
Fa Error			К =	9448.61		

C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	T+err
1.0000	1.0150	245.3519	245.3519	1.0087	1.0087	530.8	530.8
1.50%	<u>• 150</u>	0.00%	0				0

P Rtd	r	h	Flow
1114.7	47.3259	525.0	150,220

Uncertainty	_
RWCUc = 2220.0 I	b/hr

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bitchael Miller 2/14/2017 John Wilkens 3/13/2017 N/A N/A 7.2.4.4 Reactor Water Cleanup Flow Error due to Differential Pressure (DP) Loop Uncertainty (RWCUdp) This error is introduced by the differential pressure instrument loop. The uncertainties in the loop are found in: Ref.: 3.4.10 The loop is comprised of 1) flow transmitter, FT, 2) NUMAC computer. The uncertainties are in % DP span: The flow error is the difference between the rated flow minus the flow with the C coefficient error: RWCUp = Flowrated - Flowrated error RWCU_ANT	CALC NO.:		<u> </u>	REV:	5	REF:		CONT'D ON S	
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0.503% 0.100% 0.233% 0.900% 0.127% 0.127% Loop Calibration: RWCU_CEFT RWCU_CENU_A/D 0.02% 0.02% 0.139% 0.02% 0.127% 0.127% 0.127% The uncertainties are random and independent and combined by the SRSS method:				Loop Drift:					
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Uncertainty	1.0000	1.0000	240.0019						
	1.0000 0.00%	<u>1.0000</u> : : 0 r	h		·· . ·				
	1.0000 0.00%	<u>1.0000</u> : : 0 r	h						
	1.0000 0.00%	<u>1.0000</u> : : 0 r	h 524,95	149,316					
	1.0000 0.00%	<u>1.0000</u> : : 0 r	h 524.95 Uncertainty	149,316					

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Michael Miller	2/14/201	7 John Wilken	ıs	3/13/2017	N/A		N/A

7.2.4.5 Reactor Water Cleanup Flow Error due to Signal Conditioning/NSSS Computer Loop Uncertainty (RWCUNSSS_cptr)

The differential pressure is converted to flow by the Numac computer and retransmitted as flow signal to the plant computer for heat balance calculations.

This portion of the loop is comprised of 1) NUMAC computer output, 2) NSSS computer uncertainty. The uncertainties are in % flow span:

Accuracy:	
RWCU_ANU_D/A	RWCU_AA/D
0.233%	0.188%

Loop Drift:	
RWCU_VDNU_D/A	RWCU_VNA/D
0.13%	0.000%

530.8

0

Loop Calibration:

RWCU_CENU_D/A	RWCU_CEA/D
0.02%	0.188%

The uncertainties are random and independent and combined by the SRSS method:

0.38% span FLOW

The flow error is the difference between the rated flow at without loop error minus the flow plus loop error:

RWCUNSSS_cptr = Flowrated - Flowrated+error

Fa Error Rated 533F Calibrated	1.0087 1.0045		K = 9448.61 Calib Flow = 189797.2 lb/hr 500 GPM Calib inWC = 403.50 Assumed Calib Temp = 530.80 Assumed Calib Press = 1114.70				
			r =	47.33			
		Assi	umed Rated Flow =	148000 lb/hr	389 GPM		
			Rated h =	524.95 btu/lb			
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	T+err
1.0000	1.0000	245.3519	245.3519	1.0087	1.0087	530.8	530
0.00%	0						•

P Rtd	r	h	Flow
1114.7	47.3259	524.95	148,714.0

713.7 lb/hr
/ 13./ ID/IIF

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Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A

7.2.4.6 Reactor Water Cleanup Total Flow due to Flow Loop Uncertainties (RWCUf)

RWCU Inlet h - Outlet h.

The total RWCU Flow Uncertainty is calculated below:

RWCUfu =+/-SQRT(RWCUPMA1^2+RWCUc^2+RWCUdp^2+RWCUNSSS_cptr^2)-RWCUFa-RWCUPMA2

Notice that the bias PMAs are factored with both signs, since the negative uncertainty is the one that has impact in the heat balance calculations, that is, that (-) less indication means that power is higher; however, it will be factored in both directions for simplicity.

RWCUfu = 3710 lb/hr

Then, the heat error contribution is the calculated inlet flow heat error minus the outlet flow heat error:

RWCUh_in = 525.08 btu/lb RWCUh_out = 412.75 btu/lb

And the RWCU heat error contribution is calculated by the following expression:

RWCU = [RWCUfu (RWCUh_in - RWCUh_out) x MWt_BTU_hr (conversion factor)]/ Rated MWt 100%

RWCUf = 0.0032%

This total error will be treated as bias in the total heat balance error

(NC.	DE-AP.ZZ-0002(Q), Rev. 12	, Form 2)	CALCULATION CONTINUATION SHEET SHEE			SHEET:	25	
CALC NO.:	SC-BB-0525 Attach	ment 3	REV:	5	REF:		CONT'D ON SHEET:	26
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Michael Miller		2/14/2017	John Wilkens		3/13/2017	N/A		N/A

7.2.4.7 Reactor Water Cleanup Flow Enthalpy Heat Error due to Temperature Uncertainty (RWCUht)

This error is the error resultant of temperature measurement errors by the inlet/outlet RWCU thermocouple loops factored into the fluid enthalpy determination. The thermocouples are instruments with good repeatability and stability. However, fabrication errors can amount to several farenheit degrees. The fabrication errors can be calibrated out, since essentially it is a bias, systematic error. The temperature loops for RWCU are not calibrated out. Finally, since most of the thermocouples loop error is a bias, the conservative and safe way to apply the error, is for the two temperature error to be set in the same direction; therefore, the effect is additive, bias. The temperature loops error is found in:

<u>Ref. 3.4.6</u>

The heat error is the difference between the inlet flow heat error minus the outlet flow heat error:

RWCUht = [Flow [(hin - hin+error) + (hout - hout+error)]] x 2.93E-07 / 3840 x 100%

In flow heat

mineut					
TRtd	T+err	P Rtd	h rated	h+err	Flow
530.8	541.7	1020	525.08	<u>53</u> 8.82	148,000
Error (F)	10,9				

Out flow heat

TRtd	T+err	P Rtd	h rated	h+err	Flow
433.9	444.8	1020	412.75	424.78	148,000
Error(F)	10.9				· · · · · · · · · · · · · · · · · · ·

Error
<u>3,813,231</u> BTU/hr error at rated reactor water cleanup flow

Uncertainty in Rated MWt

RWCUht = 0.0291%

This error is a bias

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CALC NO.:	SC-BB-0525 Attachment 3	REV:	5	REF:	· · · · · · · · · · · · · · · · · · ·	CONT'D ON SHEET:	27
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Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A

7.2.4.8 Reactor Water Cleanup Flow Enthalpy Heat Error due to Pressure Loop Uncertainty (RWCUhp)

The reactor water cleanup enthalpy determination is affected by the loop pressure error. The pressure has a very small effect in the water enthalpy, however, it is determined in this calculation. The loop uncertainty is documented in:

Ref.: 3.4.4

The heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error:

RWCUhp = [Flow [(hin - hin+error) - (hout - hout+error)]] x 2.93E-07 / 3840 x 100%

In flow heat

P Rtd	P+err	TRtd	h rated	h+err	Flow
1020	1040.2	530.8	525.08	525.05	148,000
Error (psi)	20.2				

Out flow heat

P Rtd	P+err	TRtd	h rated	h+err	Flow
1020	1040.2	433.9	412.75	412.77	148,000
Error (psi)	20.2	,			

Error

6,681 BTU/hr at rated reactor water cleanup flow

Uncertainty in Rated MWt RWCUhp = 0.00005%

(NC	DE-AP.ZZ-0002(Q), Rev. 12, Form 2)	5	CALCU	LATION CONTINUATION S	SHEET	SHEET:	27
CALC NO.:	SC-BB-0525 Attachment 3	REV:	5			CONT'D ON SHEET:	28
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Michael Miller	2/14/2017	Joh <u>n Wilk</u> en	15 <u> </u>	3/13/2017	N/A	N	/A

7.2.5 Recirculation Pumps Heat Error due to Watts Loop Uncertainty (RRPw)

This section calculates the uncertainty due to RRP watts loop error, calculated in:

Ref.: 3.4.11

The rated power for the pump-motor and the motor efficiency (0.93) is from reference:

(Ref. 3.4.3)

There are two recirculation pumps, the calculated error below is per pump. The actual total MW for the 2 pumps is taken from above reference.

W 2 pump = 7.33

The Watt error contribution is calculated as follows:

RRPw = [(WRtd/pump + MW Loop Span x Span err) x Mottor eff] - WRtd/pump x Motor eff] / 3840 x 100%

W Rtd/pmp+err	Motor Eff	W+err
3.823	0.93	3.55
	Error =	1.50 % span
	Span =	10.5 Mwatt

TTL Mwatt 3.41 Mwatt

Error 0.1465 Mwatt

Uncertainty in Rated MWT RRPw = 0.0038%

(NC	ATOR: DATE: REVIEWER: DATE: VERIFIER:	HEET:	28					
CALC NO.:	SC-BB-0525 Attach	ment 3	REV:	5	REF:	CONT'D ON S		29
ORIGINATOR:		DATE:	REVIEWER:		DATE:	VERIFIER:	DAT	E:
Michael Miller		2/14/2017	John Wilkens		3/13/2017	N/A	N/A	4

7.2.6 Thermal Loses (TL)

This section calculates the uncertainty due to TL error. This error will be treated as a bias error since the estimated value is larger or smaller than assumed, i.e. it is a fixed error not a random error.

An assumed error equal to 20% of the specified loses is used.

The rated Heat Loss is from reference:

(Ref. 3.4.2)

W Rtd	W+err
1.1	1.32
Error =	20.00%

_		12	1.4	
П	TL	Mwat	t Heat	1
		1	.32	 MW
		_		

1.10 MW at rated conditions

Error 0.2200 MW error at rated radiated loses

Uncertainty in Rated MWT TL = 0.006%

Note: The computer utilizes this value combined with Other System Loses (Section 7.2.7) as Radiative power loses, QRAD = 1.94

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CALC NO.:	SC-BB-0525 Attach	ment 3	REV:	5	REF:	cc	ONT'D ON SHEET:	30
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Michael Miller		2/14/2017	John Wilkens		3/13/2017	N/A	1	N/A

7.2.7 Other System Loses (OSL)

The rated value includes Rod Drive seal purge flow to recirculation pumps. An assumed error equal to 20% of the specified loses is used. This error will be treated as a bias error since if the estimated value is larger or smaller than assumed, i.e. it is a fixed error not a random error.

The rated Losses figure is from reference:

(Ref. 3.4.2)

W Rtd 1.18 Error =				Rev 5
				l
	TTL Mwatt Heat 1.42	MW		Rev 5
	1.18	MW at rated condition	ns	Rev 5
	Error 0.2360	MW error at rated r	adiated loses	Rev 5
	Uncertainty in Rated OSL =	MWT 0.006%	This error is treated as bias.	Rev 5

Note: The computer utilizes this value combined with Thermal Loses (Section 7.2.6) as Radiative power loses, QRAD = 1.94

(NC			CALCULATION CONTINUATION SHEET				
CALC NO .:	SC-BB-0525 Attachment 3	REV:	5	REF:		CONT'D ON SHEET:	31
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/14/2017	John Wilkens	_	3/13/2017	N/A		N/A

7.2.8 Heat Balance Calculation Power Uncertainty (Power U)

The calculated heat balance uncertainty is the algebraic combination of the bias errors with the independent/random errors statistically combined, that contribute into the heat balance calculation, in accordance with the heat balance formula:

Power = MFW(MSh-FWh)-CRDF(hin-hout)+RWCU(hout-hin)-RRP+HL+Miscellaneous

Summary of Heat Balance Calculation Contributing Errors:

Random Errors:	FWm = 0.4507%	
	FWht = 0.2144%	1
	MSm = 1.3099%	
	MSmoist = 0.0000%	
	CRDc = 0.0054%	
	CRDdp = 0.0062%	· ·
	RRPw = 0.0038%	
	RWCUp sw = 0.0001%	
Dependent Errors:	Errors	
	FWhp = 0.0007%	
	MShp = 0.0294%	
	CRDhp = -0.00006%	
	RWCUhp = 0.00005%	
Bias Errors:	CRDt = -0.0012%	
	CRDht = -0.0097%	
	RWCUf = 0.0032%	
	RWCUht = 0.0291%	
	TL = 0.006%	1
	OSL = 0.006%	

<u>Variable</u> Rated MS pressure = 1020 psia

Rev 5

Rev 5

Heat Balance Calculation Power Error (U):

Power Error = SQRT[(MSm-FWm)^2+(MShp-FWhp+CRDhp+RWCUhp)^2+FWht^2+MSmoist^2+CRDc^2+CRDdp^2+ +RWCUp_sw^2+RRPw^2x2]+CRDt+CRDht+RWCUf+RWCUht+TL+OSL

Power Error = 0.919%

To ensure operation margin exist, due to possible instrumentation loops miss-calibration, actual drift (to be determined by history), etc., a margin is added:

Power U = Power Error + Margin

where margin is defined as 2.0% (SET POWER U) - Power Error

and

Margin = 1.081%

Power U = 2.000%

(NC	DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCUL	SHEET:	31		
CALC NO.:	SC-BB-0525 Attachment 3	REV:	5	REF:		CONT'D ON SHEET:	N/A
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Michael Miller	2/14/2017	John Wilke	ens	3/13/2017	N/A	[r	I/A

8.0 SUMMARY

The calculated Heat Balance Error performed in this calculation is applicable to the hand calculation error when determined process values and steam tables heat values are used with an accuracy of 3 decimal places. This results are applicable to hand calculated heat balance since less hardware errors are involved in the hand calculation, data collection. The Heat Balance calculation error (Section 7.0) is:

<u>Power U = 2.000%</u>

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Sections 1 thro	ugh 4 have been replaced wit	h the main body of the	calculatior	· · · · ·	·					
5.0 DESIGN IN	PUTS								Rev 5	
5.1 Rated Powe	er Conditions									
Feedwater Flow	er Conditions are listed below. and Main Steam parameters as at differential errors", actual her	deemed appropriate. 7	his is found accep	table, since f	or the purpose of	error determinati	ion	't,		
	required not the actual deviation		•			· .				
	Rated MWt = <u>3902M</u>		3.4.19, 3.2.5, Att. 8)	•					
	Rated FW flow = 1.4962		8.4.19, Att. 8)							
R	ated FW temperature = 331.5		3.4.19, Att. 8)				Ē		,	
	Rated MS flow = <u>14994</u>		3.4.19, Att. 8)							
	Rated MS pressure = <u>1001 p</u>		8.4.19, Att. 8)							
	Rated MS quality = <u>100.00</u> Rated RWCU flow = 14800	.	,							
Data	RWCU temperature = <u>517.8</u>		3.4.19, Att. 8) 3.4.19, Att. 8)							
	U return temperature = <u>419.2</u>		5.4.19, Att. 8)							
KaleuKWC	Rated CRD flow = 32000.									
000			3.4.3, 3.4.18)		-					
	Calibration pressure = <u>1474.0</u>		,							
Ra	ted CRD temperature = $\frac{77 \text{ F}}{1000 \text{ F}}$	•	3.4.19, Att. 8)							
	Radiation Loses = <u>1.10M</u>		3.4.2, 3.4.19)							
	Other System Loses = <u>1.18M</u>		· · · · ·	: These lose	s are not include	d in UFSAR Heat I	Balance, Re	ef. 3.1.1		
	MWt/BTU/hr = <u>2.9300</u>					•				
	Power = MFW(MSh-	-FWh)-CRDF(hin-hout)+	RWCU(hout-hin)-	RRP+HL+Mi	cellaneous					
						· · · ·				
Notes:	 This calculation uses rat This parameter may be This calculation specifies "other system loses" as 1 the difference would have 	revised when the actual s radiation loses as 1.10 .9 MW without specifica	MS quality is mea MW and other los Ily accounting for I	sured after th es as 0.84 M Radiation lose	e implementation N for the total los s. Since the two	n of EPU. se of 1.94 MW. Re o total numbers are	eference 3.4 e almost ide	. 17 stated ntical and		
		neghyine aneur on the f					T WINN WILL DE	mainaineu.	1	
6.0 ASSUMPTI	DNS	· · · · ·								
					•					
See sections 7 2	.3, 7.2.4, 7.2.6 and 7.2.7 for spe				~					
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Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A	N/A	

7.0 CALCULATIONS

7.1 Methodology

The methodology used to combine the uncertainties for the different contributors to the heat balance calculation is the square root of the sum of the squares of those uncertainties which are statistically independent. Then algebraically combined with the those errors that are systematic, or bias. The uncertainties are considered to be random, two sided distributions. This methodology has been utilized before, and has been endorsed by the NRC and various industry standards (Ref. 3.4.12-3.4.14).

The uncertainty calculation combines the different errors from the different parameters contributing to the heat balance in accordance to the heat balance equation. The contributing parameters errors are taken from the specific system uncertainty calculation.

These errors are generally classified in two groups:

a) Instrument loop(s) uncertainty

b) Process effects

The individual uncertainties affecting the heat balance calculation are determined by the application of the corresponding process algorithm, as described below:

- a) the appropriate algorithm for the specific process parameter is set in the form to its specific contribution to the heat balance at specified rated conditions,
- b) subsequently, the instrumentation loop error is factored in the process algorithm to calculate the corresponding process parameter with the error built-in,

c) the difference of the calculated contributed process parameter heat, with error, to the rated process rated heat is then calculated,

- d) the resultant heat error contribution is then divided by the rated 100% power thermal megawatts. The result is the error contribution by the specific process to the total heat balance uncertainty,
- e) finally, all the calculated heat errors are combined in accordance to their parameter function in the heat balance equation. The resultant combination of all contributing errors is the Heat Balance Uncertainty.

Rev 5

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	002(Q), Rev. 12, Form 2) 0525 Attachment 4	REV:	5	CONTINUATION SI REF:	HEEI	SHEET CONT'D ON SHEET	
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7.2 Uncertainties Calculation							Rev 5
7.2.1 Main Feedwater Uncert							
The Main Feedwater uncerta	inties are included in the total th	ermal power uncertain	ty provided by the LI	EFM is 0.34% per Re	eference 3.4.20.		
This includes the Main Feedv	water mass flow error, main feed	lwater heat enthalpy e	rror, and the Main St	eam mass flow errol	r		
Referring to the schematic dr	awing in section 4.0, it can be se	een that the Main Feed	dwater heat contribut	ion is affected by the	e following parameters:		
a) Mass Flow Measurement a	affected by: 1) flow, 2) temperati	ure, and 3) pressure in	strumentation loops	error.			
The error provided by the ver	ndor for the ultrasonic flow meter	r already factors the co	orresponding temper	ature and pressure l	loops effect.		
b) Feedwater Enthalpy deterr	mination affected by: 1) tempera	ture, and 2) pressure,	instrumentation loop	s error.			
The main feedwater enthalpy	is calculated using the following	g signals:					
- Feedwater Pressure and Ma	ain Feedwater Temperature				· ·		
				•			
7.2.1.1 Main Feedwater Mass	s Flow Heat Error due to Flow El	lement Uncertainty FV	Vm)	-			
Deleted		<i>.</i>					
7.2.1.2 Main Feedwater Heat	Enthalpy Error due to Pressure	Loop Uncertainty FW	/hp)				
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	.						
	Enthalpy Error due to Tempera		(TAALE)				
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Nichael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A
7.2.2 Main Steam Flow	v Uncertainty(ies)						Rev 5
eferring to the schem	natic drawing in section 4.0, It can be	seen that the Main Ste	am heat contrib	oution is affected by the	following parameters:		
i) The calculated Main	Steam Heat is affected by the mass	flow measurement erro	or (see section	7.2.1.1 Main Feedwater	Mass Error).		
o) Main Steam Enthalp	by determination is affected by the pr	essure instrumentation	loop error, doc	umented in calculation:			
Ref. 3.4.4							
7.2.2.1 Main Steam Ma	ass Flow Heat Error due to Main Fee	dwater Flow Uncertaint	y (MSm)				
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2.2.2 Main Steam Lleat F	athalau Error dua ta Draaaur					Rev 5
	nthalpy Error due to Pressur					itev 5
his Section calculates the	Main Heat Steam enthalpy e	error due to the loop press	are uncertainty, documente	d in:		
ef.: 3.4.4						
	nce in the Main Steam flow l blus pressure induced error:	neat content at rated flow a	and enthalpy conditions mir	ius the heat content a	at rated flow with	
Shp = [Flow (hrated - hra	ted+err)] x 2.93E-07 / 3902	x 100%				
P Rtd	P+err Moist Rtd	Moist+err	h rated	h+err	Flow	
1000.69	1006.79 100	100.0		1192.69	14,994,000	
Error (psi) =	6.1		0			
	. <u></u>					
	TTL MS Heat					
	17,883	129,657 BTU/hr				
	17,886	503,873 BTU/hr at rated	conditions			
	Erro					
	3	374,216 BTU/hr error at	rated main feedwater flo	w		
				-		
	Frror in Rate					
	Error in Rate	MShp = 0.0253%				
	Error in Rate					
	Error in Rate					
	Error in Rate					

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Michael Miller		2/14/2017	John Wilkens		3/13/2017	N/A	N/A
		alpy Error due to Stear		. ,			Rev 5
I his section calculat moisture content of (enthalpy error due to M	S moisture uncertaint	y. The uncertainty is	s conservatively set to	50% of rated	
plus moisture error:		in Steam flow heat con ed - hmoist-rated+err)			minus the heat conte	ent at rated moisture co	nditions
P Rtd	P+err	Moist Rtd	Moist+err	h rated	h+err	Flow]
1000.69	1000.69	100	100.0000	1192.91	1192.9	1 14,994,000	1
	0.00000	0.00%	÷ 0				-
		TTL MS Heat 17,886,503,873	3_BTU/hr				
		17,886,503,873	BTU/hr at rated cor	nditions			
		Error -	BTU/hr error at rat	ted main feedwater	flow		
		Error in Rated MWt MSmoist	= 0.0000%				

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Michael Miller	2/14/2017	John Wilke	ns	3/13/2017	N/A	N/A

7.2.3 Control Rod Drive Flow

Rev 5

Referring to the schematic drawing in section 4.0, it can be seen that CRD flow is not monitored for pressure or temperature.

The CRD calculated heat is affected by the following effects:

a) Mass Flow Measurement affected by: 1) flow, instrumentation loop effect and 2) temperature, and 3) pressure deviation from calibration values

b) The CRD Enthalpy determination is affected by: 1) temperature, from applied constants, and 2) pressure, from reactor pressure loop error

The CRD flow loop errors are documented in calculation:

Ref. 3.4.5

The flow formula is derived from the ASME (Ref. 3.4.9) as follows:

Flow = C*Fa*K*(DP*r)^0.5

where K is calculated below:

K = Calib Flow/(Calib inWC * Calib r)^0.5

(NC.DE	E-AP.ZZ-0002(Q), Rev. 12,	, Form 2)		CALCULATION C	ONTINUATION SHEE	Т	SHEET:	8
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Michael Miller	2	2/14/2017	John Wilkens		3/13/2017	N/A	N	VA
7.2.3.1 Control Rod	Drive Flow Heat Error	r due to Flow Element a	and Fluid Specific We	eight Uncertainty du	e to Temperature Erro	r (CRDt)	R	Rev 5
The uncertainty is de	pendent for the follow	ving variables:						
Fa =	FE Thermal Expansion	n	r= 1	Fluid Specific Weigl	nt			
		w with a constant flow pacts the Fa and r impa						
CRDt = [(hs rated - Q	CRDh rated) (Flowrat	ted - Flowrated+err)]x	2.93E-07 / 3902 x 1	00%				
Ref.: 3.4.5			K = 4	448.48				
			Calib Flow = 5	50154 lb/hr	100 GPM			
Fa Error			Calib inWC = 🕻	~~~~~				
Rated 77F	1.0003		Calib Temp = 7	77				
@140 F	1.0013		Calib Press = 1	<u>1474.7</u>				
@40 F	0.9995		r = 6	52.529				
Fa/F	1.8E-05	Assu	umed Rated Flow = 🗧	32000.0 lb/hr				
			Rated Press = 1					
			Rated Temp = 7					
			Rated h = 4				T+err	
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	120	
1.0000	1.0000	81.3694	81.3694	1.0003	1.0011	-	77 🌻 <u>43</u>	
0.00%	0	0.00%	; 0					
	- 1		- /	h - Dtd	Temp error = Calib T	emp - Min Temp	_	
P Rtd 1000.69	r 61.8993	<u>h Rtd</u> 47.78	Flow	hs Rtd				
1000.69	61.8993[47.78	31,862.980	1192.91				
	F	TL CRD Heat	İ					
	ľ							
	<u> </u>	36,487,315	BIU/hr					
		36,644,221	BTU/hr at rated cond	ditions				
		Error (156,906)	BTU/hr error at rate	ed CRD flow				
	E	Error in Rated MWt CRDt =	-0.0012%	This error is a bias,	nota random instrume	nt induced uncertain	ty.	

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Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A
7.2.3.2 Control Rod Drive Flo	ow Heat Error due to Flow Ele	ment Uncertainty (CRDc)					Rev 5
The CRD contributed heat is	affected by the FE error that is	s assigned to the flow eleme	ent expansion coeffi	icient.			
	- · · · ·						
С							
The FE uncertainty is determ	ined based in calculation:	e general de la terrar de la composition de la composition de la composition de la composition de la compositio Composition de la composition de la comp					
Ref.: 3.4.5							
The heat error is the difference	ce in the CRD flow heat conter	nt at rated flow conditions m	inus the heat error	content at rated cond	ditions plus error:		
					· · · · · ·		
CRDC = [(ns rated - CRDn rate	ated) (Flowrated - Flowrated+	err)]x 2.93E-0773902 x 10	00%				
Fa Error		K = 4	10 10			-	
Rated 77F	1.0003	Calib Flow = 5		100.00			
				100.00			
@140 F @60 F	1.0013	Calib inWC = 2	00.00	100.00			- - -
@140 F @60 F Fa/F	1.0013 0.9995 1.8E-05	Calib inWC = 2 Assumed Calib Temp = 7 Assumed Calib Press = 1	00.00 7.00 474.00				
@60 F	0.9995	Calib inWC = 2 Assumed Calib Temp = 7 Assumed Calib Press = 1 r = 6	00.00 7.00 474.00 2.529	0.015992	5		
@60 F	0.9995	Calib inWC = 2 Assumed Calib Temp = 7 Assumed Calib Press = 1 r = 6 Assumed Rated Flow = 3 Rated Press = 1	00.00 7.00 474.00 2.529 2000.0 lb/hr 001 psia		5		
@60 F	0.9995	Calib inWC = 2 Assumed Calib Temp = 7 Assumed Calib Press = 1 r = 6 Assumed Rated Flow = 3 Rated Press = 1 Rated Temp = 7	00.00 7.00 474.00 2.529 2000.0 lb/hr 001 psia 7 F		5	Tterr	
@60 F Fa/F	0.9995 1.8E-05 C+err DP Rtd	Calib inWC = 2 Assumed Calib Temp = 7 Assumed Calib Press = 1 r = 6 Assumed Rated Flow = 3 Rated Press = 1 Rated Temp = 7 Rated h = 4 DP+err	00.00 7.00 474.00 2.529 2000.0 lb/hr 001 psia 7 F 7.78 btu/lb Fa Rtd	0.015992 Fa+err	T Rtd		77
@60 F Fa/F	0.9995 1.8E-05 C+err DP Rtd 1.0200 81	Calib inWC = 2 Assumed Calib Temp = 7 Assumed Calib Press = 1 r = 6 Assumed Rated Flow = 3 Rated Press = 1 Rated Temp = 7 Rated h = 4 DP+err .3694 81.3694	00.00 7.00 474.00 2.529 2000.0 lb/hr 001 psia 7 F 7.78 btu/lb	0.015992	T Rtd		77 0
@60 F Fa/F C Rtd C	0.9995 1.8E-05 C+err DP Rtd 1.0200 81	Calib inWC = 2 Assumed Calib Temp = 7 Assumed Calib Press = 1 r = 6 Assumed Rated Flow = 3 Rated Press = 1 Rated Temp = 7 Rated h = 4 DP+err	00.00 7.00 474.00 2.529 2000.0 lb/hr 001 psia 7 F 7.78 btu/lb Fa Rtd	0.015992 Fa+err	T Rtd		77 0
@60 F Fa/F	0.9995 1.8E-05 C+err DP Rtd 1.0200 81 200 0	Calib inWC = 2 Assumed Calib Temp = 7 Assumed Calib Press = 1 r = 6 Assumed Rated Flow = 3 Rated Press = 1 Rated Temp = 7 Rated h = 4 DP+err .3694 81.3694 0.00% 0	00.00 7.00 474.00 2.529 2000.0 lb/hr 001 psia 7 F 7.78 btu/lb Fa Rtd 1.0003	0.015992 Fa+err	T Rtd		77 0
@60 F Fa/F <u>C Rtd</u> C	0.9995 1.8E-05 C+err DP Rtd 1.0200 81 200 0 r h Rtd	Calib inWC = 2 Assumed Calib Temp = 7 Assumed Calib Press = 1 r = 6 Assumed Rated Flow = 3 Rated Press = 1 Rated Temp = 7 Rated h = 4 DP+err .3694 81.3694	00.00 7.00 474.00 2.529 2000.0 lb/hr 001 psia 7 F 7.78 btu/lb Fa Rtd	0.015992 Fa+err	T Rtd		77 0
@60 F Fa/F	0.9995 1.8E-05 C+err DP Rtd 1.0200 81 200 0 r h Rtd 62.4396	Calib inWC = 2 Assumed Calib Temp = 7 Assumed Calib Press = 1 r = 6 Assumed Rated Flow = 3 Rated Press = 1 Rated Temp = 7 Rated h = 4 DP+err .3694 81.3694 0.00% 0 Flow	00.00 7.00 474.00 2.529 2000.0 lb/hr 001 psia 7 F 7.78 btu/lb Fa Rtd 1.0003	0.015992 Fa+err	T Rtd		77 0
@60 F Fa/F C Rtd C 1.0000 2.00%	0.9995 1.8E-05 >+err DP Rtd 1.0200 81 200 0 r h Rtd 62.4396 TTL MFW Heat	Calib inWC = 2 Assumed Calib Temp = 7 Assumed Calib Press = 1 r = 6 Assumed Rated Flow = 3 Rated Press = 1 Rated Temp = 7 Rated h = 4 DP+err .3694 81.3694 0.00% 0 Flow 47.78 32,616.541	00.00 7.00 474.00 2.529 2000.0 lb/hr 001 psia 7 F 7.78 btu/lb Fa Rtd 1.0003	0.015992 Fa+err	T Rtd		77 0
@60 F Fa/F	0.9995 1.8E-05 C+err DP Rtd 1.0200 81 200 0 r h Rtd 62.4396 TTL MFW Heat 37,350	Calib inWC = 2 Assumed Calib Temp = 7 Assumed Calib Press = 1 r = 6 Assumed Rated Flow = 3 Rated Press = 1 Rated Temp = 7 Rated h = 4 DP+err .3694 81.3694 0.00% 0 Flow	00.00 7.00 474.00 2.529 2000.0 lb/hr 001 psia 7 F 7.78 btu/lb Fa Rtd 1.0003 hs Rtd 1192.91	0.015992 Fa+err	T Rtd		77 0
@60 F Fa/F	0.9995 1.8E-05 Ferr DP Rtd 1.0200 81 200 0 r h Rtd 62.4396 TTL MFW Heat 37,350 36,644	Calib inWC = 2 Assumed Calib Temp = 7 Assumed Calib Press = 1 r = 6 Assumed Rated Flow = 3 Rated Press = 1 Rated Temp = 7 Rated h = 4 DP+err .3694 81,3694 0.00% 0 Flow 47.78 32,616.541	00.00 7.00 474.00 2.529 2000.0 lb/hr 001 psia 7 F 7.78 btu/lb Fa Rtd 1.0003 hs Rtd 1192.91	0.015992 Fa+err	T Rtd		77 0
@60 F Fa/F C Rtd C 1.0000 2.00%	0.9995 1.8E-05 5+err DP Rtd 1.0200 81 200 0 r h Rtd 62.4396 TTL MFW Heat 37,350 36,644 Error	Calib inWC = 2 Assumed Calib Temp = 7 Assumed Calib Press = 1 r = 6 Assumed Rated Flow = 3 Rated Press = 1 Rated Temp = 7 Rated h = 4 DP+err .3694 81,3694 0.00% 0 Flow 47.78 32,616.541	00.00 7.00 474.00 2.529 2000.0 lb/hr 001 psia 7 F 7.78 btu/lb Fa Rtd 1.0003 hs Rtd 1192.91	0.015992 Fa+err	T Rtd		77 0
@60 F Fa/F	0.9995 1.8E-05 5+err DP Rtd 1.0200 81 200 0 r h Rtd 62.4396 TTL MFW Heat 37,350 36,644 Error	Calib inWC = 2 Assumed Calib Temp = 7 Assumed Calib Press = 1 r = 6 Assumed Rated Flow = 3 Rated Press = 1 Rated Temp = 7 Rated h = 4 DP+err .3694 81.3694 0.00% 0 Flow 47.78 32,616.541 0,242 BTU/hr 4,221 BTU/hr at rated cond 5,021 BTU/hr error at rate	00.00 7.00 474.00 2.529 2000.0 lb/hr 001 psia 7 F 7.78 btu/lb Fa Rtd 1.0003 hs Rtd 1192.91	0.015992 Fa+err	T Rtd		77 0

(NC.	(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)			CALCULATION	CONTINUATION	SHEET	SHEET:	10
CALC NO.:	SC-BB-0525 Attach	iment 4	REV:	5	REF:		CONT'D ON SHEET:	11
ORIGINATOR:		DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
<u>Michael Miller</u>		2/14/2017	John Wilkens		3/13/2017	N/A		N/A
7.2.3.3 Control Ro	d Drive Heat Error due	to Differential Press	ure (DP) Loop Unce	rtainty (CRDdp)				Rev 5
This error is calcula	ated in calculation:							
Ref.: 3.4.5								
The loop is compris The uncertainties a Accuracy:	sed of 1) flow transmitte are in % DP span:	er, FT, 2) resistor, RI	EST, 3) computer an Loop Drift:	alog to digital card, A/	D.			
CRD AFT	CRD AREST	CRD AA/D	CRD VDFT	CRD VDA/D	7			
					1			
1.154%	0.100%	0.188%	1.450%	0.000%	<u>'I</u>			

1.88% span DP

(1101212.7.1	ZZ-0002(Q), Rev. 12,	Form 2)		CALCULATION	CONTINUATION SHE	ET	SHEE	T: <u>11</u>
ALC NO.: SC-	BB-0525 Attachr	ment 4	REV:	5	REF:		CONT'D ON SHEE	IT: 12
		· · · · · · · · · · · · · · · · · · ·	-		-	·,		
ORIGINATOR:		DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Nichael Miller	2	2/14/2017	John Wilkens		3/13/2017	N/A		N/A
he heat error is the diffe	rence in the CRD) flow heat content at r	ated flow conditions	minus the heat erro	r content at rated con	ditions plus error:		Rev 5
RDdp = [(hs rated - CF	Dh rated) (Flowr	ated - Flowrated+err)] x 2.93E-07 / 3902	x 100%				
a Error			K	= 448.51				
Rated 77F	1.0003			= 50157.2 lb/hr	100 GPM			
0140 F	1.0013		Calib in WC =	= 200				
)60 F	0.9995		umed Calib Temp =					
a/F	1.8E-05	Ass	umed Calib Press =	= 1474				
				= 62.529				
		Ass	sumed Rated Flow =					
			Rated Press =					
,			Rated Temp =					
·			CRDh rated =				T+err	
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	TRtd		7
1.0000	1.0000	81.3584		3 1.0003	1.00)3	77	0
0.00%	0	1.88%	÷					
· · · · · ·								
P Rtd	r l	CRDh rated	Flowrated+err	hs Rtd	1			
1000.69	62.4396	CKDITAted47.78] [•]			
1000.00	02.4000		02,101.010	1102.01	1			
	Г	TL MFW Heat	1					
			DTU					
	L	37,454,488	BIU/hr					
		36,644,221	BTU/hr at rated co	onditions				
	1	Error	and the second second second second second second second second second second second second second second second	•				2
		040.007	BTU/hr at rated C	RD flow				
		810,267						
		17 1 4		- 19				
	ſĒ	810,267 Error in Rated MWt]				
	Ē	17 1 4	0.0061%]				
	Ē	Fror in Rated MWt	0.0061%	1				
	Ē	Fror in Rated MWt	0.0061%]				
	Ē	Fror in Rated MWt	0.0061%					
	Ē	Fror in Rated MWt	0.0061%					

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	(NC.DE-AP.ZZ-0002(Q), Rev.	12, Form 2)		CALCULATION	CONTINUATION S	HEET	SHEET:	12
CALC NO .:	SC-BB-0525 Atta	chment 4	REV:	5	REF:		CONT'D ON SHEET:	13
DRIGINATOR:	-	DATE:	REVIEWER:		DATE:	VERIFIER:	•	DATE:
Michael Mille	r	2/14/2017	John Wilkens		3/13/2017	N/A		N/A
he plant com	ol Rod Drive Flow Enthalp nputer calculates the CRD ary as much as 43F from t	fluid enthalpy at a cor	nstant 77F and react	or pressure. However				Rev 5
ef. 3.4.5								
he heaterror	r is the difference in the C	RD flow heat content a	at rated flow conditio	ns minus the heaterro	r content at rated o	onditions plus error:		
	r is the difference in the C w (hs rated - CRDh rated)				r content at rated c	conditions plus error:		
					r content at rated c	onditions plus error:	Flow	
CRDht = [Flov	w (hs rated - CRDh rated)	- Flow (hs rated - CR	Dh rated+err)] x 2.	93E-07 / 3902 x 100%			Flow 32,000	
CRDht = [Flov TRtd	w (hs rated - CRDh rated)	- Flow (hs rated - CR T+err 37 TTL RWCU Heat 37,917,3	Dh rated+err)] x 2.1 P Rtd 1000.69 80 BTU/hr	93E-07 / 3902 x 100%	h+err	hs rated		
CRDht = [Flov TRtd	w (hs rated - CRDh rated)	- Flow (hs rated - CR T+err 37 TTL RWCU Heat 37,917,3	Dh rated+err)] x 2. P Rtd 1000.69	93E-07 / 3902 x 100%	h+err	hs rated		
CRDht = [Flov TRtd	w (hs rated - CRDh rated)	- Flow (hs rated - CR T+err 37 TTL RWCU Heat 37,917,3 36,644,2 Error	Dh rated+err)] x 2.1 P Rtd 1000.69 80 BTU/hr	93E-07 / 3902 x 100%	h+err	hs rated		

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	E-AP.ZZ-0002(Q), Rev. SC-BB-0525 Atta								_
					CONTINUATION SHE	ET	SHEE		
	5C-BB-0525 Atta	coment 4	REV:	5	REF		CONT'D ON SHEE	T: <u>14</u>	
Michael Miller		DATE: 2/14/2017	REVIEWER: John Wilkens		DATE: 3/13/2017	VERIFIER: N/A		DATE: N/A	
7.2.3.5 Control Rod	Drive Flow Enthalp	y Heat Error due to Pre	ssure Loop Uncertaint	y (CRDhp)	-	-		Rev 5	
The plant computer on The pressure loop un	alculates the CRD) fluid enthalpy at a cons	stant 77Fand reactor lo	oop pressure, that i	affected by the loop	uncertainty.			
*						2			
Ref.: 3.4.4				• *					
The heat error is the	difference in the C	RD flow heat content at	t rated flow conditions	minus the heaterro	r content at rated con	ditions plus error:			
	-					•			
CRDhp = [Flow (hs r	ated - CRDh rated	l) - Flow (hs rated+err -	- CRDh rated)] x 2.93	E-07 / 3902 x 100%					
P Rtd	P+err	TRtd	CRDh rated	hs rated	hs rated+err	Flow	7		
1000.69	1006.79	77	47.78	1192.91	1192.6	9 32,000]		
Error (psi) =	<u>6.1</u>	TTI MENALII							
	-	TTL MFW Heat							
		36,637,02	20 BTU/hr	•	··· ·				
		36,644,22	21 BTU/hr at rated cor	nditions					
		Error)1) BTU/hr at rated Cl						
		(1,20							
		Uncertainty in Rate							
		CRDhp	b = -0.00005%					. <u> </u>	
		1	and the second sec		,				
1	1999 - 1999 - 1999 - 1999 - 1999 - 1999 - 1999 - 1999 - 1999 - 1999 - 1999 - 1999 - 1999 - 1999 - 1999 - 1999 -						1. 1 . 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.		
11 A					а — с		•	•	
					·				
					-				

(NC.E	E-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCULATION CONTINUATION SHEET				
CALC NO.:	SC-BB-0525 Attachment 4	REV:	5	REF:		CONT'D ON SHEET:	15
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	D/	TE:
Michael Miller	2/14/2017	John Wilken	S	3/13/2017	N/A	N	/A
Referring to the sche Differential pressure	<u>r Cleanup Uncertainty(ies)</u> ematic drawing in section 4.0, it can be , temperature, by dedicated thermoco	uples, and reactor pre			•	R	ev5
	ed heat is affected by the following pa						
a) Mass Flow Measu	urement affected by: 1) flow, 2) temper	ature, and 3) pressu	re induced facto	rs/instrumentation loops er	rors		
b) The RWCU Entha	alpy determination is affected by: 1) te	mperature instrument	tation loop error	(see discussion for pressu	e)		
The flow formula is o	derived from the ASME (Ref. 3.4.9) as	follows:					
Flow = C*K*(DP)^0	.5						
where K is:							
K = Calib Flow / [C	*(Calib inWC)^0.5]						

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(NC	.DE-AP.ZZ-0002(Q), Rev. 1	2, Form 2)		CALCULATION	CONTINUATION	SHEET	SHEET:	15
CALC NO .:	SC-BB-0525 Attack	hment 4	REV:	5	REF:		CONT'D ON SHEET:	16
ORIGINATOR:		DATE:	REVIEWER	· · · · ·	DATE:	VERIFIER:		DATE:
						1		
Michael Miller		2/14/2017	John Wilkens		3/13/2017	N/A		N/A
	et/Outlet Flow Heat Err	-					·	Rev 5
temperature of 533	iter calculating the mas BF. This induces a bias erature conditions, bac	error. Furthermore	e, the plant NUMAC n	ormalizes the flow ma	ss signal to a spe			
Pressure Density (The Fa used in the The correct Fa at r	calculation is fixed to:	48.01 lb	o/cuft 517.8 F 1.0045 1.0087	<u>908 psia</u>				
Based on the Fa d	ifferences the induced	flow error is calcula	ated below:					
Fa	= FE Thermal Expans	ion					А.	
Ref.: 3.4.10								
Flow+err = C x Fa+	err / Fax Kx (DP)^0.5							
			I	K = 9449.90				
· · ·	•			w = 189823.1 lb/hr	500 GPM	(Note)		
Fa Error			Calib inW					
Rated 533F	<u>1.0087</u>		Assumed Calib Tem	p = <u>530.7</u>				
Calibrated	<u>1.0045</u>		Assumed Calib Pres	s = <u>1114.7</u>	· .			
	· * · · · ·			r = 47.332				
			Assumed Rated Flow	w = 148021 lb/hr	<u>389 GPM</u>			
	- • .		Rated	h = 524.83 btu/lb				
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtc		
1.000				520 1.008	7	1.0045	530.7 530.7	
0.00	% 💼 0	0.	00%	0			÷ 0	
P Rtd	P+err	r	h Rtd	Flow+err				
1114	 Baserographic or entries a 		3324 524	.83 147,404				
-	0			-	the second second			
		Uncerta	inty CUFa -616.3 lb/hr	This a hias and the	a actual contribute	ed Heat is Higher tha	n indicated	
÷ .								
** ***		KWC					in indication	

(NC.DE-/	AP.ZZ-0002(Q), Rev. 12, Fo	rm 2)		CALCULATION	CONTINUATION SHE	ET	SHEET:	16
CALC NO.: S	C-BB-0525 Attachme	nt 4 RI	EV:	5	REF:		CONT'D ON SHEET:	17
					1			
ORIGINATOR:	DATE		EVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/14	J/2017 J	ohn Wilkens		3/13/2017	N/A		N/A
7.2.4.2 RWCU Inlet/O	utlet Flow Heat Error d	ue to Fluid Specific W	eight deviation (R	WCUPMA)				Rev 5
This error is the combine	nation of several uncer	tainties calculated bel	ow:					
7.2.4.2.1 RWCU Inlet/	Outlet Flow Error due t	o Fluid Specific Weigl	nt Numac Lookup	Tables Error (RWC	UPMA1)			
The Numac performs the	ne fluid specific weight	determination with an	error of 0.1 speci	ific weight, this effe	t in the flow is calculat	ed below.		
r = F	uid Specific Weight							
Ref.: 3.4.10								
Flow+err = C x K x (DP	x r+err / r)^0.5							
The flow error is the dif	ference between the ra	ated flow at rated spec	cific weight minus	the flow at specific	weight plus error:			
RWCUPMA1 = Flowrate	ed - Flowrated+error							
			К=	9449.90				
				189823.1 lb/hr	500 GPM	(Note)		
FaError			Calib inWC =					
Rated 533F	1.0087		ned Calib Temp =					
Calibrated	1.0045	Assun	ned Calib Press =	47.332				
		Áceun	r = = ned Rated Flow		388.8 GPM			
		73301		524.83 btu/lb				
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd		
1.0000	1.0000	245.3520	245.3520					
0.00%	0	0.00%			-			
P Rtd	P+err		umac err	r+perr+Numac	h Rtd	Flow		
1114.7	1114.7 psi	47.332	<u>0.1</u>	47.432	524.83	3 148,177		
line line	0 psi							
	—	Uncertainty		1				
		RWCUPMA1 = 1	56.3 lb/hr					
				4				
Note: This value is slig	ntly different to the 189	,197 lb/hr calculated i	n the reference du	ue to rounding				

(1	NC.DE-AP.ZZ-0002(Q), Rev	v. 12, Form 2)		CALCULATION	CONTINUATION SHE	ET	SHEET:	17
CALC NO .:	SC-BB-0525 Atta	achment 4	REV:	5	REF:	.	CONT'D ON SHEET	18
DRIGINATOR: Michael Miller		DATE: 2/14/2017	REVIEWER: John Wilkens		DATE: 3/13/2017	VERIFIER:		DATE: N/A
7.2.4.2.2 RWCL	J Inlet/Outlet Flow Erro	or due to Fluid Specific	Weight Numac 0.75	actor Pressure Corre	ction Factor Error (RW	CUPMA2)		Rev 5
The Numac com which bias the a		5 factor to the input pr	essure raw value and	calculates the specific	weight for saturated o	conditions,		
Ref.: 3.4.10					. <u></u>			
Flow+err = C x K	x (DP x r+err / r)^0.5							
The flow error is	the difference betwee	n the rated flow at rate	ed specific weight minu	is the flow at specific	weight plus error:			
RWCUPMA2 = F	lowrated - Flowrated+e	rror				•• • • • •	-	
	r = Fluid Specific We	eight						
Fa Error				= 9449.90 = 189823.1 lb/hr = 403.5	500 GPM	(Note)	-	
Rated 533F	1.00		Assumed Calib Temp	= 530.7			н. - С	
Calibrated	1.004	45	Assumed Calib Press	= 1114.7 = 47.332				
• •		· · · · ·	Assumed Rated Flow Rated	= 148021 lb/hr = 524.83 btu/lb	388.8 GPM			
<u> </u>	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	h Rtd return	Flow
	000 1.000 00% 		3520 245.352 00%	20 1.0087 0	1.008	7 530.7	396.68	148,422
				<u> </u>			· .	
P Rtd	P+err	T Sat	r+perr	Numac rerr	r+perr+Numac	h Rtdout		l
1114.7	840 psi	523.8	47.589	95 <u> </u> C	47.589	5 524.83	i l	
	75%	-	75					1
			· · · · · · · · · · · · · · · · · · ·					1

(NC.	DE-AP.ZZ-0002(Q), Rev. 12,	Form 2)		CALCULATION	ONTINUATION SHEE	Т	SHEET	18
ALC NO.:	SC-BB-0525 Attachn	nent 4	REV:	5	REF:		CONTDONSHEET	19
					·····			
ORIGINATOR:		ATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2	/14/2017	John Wilkens		3/13/2017	N/A		N/A
Pressure is utilized	let/Outlet Flow Heat En	ac to determine the sp	ecific weight of the t	fluid. The pressure I	oop			Rev 5
incertainty combine	ed with the Numac com	puter uncertainty intro	duces an error in th	e calculated specific	weight.			
The loop error is co	mprised of 1) pressure	loop, PT, 2) NUMAC o	computer uncertaint	ies. The combined u	uncertainties are:			
RWCUpress error	= <mark>21 psi</mark>							
Ref.: 3.4.10								
$Flow+err = C \times K \times ($	(DP x r+err / r)^0.5							
The flow error is the	e difference between the	e rated flow at rated sp	ecific weight minus	the flow at specific \	weight plus error:			
	wrated (h in h at "	Flowrotody orror (h ==						
	owrated (h_in - h_out) -	riowrateu+error (h_ir	i - n_out)] x 2.93E-	07 / 3902 X 100%				
r:	= Fluid Specific Weight			9449.90				
F - F				= 189823.1 lb/hr	500 GPM	(Note)		
F a Error Rated 533F	1.0087	, ^	Calib inWC = = umed Calib Temp					
Calibrated	1.0087		umed Calib Temp = umed Calib Press =					
	1.00+0	A92		47.332				
		Ass	umed Rated Flow =		388.8 GPM			
			Rated h =	524.83 btu/lb				
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd in	T Rtd out	
1.0000	-	245.3520			1.0087	530.7	419.2	4
0.00%	6	0.00%	÷ 0	<u>u</u>				
P Rtd	P+err	r+perr	Numac rerr	r+perr+Numac	h Rtd in	h Rtd out	Flow	
1000.69	1022 psi	47.2689	0	47.2689	509.11	396.68	147,921	
			_					
		TTL MFW Heat 16,631,277	RTI i/br					
	<u> </u>	10,031,277	BIU/M					
		16,642,445	BTU/hr at rated co	nditions				
		Error						
		11,168						
				_				
	<u>u</u>	ncertainty in Rated						
	<u>L</u>	RWCUp_sw =	0.0001%					
		89,197 lb/hr calculate	1					

And the second sec

CALC NO.: ORIGINATOR: Michael Miller	SC-BB-0525 Attachme			CALCULATION (SHEE	-10 <u>-</u>
		nt 4	REV: 5		REF:		CONT'D ON SHEE	т:
	DAT 2/1		REVIEWER: John Wilkens		DATE: 3/13/2017	VERIFIER: N/A	· · · ·	DA N
		4/2011			3/13/2017			
7.2.4.3 Reactor Wat	er Cleanup Flow Error d	lue to Flow Element l	Jncertainty (RWCUc)					R
	fected by the FE error t			ion coofficient				
		lat is assigned to the	now element expans	IUIT COEMCIENT.				
С		-						
The FE uncertainty is	determined based in c	alculation:						
Ref.: 3.4.10				•			·	
Flow+err = C+err x K :	x (DP)^0.5	· .						
I ne flow error is the o	difference between the i	ated flow minus the f	iow with the C coeffic	ient error:				
RWCUc = Flowrated	- Flowrated+error				2. 1997			
Fa Error				449.90				
Rated 533F Calibrated	1.0087 1.0045		Calib Flow = 18 Calib inWC = 40		500 GPM	(Note)		
			med Calib Temp = 53 med Calib Press = 11	30.70				
			r = 47	7.332				
		Assu	med Rated Flow = 14 Rated h = 52		389 GPM			
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	TRto		_
	<u>1.0150</u>	245.3520	245.3520	1.0087	1 1.0	0087	530.7 530.	<u>/</u>
	•	0.0070	······································					
P Rtd		h	Flow					
1114.7	47.3324	524.8	150,241					
		Uncertainty						
		RWCUc =	2220.3 lb/hr					

(NC.DI	E-AP.ZZ-0002(Q), Rev. 12	2, Form 2)		CALCULATION O	ONTINUATION SHEE	T	SHEET:
CALC NO .:	SC-BB-0525 Attach	ment 4	REV:	5	REF:		CONT'D ON SHEET:
					-		
ORIGINATOR:		DATE:	REVIEWER:		DATE:	VERIFIER:	DATE:
Michael Miller		2/14/2017	John Wilkens		3/13/2017	N/A	N/A
7.2.4.4 Reactor Wat	er Cleanup Flow Erro	or due to Differential Pre	ssure (DP) Loop Ur	ncertainty (RWCUdp)		Rev 5
This error is introduce	ed by the differential	pressure instrument loo	p. The uncertaintie	s in the loop are fou	nd in:	Ref.: 3.4.10	
The loop is comprise	d of 1) flow transmitt	er, FT, 2) NUMAC comp	uter. The uncertair	nties are in % DP sp	an:		
The flow error is the	difference between tl	he rated flow minus the t	flow with the C coef	ficient error:			
RWCUdp = Flowrated	- Flowrated+error						
Accuracy:			Loop Drift:				
RWCU AFT	RWCU_ANU_IE	RWCU ANU_A/D	RWCU VDFT	RWCU VDNU IE	RWCU_VDNU_A/D	7	
0.503%	0.100%	0.233%	0.900%	0.127%	0.127%	-	
0.139% The uncertainties are	span DP	Assu	K = Calib Flow = Calib inWC = umed Calib Temp = umed Calib Press =	530.70 1114.70 47.332	500 GPM 389 GPM	(Note)	
0.0(1)	<u> </u>			524.83 btu/lb	F -1	TDtd	T 1
<u>C Rtd</u> 1.0000	C+err 1.0000	DP Rtd 245.3520	DP+err 249.7338	Fa Rtd 1.0087	Fa+err 1.0087	T Rtd	T+err 30.7 530.7
0.00%		243.3320	249.1330	1.0007	1.0067	1 5.	
P Rtd		h	Flowrated+err	1			
<u>ר אנס</u> 1114.7	r 47.3324	<u>h</u> 524.83		<u>.</u>			
1114.7	41.3324	524.63	149,000	1			
	[Uncertainty RWCUdp =	1315.9 lb/hr				

Note: This value is slightly different to the 189,197 lb/hr calculated in the reference due to rounding

Bante Date Date Date Date Date Indexed Miller 214/2017 John Wilkens 3/13/2017 N/A N/A 2.4.5 Reactor Water Cleanup Flow Error due to Signal Conditioning/NSSS Computer Loop Uncertainty RWCUNSSS_optr) Rev 5 he differential pressure is converted to flow by the Numac computer and retransmitted as flow signal to the plant computer for heat balance calculations. Rev 5 he differential pressure is converted to flow by the Numac computer and retransmitted as flow signal to the plant computer for heat balance calculations. Rev 5 he upper state 0.000 fill RWCU VAUD RWCU VAUD 0.233% 0.188% 0.108 for mode of the loop brift: RWCU CENU D/A RWCU CEA/D 0.000 fill 0.000 fill 0.023% 0.188% 0.000 fill 0.000 fill 1.0045 0.188% 0.188 0.188 0.188 a fror ated 5351 1.0087 Calib Flow = 1898231 b/hr 389 GPM <td< th=""><th>(NC</th><th>DE-AP.ZZ-0002(Q), Rev.</th><th>12, Form 2)</th><th></th><th>CALCULATION</th><th>CONTINUATION S</th><th>HEET</th><th>SHEET: 21</th></td<>	(NC	DE-AP.ZZ-0002(Q), Rev.	12, Form 2)		CALCULATION	CONTINUATION S	HEET	SHEET: 21
Withead Millier 2/14/2017 John Wilkens 3/13/2017 N/A N/A 7.2.4.5 Reactor Water Cleanup Flow Error due to Signal Conditioning/NSSS Computer Loop Uncertainty RWCUNSSS_cptr) Rev 5 The differential pressure is converted to flow by the Numac computer and retransmitted as flow signal to the plant computer for heat balance calculations. Rev 5 This portion of the loop is comprised of 1) NUMAC computer output, 2) NSSS computer uncertainty. The uncertainties are in % flow span: Accuracy: Excuracy: NA NA Cognitization: RWCU_VDNU_D/A RWCU_VNAD 0.18% 0.186% 0.000% 0.18% 0.000% 0.000% 0.18% 0.000% 0.18% 0.000% 0.0	CALC NO .:	SC-BB-0525 Attac	hment 4	REV:	5	REF:		CONT'D ON SHEET: 22
Attended Millier 2/14/2017 John Witkens 3/13/2017 N/A N/A /2.4.5. Reactor Water Cleanup Flow Error due to Signal Conditioning/NSSS Computer Loop Uncertainty RWCUNSSS_optr) Rev 5 The differential pressure is converted to flow by the Numac computer and retransmitted as flow signal to the plant computer for heat balance calculations. Rev 5 The portion of the loop is comprised of 1) NUMAC computer output, 2) NSSS computer uncertainty. The uncertainties are in % flow span: Loop Orifi: RWCU AND RWCU CONLL D/A RWCU VIAID 0.233% 0.188% 0.198% 0.232% 0.188% 0.000% 0.232% 0.188% 0.000% 0.232% 0.188% 0.000% 0.232% 0.188% 0.000% 0.238% [span FLOW 0.000% 0.000% The uncertainties are random and independent and combined by the SRSS method: 0.389% [span FLOW 0.389% [span FLOW Tertor Ke 9449.90 tated 5337 1.0087 Calib Flow = 189823.1 b/hr Stated 5335 1.0087 Calib Flow = 189823.1 b/hr Stated 5335 1.0087 Calib Flow = 189823.1 b/hr Stated 5335 1.0087 Calib Flow = 530.70 Assumed Calib Terp = 530.70 Assumed Calib Terp = 530.70 Assumed Calib Terp = 530.70 Assumed Calib Terp =	RIGINATOR:		DATE:	REVIEWER:		DATE:	VERIFIER:	DATE:
7.2.4.5 Reactor Water Cleanup Flow Error due to Signal Conditioning/NSSS Computer Loop Uncertainty RWCUNSSS_opr) Rev 5 7.2.4.5 Reactor Water Cleanup Flow Error due to Signal Conditioning/NSSS Computer Loop Uncertainty RwCUNSSS_opr) Rev 5 The differential pressure is converted to flow by the Numac computer and retransmitted as flow signal to the plant computer for heat balance calculations. This portion of the loop is comprised of 1) NUMAC computer output, 2) NSSS computer uncertainty. The uncertainties are in % flow span: Accuracy: RWCU ANU D/A RWCU VAND Do Drift: RWCU ANU D/A RWCU VAND Do 10% 0.02% 0.188% 0.000% 0.02% 0.188% 0.000% 0.02% 0.188% 0.000% 0.02% 0.188% 0.000% 0.02% 0.188% 0.000% The uncertainties are random and Independent and combined by the SRSS method: 0.38% lepan FLOW The flow error is the difference between the rated flow at without loop error minus the flow plus loop error: RWCUNSS_opt = Flowrated - Flowrated Herror *a Error K = 9449.90 Saured Calib Frees = 1114.70 free 7.33.70 Assumed Calib Frees = 1111.70 r = 47.332 Assumed Calib Frees = 1114.70 r = 47.332 Calib Frees = 1111.70 r = 47.332	Michael Miller	1. 				3/13/2017		
he differential pressure is converted to flow by the Numac computer and retransmitted as flow signal to the plant computer for heat balance calculations. his portion of the loop is comprised of 1) NUMAC computer output, 2) NSSS computer uncertainty. The uncertainties are in % flow span: <u>couracy:</u> <u>RWCU_ANU_DARWCU_AAD</u>	2.4.5 Reactor W	ater Cleanup Flow Fr	ror due to Signal Condit	ionina/NSSS Compute	er Loop Uncertain	tv RWCUNSSS ontr		Rev 5
This portion of the loop is comprised of 1) NUMAC computer output, 2) NSSS computer uncertainty. The uncertainties are in % flow span: Accuracy: RWCU AND RWCU VNU/DA RWCU VNU/DD 0.233% 0.188% 0.000% 0.13% 0.000% Loop Crift: RWCU VNU/DA RWCU VNU/DD RWCU VNU/DD NUMAC computer output, 2) NSSS computer uncertainty. The uncertainties are in % flow span: Loop Calibration: RWCU CEA/D 0.13% 0.000% RWCU CEA/D 0.138% 0.000% 0.000% The uncertainties are random and independent and combined by the SRSS method: 0.38% Ispan FLOW 0.388% Ispan FLOW The uncertainties are random and independent and combined by the SRSS method: 0.388% Ispan FLOW Note the rated flow at without loop error minus the flow plus loop error: RWCUNSSS_optr = Flowrated - Flowrated + error K = 9449.90 Note the rated flow at without loop error minus the flow plus loop error: RWCUNSSS_optr = Flowrated - Flowrated + error Calib inWC = 403.50 Note the second the reset plus and calib Temp = 530.70 Assumed Calib Temp = 530.70 Assumed Calib Temp = 530.70 Assumed Rate Flow = 1480.21 Ib/hr Star Temp C Rtd C Peter D P Rtd Fa Rtd Fa + err Temp 530.7 530.7 530.7 <t< td=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>ĺ</td></t<>								ĺ
RWCU ANU D/A RWCU AAD 0.233% 0.188% Loop Calibration: 0.13% RWCU CUVAL 0.000% 0.22% 0.188% The uncertainties are random and independent and combined by the SRSS method: 0.38% [span FLOW] The uncertainties are random and independent and combined by the SRSS method: 0.38% [span FLOW] The flow error is the difference between the rated flow at without loop error minus the flow plus loop error: RWCUNSSS_cptr = Flowrated - Flowrated+error Fa Error K = 9449.90 Rated 533F 1.0087 Calib Flow = 188823.1 lb/hr 500 GPM Notes) Assumed Calib Temp = 530.70 Assumed Rated Flow = 149021 bh/r 389 GPM Rated 53.37 1.0045 Calib Flow = 18823.3 lb/hr 389 GPM Rated Temp 524.83 bt/hr Catid Cherr DP Rtd DP+err Fa Rtd Fa+err 1.0000 1.0000 245.3520 0 0 0 0 0 0 P Rtd r <td>The differential pre</td> <td>essure is converted to</td> <td>flow by the Numac com</td> <td>puter and retransmitte</td> <td>d as flow signal t</td> <td>o the plant computer</td> <td>for heat balance cal</td> <td>culations.</td>	The differential pre	essure is converted to	flow by the Numac com	puter and retransmitte	d as flow signal t	o the plant computer	for heat balance cal	culations.
RWCU AND D/A RWCU AND 0.233% 0.188% Loop Calibration: 0.13% RWCU COUD/A RWCU CAD 0.02% 0.188% The uncertainties are random and independent and combined by the SRSS method: 0.38% [span FLOW The uncertainties are random and independent and combined by the SRSS method: 0.38% [span FLOW The flow error is the difference between the rated flow at without loop error minus the flow plus loop error: RWCUNSSS_optr = Flowrated - Flowrated+error Fa Error K = 9449.90 Rated 533F 1.0087 Calib Flow = 18823.1 lb/hr 500 GPM Assumed Calib Temp = 530.70 Assumed Calib Temp = 530.70 Assumed Calib Temp = 530.70 Assumed Calib Temp = 548.8 bt/b/r Reated h = 524.83 bt/b/r C Rtd C+err 0 1.0000 1114.71 47.3324 524.83 148,734.3	This portion of the	loop is comprised of 1	I) NUMAC computer out	put, 2) NSSS compute	er uncertainty. Th	ne uncertainties are i	n % flo w span:	
0.233% 0.188% 0.13% 0.000% Loop Calibration:				· <u> </u>	.oop Drift:	- 		
Loop Calibration: RWCU CENU D/A RWCU CEA/D 0.02% 0.188% The uncertainties are random and independent and combined by the SRSS method: 0.38% span FLOW The flow error is the difference between the rated flow at without loop error minus the flow plus loop error: RWCUNSSS_cptr = Flowrated - Flowrated+error Fa Error K = 9449.90 Rated 533F 1.0087 Calib Flow = 189823.1 b/hr 500 GPM Calib intCe = 403.50 Assumed Calib Frees = 1114.70 Assumed Calib Trees = 530.70 Assumed Flow = 14802.1 b/hr 389 GPM Rated 524.83 btu/ho C Rtd C+err DP Rtd DP+err F a Rtd Fa+err T Rtd T+err 1.0000 1.0007 245.3520 1.0087 530.71 0 0 0 0 0 0 P Rtd r h Flow 1 0 0 P Rtd r h States h = 24.83 btu/ho 0 0 0 0 0 0 0 0 0 0 0 0 0			· ·	L L)	
RWCU CENU D/A RWCU CEAD 0.02% 0.188% The uncertainties are random and independent and combined by the SRSS method: 0.38% span FLOW The flow error is the difference between the rated flow at without loop error minus the flow plus loop error: RWCUNSSS_cptr = Flowrated - Flowrated +error Fa Error K = 9449.90 Rated 533F 1.0087 Calib Flow = 189823.1 b/hr Calibrated 1.0045 Calib Flow = 189823.31 b/hr Subscript = Flowrated - Flowrated +error Fa Error K = 9449.90 Rated 533F 1.0087 Calib Flow = 18982.31 b/hr 500 GPM (Note) Calibrated 1.0045 Calib Flow = 18982.31 b/hr 500 GPM (Note) Calibrated 1.0045 Calib Flow = 14802.11 b/hr 389 GPM Rated Flow = 14802.11 b/hr Stasumed Calib Prese = 1114.70 r +err T+err 1.0000 245.3520 245.3520 1.0087 530.7 530.7 0	0.233%	0.188%]	Ļ	0.13%	0.000%		
0.02% 0.188% The uncertainties are random and independent and combined by the SRSS method: 0.38% span FLOW The flow error is the difference between the rated flow at without loop error minus the flow plus loop error: RWCUNSSS_cptr = Flowrated - Flowrated+error Fa Error K = 9449.90 Rated 533F 1.0087 Calib Flow = 188823.1 lb/hr 500 GPM Note) Calib Temp = 530.70 Assumed Calib Temp = 530.70 Assumed Calib Temp = 530.70 Assumed Calib Temp = 530.70 Assumed Calib Temp = 530.70 Assumed Calib Temp = 530.70 Assumed Calib Temp = 530.70 Assumed Calib Temp = 530.70 Assumed Calib Temp = 530.70 Assumed Rated Flow = 148021 lb/hr 389 GPM Rated h = 524.83 bt//b Terr C Rtd C+err DP Rtd 0 245.3520 1.0087 1.0087 0.000% 0 245.3520 1.0087 530.7 0.000% 0 245.3520 1.0087 530.7 0 0 0 0 0	Loop Calibration							
The uncertainties are random and independent and combined by the SRSS method: 0.38% [span FLOW The flow error is the difference between the rated flow at without loop error minus the flow plus loop error: RWCUNSSS_cptr = Flowrated - Flowrated+error Fa Error K = 9449.90 Rated 533F 1.0087 Calib Flow = 189823.1 lb/hr 500 GPM Calib in/VC = 403.50 Assumed Calib Temp = 530.70 Assumed Calib Press = 1114.70 r = 47.332 Assumed Rate How = 148921 lb/hr 389 GPM Rated h = 524.83 bttr/b CRtd C+err DP Rtd DP+err Fa Rtd Fa+err T Rtd T +err 1.0000 1.0000 245.3520 1.0087 530.7 530.7 0 0 0 0 0 0 0	RWCU_CENU_D/	A RWCU CEA/D]					
The uncertainties are random and independent and combined by the SRSS method: 0.38% [span FLOW The flow error is the difference between the rated flow at without loop error minus the flow plus loop error: RWCUNSSS_optr = Flowrated - Flowrated+error Fa Error K = 9449.90 Rated 533F 1.0087 Calib Flow 189823.1 lb/hr 500 GPM (Note) Calib Flow Calib Temp = 530.70 Assumed Calib Temp = 530.70 Assumed Calib Temp = 530.70 Assumed Calib Temp = 530.70 Rated Flow = 148021 lb/hr 389 GPM Rated Flow = 148021 lb/hr 389 GPM Rated Tow Fa err T Rtd The rer 1.0000 245.3520 245.3520 1.0087 1.0087 530.7 0 0 0 0 0 0 0		0.188%	<u> </u>					
The flow error is the difference between the rated flow at without loop error minus the flow plus loop error: RWCUNSSS_cptr = Flowrated - Flowrated + error Fa Error K = 9449.90 Rated 533F 1.0087 Calib Flow = 189823.1 lb/hr 500 GPM (Note) Calib rated 1.0045 Calib inWC = 403.50 Assumed Calib Temp = 530.70 Assumed Calib Temp = 530.70 Assumed Calib Press = 1114.70 r = 47.332 Assumed Rated Flow = 148021 lb/hr 389 GPM Rated h = 524.83 btu/lb C Rtd C+err DP Rtd DP+err Fa Rtd Fa+err T Rtd T+err 1.0000 1.0000 245.3520 245.3520 1.0087 1.0087 530.7 530.7 530.7 0.00% 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0				· · · ·				
0.38% span FLOW The flow error is the difference between the rated flow at without loop error minus the flow plus loop error: RWCUNSSS_optr = Flowrated - Flowrated+error Fa Error K = 9449.90 Rated 533F 1.0087 Calib Flow = 189823.1 lb/hr 500 GPM Calib inWC = 403.50 Assumed Calib Temp = 530.70 Assumed Calib Temp = 54.83 bt/lb Calib row = 148021 lb/hr 389 GPM Rated Flow = 148021 lb/hr 389 GPM Rated flow = 148021 lb/hr 1.0087 530.7 0.00% 0 245.3520 245.3520 1.0087 10000 245.3520 10000 245.3520 10000 245.3520 10000 245.3520 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 <	The uncertainties a	are random and indep	endent and combined b	v the SRSS method:				
The flow error is the difference between the rated flow at without loop error minus the flow plus loop error: RWCUNSSS_cptr = Flowrated - Flowrated+error Fa Error K = 9449.90 Rated 533F 1.0087 Calib Flow = 189823.1 lb/hr 500 GPM (Note) Calibrated 1.0045 Calib Terms = 530.70 Assumed Calib Terms = 530.70 Assumed Calib Press = 1114.70 r = 47.332 Assumed Rated Flow = 148021 lb/hr 389 GPM Rated h = 524.83 bt/l/b C Rtd C+err DP Rtd DP+err Fa Rtd Fa+err T Rtd T+err 1.0000 1.0000 245.3520 245.3520 1.0087 1.0087 530.7 530.7 0.00% 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0			-	, <u> </u>				
RWCUNSSS_cptr = Flowrated - Flowrated + error K = 9449.90 Rated 533F 1.0087 Calib flow = 189823.1 lb/hr 500 GPM (Note) Calib inWC = 403.50 Assumed Calib Temp = 530.70 Assumed Calib Temp = 530.70 Assumed Calib Press = 1114.70 r = 47.332 Assumed Rated Flow = 148021 lb/hr 389 GPM Rated h = 524.83 bt/lb Rated h = 524.83 bt/lb T+err 1.0007 1.0000 245.3520 245.3520 1.0087 530.7 530.7 0.00% 0 0 0 0 0 0 0 0 Uncertainty RWCUNSSS_cptr = 713.8 lb/hr	0.38	% span FLOW						
RWCUNSSS_cptr = Flowrated - Flowrated + error K = 9449.90 Rated 533F 1.0087 Calib flow = 189823.1 lb/hr 500 GPM (Note) Calib inWC = 403.50 Assumed Calib Tow = 530.70 Assumed Calib Temp = 530.70 Assumed Calib Temp = 530.70 Assumed Calib Temp = 530.70 Assumed Rated Flow = 148021 lb/hr 389 GPM Rated h = 524.83 bt/lb r = 47.332 Assumed Rated Flow = 148021 lb/hr 389 GPM Rated h = 524.83 bt/lb 0 0 0 0 C Rtd C+err DP Rtd DP+err Fa Rtd Fa+err T Rtd T+err 1.0000 1.0000 245.3520 245.3520 1.0087 530.7 530.7 0 0 0 </th <th></th> <th></th> <th></th> <th></th> <th></th> <th></th> <th></th> <th></th>								
Rated 533F 1.0087 Calib Flow = 189823.1 lb/hr 500 GPM (Note) Calib rated 1.0045 Calib Iow = 189823.1 lb/hr 500 GPM (Note) Calib inWC = 403.50 Assumed Calib Temp = 530.70 Assumed Calib Temp = 530.70 Assumed Calib Press = 1114.70 r = 47.332 Assumed Rated Flow = 148021 lb/hr 389 GPM ret 47.332 Assumed Rated Flow = 148021 lb/hr 389 GPM Tetr Tetr 1.0000 1.0000 245.3520 245.3520 1.0087 530.7 0.00% 0 0 0 0 0 Uncertainty RWCUNSSS_cptr= 713.8 lb/hr				K = 0	9449 90			
Assumed Calib Temp = 530.70 Assumed Calib Press = 1114.70 r = 47.332 Assumed Rated Flow = 148021 lb/hr 389 GPM Rated h = 524.83 btu/lb C Rtd C+err DP Rtd DP+err Fa Rtd Fa+err T Rtd T+err 1.0000 1.0000 245.3520 245.3520 1.0087 1.0087 530.7 530.7 0.00% 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0		1.0087				500 GPM	(Note)	
Assumed Calib Press = 1114.70 r = 47.332 Assumed Rated Flow = 148021 lb/hr 389 GPM Rated h = 524.83 btu/lb C Rtd C+err DP Rtd DP+err Fa Rtd Fa+err T Rtd T+err 1.0000 1.0000 245.3520 245.3520 1.0087 530.7 530.7 0.00% • 0 • 0 • 0 Uncertainty RWCUNSSS_cptr= 713.8 lb/hr	Calibrated	1.0045						
r = 47.332 Assumed Rated Flow = 148021 lb/hr 389 GPM Rated h = 524.83 btu/lb C Rtd C+err DP Rtd DP+err Fa Rtd Fa+err T Rtd T+err 1.0000 1.0000 245.3520 245.3520 1.0087 1.0087 530.7 530.7 530.7 0.00% ↓ 0 ↓ 0 ↓ 0 ↓ 0 ↓ 0 ↓ 0 ↓ 0 ↓ 0 ↓ 0	-							
Assumed Rated Flow = 148021 lb/hr 389 GPM Rated h = 524.83 btu/lb Rated h = 524.83 btu/lb C Rtd C+err DP Rtd DP+err Fa Rtd Fa+err T Rtd T+err 1.0000 1.0000 245.3520 245.3520 1.0087 1.0087 530.7 530.7 0.00% 1.00% 0 0 245.3520 1.0087 1.0087 530.7 530.7 P Rtd r h Flow Flow Image: Second S			Ass					
C Rtd C+err DP Rtd DP+err Fa Rtd Fa+err T Rtd T+err 1.0000 1.0000 245.3520 245.3520 1.0087 1.0087 530.7 530.7 0.00% 0 0 1.0087 1.0087 1.0087 530.7 530.7 0 P Rtd r h Flow 1114.7 47.3324 524.83 148,734.3			As			389 GPM		
1.0000 1.0000 245.3520 245.3520 1.0087 1.0087 530.7 530.7 0.00% 0 0 1.0087 1.0087 530.7 0 0 P Rtd r h Flow 1114.7 47.3324 524.83 148,734.3 Uncertainty RWCUNSSS_cptr= 713.8 lb/hr Uncertainty 111.0087 1.0087 1.0087 1.0087	C Btd	Ctorr				- Eators	T Dtd	Ttorr
0.00% 0 P Rtd r h Flow 1114.7 47.3324 524.83 148,734.3 Uncertainty RWCUNSSS_cptr= 713.8 lb/hr								
P Rtd r h Flow 1114.7 47.3324 524.83 148,734.3 Uncertainty RWCUNSSS_cptr= 713.8 lb/hr		REFERENCE CONTRACTOR		,				
1114.7 47.3324 524.83 148,734.3 Uncertainty RWCUNSSS_cptr= 713.8 lb/hr	0.00	<u> </u>		• •				
Uncertainty RWCUNSSS_cptr= 713.8 lb/hr	P Rtd	<u> </u>	h	Flow				
RWCUNSSS_cptr= 713.8 lb/hr	1114	.7 47.3324	524.83	3 148,734.3	x	•		
RWCUNSSS_cptr= 713.8 lb/hr								
	Note: This value is	slightly different to the			e to roundina		1	
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CALC NO .:	SC-BB-0525 Attachment 4	REV:	5	REF:		CONT'D ON SHEET: 23
ORIGINATOR:	DATE:	REV EWER:		DATE:	VERIFIER	DATE:
Michael Miller	2/14/2017	John Wilker	ns	3/13/2017	N/A	N/A
7.2.4.6 React	or Water Cleanup Total Flow due to F	ow Loop Uncertainties (RV	VCUf)			Rev 5
RWCU Inlet h	- Outlet h.					
The total RWC	CU Flow Uncertainty is calculated belo	N:				
RWCUfu =+/-S	QRT(RWCUPMA1^2+RWCUc^2+RV	/CUdp^2+RWCUNSSS_q	ptr^2)-RWCUFa	a-RWCUPMA2		
	bias PMAs are factored with both sig ations, that is, that (-) less indication n		-	•		
	RWCUfu = 3700 lb/hr					
Then, the heat	error contribution is the calculated inl	et flow heat error minus th	e outlet flow he	at error:		
	h_in = 509.11 btu/lb _out = 396.68 btu/lb					
And the RWCL	J heat error contribution is calculated	by the following expression	n:			
RWCU = [RW	CUfu(RWCUh_in - RWCUh_out)x I	/Wt_BTU_hr (conversion	factor)]/Rateo	MWt 100%		
	RWCUf = 0.0031%	This total err	or will be treate	d as bias in the total heat ba	lance error	

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(N	C.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)	CALCULATION CONTINUATION SHEET				SHEET:	23
CALC NO .:	SC-BB-0525 Attachment 4	REV:	5	REF:		CONT'D ON SHEET:	24
				_			
ORIĢINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A

7.2.4.7 Reactor Water Cleanup Flow Enthalpy Heat Error due to Temperature Uncertainty (RWCUht)

This error is the error resultant of temperature measurement errors by the inlet/outlet RWCU thermocouple loops factored into the fluid enthalpy determination. The thermocouples are instruments with good repeatability and stability. However, fabrication errors can amount to several farenheit degrees. The fabrication errors can be calibrated out, since essentially it is a bias, systematic error. The temperature loops for RWCU are not calibrated out. Finally, since most of the thermocouples loop error is a bias, the conservative and safe way to apply the error, is for the two temperature error to be set in the same direction; therefore, the effect is additive, bias. The temperature loops error is found in:

<u>Ref. 3.4.6</u>

The heat error is the difference between the inlet flow heat error minus the outlet flow heat error:

RWCUht = [Flow [(hin - hin+error) + (hout - hout+error)]] x 2.93E-07 / 3902 x 100%

In flow heat

	in nour					
	TRtd	T+err	P Rtd	h rated	h+err	Flow
į	517.8	528.7	1000.69	509.11	522.50	148,021
	Error (F)	10.9 million				

Out flow heat

outhouthout	1	the second second second second second second second second second second second second second second second se			
TRtd	T+err	P Rtd	h rated	h+err	Flow
419.2	430,1	1000.69	396.68	408.57	148,021
Error (F)	10.9			-	

Error 3,741,117 BTU/hr error at rated reactor water cleanup flow

Uncertainty in Rated MWt RWCUht = 0.0281%

This error is a bias

Rev 5

(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)				CALCULATION CO	ET	SHEET:	24	
CALC NO.:	SC-BB-0525 Attach	ment 4	REV:	<u>5</u>	REF:		CONT'D ON SHEET:	25
DRIGINATOR:		DATE:	REVIEWER:		DATE:	VERIFIER:	D	ATE:
Michael Miller		2/14/2017	John Wilkens		3/13/2017	N/A	N	I/A
7.2.4.8 Reactor W	later Cleanup Flow Enth	alpy Heat Error due	to Pressure Loop Und	certainty (RWCUhp)			F	Rev 5
	cleanup enthalpy deter r, it is determined in this				s a very small effect	in the water		
Ref.: 3.4.4								
The heat error is t	he difference in the CRI) flow heat content a	t rated flow conditions	s minus the heat error	content at rated cond	litions plus error:		
The fleat error is t		o now near content a	a rated now conditions					
RWCUhp = [Flow	/ [(hin - hin+error) - (h	out - hout+error)]]	x 2.93E-07 / 3902 x 1	100%				
In flow heat								
P Rtd	P+err	TRtd	h rated	h+err	Flow	7		
1000.69	1020.89	517.8	509.11	509.09	148,000			
Error (psi)	20.2					-		
Out flow heat								
P Rtd	P+err	TRtd	h rated	h+err	Flow	7		
1000.69	1020.89	419.2	396.68	396.70	148,000			
Error (psi)	20.2					—		
	L							
		Error						
		5,76	64 BTU/hr at rated r	eactor water cleanup	flow			
	_			_				
	[Uncertainty in Rate	ed MWt 5 = 0.00004%					

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	02(Q), Rev. 12, Form 2)	CA	LCULATION CONTINUATION S	HEET	SHEET:	
LC NO.: SC-BB-(525 Attachment 4	REV:5	REF:	<u> </u>	CONT'D ON SHEET:	26
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IGINATOR:	DATE:	REVIEWER:	DATE:	VERIFIER:		DATE:
chael Miller	2/14/2017	John Wilkens	3/13/2017	N/A		N/A
	eat Error due to Watts Loop L	· · · · · · · · · · · · · · · · · · ·				Rev 5
is section calculates the un	certainty due to RRP watts lo	op error, calculated in:				
ef.: 3.4.11						
e rated power for the pump	-motor and the motor efficien	cy (0.93) is from reference:				
ef. 3.4.3)						
ere are two recirculation pu	mps, the calculated error belo	ow is per pump. The actual tota	al MW for the 2 pumps is taken fr	om above reference.		
W 2 pump = 7.33					-	** *
e Watterror contribution is	calculated as follows:	* * •				
	or Eff W+err	lottor eff] - W Rtd/pump x Moto				
	Error = 1.50 % span Span = 10.5 Mwatt					
	TTL Mwatt	3.41 Mwatt				
	Error 0.	.1465 Mwatt				
						1
	Uncertainty in F					
	Uncertainty in F	Rated MWT RPw = 0.0038%				
	Uncertainty in F					

(NC.DE-AP	2.ZZ-0002(Q), Rev. 12, Form 2)	CALC	CALCULATION CONTINUATION SHEET				
ALC NO.:	-BB-0525 Attachment 4	REV:5	REF:		CONT'D ON SHEET: 27		
DRIGINATOR:	DATE:	REVIEWER:	DATE:	VERIFIER:	DATE:		
Michael Miller	2/14/2017	John Wilkens	3/13/2017	N/A	N/A		
				N/A	IN/A		
7.2.6 Thermal Loses (TL	<u>_}</u>				Rev 5		
This section calculates th	ne uncertainty due to TL error. Th	s error will be treated as a bias er	ror since the estimated value				
	assumed, i.e. it is a fixed error not						
An assumed error equal	to 20% of the specified loses is us	ea.					
The rated Heat Loss is fr	om reference:						
(Ref. 3.4.2)							
W Rtd	W+err						
1.1	1.32						
Error = 20.0)0% : An Alexandro						
	TTL Mwatt Heat						
	1.32	MW		\$			
	1.10	MW at rated conditions					
	Error						
		2200 MW error at rated radiate	d loses				
	Uncertainty in F		ror is treated as bias.				
		TL = 0.006%					
	zes this value combined with Othe						

(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCULATION CONTINUATION SHEET					27
CALCNO.:	SC-BB-0525 Attachment 4	REV:	5	REF:		CONT'D ON SHEET:	28
	· · · · ·			· · ·		·	
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/14/2017	John Wilke	ns	3/13/2017	N/A		N/A

7.2.7 Other System Loses (OSL)

The rated value includes Rod Drive seal purge flow to recirculation pumps. An assumed error equal to 20% of the specified loses is used. This error will be treated as a bias error since if the estimated value is larger or smaller than assumed, i.e. it is a fixed error not a random error.

The rated Losses figure is from reference:

(Ref. 3.4.2)

W Rtd	W+err	ī ·	
1.18	1.416	-	
Error =			
		2	
		TTL Mwatt Heat	
		1.42	. MW
		1.18	MW at rated conditions
		Error	
		0.236	0 MW error at rated radiated loses
		<u></u>	<u> </u>
		Uncertainty in Rate	d MWT This error is treated as bias.
		OSL	= 0.006%
	• •		

Note: The computer utilizes this value combined with Thermal Loses (Section 7.2.6) as Radiative power loses, QRAD = 1.94

Rev 5

(NC.DE-AP.ZZ-	0002(Q), Rev. 12, Form 2)		CALCULATION CONTINUATION SHEET			SHEET	:2
CALC NO.: SC-BB	-0525 Attachment 4	REV:	5	REF:		CONT'D ON SHEET	: 2 9
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A
	tion Power Uncertainty (Power uncertainty is the algebraic co	,	ors with the indep	endent/random error	rs statistically combined		Rev 5
	balance calculation, in accorda				,	,	
Power = MFW(MSh-	FWh)-CRDF(hin-hout)+RWC	U(hout-hin)-RRP+H L+ M	liscellaneous				
Summary of Heat Balance	Calculation Contributing Er	rors:					
Random Errors:	MSmoist = 0.0000%						
	CRDc = 0.0053%						}
	CRDdp = 0.0061%						
	RRPw = 0.0038%						
	NCUp_ sw = 0.0001%						
Dependent Errors: <u>I</u>	Errors		<u>Variable</u>				
	FWm = **						
	FWht = **						
	MSm = **						
	FWhp = **	6	Rated MS pressu	re = 1001 psia			
	MShp = 0.0253%						
	CRDhp = -0.00005%						
	RWCUhp = 0.00004%						
Bias Errors:	CRDt = -0.0012%						
	CRDht = -0.0096%						
	RWCUf = 0.0031%						
	RWCUht = 0.0281%						1
	TL = 0.006%						
** Noto that the to	OSL = 0.006%	for an aver all un sont i i	(of 0 2 404 fra 5)				ļ
* Note that these terms are Heat Balance Calculation F	combined in reference 3.4.20 Power Error (U):	ior an over all uncertainty	y of 0.34% TOP HVV	in, r whit and F whp			
	0.0034)^2+(MShp+CRDhp+R	WCUbp)^2+MSmoist^2+	CRDc^2+CRDdo/	2+			
	RWCUp_sw^2+RRPw^2x2]+(
Power Error = 0.373%	5						
To ensure operation margin	exist, due to possible instrume	ntation loops miss-calibr	ation, actual drift (to be determined by	history), etc., a margin	is added:	
Power U = Power Err	or + Margin						
where margin is defined as 3	840 * 102% –Rated Thermal I	Power – Power Error					
Margin - 3016 8	- 3902 - Power Error						
Margin – 5310.0							

where the second s

(NC.DE-A	AP.ZZ-0002(Q), Rev. 12, Form 2)	CAL	CULATION CONTINUATION SHEET	SHEET: 29
CALCNO.: S	C-BB-0525 Attachment 4	REV: 5	REF:	CONT'D ON SHEET: N/A
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ORIGINATOR:	DATE:	REVIEWER:	DATE: VERIFIER:	DATE:
Michael Miller	2/14/2017	John Wilkens	3/13/2017 N/A	N/A

8.0 SUMMARY

The calculated Heat Balance Error performed in this calculation is applicable to fully operational LEFM. The Power Uncertainty is the difference between the 2% design basis and the rated termal power for the current LEFM mode of operation. Positive margin is maintained between the Power Uncertainty and the Power Error. The Heat Balance calculation error (Section 7.0) is:

Power U = 0.379%

Rev 5

(NC.DE-AP.ZZ-000	2(Q), Rev. 12, Form 2)	CALCU	LATION CONTINUATION S	HEET	SHEET: 1
CALCNO.: SC-BB-0	525 Attachment 5	REV: 5	REF:	CC	NT'D ON SHEET: 2
	DATE:		DATE:	VERIFIER:	DATE:
Michael Miller	2/14/2017	John Wilkens	3/13/2017	N/A	N/A
Sections 1 through 4 have be	een replaced with the main b	ody of the calculatior			
5.0 DESIGN INPUTS					Rev 5
5.1 Rated Power Conditions					
Feedwater Flow and Main Stea	am parameters as deemed app errors", actual heat contributior	operation values might be used ropriate. This is found acceptab a deviation from measured/calcul	le, since for the purpose of e	rror determination	
	$ed MWt = \frac{3889MW}{1000000000000000000000000000000000000$	•	e highest whole MWt power le	evel which produces positive m	argin
	W flow = <u>1.4962E+07lbm/hr</u> erature = 331.5 F	(Ref. 3.4.19, Att. 8) (Ref. 3.4.19, Att. 8)			
•	MS flow = 14994000	(Ref. 3.4.19, Att. 8)			
	ressure = 1001 psia	(Ref. 3.4.19, Att. 8)			
•	quality = 100.000	(Ref. 3.4.1)			
	CU flow = 148000.0 lb/hr	(Ref. 3.4.19, Att. 8)			
Rated RWCU temp		(Ref. 3.4.19, Att. 8)			
Rated RWCU return temp		(Ref. 3.4.19, Att. 8)			
-	RD flow = 32000.0 lb/hr	(Ref. 3.4.3, 3.4.18)			
	ressure = 1474.0 psia	(Ref. 3.4.5)			
Rated CRD temp	perature = 77 F	(Ref. 3.4.19, Att. 8)			
Radiatio	n Loses = <u>1.10MW</u>	(Ref. 3.4.2, 3.4.19)			
Other System	n Loses = <u>1.18MW</u>	(Ref. 3.4.2, 3.4.19) Note: T	hese loses are not included i	in UFSAR Heat Balance, Ref. 3	.1.1
MWt	/BTU/hr = <u>2.9300E-07</u>	(Ref. 3.4.1)			
Por	wer = MFW(MSh-FWh)-CRDF	(hin-hout)+RWCU(hout-hin)-RR	P+HL+Miscellaneous		
	• •	of 100.00%, which will produce		•	t MS quality.
		the actual MS quality is measur ses as 1.10 MW and other loses			stated
	-	ut specifically accounting for Rac ect on the Power Error, radiation			
6.0 ASSUMPTIONS					
	evel of 3902MWt. This is not ir	nal power uncertainty provided by Iterpolated based on a 3889MWt			
		g design inputs and a 3889MWt e inputs of 3902MWt and 3889M			nce
See sections 7.2.3, 7.2.4, 7.2.6	and 7.2.7 for specific assump	tions.			

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(NC.DE-AP.ZZ-	0002(Q), Rev. 12, Form 2)		CALCUL	ATION CONTINUATION	SHEET	SHEET	: 2
CALC NO.: SC-BE	-0525 Attachment 5	REV:	5	REF:		CONT'D ON SHEET	3
ORIGINATOR: Michael Miller	DATE: 2/14/2017	REVIEWER: John Wilkens	; ;	DATE: 3/13/2017	VERIFIER: N/A		DATE: N/A
7.0 CALCULATIONS		Alexandro de Santa de Santa de Santa de Santa de Santa de Santa de Santa de Santa de Santa de Santa de Santa d Santa de Santa		-		Rev 5	
7.1 Methodology							
					· · · · · · · · · · · · · · · · · · ·		
	ombine the uncertainties for the ertainties which are statistically			•	are root of the sum		
	r bias. The uncertainties are c				ogy		
	d has been endorsed by the N						
The uncertainty calculation	combines the different errors fr	rom the different parar	neters contribut	ng to the heat balance in			
2	nce equation. The contributing			0	ity calculation.		
These errors are generally of	lassified in two groups:	.*					
a) Instrument loop(s) uncer	tainty	-' -					
b) Process effects				1			
The individual uncertainties	affecting the heat balance calc	culation are determine	d by the applica	ion of the corresponding r	rocess		
algorithm, as described belo				ier er tile een oppending p			
algorithm, as described beid	for the provision provide	unter is not in the form	to ito oposifio o	antribution to the boot bala	and at an acified roted	anditiona	
0			•		•		
a) the appropriate algorithm		n the process algorithm					
a) the appropriate algorithmb) subsequently, the instrumc) the difference of the calc	entation loop error is factored in ulated contributed process par	ameter heat, with erro	or, to the rated p	ocess rated heat is then c	alculated,		
 a) the appropriate algorithm b) subsequently, the instrum c) the difference of the calc d) the resultant heat error c 	entation loop error is factored in ulated contributed process par ontribution is then divided by t	ameter heat, with erro he rated 100% power	or, to the rated p	ocess rated heat is then c	alculated,		
 a) the appropriate algorithm b) subsequently, the instrum c) the difference of the calc d) the resultant heat error c by the specific process to 	entation loop error is factored in ulated contributed process par	ameter heat, with erro he rated 100% power ainty,	or, to the rated p thermal megawa	ocess rated heat is then o atts. The result is the error	alculated, r contribution		:
 a) the appropriate algorithm b) subsequently, the instrum c) the difference of the calc d) the resultant heat error c by the specific process to e) finally, all the calculated 	entation loop error is factored in ulated contributed process par ontribution is then divided by the to the total heat balance uncerta	ameter heat, with erro he rated 100% power ainty, coordance to their para	or, to the rated p thermal megawa ameter function i	ocess rated heat is then o atts. The result is the error	alculated, r contribution		:
 a) the appropriate algorithm b) subsequently, the instrum c) the difference of the calc d) the resultant heat error c by the specific process to e) finally, all the calculated 	entation loop error is factored in ulated contributed process par ontribution is then divided by the to the total heat balance uncerta heat errors are combined in ac	ameter heat, with erro he rated 100% power ainty, coordance to their para	or, to the rated p thermal megawa ameter function i	ocess rated heat is then o atts. The result is the error	alculated, r contribution		:
 a) the appropriate algorithm b) subsequently, the instrum c) the difference of the calc d) the resultant heat error c by the specific process to e) finally, all the calculated 	entation loop error is factored in ulated contributed process par ontribution is then divided by the to the total heat balance uncerta heat errors are combined in ac	ameter heat, with erro he rated 100% power ainty, coordance to their para	or, to the rated p thermal megawa ameter function i	ocess rated heat is then o atts. The result is the error	alculated, r contribution		:
 a) the appropriate algorithm b) subsequently, the instrum c) the difference of the calc d) the resultant heat error c by the specific process to e) finally, all the calculated 	entation loop error is factored in ulated contributed process par ontribution is then divided by the to the total heat balance uncerta heat errors are combined in ac	ameter heat, with erro he rated 100% power ainty, coordance to their para	or, to the rated p thermal megawa ameter function i	ocess rated heat is then o atts. The result is the error	alculated, r contribution		
 a) the appropriate algorithm b) subsequently, the instrum c) the difference of the calc d) the resultant heat error c by the specific process to e) finally, all the calculated 	entation loop error is factored in ulated contributed process par ontribution is then divided by the to the total heat balance uncerta heat errors are combined in ac	ameter heat, with erro he rated 100% power ainty, coordance to their para	or, to the rated p thermal megawa ameter function i	ocess rated heat is then o atts. The result is the error	alculated, r contribution		
 a) the appropriate algorithm b) subsequently, the instrum c) the difference of the calc d) the resultant heat error c by the specific process to e) finally, all the calculated 	entation loop error is factored in ulated contributed process par ontribution is then divided by the to the total heat balance uncerta heat errors are combined in ac	ameter heat, with erro he rated 100% power ainty, coordance to their para	or, to the rated p thermal megawa ameter function i	ocess rated heat is then o atts. The result is the error	alculated, r contribution		
 a) the appropriate algorithm b) subsequently, the instrum c) the difference of the calc d) the resultant heat error c by the specific process to e) finally, all the calculated 	entation loop error is factored in ulated contributed process par ontribution is then divided by the to the total heat balance uncerta heat errors are combined in ac	ameter heat, with erro he rated 100% power ainty, coordance to their para	or, to the rated p thermal megawa ameter function i	ocess rated heat is then o atts. The result is the error	alculated, r contribution		

(NC.D	E-AP.ZZ-0002(Q), Rev. 12	2, Form 2)			CALCULATION (CONTINUATION SHE	ET	SHEET:	3
CALC NO.:	SC-BB-0525 Attack	nment 5		REV:	5	REF:		ON SHEET:	4
ORIGINATOR:		DATE:	•	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller		2/14/2017		John Wilkens		3/13/2017	N/A		N/A

Rev 5

7.2 Uncertainties Calculation

7.2.1 Main Feedwater Uncertainty(ies)

The Main Feedwater uncertainties are included in the total thermal power uncertainy provided by the LEFM while in mantenance mode is 0.66% per Reference 3.4.20. This includes the Main Feedwater mass flow error, main feedwater heat enthalpy error, and the Main Steam mass flow error

Referring to the schematic drawing in section 4.0, it can be seen that the Main Feedwater heat contribution is affected by the following parameters:

a) Mass Flow Measurement affected by: 1) flow, 2) temperature, and 3) pressure instrumentation loops error.

The error provided by the vendor for the ultrasonic flow meter already factors the corresponding temperature and pressure loops effect.

b) Feedwater Enthalpy determination affected by: 1) temperature, and 2) pressure, instrumentation loops error.

The main feedwater enthalpy is calculated using the following signals:

- Feedwater Pressure and Main Feedwater Temperature

7.2.1.1 Main Feedwater Mass Flow Heat Error due to Flow Element Uncertainty FWm)

Deleted

7.2.1.2 Main Feedwater Heat Enthalpy Error due to Pressure Loop Uncertainty FWhp)

Deleted

7.2.1.3 Main Feedwater Heat Enthalpy Error due to Temperature Loop Uncertainty FWht)

Deleted

(N0	C.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCUL	ATION CONTINUATION S	HEET	SHEET:	4
CALC NO .:	SC-BB-0525 Attachment 5	REV:	5	REF:		CONT'D ON SHEET:	5
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A

7.2.2 Main Steam Flow Uncertainty(ies)

Referring to the schematic drawing in section 4.0, It can be seen that the Main Steam heat contribution is affected by the following parameters:

a) The calculated Main Steam Heat is affected by the mass flow measurement error (see section 7.2.1.1 Main Feedwater Mass Error).

b) Main Steam Enthalpy determination is affected by the pressure instrumentation loop error, documented in calculation:

<u>Ref. 3.4.4</u>

7.2.2.1 Main Steam Mass Flow Heat Error due to Main Feedwater Flow Uncertainty (MSm)

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Rev 5

(NC.DE-	AP.ZZ-0002(Q), Rev. 1	2, Form 2)		CALCULATION CO	NTINUATION SHEET		SHEET: 5
CALC NO.: S	C-BB-0525 Attac	hment 5	REV:	5 RE	F: -		CONT'D ON SHEET: 6
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ORIGINATOR:		DATE:	REVIEWER:	1		VERIFIER:	DATE:
Michael Miller		2/14/2017	John Wilkens	3/	13/2017	N/A	N/A
7.2.2.2 Main Steam He	eat Enthalpy Error	due to Pressure Lo	op Uncertainty (MShp)				Rev 5
This Section calculates	the Main Heat St	eam enthalpy error	due to the loop pressure u	uncertainty, documen	ted in:		
Ref.: 3.4.4							
enthalpy at rated press	sure plus pressure	induced error:	content at rated flow and e	enthalpy conditions m	inus the heat content	at rated flow with	
MShp = [Flow (hrated							
P Rtd		Moist Rtd	Moist+err	h rated	h+err	Flow	
1000.69	1006.79	100	100.000	1192.91	1192.69	14,994,000	
Error (psi) =	6.1	l	0				
Ľ	÷						
		TTL MS Heat					
		17 883 129	657 BTU/hr				
		17,000,120,					
		17,886,503,	873 BTU/hr at rated cond	ditions			
		Error 3,374,	216 BTU/hr error at rate	ed main feedwater fl	ow		
		Error in Rated MW	Vt				
		MS	hp = 0.0254%				

(N0	C.DE-AP.ZZ-0002(Q), Rev. 12, Form	2)		CALCULATION C	ONTINUATION SHEE	T SHE	ET:	6
CALC NO.:	SC-BB-0525 Attachment	5	REV:	5	REF:	CONT'D ON SHE	T:	7
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ORIGINATOR:	DATE:		REVIEWER:		DATE:	VERIFIER:	DATE	2
Michael Miller	2/14/2	2017	John Wilkens		3/13/2017	N/A	N/A	

Rev 5

7.2.2.3. Main Steam Moisture Heat Enthalpy Error due to Steam Moisture Uncertainty (MSmoist)

This section calculates the Main Steam enthalpy error due to MS moisture uncertainty. The uncertainty is conservatively set to 50% of rated moisture content of 0.0%.

The heat error is the difference in the Main Steam flow heat content at rated flow and moisture conditions minus the heat content at rated moisture conditions plus moisture error:

MSmoist = [Flowrated hrated (hmoist-rated - hmoist-rated+err)] x 2.93E-07 / 3889 x 100%

	P Rtd	P+err M	oist Rtd	Moist+err		h rated	h+err	Flow
<u> </u>	1000.69	1000.69	100	1(0000.00	1192.91	1192.91	14,994,000
	Ľ	0.0000	0.00%	÷ 0				

TTL MS Heat 17,886,503,873 BTU/hr

17,886,503,873 BTU/hr at rated conditions

Error

- BTU/hr error at rated main feedwater flow

Error in Rated MWt MSmoist = 0.0000%

(NC	.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCULATION	CONTINUATION	SHEET	SHEET:	7
CALC NO .:	SC-BB-0525 Attachment 5	REV:	5	REF:	·	CONT'D ON SHEET	8
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
<u>Michael Miller</u>	2/14/2017	John Wilkens		3/13/2017	N/A		N/A
7.2.3 Control Rod	Drive Flow						Rev 5
Referring to the scl	hematic drawing in section 4.0, it can be s	een that CRD flow is i	not monitored for pre	ssure or temperatu	re.		
The CRD calculate	d heat is affected by the following effects						
a) Mass Flow Meas	surement affected by: 1) flow, instrumenta	tion loop effect and 2)	temperature, and 3)	pressure deviation	from calibration values		
b) The CRD Enthal	py determination is affected by: 1) temper	ature, from applied co	onstants, and 2) pres	sure, from reactor p	pressure loop error		
The CRD flow loop	errors are documented in calculation:						
Ref. 3.4.5							
The flow formula is	derived from the ASME (Ref. 3.4.9) as fol	lows:					
Flow = C*Fa*K*(D	P*r)^0.5						
where K is calculate	ed below:						
K = Calib Flow/(Ca	alib inWC * Calib r)^0.5						

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	02(Q), Rev. 12, Form 2)		CALCULATION	CONTINUATION SH	EET _	SHEET	88	
CALC NO.: SC-BB-0	525 Attachment 5	REV:	5	REF:		CONT'D ON SHEET	9	
ORIGINATOR:	DATE:			loare: · ·	VERIFIER:			
Michael Miller	2/14/2017	REVIEWER: John Wilkens		DATE: 3/13/2017	N/A		DATE: N/A	
Michael Miller	[2/14/2011		· · · · · · · · · · · · · · · · · · ·	5/15/2011		<u> </u>		
7.2.3.1 Control Rod Drive Flow	w Heat Error due to Flow El	ement and Fluid Specific W	/eight Uncertainty d	ue to Temperature E	rror (CRDt)		Rev 5	
The uncertainty is dependent f	or the following variables:							
Fa = FE Thern	nal Expansion	r =	Fluid Specific Weig	ht				
The plant computer calculates	the CRD flow with a consta	nt flow K factor. However,	the actual tempera	ure could vary as m	uch			
as 43F from the expected 77F								
deviation is:								
CRDt = [(hs rated - CRDh rate	ed) (Flowrated - Flowrated+	err)]x2.93E-07/3889x	100%	-				
		•						
Ref.: 3.4.5		K = Calib Flow =	448.48 50154 lb/br	100 GPM				
Fa Error		Calib inWC =						
Rated 77F	1.0003	Calib Temp =						
@140 F	1.0013	Calib Press =		· ·				
@40 F	0.9995		62.529					
Fa/F	1.8E-05	Assumed Rated Flow =						
		Rated Press =						
		Rated Temp =			÷ .		1	
			47.78 btu/lb			T+err		
C Rtd C+	err DP Rtd	DP+err	Fa Rtd	Fa+err	TRtd	120	7	
1.0000		1.3694 81.3694	· · · · · · · · · · · · · · · · · · ·			77 : 43	-	
0.00%		0.00%						
•••••••••••••••••••••••••••••••••••••••	····		·	Temp error = Calib	Temp - Min Temp	·	1	
	r h Rtd	Flow	hs Rtd		• •			
1000.69	61.8993	47.78 31,862.980	1192.91					
	TTL CRD Heat			:				
	36,48	37,315 BTU/hr					* 	
	36.6/	4,221 BTU/hr at rated cor	ditione	s	· ·			
4	30,04		IUILIONS				1	
	Error						· ·	
		6,906) BTU/hr error at ra	ted CRD flow					
	Error in Rated M	/W/t	[
the second second second			This error is a bias	not a random instru	ment induced uncertai	ntv		
	1					ity.		
· · · · · · · · · · · · · · · · · · ·				-				
				· · · ·				
	a, provide a construction de la construcción de la					.		
			· · ·					
			and the second second					

(NC	.DE-AP.ZZ-0002(Q), Rev. 12, F	Form 2)		CALCULATION C	ONTINUATION SHEE	Т	SHEET	9
CALC NO.:	SC-BB-0525 Attachm	ent 5	REV: 5		REF:		CONT'D ON SHEET	10
ORIGINATOR:	DA.	TE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/ ⁻	14/2017	John Wilkens		3/13/2017	N/A		N/A
7.2.3.2 Control Ro	d Drive Flow Heat Error o	due to Flow Element U	Incertainty (CRDc)			,		Rev 5
The CRD contribute	ed heat is affected by the	FE error that is assig	ned to the flow eleme	ent expansion coef	ficient.			
С								
The FE uncertainty	is determined based in c	calculation:						
Ref.: 3.4.5								
The heat error is th	e difference in the CRD f	low heat content at ra	ted flow conditions m	inus the heat erro	content at rated condit	ions plus error:		
CRDc = [(hs rated	- CRDh rated) (Flowrate	ed - Flowrated+err)]x	2.93E-07 / 3889 x 10	00%				
Fa Error			K = 4	48.48				
Rated 77F	1.0003		Calib Flow = 5		100.00			
@140 F	1.0013		Calib inWC = 20					
@60 F	0.9995		med Calib Temp = 7					
Fa/F	1.8E-05	Assu	med Calib Press = 14					
				2.529	0.0159925			
		Assu	med Rated Flow = 3					
			Rated Press = 10					
			Rated Temp = 7					4
			Rated h = 4		– .		T+err	4
C Rtd 1.000	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	77	+
2.009		81.3694 0.00%	81.3694	1.0003	1.0003		77 2 0	
2.007	/0	0.00%	• 0					
P Rtd	r	h Rtd	Flow	hs Rtd				
1000.6		47.78	32,616.541	1192.91				
	· · · · · ·	ļ						
	TT	L MFW Heat						
		37,350,242	BTU/hr					
	<u>I</u>							
		36,644,221	BTU/hr at rated cond	itions				
		Error						
			BTU/hr error at rate	d CRD flow				
	[E-	rox in Dated MM/						
	Er	ror in Rated MWt CRDc =	0.0053%					
	1	UNDC -	0.003370					<u>I</u>

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IGINATOR: DATE: REVIEWER: DATE: VERIFIER: DATE: ichael Miller 2/14/2017 John Wilkens 3/13/2017 N/A N/A 2.3.3 Control Rod Drive Heat Error due to Differential Pressure (DP) Loop Uncertainty (CRDdp) Rev 5	(NC.I	DE-AP.ZZ-0002(Q), Rev.			CALCUL	ATION CON	TINUATION S	HEE	SHEET:	
ichael Miller 2/14/2017 John Wilkens 3/13/2017 N/A N/A 2.3.3 Control Rod Drive Heat Error due to Differential Pressure (DP) Loop Uncertainty (CRDdp) Rev 5 its error is calculated in calculation: aff: 3.4.5 Rev 5 aff: 3.4.5	ALC NO.:	SC-BB-0525 Atta	chment 5	REV:	5	REF		·	CONTD ON SHEET:	11
ichael Miller 2/14/2017 John Wilkens 3/13/2017 N/A N/A 2.3.3 Control Rod Drive Heat Error due to Differential Pressure (DP) Loop Uncertainty (CRDdp) Rev 5 its error is calculated in calculation: af.: 3.4.5 Rev 5 af.: 3.4.5						an titte <u>an titte a</u> n a				
2.3.3 Control Rod Drive Heat Error due to Differential Pressure (DP) Loop Uncertainty (CRDdp) Rev 5 tils error is calculated in calculation: af.: 3.4.5 tel loop is comprised of 1) flow transmitter, FT, 2) resistor, REST, 3) computer analog to digital card, A/D. Rev 5 tel uncertainties are in % DP span: Loop Drift: CRD_AFT CRD_AREST CRD_AA/D CRD_VDFT CRD VD/D 1.154% 0.100% 0.188% 1.450% 0.000% opp Calibration: CRD_CEFT CRD_CEA/D 0.188% e uncertainties are random and independent and combined by the SRSS method: Rev 5 Rev 5	RIGINATOR:		DATE:	REVIEWER:		DATI	÷ • ·	VERIFIER:		
alis error is calculated in calculation: af.: 3.4.5 the loop is comprised of 1) flow transmitter, FT, 2) resistor, REST, 3) computer analog to digital card, A/D. the uncertainties are in % DP span: <u>CRD_AFT CRD_AREST CRD_AA/D CRD_VDFT CRD_VDA/D</u> 1.154% 0.100% 0.188% 1.450% 0.000% <u>cop Calibration:</u> <u>CRD_CEFT CRD_CEA/D</u> 0.140% 0.188% the uncertainties are random and independent and combined by the SRSS method:	lichael Miller		2/14/2017	John Wilkens		3/1	3/2017	N/A	en en en en en en en en en en en en en e	N/A
ef.: 3.4.5 ne loop is comprised of 1) flow transmitter, FT, 2) resistor, REST, 3) computer analog to digital card, A/D. ne uncertainties are in % DP span: <u>CCUTACY: Loop Drift:</u> <u>CRD_AFT CRD_AREST CRD_AA/D CRD_VDFT CRD_VDA/D</u> 1.154% 0.100% 0.188% 1.450% 0.000% <u>COp Calibration:</u> <u>CRD_CEFT CRD_CEA/D</u> 0.140% 0.188% ne uncertainties are random and independent and combined by the SRSS method:	.2.3.3 Control Roc	l Drive Heat Error d	ue to Differential Pressu	re (DP) Loop Uncer	tainty (CRDdp	b)		· ·		Rev 5
the loop is comprised of 1) flow transmitter, FT, 2) resistor, REST, 3) computer analog to digital card, A/D. the uncertainties are in % DP span: <u>CRD_AFT CRD_AREST CRD_AA/D CRD_VDFT CRD_VDA/D</u> 1.154% 0.100% 0.188% 1.450% 0.000% <u>oop Calibration:</u> <u>CRD_CEFT CRD_CEA/D</u> 0.140% 0.188% the uncertainties are random and independent and combined by the SRSS method:	his error is calcula	ted in calculation:	· · · .							
the loop is comprised of 1) flow transmitter, FT, 2) resistor, REST, 3) computer analog to digital card, A/D. the uncertainties are in % DP span: <u>CRD_AFT CRD_AREST CRD_AA/D CRD_VDFT CRD_VDA/D</u> 1.154% 0.100% 0.188% 1.450% 0.000% <u>oop Calibration:</u> <u>CRD_CEFT CRD_CEA/D</u> 0.140% 0.188% the uncertainties are random and independent and combined by the SRSS method:										
Loop Drift: CRD_AFT CRD_AREST CRD_AA/D CRD_VDFT CRD_VDA/D 1.154% 0.100% 0.188% 1.450% 0.000% oop Calibration: CRD_CEFT CRD_CEA/D 0.188% 0.140% 0.188% 1 0.188% 1.450%	ef.: 3.4.5									
Loop Drift: CRD_AFT CRD_AREST CRD_AA/D CRD_VDFT CRD_VD/D 1.154% 0.100% 0.188% 1.450% 0.000% oop Calibration: CRD_CEFT CRD_CEA/D 0.188% 0.140% 0.188% 1 0.188% 1.450%				· · · · · ·						
Loop Drift: CRD_AFT CRD_AREST CRD AA/D CRD VDFT CRD VDA/D 1.154% 0.100% 0.188% 1.450% 0.000% oop Calibration: CRD_CEFT CRD_CEA/D 0.188% 0.140% 0.188% 1 0.000%			itter, FT, 2) resistor, RE	ST, 3) computer and	alog to digital (card, A/D.				
CRD_AFT CRD_AREST CRD_AA/D CRD_VDFT CRD VDA/D 1.154% 0.100% 0.188% 1.450% 0.000% oop Calibration: CRD_CEFT CRD_CEA/D 0.188% 0.140% 0.188% 1.450% 0.000% me uncertainties are random and independent and combined by the SRSS method: 0.100%	he uncertainties ar	e in % DP span:								
CRD_AFT CRD_AREST CRD_AA/D CRD_VDFT CRD VDA/D 1.154% 0.100% 0.188% 1.450% 0.000% oop Calibration: CRD_CEFT CRD_CEA/D 0.188% 0.140% 0.188% 1.450% 0.000% me uncertainties are random and independent and combined by the SRSS method: 0.100%	· · ·									
1.154% 0.100% 0.188% 1.450% 0.000% oop Calibration:										
oop Calibration: CRD_CEFT CRD_CEA/D 0.140% 0.188% ne uncertainties are random and independent and combined by the SRSS method:										
CRD_CEFT CRD_CEA/D 0.140% 0.188% ne uncertainties are random and independent and combined by the SRSS method:	1.154%	0.100%	0.188%	1.450%		0.000%]				
CRD_CEFT CRD_CEA/D 0.140% 0.188% ne uncertainties are random and independent and combined by the SRSS method:	Loon Calibration:		e			• •				
0.140% 0.188%			- - - - -							
e uncertainties are random and independent and combined by the SRSS method:			-							
	0.14070	0.10078								
							,			
	he uncertainties ar	e random and inder	pendent and combined b	ov the SRSS method	d:	r .				
1.88% span DP				.,						
	1.88%	span DP	Τ.							
	•									
				· .		·				
		.•								

(NC.DE	E-AP.ZZ-0002(Q), Rev. 12	2, Form 2)		CALCULATION	CONTINUATION SHE	ET	SHEET	: 11
CALC NO .:	SC-BB-0525 Attach	iment 5	REV:	5	REF:		CONT'D ON SHEET	12
-					_			
ORIGINATOR:	I	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller		2/14/2017	John Wilkens		3/13/2017	N/A		N/A
The heat error is the	difference in the CRI	D flow heat content at ra	ted flow conditions	minus the heat erro	or content at rated cor	nditions plus error:		Rev 5
				40004				
CRDdp = [(hs rated -	- CRDh rated) (Flow	rated - Flowrated+err)	x 2.93E-07 / 3889 :	x 100%				
Fa Error			К=	448.51				
Rated 77F	1.0003		Calib Flow =	50157.2 lb/hr	100 GPM			
@140 F	1.0013		Calib inWC =					
@60 F	0.9995	Ass	umed Calib Temp =	77				
Fa/F	1.8E-05		umed Calib Press =					
			r =	62.529				
		Ass	umed Rated Flow =	32000.0 lb/hr				
			Rated Press =	1000.7 lb/hr				
			Rated Temp =	77 F				
			CRDh rated =	47.78 btu/lb			T+err	
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	77	,
1.0000	1.0000	81.3584		1.0003	3 1.00	03	77 👷 0)
0.00%	0	1.88%	**************************************]				
P Rtd	r	CRDh rated	Flowrated+err	hs Rtd	-			
1000.69	62.4396	47.78	32,707.575	1192.91	1			
	ľ	TTL MFW Heat						
		37,454,488	BTU/hr					
	L		l de la constante de					
		30,044,221	BTU/hr at rated cor	naitions				
		Error						
			BTU/hr at rated CF					
		010,207						
		Frror in Rated MWt						
	[Error in Rated MWt CRDdp =	0 0061%					

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(NC.DE-AP.ZZ-0	0002(Q), Rev. 12, Form 2)		CALCULATION	I CONTINUATION S	HEET	SHEET:
CALC NO.: SC-BB	-0525 Attachment 5	REV:	5	REF:	<u> </u>	CONT'D ON SHEET:
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	DATE
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A	N/A
7.2.3.4 Control Rod Drive Fl	low Enthalpy Heat Error due to	o Temperature Calibration [Deviation (CRDht)			Rev 5
	es the CRD fluid enthalpy at a 43F from the expected 77F; t					
<u>Ref. 3.4.5</u>						
The heat error is the differen	ce in the CRD flow heat conte	nt at rated flow conditions r	minus the heat er	ror content at rated c	onditions plus error:	
CRDht = [Flow (he rated - C	RDh rated) - Flow (hs rated -	CRDb rated+err) 1 v.2 93E	-07 / 3889 v 1009	26		
			-017 3003 X 100	<u>/0</u>		
	Max/Min T+err	P Rtd	h rated	h+err	hs rated	Flow
77	40 37	1000.69	47.78	7.99	1192.91	32,000
	TTL RWCU H 37,91	leat 17,380 BTU/hr				
		• • • •				
	36.64	4.221 BTU/hr at rated con	ditions			
	36,64	4,221 BTU/hr at rated con	iditions			
	Error	4,221 BTU/hr at rated con 3,159) BTU/hr at rated CR				
	Error (1,27 Uncertainty in f	'3,159) BTU/hr at rated CR Rated MWt	RD flow	s, not a random instr	ument induced uncertainty	
	Error (1,27 Uncertainty in f	'3,159) BTU/hr at rated CR Rated MWt	RD flow	s, not a random instr	rument induced uncertainty	
	Error (1,27 Uncertainty in f	'3,159) BTU/hr at rated CR Rated MWt	RD flow	s, not a random instr	rument induced uncertainty	
	Error (1,27 Uncertainty in f	'3,159) BTU/hr at rated CR Rated MWt	RD flow	s, not a random instr	rument induced uncertainty	
	Error (1,27 Uncertainty in f	'3,159) BTU/hr at rated CR Rated MWt	RD flow	s, not a random instr	rument induced uncertainty	
	Error (1,27 Uncertainty in f	'3,159) BTU/hr at rated CR Rated MWt	RD flow	s, not a random instr	ument induced uncertainty	

(NC.D	E-AP.ZZ-0002(Q), Rev. 12,	Form 2)		CALCULATION	CONTINUATION SH	EET	SHEET	13
LC NO.:	SC-BB-0525 Attachn	nent 5	REV:	5	REF:		CONT'D ON SHEET	14
RIGINATOR:	Di	ATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2	/14/2017	John Wilkens		3/13/2017	N/A		N/A
	Drive Flow Enthalpy H		·	, , , , , , , , , , , , , , , , , , ,				Rev 5
•	calculates the CRD flui ncertainty is document		ant 77Fand reactor	loop pressure, that	is affected by the loop	uncertainty.		
Ref.: 3.4.4								
he heat error is the	difference in the CRD	flow heat content at r	rated flow condition	s minus the heat err	or content at rated co	nditions plus error:		
CRDhp = [Flow (hs	rated - CRDh rated) - I	-low (hs rated+err -)	CRDh rated)]x 2.9	93E-07 / 3889 x 100	%			
P Rtd	P+err	TRtd	CRDh rated	hs rated	hs rated+err	Flow		
1000.69	1006.79	77	47.78	1192.91	1192	.69 32,00	0	
Error (psi) =	6.1		-					
	<u> </u>	TTL MFW Heat	-					
		36,637,020	BTU/hr					
		36,644,221	BTU/hr at rated c	onditions				
		Error						
) BTU/hr at rated (CRD flow				
				-				
	U	ncertainty in Rated	MWt = -0.00005%					
	1	CICDIIP.	0.00000 /0	ļ				I

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(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALO	SHEET:	: 14		
ALC NO.: SC-BB	0525 Attachment 5	RE: 5	REF:	. <u></u>	CONT'D ON SHEET:	15
RIGINATOR:	DATE:	REVIEWER:	DATE:	VERIFIER:	· .	DATE:
Aichael Miller	2/14/2017	John Wilkens	3/13/2017	N/A		N/A
.2.4 Reactor Water Cleanu	<u>p Uncertainty(ies)</u>					Rev 5

b) The RWCU Enthalpy determination is affected by: 1) temperature instrumentation loop error (see discussion for pressure)

The flow formula is derived from the ASME (Ref. 3.4.9) as follows:

Flow = C*K*(DP)^0.5

where K is:

K = Calib Flow / [C*(Calib inWC)^0.5]

(NC	DE-AP.ZZ-0002(Q), Rev. 12, I	Form 2)		CALCULATION	CONTINUATION S	HEET	SHEET:
ALC NO.:	SC-BB-0525 Attachm	ent 5	REV:	5	REF:		CONT'D ON SHEET:
		TE:	REVIEWER:		IDATE:	VERIFIER:	
ORIGINATOR:							DATE:
Michael Miller	2/	14/2017	John Wilkens		3/13/2017	N/A	<u>N/A</u>
7.2.4.1 RWCU Inle	et/Outlet Flow Heat Error	due to Flow Element I	Expansion deviat	tion from Calibration (RWCUFa)		Rev 5
	uter calculating the mass 3F. This induces a bias e						
	perature conditions, back						
Pressure Density (Compensated to :	48.01 lb/cuft	517.8 F	908 psia			
The Fa used in the The correct Fa at r	e calculation is fixed to: ated 533 F is:		1.0045 1.0087				
Based on the Fa di	ifferences the induced flo	w error is calculated b	elow:				
Fa	= FE Thermal Expansion	ſ					
Ref.: 3.4.10							
Flow+err = C x Fa+	err / Fa x K x (DP)^0.5		K	= 9449.90			
				/ = 189823.1 lb/hr	500 GPM	(Nlata)	
Fa Error			Calib Flow		DUU GPM	(Note)	
Rated 533F	1.0087	A	Imed Calib Temp				
Calibrated	1.0087		imed Calib Temp imed Calib Press	Management of the second second second second second second second second second second second second second s			
Calibrateu	1.0045	ASSU		s = <u>1114.7</u> = 47.332			
		٨٥٥	ر imed Rated Flow		389 GPM	E C	
		ASSL		r = 524.83 btu/lb	<u>507 GE MI</u>	ninciado ISI	
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	T+err
1.000	1.0000	245.3520	245.352	20 1.008	7 1.(0045 5	30.7 530.7
0.00	% 🔹 0	0.00%	2	0		•	0
					_		
P Rtd	P+err	r	h Rtd	Flow+err			
1114.		47.3324	524.8	83 147,404			
	0				— .		
	Г-	Uncertainty		-1			
			-616.3 lb/hr	This a hias and the	actual contributed	Heat is Higher than in	dicated
						rication light than in	dicated

т a.

Note: This value is slightly different to the 189,197 lb/hr calculated in the reference due to rounding

(NC.DE-/	AP.ZZ-0002(Q), Rev. 12, F	orm 2)		CALCULATION C	ONTINUATION SHEE	T .	SHEET:	16
CALC NO.:	C-BB-0525 Attachme	ent 5	REV:	5	REF:		CONT'D ON SHEET:	17
ORIGINATOR:	IDAT	r	REVIEWER:		DATE:	IVERIFIER:		DATE:
Michael Miller		⊧ 4/2017	John Wilkens		3/13/2017	N/A		N/A
			••••			· .		
2.4.2 RWCU Inlet/O	utlet Flow Heat Error (due to Fluid Specifi	c Weight deviation (R	WCUPMA)				Rev 5
his error is the combin	nation of several unce	rtainties calculated	below:					
2.4.2.1 RWCU Inlet/	Outlet Flow Error due	to Fluid Specific W	eight Numac Lookup	Tables Error (RWCU	PMA1)			
he Numac performs ti	he fluid specific weigh	t determination wit	h an error of 0.1 spec	ific weight, this effect	in the flow is calculate	ed below.		
r = FI	uid Specific Weight			•				
		• • • • • • • • • • • • • • • • • • •						
Ref.: 3.4.10			. ·			•		
low+err = C x K x (DP	x r+err / r)^0.5							
he flow error is the dif	ference between the	ated flow at rated	specific weight minus	the flow at specific w	reight plus error:			
WCUPMA1 = Flowrate	ed - Flowrated+error							
				9449.90 189823.1 lb/hr	500 GPM	(Note)		
a Error			Calib inWC =			(1010)		
ated 533F	1.0087		sumed Calib Temp =					
alibrated	1.0045	As	sumed Calib Press =	1114.7 47.332				
		Δ	r = = sumed Rated Flow		388.8 GPM			
	:			524.83 btu/lb				
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd]	
1.0000	1.0000	245.352			1.0087	530.7]	
0.00%	•0	0.00	%		*			
P Rtd	P+err	r	Numac err	r+perr+Numac	h Rtd	Flow]	
1114.7	1114.7 psi	47.33	<u>0.1</u>	47.432	524.83	148,177] .	
	0 psi							
	· · · · · ·	Uncertaint	·	1 .				
			y = 156.3 lb/hr	•				
				1				

Note: This value is slightly different to the 189,197 lb/hr calculated in the reference due to rounding

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(NC	.DE-AP.ZZ-0002(Q), Rev. 1	2, Form 2)		CALCULATION C	ONTINUATION SHEE	T	SHEET	17
CALC NO.:	SC-BB-0525 Attack	nment 5	REV:	5	REF:		CONT'D ON SHEET	18
ORIGINATOR:		DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller		and the second second second second second second second second second second second second second second second	John Wilkens		3/13/2017	N/A		N/A
The Numac compu which bias the actu Ref.: 3.4.10 Flow+err = C x K x	uter introduces a 0.75 f ual flow. (DP x r+err / r)^0.5	due to Fluid Specific Weig factor to the input pressur he rated flow at rated spe	re raw value and ca	alculates the specific	weight for saturated c			Rev 5
	wrated - Flowrated+erro							
F a Error Rated 533F Calibrated	1.0087 1.0045	Assu	Calib Flow = Calib inWC = med Calib Temp = med Calib Press = r = med Rated Flow =	403.5 530.7 1114.7 47.332	500 GPM 388.8 GPM	(Note)		
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	h Rtd return	Flow
1.000		245.3520	245.3520	1.0087	1.0087	530.7	396.68	148,422
0.00	%	0.00%	÷ 0					
P Rtd	P+err	T Sat	r+perr	Numac rerr	r+perr+Numac	h Rtdout		
1114.7	840 psi	523.8	47.5895	0	47.5895			
11114.7	840 psi 75%	Uncertainty RWCUPMA2 =				at is Higher than indicat	ed	

(NC.DE-AP.ZZ-0002	2(Q), Rev. 12, Form 2)		CALCULATION C	ONTINUATION SHEE	Т	SHEET: 1	8
CALC NO.: SC-BB-05	25 Attachment 5	REV:	5	REF:		CONT'D ON SHEET: 1	9
		-					
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	DATE:	
Michael Miller	2/14/2017	John Wilkens	-	3/13/2017	N/A	N/A	
7.2.4.2.3 RWCU Inlet/Outlet Flo	ow Heat Error due to Fluid Specif	ic Weight Pressure L	oop Uncertainty (RV	ICUP_SW)		Rev 5	
	to the Numac to determine the sp lumac computer uncertainty intro						
The loop error is comprised of 1) pressure loop, PT, 2) NUMAC	computer uncertaintie	es. The combined u	ncertainties are:			
RWCUpress error= 21 psi		· · ·					
Ref.: 3.4.10							
Flow+err = C x K x (DP x r+err /	r)^0.5						
The flow error is the difference I	between the rated flow at rated s	pecific weight minus t	he flow at specific w	eight plus error:			
RWCUp_SW = [Flowrated (h_i	n - h_out) - Flowrated+error(h_i	n - h_out)] x 2.93E-0	7 / 3889 x 100%				
r = Fluid Spec	ific Weight	К =	9449.90			1	
Fa Error Rated 533F Calibrated	1.0045 Ass	Calib inWC = sumed Calib Temp = sumed Calib Press = r = sumed Rated Flow =	403.5 530.7 1114.7 47.332 148021 lb/hr	500 GPM 388.8 GPM	(Note)		
			524.83 btu/lb	Festern	TÓM		
C Rtd C+e	err DP Rtd 1.0000 245.3520	DP+err 245.3520	Fa Rtd 1.0087	Fa+err 1.0087	T Rtd in 530.7	T Rtd out 419.2	
0.00%	0 0.00%		1.0007	1.0007	030.7	+ 13.2	
	0.007						
P Rtd P+e	err r+perr	Numac rerr	r+perr+Numac	h Rtd in	h Rtd out	Flow	
1000.69 1022	psi 47.2689) 0	47.2689	509.11	396.68	147,921	
	TTL MFW Heat 16,631,277 16,642,445	BTU/hr BTU/hr at rated con	ditions				
	Error	· · ·					
	11,168			· · •			
Note: This value is slightly differ	Uncertainty in Rated RWCUp_sw = ent to the 189,197 lb/hr calculate	• 0.0001%	e to rounding				

(NC	DE-AP.ZZ-0002(Q), Rev. 12	•		CALCULATION	CONTINUATION SH	IEET	SHEET:	19
CALC NO .:	SC-BB-0525 Attach	ment 5	REV:	5	REF:		CONT'D ON SHEET:	20
ORIGINATOR:	İc	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller		2/14/2017	John Wilkens		3/13/2017	N/A		N/A
7.2.4.3 Reactor W	ater Cleanup Flow Erro	r due to Flow Element I	Uncertainty (RWCU	JC)				Rev 5
The RWCU flow is	affected by the FE erro	r that is assigned to the	e flow element exp	ansion coefficient.				
С								
The FE uncertaint	y is determined based ir	n calculation:						
Ref.: 3.4.10								
Flow+err = C+err x	K x (DP)^0.5							
The flow error is th	ne difference between th	ne rated flow minus the	flow with the C coe	efficient error:				
RWCUc = Flowrat	ed - Flowrated+error							
Fa Error			ĸ	= 9449.90				
Rated 533F	1.0087			= 189823.1 LB/HR	500 GPM	(Note)		
Calibrated	1.0045		Calib inWC					
			umed Calib Temp					
		ASSI		= 1114.70 = 47.332				
		Ass	umed Rated Flow		389 GPM			
		7,00		= 524.83 btu/lb				
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	T+err	
1.00		245.3520	245.352	0 1.008	1.0	087	530.7 530.7	
1.50	% <u>• 150</u>	0.00%		0			÷0	
P Rtd	1 . Î	L	Flow	7				
<u> </u>	.7 47.3324	h 524.8	Flow 150,241	-				
1114	41.3324	524.8	150,24	<u> </u>				
	Г	Uncertainty		Т				
			2220.3 lb/hr					
	L			_				
Note: This value is	slightly different to the	189 197 lb/hr calculated	in the reference (due to rounding				

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CALC NO.: SC-BB-052	(Q), Rev. 12, Form 2)		CALCULATION	CONTINUATION SHE	ET si	HEET: 2
	25 Attachment 5	REV:	5	REF:	CONT'D ON \$	HEET: 2
DRIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A	N/A
7.2.4.4 Reactor Water Cleanup This error is introduced by the di The loop is comprised of 1) flow The flow error is the difference b	ifferential pressure instrum transmitter, FT, 2) NUMA	nent loop. The uncertain C computer. The uncert	nties in the loop are fo tainties are in % DP s	bund in:	Ref.: 3.4.10	Rev 5
RWCU.dp = Flowrated - Flowrated			Jennelent en or.			
Accuracy:		Loop Drift:				
RWCU AFT RWCU /		AVD RWCU VDFT		E RWCU VDNU A/D		
0.503% 0.100	0.233%	0.900%	0.127%	0.127%		~
Loop Calibration: RWCU_CEFT RWCU_CF 0.139% 0.02	%					
The uncertainties are random ar			<i>i</i> u.			
Flow+err = C x K x (DP+err)^0.5				• • • • • • • • • • • • • • • • • • •		
FaError		ĸ	(= 9449.90			
Rated 533F	1.0087	Calib Flow	v = 189823.1 LB/HR	500 GPM	(Note)	
Calibrated	1.0045	Calib inWC	; = 403.50			
			500 70			
		Assumed Calib Temp				
		Assumed Calib Press	s = 1114.70			
		Assumed Calib Press r Assumed Rated Flow	s = 1114.70 r = 47.332 v = 148021 LB/HR	389 GPM		-
C Rtd C+e		Assumed Calib Press r Assumed Rated Flow Rated h DP+err	s = 1114.70 r = 47.332 v = 148021 LB/HR n = 524.83 btu/lb Fa Rtd	Fa+err	T Rtd T+err	
C Rtd C+e		Assumed Calib Press r Assumed Rated Flow Rated h	s = 1114.70 r = 47.332 v = 148021 LB/HR n = 524.83 btu/lb Fa Rtd	Fa+err	37 530.7 53	30.7
		Assumed Calib Press r Assumed Rated Flow Rated h DP+err	s = 1114.70 r = 47.332 v = 148021 LB/HR n = 524.83 btu/lb Fa Rtd	Fa+err		<u>30.7</u>
1.0000	1.0000 24 0	Assumed Calib Press r Assumed Rated Flow Rated h DP+err 5.3520 249.73	s = 1114.70 r = 47.332 v = 148021 LB/HR n = 524.83 btu/b Fa Rtd 38 1.008	Fa+err	37 530.7 53	<u>30.7</u> 0
1.0000 0.00%	1.0000 24 0 h	Assumed Calib Press r Assumed Rated Flow Rated h DP+err 5.3520 249.73 Flowrated+err	s = 1114.70 r = 47.332 v = 148021 LB/HR n = 524.83 btu/lb Fa Rtd 38 1.008	Fa+err	37 530.7 53	<u>30.7</u> 0
1.0000	1.0000 24 0 h	Assumed Calib Press r Assumed Rated Flow Rated h DP+err 5.3520 249.73	s = 1114.70 r = 47.332 v = 148021 LB/HR n = 524.83 btu/lb Fa Rtd 38 1.008	Fa+err	37 530.7 53	<u>30.7</u> 0
1.0000 0.00%	1.0000 24 0 47.3324	Assumed Calib Press r Assumed Rated Flow Rated h DP+err 5.3520 249.73 Flowrated+err 524.83 149,33 tainty	s = 1114.70 r = 47.332 v = 148021 LB/HR n = 524.83 btu/lb Fa Rtd 38 1.008	Fa+err	37 530.7 53	<u>30.7</u> 0
1.0000 0.00%	1.0000 24 0 47.3324	Assumed Calib Press r Assumed Rated Flow Rated h DP+err 5.3520 249.73 Flowrated+err 524.83 149,33	s = 1114.70 r = 47.332 v = 148021 LB/HR n = 524.83 btu/lb Fa Rtd 38 1.008	Fa+err	37 530.7 53	<u>30.7</u> 0
1.0000 0.00%	1.0000 24 0 47.3324	Assumed Calib Press r Assumed Rated Flow Rated h DP+err 5.3520 249.73 Flowrated+err 524.83 149,33 tainty Udp = 1315.9 lb/hr	s = 1114.70 r = 47.332 v = 148021 LB/HR n = 524.83 btu/lb Fa Rtd 38 1.008 r 36	Fa+err	37 530.7 53	<u>30.7</u> 0
1.0000 0.00%	1.0000 24 0 47.3324	Assumed Calib Press r Assumed Rated Flow Rated h DP+err 5.3520 249.73 Flowrated+err 524.83 149,33 tainty Udp = 1315.9 lb/hr	s = 1114.70 r = 47.332 v = 148021 LB/HR n = 524.83 btu/lb Fa Rtd 38 1.008 r 36	Fa+err	37 530.7 53	<u>30.7</u> 0

	.DE-AP.ZZ-0002(Q), Rev. 12	2, Form 2)		CALCULATION C	ONTINUATION SHEE	T	SHEET:	2
CALCNO .:	SC-BB-0525 Attach	nment 5	REV:	5	REF:		CONT'D ON SHEET:	
					•			
DRIGINATOR:		DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller		2/14/2017	John Wilkens		3/13/2017	N/A		N/A
		or due to Signal Conditic low by the Numac compi				heat balance cal	culations.	Rev 5
This portion of the Accuracy: RWCU ANU_D/A	,) NUMAC computer outp	ut, 2) NSSS comp	uter uncertainty. The Loop Drift: [RWCU_VDNU_D/A		flowspan:		
0.233%	0.188%			0.13%	0.000%	1		
RWCU_CENU_D// 0.02% The uncertainties a	0.188%	endent and combined by	the SRSS method:					
The flow error is th	% span FLOW e difference between t = Flowrated - Flowrated+	he rated flow at without I	oop error minus the	e flow plus loop errol	-			
The flow error is th	e difference between t				<u>.</u>			
The flow error is th RWCUNSSS_cptr = Fa Error	e difference between t = Flowrated - Flowrated+		K=	= 9449.90		(Noto)		
The flow error is th RWCUNSSS_cptr = Fa Error Rated 533F	e difference between t = Flowrated - Flowrated+ 1.0087		K = Calib Flow =	= 9449.90 = 189823.1 lb/hr	: 500 GPM	(Note)		
The flow error is th RWCUNSSS_cptr = Fa Error Rated 533F	e difference between t = Flowrated - Flowrated+	-error	K = Calib Flow = Calib inWC =	= 9449.90 = 189823.1 lb/hr = 403.50		(Note)		
The flow error is th RWCUNSSS_cptr = Fa Error Rated 533F	e difference between t = Flowrated - Flowrated+ 1.0087	-error Assu	K = Calib Flow = Calib inWC = uned Calib Temp =	= 9449.90 = 189823.1 lb/hr = 403.50 = 530.70		(Note)		
The flow error is th RWCUNSSS_cptr = Fa Error Rated 533F	e difference between t = Flowrated - Flowrated+ 1.0087	-error Assu	K = Calib Flow = Calib inWC = uned Calib Temp = uned Calib Press =	= 9449.90 = 189823.1 lb/hr = 403.50 = 530.70		(Note)		
The flow error is th RWCUNSSS_cptr = Fa Error Rated 533F	e difference between t = Flowrated - Flowrated+ 1.0087	-error Assu Assu	K = Calib Flow = Calib inWC = uned Calib Temp = uned Calib Press =	= 9449.90 = 189823.1 lb/hr = 403.50 = 530.70 = 1114.70 = 47.332		(Note)		
The flow error is th RWCUNSSS_cptr = Fa Error Rated 533F Calibrated	e difference between t Flowrated - Flowrated+ 1.0087 1.0045	-error Assı Assı Assı	K = Calib Flow = Calib inWC = umed Calib Temp = umed Calib Press = r = umed Rated Flow = Rated h =	= 9449.90 = 189823.1 lb/hr = 403.50 = 530.70 = 1114.70 = 47.332 = 148021 lb/hr = 524.83 btu/lb	500 GPM 389 GPM			
The flow error is th RWCUNSSS_cptr = Fa Error Rated 533F Calibrated C Rtd	e difference between t Flowrated - Flowrated+ 1.0087 1.0045 C+err	-error Assı Assı DP Rtd	K = Calib Flow = Calib inWC = umed Calib Temp = umed Calib Press = r = umed Rated Flow = Rated h = DP+err	 9449.90 189823.1 lb/hr 403.50 530.70 1114.70 47.332 148021 lb/hr 524.83 btu/lb 	500 GPM 389 GPM Fa+err	T Rtd	T+err	
The flow error is th RWCUNSSS_cptr = =a Error Rated 533F Calibrated	e difference between t Flowrated - Flowrated+ 1.0087 1.0045	-error Assı Assı Assı	K = Calib Flow = Calib inWC = umed Calib Temp = umed Calib Press = r = umed Rated Flow = Rated h =	 9449.90 189823.1 lb/hr 403.50 530.70 1114.70 47.332 148021 lb/hr 524.83 btu/lb 	500 GPM 389 GPM Fa+err	T Rtd	530.7 530.7	
The flow error is th RWCUNSSS_cptr = Fa Error Rated 533F Calibrated C Rtd	e difference between t Flowrated - Flowrated+ 1.0087 1.0045 C+err 1.0000	-error Assı Assı DP Rtd	K = Calib Flow = Calib inWC = umed Calib Temp = umed Calib Press = r = umed Rated Flow = Rated h = DP+err	 9449.90 189823.1 lb/hr 403.50 530.70 1114.70 47.332 148021 lb/hr 524.83 btu/lb 	500 GPM 389 GPM Fa+err	T Rtd		
The flow error is th RWCUNSSS_cptr = Fa Error Rated 533F Calibrated <u>C Rtd</u> 1.000 0.00	e difference between t Flowrated - Flowrated+ 1.0087 1.0045 C+err 00 1.0000 % 0	-error Assu Assu Assu DP Rtd 245.3520	K = Calib Flow = Calib inWC = umed Calib Temp = umed Calib Press = r = umed Rated Flow = <u>Rated h =</u> <u>DP+err</u> 245.3520	 9449.90 189823.1 lb/hr 403.50 530.70 1114.70 47.332 148021 lb/hr 524.83 btu/lb 	500 GPM 389 GPM Fa+err	T Rtd	530.7 530.7	
The flow error is th RWCUNSSS_cptr = Fa Error Rated 533F Calibrated <u>C Rtd</u> 1.000 0.00 ⁴	e difference between t Flowrated - Flowrated+ 1.0087 1.0045 C+err 00 1.0000 % 0	-error Assu Assu Assu DP Rtd 245.3520	K = Calib Flow = Calib inWC = uned Calib Temp = uned Calib Press = r = uned Rated Flow = <u>DP+err</u> 245.3520	= 9449.90 = 189823.1 lb/hr = 403.50 = 530.70 = 1114.70 = 47.332 = 148021 lb/hr = 524.83 btu/lb Fa Rtd 0 1.0087	500 GPM 389 GPM Fa+err	T Rtd	530.7 530.7	
The flow error is th RWCUNSSS_cptr = Fa Error Rated 533F Calibrated <u>C Rtd</u> 1.000 0.00 ⁴	e difference between t Flowrated - Flowrated+ 1.0087 1.0045 C+err 00 1.0000 % 0	-error Assu Assu Assu DP Rtd 245.3520	K = Calib Flow = Calib inWC = umed Calib Temp = umed Calib Press = r = umed Rated Flow = <u>Rated h =</u> <u>DP+err</u> 245.3520	= 9449.90 = 189823.1 lb/hr = 403.50 = 530.70 = 1114.70 = 47.332 = 148021 lb/hr = 524.83 btu/lb Fa Rtd 0 1.0087	500 GPM 389 GPM Fa+err	T Rtd	530.7 530.7	
The flow error is th RWCUNSSS_cptr = Fa Error Rated 533F Calibrated <u>C Rtd</u> 1.000 0.00 ⁴	e difference between t Flowrated - Flowrated+ 1.0087 1.0045 C+err 00 1.0000 % 0	-error Assu Assu Assu DP Rtd 245.3520	K = Calib Flow = Calib inWC = umed Calib Temp = umed Calib Press = r = umed Rated Flow = Rated h = DP+err 245.3520 Flow 148,734.3	= 9449.90 = 189823.1 lb/hr = 403.50 = 530.70 = 1114.70 = 47.332 = 148021 lb/hr = 524.83 btu/lb Fa Rtd 0 1.0087	500 GPM 389 GPM Fa+err	T Rtd	530.7 530.7	

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(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)	<u> </u>	CALCULATION C	ONTINUATION SI	HEET	SHEET:	22	
ALC NO.: SC-BB-0525 Attachment 5	REV:		REF:		CONT'D ON SHEET:	23	
RIGINATOR: DATE:	REVIEWER		DATE:	VERIFIER:		DATE:	
Aichael Miller 2/14/2017	John Wilkens		3/13/2017	N/A		N/A	
.2.4.6 Reactor Water Cleanup Total Flow due to Flow Lo	oop Uncertainties (RWCUf)	·			Rev 5	
RWCU Inlet h - Outlet h.		· .					
he total RWCU Flow Uncertainty is calculated below:	· · · · · ·	•					
WCUfu =+/-SQRT(RWCUPMA1^2+RWCUc^2+RWCUdp	o^2+RWCUNSSS_cptr^2)-RWCUFa-RWCUPM	IA2		2 P		
otice that the bias PMAs are factored with both signs, sir	nce the negative uncertair	ntv is the one that has i	impact in the heat				
alance calculations, that is, that (-) less indication means	that power is higher, how	vever, it will be factored	d in both directions	s for simplicity.			
RWCUfu = 3700 lb/hr							
bon the best error contribution is the calculated inlet flow	y boot orror minus the sut	lat flow boot orror					
hen, the heat error contribution is the calculated inlet flow	v heat error minus the out	let flow heat error:			х.		
	v heat error minus the out	let flow heat error:					
hen, the heat error contribution is the calculated inlet flow RWCUh_in = 509.11 btu/lb RWCUh_out = 396.68 btu/lb	v heat error minus the out	let flow heat error:					
RWCUh_in = 509.11 btu/lb RWCUh_out = 396.68 btu/lb		let flow heat error:					
RWCUh_in = 509.11 btu/lb RWCUh_out = 396.68 btu/lb and the RWCU heat error contribution is calculated by the	following expression:						
RWCUh_in = 509.11 btu/lb RWCUh_out = 396.68 btu/lb nd the RWCU heat error contribution is calculated by the	following expression:			·			
RWCUh_in = 509.11 btu/lb RWCUh_out = 396.68 btu/lb nd the RWCU heat error contribution is calculated by the	o following expression: BTU_hr (conversion facto			nce error			
RWCUh_in = 509.11 btu/lb RWCUh_out = 396.68 btu/lb and the RWCU heat error contribution is calculated by the RWCU = [RWCUfu (RWCUh_in - RWCUh_out) x MWt_	o following expression: BTU_hr (conversion facto	r)] / Rated MWt 100%		ince error			
RWCUh_in = 509.11 btu/lb RWCUh_out = 396.68 btu/lb and the RWCU heat error contribution is calculated by the RWCU = [RWCUfu (RWCUh_in - RWCUh_out) x MWt_	o following expression: BTU_hr (conversion facto	r)] / Rated MWt 100%		Ince error			
RWCUh_in = 509.11 btu/lb RWCUh_out = 396.68 btu/lb and the RWCU heat error contribution is calculated by the RWCU = [RWCUfu (RWCUh_in - RWCUh_out) x MWt_	o following expression: BTU_hr (conversion facto	r)] / Rated MWt 100%		ince error			
RWCUh_in = 509.11 btu/lb RWCUh_out = 396.68 btu/lb and the RWCU heat error contribution is calculated by the RWCU = [RWCUfu (RWCUh_in - RWCUh_out) x MWt_	o following expression: BTU_hr (conversion facto	r)] / Rated MWt 100%		ince error			
RWCUh_in = 509.11 btu/lb RWCUh_out = 396.68 btu/lb and the RWCU heat error contribution is calculated by the RWCU = [RWCUfu (RWCUh_in - RWCUh_out) x MWt_	o following expression: BTU_hr (conversion facto	r)] / Rated MWt 100%		Ince error			
RWCUh_in = 509.11 btu/lb RWCUh_out = 396.68 btu/lb and the RWCU heat error contribution is calculated by the RWCU = [RWCUfu (RWCUh_in - RWCUh_out) x MWt_	o following expression: BTU_hr (conversion facto	r)] / Rated MWt 100%		ince error			
RWCUh_in = 509.11 btu/lb RWCUh_out = 396.68 btu/lb and the RWCU heat error contribution is calculated by the RWCU = [RWCUfu (RWCUh_in - RWCUh_out) x MWt_	o following expression: BTU_hr (conversion facto	r)] / Rated MWt 100%		ince error			
RWCUh_in = 509.11 btu/lb RWCUh_out = 396.68 btu/lb nd the RWCU heat error contribution is calculated by the WCU = [RWCUfu (RWCUh_in - RWCUh_out) x MWt_	e following expression: BTU_hr (conversion facto This total error wil	r)]/Rated MWt 100%	the total heat bala	ince error		·	
RWCUh_in = 509.11 btu/lb RWCUh_out = 396.68 btu/lb and the RWCU heat error contribution is calculated by the RWCU = [RWCUfu (RWCUh_in - RWCUh_out) x MWt_ RWCUf = 0.0031%	e following expression: BTU_hr (conversion facto This total error wil	r)] / Rated MWt 100% Il be treated as bias in	the total heat bala				
RWCUh_in = 509.11 btu/lb RWCUh_out = 396.68 btu/lb and the RWCU heat error contribution is calculated by the RWCU = [RWCUfu (RWCUh_in - RWCUh_out) x MWt_ RWCUf = 0.0031%	e following expression: BTU_hr (conversion facto This total error wil	r)] / Rated MWt 100% Il be treated as bias in	the total heat bala				
RWCUh_in = 509.11 btu/lb RWCUh_out = 396.68 btu/lb and the RWCU heat error contribution is calculated by the RWCU = [RWCUfu (RWCUh_in - RWCUh_out) x MWt_] RWCUf = 0.0031%	e following expression: BTU_hr (conversion facto This total error wil	r)]/Rated MWt 100%	the total heat bala				

1)	NC.DE-AP.ZZ-0002(Q), Rev. 12,	Form 2)		CALCULATION C	ONTINUATION SHE	ET	SHEET:	23
ALĊ NÓ.:	SC-BB-0525 Attachr	ment 5	_REV:	5	REF:		CONT'D ON SHEET:	24
RIGINATOR:	D	ATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2	2/14/2017	John Wilkens		3/13/2017	N/A		N/A
This error is the The thermocoup The fabrication e Finally, since mo	Water Cleanup Flow Enth error resultant of temperat les are instruments with g errors can be calibrated ou ost of the thermocouples lo came direction; therefore, t	ture measurement erro ood repeatability and s t, since essentially it is oop error is a bias, the	ors by the inlet/outle stability. However, s a bias, systematic conservative and s	et RWCU thermocoup fabrication errors can cerror. The temperat safe way to apply the o	amount to several far ure loops for RWCU a error, is for the two ter	enheit degrees. re not calibrated out.		Rev 5
Ref. 3.4.6								
The heat error is	the difference between th	ne inlet flow heat error	minus the outlet flo	w heat error:				
RWCLIbt = [Flow	w[(hin - hin+error)+(ho	$h_{\rm res}$	93E-07 / 3880 v 1	00%				
			L93L-077 3009 X 1	00 %				
n flow heat	·					_		
TRtd 517.8	528.7	P Rtd	h rated	h+err	Flow			
Error (F)	10.9	1000.69	509.11	522.50	148,021			
	1055							
Out flow heat						_		
TRtd	T+err	P Rtd	h rated	h+err	Flow	_		
419.2	430.1	1000.69	396.68	408.57	148,021	1		
Error (F)	10.9							
	C	Error 3,741,117	BTU/hr error at r	rated reactor water c	leanup flow			
	ľ	Incertainty in Rated RWCUht =		This error is a bias				

and and the second states of the second

Michael Miller 2/14/2017 John Wilkens 3/13/2017 N/A N/A	25				CALCULATION (FOIDE	E-AP.ZZ-0002(Q), Rev. 12, F	(NC.D
Vitichael Miller 2/14/2017 John Wilkens 3/13/2017 N/A N/A N/A 7.2.4.8 Reactor Water Cleanup Flow Enthalpy Heat Error due to Pressure Loop Uncertainty RWCUhp) Ref The reactor water cleanup enthalpy determination is affected by the loop pressure error. The pressure has a very small effect in the water enthalpy, however, it is determined in this calculation. The loop uncertainty is documented in: Ref Ref.: 3.4.4 Ref.: 3.4.4 The heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error: Ref RWCUhp = [Flow [(hin - hin+error) - (hout - hout+error)]] x 2.93E-07 / 3889 x 100% n n flow heat Image: state		CONT'D ON SHEET:		REF:	5	REV:	ment 5	SC-BB-0525 Attachm	ALC NO.:
Alichael Miller 2/14/2017 John Wilkens 3/13/2017 N/A N/A N/A *.2.4.8 Reactor Water Cleanup Flow Enthalpy Heat Error due to Pressure Loop Uncertainty RWCUhp) Ref The reactor water cleanup enthalpy determination is affected by the loop pressure error. The pressure has a very small effect in the water enthalpy, however, it is determined in this calculation. The loop uncertainty is documented in: Ref Ref.: 3.4.4 The heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error: Ref RWCUhp = [Flow [(hin - hin+error) - (hout - hout+error)]] × 2.93E-07 / 3889 × 100% n n flow heat Image: transmission of the terror is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error: RWCUhp = [Flow [(hin - hin+error) - (hout - hout+error)]] × 2.93E-07 / 3889 × 100% n n flow heat Image: transmission of the terror is the difference in the terror is in the terror is in the terror is in the terror is in the terror is in the terror is in the terror is in the terror is interveries in the terror is in the terror is in the terror is in the terror is in the terror is in the terror is in terror is in the terror is in the terror is in the terror is in the terror is in the terror is in the terror is in the terror is in terror is in terror is in terror is in terror is in terror is in terror is in terror is in terror is in terror is in terror is in terror is in terror is in terror is in terror is in terror is in terror	DATE:		VERIFIER:			IREVIEWER:	ATE		RIGINATOR:
R.2.4.8 Reactor Water Cleanup Flow Enthalpy Heat Error due to Pressure Loop Uncertainty RWCUhp) Ref The reactor water cleanup enthalpy determination is affected by the loop pressure error. The pressure has a very small effect in the water enthalpy, however, it is determined in this calculation. The loop uncertainty is documented in: Ref Ref:3.4.4 The heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error: RWCUhp = [Flow [(hin - hin+error) - (hout - hout+error)]] x 2.93E-07 / 3889 x 100% n flow heat P+err TRtd h rated h+err Flow 1000.69 1020.89 517.8 509.11 509.09 148,000 Error (psi) 20.2	N/A								
he reactor water cleanup enthalpy determination is affected by the loop pressure error. The pressure has a very small effect in the water nthalpy, however, it is determined in this calculation. The loop uncertainty is documented in: he f.: 3.4.4 he heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error: WCUhp = [Flow [(hin - hin+error) - (hout - hout+error)]] x 2.93E-07 / 3889 x 100% In flow heat P Rtd P+err TRtd h rated h+err Flow 1000.69 1020.89 517.8 509.11 509.09 148,000 Error (psi) 20.2 Put flow heat P Rtd P+err TRtd h rated h+err Flow 1000.69 1020.89 419.2 396.68 396.70 148,000 Error (psi) 20.2				10/10/2011					
Anthalpy, however, it is determined in this calculation. The loop uncertainty is documented in: Ref.: 3.4.4 The heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error: RWCUhp = [Flow [(hin - hin+error) - (hout - hout+error)]] x 2.93E-07 / 3889 x 100% In flow heat P Rtd P+err TRtd h rated h+err Flow 1000.69 1020.89 517.8 509.09 148,000 Error (psi) 20.2 Dut flow heat P Rtd P+err TRtd h rated h+err Flow 1000.69 1020.89 419.2 396.68 396.70 148,000 Error (psi) 20.2 Error 20.2	Rev 5				certainty (RWCUhp)	to Pressure Loop Ur	alpy Heat Error due t	er Cleanup Flow Enthal	.2.4.8 Reactor Wate
nthalpy, however, it is determined in this calculation. The loop uncertainty is documented in: ef.: 3.4.4 he heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error: WCUhp = [Flow [(hin - hin+error) - (hout - hout+error)]] x 2.93E-07 / 3889 x 100% Inflow heat P Rtd P+err TRtd h rated h+err Flow 1000.69 1020.89 517.8 509.11 509.09 148,000 Error (psi) 20.2 ut flow heat					·				
Ref.: 3.4.4 The heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error: RWCUhp = [Flow [(hin - hin+error) - (hout - hout+error)]] x 2.93E-07 / 3889 x 100% n flow heat P Rtd P+err Tttd h rated h+err Flow 1000.69 1020.89 517.8 509.11 509.09 148,000 Error (psi) 20.2 Dut flow heat			l effect in the water	as a v ery small el					
The heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error:					mented in:	p uncertainty is docu	calculation. The loo	is determined in this ca	nthalpy, however, it
The heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error:									
WCUhp = [Flow [(hin - hin+error) - (hout - hout+error)]] x 2.93E-07 / 3889 x 100% n flow heat P Rtd P+err TRtd h rated h+err Flow 1000.69 1020.89 517.8 509.11 509.09 148,000 Error (psi) 20.2 Dut flow heat Flow Flow 000.69 1020.89 419.2 396.68 396.70 148,000 Error (psi) 20.2 Error (psi) 20.2 Error (psi) 20.2									et.: 3.4.4
WCUhp = [Flow [(hin - hin+error) - (hout - hout+error)] x 2.93E-07 / 3889 x 100% Inflow heat P Rtd P+err TRtd h rated h+err Flow 1000.69 1020.89 517.8 509.11 509.09 148,000 Error (psi) 20.2 Description Flow Flow 1000.69 1020.89 419.2 396.68 396.70 148,000 Error (psi) 20.2 Error (psi) 20.2 Error (psi) 20.2									
Inflow heat P Rtd P+err T Rtd h rated h+err Flow 1000.69 1020.89 517.8 509.11 509.09 148,000 Error (psi) 20.2 20.2 Dut flow heat Flow 1000.69 1020.89 419.2 396.68 396.70 148,000 Error (psi) 20.2			ed conditions plus error:	r content at rated	s minus the heat erro	t rated flow condition	flow heat content a	difference in the CRD f	he heat error is the
P Rtd P+err TRtd h rated h+err Flow 1000.69 1020.89 517.8 509.11 509.09 148,000 Error (psi) 20.2 Dut flow heat P Rtd P+err TRtd h rated h+err Flow 1000.69 1020.89 419.2 396.68 396.70 148,000 Error (psi) 20.2 Error Error Flow					· ·	,			
P Rtd P+err TRtd h rated h+err Flow 1000.69 1020.89 517.8 509.11 509.09 148,000 Error (psi) 20.2 20.2 Flow 148,000 Dut flow heat Flow 1000.69 1020.89 419.2 396.68 396.70 148,000 Error (psi) 20.2 Error (psi) 20.2 Error (psi) Error (psi) 1020.89 419.2 396.68 396.70 148,000					00%	x 2.93E-07 / 3889 x	out - hout+error)]]	hin - hin+error) - (hou	WCUhp = [Flow [(
P Rtd P+err TRtd h rated h+err Flow 1000.69 1020.89 517.8 509.11 509.09 148,000 Error (psi) 20.2 20.2 Flow 148,000 Dut flow heat Flow 1000.69 1020.89 419.2 396.68 396.70 148,000 Error (psi) 20.2 Error (psi) 20.2 Error (psi) Error (psi) 1020.89 419.2 396.68 396.70 148,000					4				
1000.69 1020.89 517.8 509.11 509.09 148,000 Error (psi) 20.2 20.2 1000.69 148,000 148,000 P Rtd P+err TRtd h rated h+err Flow 1000.69 1020.89 419.2 396.68 396.70 148,000 Error (psi) 20.2 Error Error Flow 1000.69							1		n flow heat
Error (psi) 20.2 Dut flow heat P Rtd P+err TRtd h rated h+err Flow 1000.69 1020.89 419.2 396.68 396.70 148,000 Error (psi) 20.2 Error Error Error				Flow	h+err	h rated	TRtd	P+err	P Rtd
Dut flow heat P Rtd P +err TRtd h rated h+err Flow 1000.69 1020.89 419.2 396.68 396.70 148,000 Error (psi) 20.2 Error Error Error True			148,000	148	509.09	509.11	517.8	1020.89	1000.69
P Rtd P+err TRtd h rated h+err Flow 1000.69 1020.89 419.2 396.68 396.70 148,000 Error (psi) 20.2 Error Error Error Error				· · · · · · · · · · · · · · · · · · ·				20.2	Error (psi)
P Rtd P+err TRtd h rated h+err Flow 1000.69 1020.89 419.2 396.68 396.70 148,000 Error (psi) 20.2 Error Error Error Error		4						· · · · ·	
1000.69 1020.89 419.2 396.68 396.70 148,000 Error (psi) 20.2						e e e e		the second second	out flow heat
Error (psi) 20.2			5 A	Flow	h+err	h rated	TRtd	P+err	P Rtd
Error			148,000	148	396.70	396.68	419.2	1020.89	1000.69
Error								20.2	Error (nsi)
								20.2	
						,			
5,764 BTU/hr at rated reactor water cleanup flow					142.00	· · · ·	Error		
				p flow	eactor water cleanu	4 BTU/hr at rated	5,76	· · · · ·	
				-					

RWCUhp = 0.00004%

(NC.DE-AP.ZZ-0002(Q), Rev. 1	2, Form 2)	CALCULA	TION CONTINUATION SH	IEET	SHEET: 25
CALC NO.: SC-BB-0525 Attac	hment 5	REV: 5	REF:		CONT'D ON SHEET: 26
ORIGINATOR:	DATE:	REVIEWER:	DATE:	VERIFIER:	DATE:
Michael Miller	2/14/2017	John Wilkens	3/13/2017	N/A	N/A
7.2.5 Recirculation Pumps Heat Error du	e to Watts Loop Uncerta	ainty (RRPw)			Rev 5
This section calculates the uncertainty de	ue to RRP watts loop err	or, calculated in:			
Ref.: 3.4.11					
The rated power for the pump-motor and	the motor efficiency (0.9	93) is from reference:			
(Ref. 3.4.3)					
There are two recirculation pumps, the c	alculated error below is p	per pump. The actual total MW fo	or the 2 pumps is taken fro	om above reference.	
W 2 pump = 7.33					
The Watt error contribution is calculated	as follows:				
RRPw = [(W Rtd/pump + MW Loop Spa	an x Span err) x Mottor e	eff] - W Rtd/pump x Motor eff] /	3889 x 100%		
	W+err 3.55 1.50 % span 10.5 Mwatt				
	TTL Mwatt 3.41	Mwatt			
	Error 0.1465	Mwatt			
	Uncertainty in Rated RRPw =	MWT = 0.0038%			

(NC.DE-AP.ZZ	Z-0002(Q), Rev. 12, Form 2)	CALC	ULATION CONTINUATION	SHEET	SHEET:	26
CALCNO.: SC-B	B-0525 Attachment 5	REV:5	REF:	·	CONT'D ON SHEET:	27
ORIGINATOR: Michael Miller	DATE: 2/14/2017	REVIEWER: John Wilkens	DATE: 3/13/2017	VERIFIER:		ате: I/A
7.2.6 Thermal Loses (TL)					R	lev 5
	uncertainty due to TL error. Thi sumed, i.e. it is a fixed error not	s error will be treated as a bias erro a random error.	or since the estimated value			
An assumed error equal to	20% of the specified loses is us	ed.				
The rated Heat Loss is from	n reference:					
(Ref. 3.4.2)						
W Rtd 1.1 Error = 20.00	W+err 1.32 %					
	TT L Mwatt Heat 1.32	MW				
· · ·	1.10	MW at rated conditions				
	Error 0.	2200 MW error at rated radiated	lloses			
	Uncertainty in R	Rated MWTThis errorTL = 0.006%	or is treated as bias.			

Note: The computer utilizes this value combined with Other System Loses (Section 7.2.7) as Radiative power loses, QRAD = 1.94

(NC.DE-AP.ZZ	Z-0002(Q), Rev. 12, Form 2)	CAI	CALCULATION CONTINUATION SHEET				
CALC NO.: SC-BI	B-0525 Attachment 5	REV: 5	REF:	<u> </u>	CONT'D ON SHEET:		
ORIGINATOR:	DATE:	REVIEWER:	DATE:	VERIFIER:	DATE:		
Michael Miller	2/14/2017	John Wilkens	3/13/2017	N/A	N/A		
7.2.7 Other System Loses	<u>(OSL)</u>				Rev 5		
		rculation pumps. An assumed e					
This error will be treated as	s a bias error since if the estima	ted value is larger or smaller that	n assumed, i.e. it is a fixed erro	or not a random error.			
The rated Losses figure is f	from reference:						
(Ref. 3.4.2)							
W Rtd 1.18 Error = 20%	W+err 1.416		•				
	TTL Mwatt Heat 1.42	MW					
	1.18	MW at rated conditions					
	Error 0	.2360 MW error at rated radia	ted loses				
	Uncertainty in I	Rated MWT This e	error is treated as bias.				
Note: The computer utilize	s this value combined with The	mal Loses (Section 7.2.6) as Ra	idiative nower loses ORAD = 1	.94			

Note: The computer utilizes this value combined with Thermal Loses (Section 7.2.6) as Radiative power loses, QRAD = 1.94

(NC.DE-AP.ZZ-		CALCULATION CONTINUATION SHEET			SHEET	SHEET: 28	
•	-0525 Attachment 5	REV:	5	REF:	·	CONT'D ON SHEET	
RIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	<u> </u>	DATE:
lichael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A
					· · · · ·		
.2.8 Heat Balance Calcula	tion Power Uncertainty (Power	· U)					Rev 5
The calculated heat halance	uncertainty is the algebraic co	mbination of the bias e	errors with the inde	nendent/random error	e statistically combine	d	
	balance calculation, in accorda				o otationouny combine	u,	
			· • •				
Power – Mr W(MSh	-FWh)-CRDF(hin-hout)+RWC	U(nout-nin)-KKP+nL	TWISCENAREOUS				
Summary of Heat Balance	Calculation Contributing Err	ors:					
Random Errors:	MSmoist = 0.0000%						
	CRDc= 0.0053%						
	CRDdp = 0.0061%						
	RRPw = 0.0038%						
R	WCUp sw = 0.0001%						
Dependent Errors:	Errors	•	Variable				
	FWm = **						
	FWht = **						
	MSm = **						
	FWhp = **		Rated MS press	ure = 1001 psia			
	MShp = 0.0254%						
	CRDhp = -0.00005%						
	RWCUhp = 0.00004%						
Bias Errors:	CRDt = -0.0012%			•			
	CRDht = -0.0096%						
	RWCUf = 0.0031%						
	RWCUht = 0.0282%						
	TL = 0.006%						
	OSL = 0.006%						
	combined in reference 3.4.20	for an over all uncertai	nty of 0.66% for F	Wm, FWht and FWhp			
leat Balance Calculation	³ ower Error (U):						
				-401			
	(0.0066)^2+(MShp+CRDhp+R -RWCUp_sw^2+RRPw^2x2]+(
				L			
Power Error = 0.693%							
	exist, due to possible instrume	entation loops miss-cali	bration actual drif	t (to be determined by	history) etc. a margir	n is added	
•					nietory, etc., a margi		
Power U = Power Err	or + Margin						
vhere margin is defined as 3	3840 * 102% – Rated Thermal	Power – Power Error		i .			
Margin = 3916.8	- 3889 - Power Error						
Margin = 0.022%		Power	U = 0.715%				
margin orocer							

(N	C.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCL	ILATION CONTINUATION S	HEET	SHEET:	29
CALC NO .:	SC-BB-0525 Attachment 5	REV:	5	REF:		CONT'D ON SHEET:	N/A
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A
difference betwee	eat Balance Error performed in this calcula on the 2% design basis and the rated term en the Power Uncertainty and the Power I	al power for the current	LEFM mod	e of operation. Positive marg	•		Rev 5
<u>Power U</u>	<u>= 0.715%</u>						

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1)	IC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)	CALCULATION CONTINUATION SHEET				SHEET:	1
CALC NO.: SC-BB-0525 Attachment 6		REV:	5	REF:	·	CONT'D ON SHEET:	2
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	 [t	DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A

Sections 1 through 4 have been replaced with the main body of the calculation

5.0 DESIGN INPUTS

5.1 Rated Power Conditions

100% rated Power Conditions are listed below. Actual 100% operation values might be used in lieu of rated nominal values, for other than Rated MWt, Feedwater Flow and Main Steam parameters as deemed appropriate. This is found acceptable, since for the purpose of error determination to rated MWt "heat differential errors", actual heat contribution deviation from measured/calculated heat to rated MWt due to instrumentation uncertainties, is required not the actual deviation value.

Rated MWt = <u>3840MW</u>	(Ref. 3.4.19, 3.2.4, Att 8)	,	Rev 5
Rated FW flow = 1.4690E-	•07lbm/hr (Ref. 3.4.19, Att 8)		
Rated FW temperature = <u>329.6 F</u>	(Ref. 3.4.19, Att 8)		
Rated MS flow = <u>1.4722E</u>	<u>+07lbm/hr</u> (Ref. 3.4.19, Att 8)		
Rated MS pressure = 1001 psi	a (Ref. 3.4.19, Att 8)		
Rated MS quality = <u>100.000</u>	(Ref. 3.4.1)		· · · · ·
Rated RWCU flow = <u>148000.0</u>	lb/hr (Ref. 3.4.19, Att 8)		Rev 5
Rated RWCU temperature = 517.9 F	(Ref. 3.4.19, Att 8)		
Rated RWCU return temperature = <u>419.4 F</u>	(Ref. 3.4.19, Att 8)		
Rated CRD flow = <u>32000.0</u>	lb/hr (Ref. 3.4.3, 3.4.17)		
CRD Calibration pressure = <u>1474.0 p</u>	sia (Ref. 3.4.5)		, ·
Rated CRD temperature = 77 F	(Ref. 3.4.19, Att 8)		Rev 5
Radiation Loses = 1.10MW	(Ref. 3.4.2, 3.4.17)		
Other System Loses = <u>1.18MW</u>	(Ref. 3.4.2, 3.4.17) Note:	These loses are not included in UFSAR Hea	t Balance, Ref. 3.1.1
MWt/BTU/hr = <u>2.9300E</u> -	07 (Ref. 3.4.1)		•
Power = MFW(MSh-FV	Wh)-CRDF(hin-hout)+RWCU(hout-hin)-R	RP+HL+Miscellaneous	

Notes:

1) This calculation uses rated MS quality of 100.00%, which will produce a more conservative number with respect to the actual plant MS quality. This parameter may be revised when the actual MS quality is measured after the implementation of EPU.

2) This calculation specifies radiation loses as 1.10 MW and other loses as 0.84 MW for the total lose of 1.94 MW. Reference 3.4.17 stated "other system loses" as 1.9 MW without specifically accounting for Radiation loses. Since the two total numbers are almost identical and the difference would have negligible affect on the Power Error, radiation loses of 1.10 MW and the other loses of 0.84 MW will be maintained.

6.0 ASSUMPTIONS

See sections 7.2.3, 7.2.4, 7.2.6 and 7.2.7 for specific assumptions.

Rev 5

(NC.	.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCULATION CONTINUATION SHEET SHEET:				2
CALC NO.: SC-BB-0525 Attachment 6		REV:	5	REF:		CONT'D ON SHEET:	3
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A

7.0 CALCULATIONS

7.1 Methodology

The methodology used to combine the uncertainties for the different contributors to the heat balance calculation is the square root of the sum of the squares of those uncertainties which are statistically independent. Then algebraically combined with the those errors that are systematic, or bias. The uncertainties are considered to be random, two sided distributions. This methodology has been utilized before, and has been endorsed by the NRC and various industry standards (Ref. 3.4.12-3.4.14).

The uncertainty calculation combines the different errors from the different parameters contributing to the heat balance in accordance to the heat balance equation. The contributing parameters errors are taken from the specific system uncertainty calculation.

These errors are generally classified in two groups:

a) Instrument loop(s) uncertainty

b) Process effects

The individual uncertainties affecting the heat balance calculation are determined by the application of the corresponding process algorithm, as described below:

- a) the appropriate algorithm for the specific process parameter is set in the form to its specific contribution to the heat balance at specified rated conditions,
- b) subsequently, the instrumentation loop error is factored in the process algorithm to calculate the corresponding process parameter with the error built-in,
- c) the difference of the calculated contributed process parameter heat, with error, to the rated process rated heat is then calculated,
- d) the resultant heat error contribution is then divided by the rated 100% power thermal megawatts. The result is the error contribution by the specific process to the total heat balance uncertainty,
- e) finally, all the calculated heat errors are combined in accordance to their parameter function in the heat balance equation. The resultant combination of all contributing errors is the Heat Balance Uncertainty.

	(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2) CALCULATION CONTINUATION SHEET					SHEET:	3		
CÁLC NO.: SC-BB-0525 Attachment 6		· · · · · · · · · · · · · · · · · · ·	REV:	5	REF:		CONT'D ON SHEET:	4	
ORIGINATOR:		DATE:		REVIEWER:		DATE:	VERIFIER:	- <u></u>	DATE:
Michael Miller		2/14/2017	•	John Wilkens		3/13/2017	N/A		N/A

7.2 Uncertainties Calculation

7.2.1 Main Feedwater Uncertainty(ies)

Referring to the schematic drawing in section 4.0, it can be seen that the Main Feedwater heat contribution is affected by the following parameters:

a) Mass Flow Measurement affected by: 1) flow, 2) temperature, and 3) pressure instrumentation loops error.

The error provided by the vendor for the ultrasonic flow meter already factors the corresponding temperature and pressure loops effect.

b) Feedwater Enthalpy determination affected by: 1) temperature, and 2) pressure, instrumentation loops error.

The main feedwater enthalpy is calculated using the following signals:

- Main Steam Pressure and Main Feedwater Temperature

The main feedwater mass error is provided as percentage of span at 100% rated power at span of 20,000,000 lbm/hr as documented in Ref.: 3.4.7 Section 7.12.3. The number to be used for 100% flow with reduced reactor feedwater flow is positive error of +0.77% flow span at 20,000,000 lbm/hr span or 155,000 lbm/hr. (Note: Ref.: 3.4.7 Section 7.12.1 NSSS Computer-Feedwater Flow took credit for constant correction of feedwater flow by LEFM. For this calculation where LEFM correction is not credited, the number in Section 7.12.1 cannot be used. Instead the error calculated in Section 7.12.3: GETARS Total Flow 3840 MWt should be used. The propagation of feedwater flow error is identical between NSSS computer and GETARS computer, i.e. both their loops consist of feedwater nozzles, flow transmitters, DFCS Foxboro interface modules, and computers.)

Rev 5

The heat error is the difference in the MFW heat content at rated flow conditions minus the heat error content at rated conditions plus flow error:

FWm = [hrated (Flowrated - Flowrated+err)] x 2.93E-07/3840 x100%

F Rtd	F+err	P Rtd	TRtd	h rated
14,690,000	14,844,000	1000.69	329.6	301.91
Error % reading	0 77000/			

Error% reading 0.770

TTL MFW Heat 4,481,568,938 BTU/hr

4,435,074,622 BTU/hr at rated conditions

Error

46,494,315 BTU/hr at rated main feedwater flow

Uncertainty in Rated MWT FWm = 0.3548%

(NC.	DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCULATION CONTINUATION SHEET				
CALC NO.: SC-BB-0525 Attachment 6		REV:	5	REF:	REF:		5
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/14/201	17 John Wilke	ns	3/13/2017	N/A		N/A

7.2.1.2 Main Feedwater Heat Enthalpy Error due to Pressure Loop Uncertainty (FWhp)

The main feedwater enthalpy is determined from reactor loop pressure, that is affected by the loop uncertainty. The pressure loop uncertainty is documented in:

Ref.: 3.4.4

The heat error is the difference in the MFW heat content at rated flow and enthalpy conditions minus the heat content at rated flow with enthalpy at rated pressure plus pressure induced error:

FWhp = [Flow (hrated - hrated+err)] x 2.93E-07 / 3840 x 100%

Г	P Rtd	P+err	TRtd	h rated	h+err	Flow			
	1000.69	1006.79	329.6	301.91	301.92	14,690,000	Rev 5		
	Error(psi) =	<u>6.1</u>	,						
		r		ſ					
			TTL MFW Heat 4,435,227,702	BTI I/br			Rev 5		
		L	4,400,227,702	BIO/III					
			4,435,074,622	BTU/hr at rated co	nditions		Rev 5		
			. , .				•		
			Error				Rev 5		
	153,080 BTU/hr at rated main feedwater flow								
					7				
			Uncertainty in Rated M				Day 5		
			F WNP =	0.0012%			Rev 5		

	(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2) CALCULATION CONTINUATION SHEET			T SHEET:		5			
CALC NO .:		SC-BB-0525 Attach	ment 6	REV:	5	REF:	CONT'D ON SHE	ET:	6
ORIGINATOR:		1	DATE:	REVIEWER:		DATE:	VERIFIER:	DATE:	
Michael Mille	er		2/14/2017	John Wilkens		3/13/2017 -	N/A	N/A	

7.2.1.3 Main Feedwater Heat Enthalpy Error due to Temperature Loop Uncertainty (FWht)

The main feedwater enthalpy determination is affected by the loop temperature error, documented in:

Ref.: 3.4.8

The heat error is the difference in the MFW heat content at rated flow and enthalpy conditions minus the heat content at rated flow conditions with enthalpy at rated temperature plus temperature induced error:

FWht = [Flow (hrated - hrated+err)] x 2.93E-07 / 3840 x 100%

TRtd	T+err	P Rtd	h rated	h+err	Flow			
329.6	331	1000.69	301.91	303.49	14,690,000			

Error (F) = 1.53 This error is subject to change depending in performance history

TTL MFW Heat	
4,458,340,678	BTU/hr

4,435,074,622 BTU/hr at rated conditions

Error

23,266,056 BTU/hr error at rated main feedwater flow

Uncertainty in Rated MWt FWht = 0.1775%

(NC	(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)			CALCULATION CONTINUATION SHEET				6
CALC NO.:	SC-BB-0525 Attac	nment 6	REV:	5	REF:	CONT'D ON SH	EET:	7
ORIGINATOR:	4	DATE:	REVIEWER:		DATE:	VERIFIER:	DATE	:
Michael Miller		2/14/2017	John Wilkens		3/13/2017	N/A	N/A	

7.2.2 Main Steam Flow Uncertainty(ies)

Referring to the schematic drawing in section 4.0, It can be seen that the Main Steam heat contribution is affected by the following parameters:

a) The calculated Main Steam Heat is affected by the mass flow measurement error (see section 7.2.1.1 Main Feedwater Mass Error).

b) Main Steam Enthalpy determination is affected by the pressure instrumentation loop error, documented in calculation:

Ref. 3.4.4

7.2.2.1 Main Steam Mass Flow Heat Error due to Main Feedwater Flow Uncertainty (MSm)

The main feedwater mass error is provided from Section 7.2.1.1:

The heat error is the difference in the Main Steam flow heat content at rated flow conditions minus the heat content at rated conditions plus flow error:

MSm = [hs rated (Flowrated - Flowrated+err)] x 2.93E-07 / 3840 x 100%

FWFEerr = 0.7700%

Span Mass Flow

F Rtd	F+err	P Rtd	Moist Rtd	hs rated
14,722,000	14,876,000	1000.69	100	1192.91

TTL MFW Heat 17,745,740,403 BTU/hr

17,562,032,147 BTU/hr at rated conditions

Error 183,708,256 BTU/hr at rated main feedwater flow

Uncertainty in Rated MWT MSm = 1.4017%

(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)	CALCULATION CONTINUATION SHEET			SHEET:	7	
CALC NO .:	SC-BB-0525 Attachment 6	REV:	5	REF:		CONT'D ON SHEET:	8
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A

7.2.2.2 Main Steam Heat Enthalpy Error due to Pressure Loop Uncertainty (MShp)

This Section calculates the Main Heat Steam enthalpy error due to the loop pressure uncertainty, documented in:

Ref.: 3.4.4

The heat error is the difference in the Main Steam flow heat content at rated flow and enthalpy conditions minus the heat content at rated flow with enthalpy at rated pressure plus pressure induced error:

MShp = [Flow (hrated - hrated+err)] x 2.93E-07 / 3840 x 100%

P Rtd	P+err	Moist Rtd	Moist+err	h rated	h+err	Flow	
1000.69	1006.79	100	100.000	1192.91	1192.69	14,722,000	Rev
Error (psi) =	6.1		0	<i>h</i>			1
	÷						
		TTL MS Heat					
		17,558,719,1	42 BTU/hr				Re
		47 500 000 4	47 DTU/by at yoth dia and	41			lo.
		17,302,032,1	47 BTU/hr at rated cond	lions			Re
		Error		· · ·	4		
	• .		05 BTU/hr error at rate	d main feedwater flo			Rev
		0,010,0			••		li co
		Error in Rated MW					
			p = 0.0253%	,			Re
	-						1

(NC	.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCULATION CONTINUATION SHEET				8
CALC NO.:	SC-BB-0525 Attachment 6	REV:	5	REF:		CONT'D ON SHEET:	9
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/14/2017	John Wilker	ns	3/13/2017	N/A		N/A

7.2.2.3. Main Steam Moisture Heat Enthalpy Error due to Steam Moisture Uncertainty (MSmoist)

This section calculates the Main Steam enthalpy error due to MS moisture uncertainty. The uncertainty is conservatively set to 50% of rated moisture content of 0.0%.

The heat error is the difference in the Main Steam flow heat content at rated flow and moisture conditions minus the heat content at rated moisture conditions plus moisture error:

MSmoist = [Flowrated hrated (hmoist-rated - hmoist-rated+err)] x 2.93E-07 / 3840 x 100%

Γ	P Rtd	P+err N	loist Rtd	Moist+err	h rated	h+err	Flow
	1000.69	1000.69	100	100.0000	1192.91	1192.91	14,722,000
_		0.00000	0.00%	0			

TTL MS Heat 17,562,032,147 BTU/hr

17,562,032,147 BTU/hr at rated conditions

Error

- BTU/hr error at rated main feedwater flow

Error in Rated MWt MSmoist = 0.0000%

(NC	.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCULATION CONTINUATION SHEET				9
CALC NO.:	SC-BB-0525 Attachment 6	REV:	5	REF:	<u> </u>	CONT'D ON SHEET:	10
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	D	ATE:
Michael Miller	2/14/2017	John Wilkens	s	3/13/2017	N/A	Ň	I/A

7.2.3 Control Rod Drive Flow

Referring to the schematic drawing in section 4.0, it can be seen that CRD flow is not monitored for pressure or temperature.

The CRD calculated heat is affected by the following effects:

a) Mass Flow Measurement affected by: 1) flow, instrumentation loop effect and 2) temperature, and 3) pressure deviation from calibration values

b) The CRD Enthalpy determination is affected by: 1) temperature, from applied constants, and 2) pressure, from reactor pressure loop error

The CRD flow loop errors are documented in calculation:

Ref. 3.4.5

The flow formula is derived from the ASME (Ref. 3.4.9) as follows:

Flow = C*Fa*K*(DP*r)^0.5

where K is calculated below:

K = Calib Flow/(Calib inWC * Calib r)^0.5

(NC	.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCULATION CONTINUATION SHEET				10
CALÇ NO.:	SC-BB-0525 Attachment 6	REV:	5	REF:		CONT'D ON SHEET:	11
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	ļ	DATE:
Michael Miller	2/14/2017	John Wilken	າຣ	3/13/2017	N/A		N/A

7.2.3.1 Control Rod Drive Flow Heat Error due to Flow Element and Fluid Specific Weight Uncertainty due to Temperature Error (CRDt)

The uncertainty is dependent for the following variables:

Fa = FE Thermal Expansion

r = Fluid Specific Weight

The plant computer calculates the CRD flow with a constant flow K factor. However, the actual temperature could vary as much as 43F from the expected 77F, and this impacts the Fa and r impacting the calculated flow; therefore, the effect due to this temperature deviation is:

CRDt = [(hs rated - CRDh rated) (Flowrated - Flowrated+err)] x 2.93E-07 / 3840 x 100%

Ref.: 3.4.5			К=	448.48			
			Calib Flow =	50154 lb/hr	100 GPM		
Fa Error			Calib inWC =	200			
Rated 77F	1.0003		Calib Temp =	77			
@140 F	1.0013		Calib Press =				
@40 F	0.9995		r = 62.529				
Fa/F	1.8E-05	Ass	Assumed Rated Flow = 32000.0 lb/hr				
			Rated Press =	1001 psia			
			Rated Temp =	77 F			
			Rated h =	47.78 btu/lb			
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	T+err
1.0000	1.0000	81.3694	81.3694	1.0003	1.0011	7	7 120
0.00%	• 🗧 🛛 0	0.00%	÷0				43
	-				Temp error = Calib Ter	np - Min Temp	
P Rtd	r	h Rtd	Flow	hs Rtd			
1000.69	61.8993	47.78	31,862.980	1192.91	1		

TTL CRD Heat 36,487,315 BTU/hr

36,644,221 BTU/hr at rated conditions

Error

(156,906) BTU/hr error at rated CRD flow

Error in Rated MWt CRDt = -0.0012%

This error is a bias, not a random instrument induced uncertainty.

(NC		CALCULATION CONTINUATION SHEET				11	
CÁLC NO.:	SC-BB-0525 Attachment 6	REV:	5	REF:		CONT'D ON SHEET:	12
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A

7.2.3.2 Control Rod Drive Flow Heat Error due to Flow Element Uncertainty (CRDc)

The CRD contributed heat is affected by the FE error that is assigned to the flow element expansion coefficient.

С

The FE uncertainty is determined based in calculation:

Ref.: 3.4.5

The heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error:

CRDc = [(hs rated - CRDh rated) (Flowrated - Flowrated+err)] x 2.93E-07 / 3840 x 100%

۰ <u>۱</u>			1		· · · · · ·		
Fa Error			K = 4	448.48			
Rated 77F	1.0003		Calib Flow = {	50154	100.00		
@140 F	1.0013		Calib inWC = 2	200.00			
@60 F	0.9995	Assur	ned Calib Temp = 7	77.00			
Fa/F	1.8E-05	Assun	ned Calib Press = '	1474.00			
			r = 6	62.529	0.0159925		
		Assur	ned Rated Flow = 3	32000.0 lb/hr			
			Rated Press =	1001 psia			
			Rated Temp = 7	77 F			
			Rated h = 4	47.78 btu/lb			
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	T+err
1.0000	1.0200	81.3694	81.3694	1.0003	1.0003		77 77
2.00%	200	0.00%	: 0				0

P Rtd	r	h Rtd	Flow	hs Rtd
1000.69	62.4396	47.78	32,616.541	1192.91

TTL MFW Heat 37,350,242 BTU/hr

36,644,221 BTU/hr at rated conditions

Error

706,021 BTU/hr error at rated CRD flow

Err	ÓI	r in	Rated	MWt			
				CRDc =	= 0.	0054	%

(NC	DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCULATION CONTINUATION SHEET				12
CALC NO.:	SC-BB-0525 Attachment 6	REV:	5	REF:		CONT'D ON SHEET:	13
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	D	ATE:
Michael Miller	2/14/2017	John Wilker	ns	3/13/2017	N/A	Ν	I/A

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7.2.3.3 Control Rod Drive Heat Error due to Differential Pressure (DP) Loop Uncertainty (CRDdp)

This error is calculated in calculation:

Ref.: 3.4.5

The loop is comprised of 1) flow transmitter, FT, 2) resistor, REST, 3) computer analog to digital card, A/D. The uncertainties are in % DP span:

Accuracy:

Accuracy:			Loop Drift:			
CRD_AFT	CRD_AREST	CRD_AA/D	CRD_VDFT	CRD_VDA/D		
1.154%	0.100%	0.188%	1.450%	0.000%		

Loop Calibration:

CRD_CEFT	CRD_CEA/D
0.140%	0.188%

The uncertainties are random and independent and combined by the SRSS method:

1.88% span DP

	(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALC	ULATION CONTINUATION	SHEET	SHEET:	13	
CALC NO .:	SC-BB-0525 Attachment 6	REV:	5	REF:		CONT'D ON SHEET:	14	
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:	
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A	

The heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error:

CRDdp = [(hs rated - CRDh rated) (Flowrated - Flowrated+err)] x 2.93E-07 / 3840 x 100%

Fa Error				448.51			
Rated 77F	1.0003		Calib Flow =		100 GPM	•	
@140 F	1.0013	1	Calib inWC =	200			
@60 F	0.9995	Assi	med Calib Temp =	77			
Fa/F	1.8E-05	Assı	med Calib Press =	1474			
			r =	62.529			
		Assi	med Rated Flow =	32000.0 lb/hr			
			Rated Press =	1000.7 lb/hr			
			Rated Temp =	77 F			
			CRDh rated =	47.78.btu/lb			
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	I
1.0000	1 00001	81 3584	85 1183	1 000:	1 0003	77	Ŧ

C Rtd	C+ei	rr	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	T+err
1.00	00	1.0000	81.3584	85.1183	1.0003	1.0003		77 77
0.00	%	0	1.88%	*				0

P Rtd	r	CRDh rated	Flowrated+err	hs Rtd
1000.69	62.4396	47.78	32,707.575	1192.91

TTL MFW Heat 37,454,488 BTU/hr

36,644,221 BTU/hr at rated conditions

Error

810,267 BTU/hr at rated CRD flow

Error in Rated MWt

CRDdp = 0.0062%

(NC	C.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALC	ULATION CONTINUATION SH	EET	SHEET:	14
CALC NO.:	SC-BB-0525 Attachment 6	REV:	5	REF:		CONT'D ON SHEET:	15
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A

7.2.3.4 Control Rod Drive Flow Enthalpy Heat Error due to Temperature Calibration Deviation (CRDht)

The plant computer calculates the CRD fluid enthalpy at a constant 77F and reactor pressure. However, the actual temperature varies and it is assumed to vary as much as 43F from the expected 77F; therefore, the effect due to this temperature deviation in the calculated enthalpy is:

<u>Ref. 3.4.5</u>

The heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error:

CRDht = [Flow (hs rated - CRDh rated) - Flow (hs rated - CRDh rated+err)] x 2.93E-07 / 3840 x 100%

TRtd	T Max/Min	T+err	P Rtd	h rated	h+err	hs rated	Flow
77	<u>40</u>	37	1000.69	47.78	7.99	1192.91	32,000

TTL RWCU Heat 37,917,380 BTU/hr

36,644,221 BTU/hr at rated conditions

Error

(1,273,159) BTU/hr at rated CRD flow

Uncertainty in Rated MWt CRDht = -0.0097%

This error is a bias, not a random instrument induced uncertainty.

((NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)	CALCULATION CONTINUATION SHEET SHEET:				15	
CALC NO .:	SC-BB-0525 Attachment 6	REV:	5	REF:		CONT'D ON SHEET:	16
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	le la la la la la la la la la la la la la	DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A

7.2.3.5 Control Rod Drive Flow Enthalpy Heat Error due to Pressure Loop Uncertainty (CRDhp)

The plant computer calculates the CRD fluid enthalpy at a constant 77Fand reactor loop pressure, that is affected by the loop uncertainty. The pressure loop uncertainty is documented in:

Ref.: 3.4.4

The heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error:

CRDhp = [Flow (hs rated - CRDh rated) - Flow (hs rated+err - CRDh rated)] x 2.93E-07 / 3840 x 100%

P Rtd	P+err	TRtd	CRDh rated	hs rated	hs rated+err	Flo	w	
1000.69	1006.79	77	47.78	1192.91	1192.0	69	32,000	Re
Error (psi) =	<u>6.1</u>		<u> </u>					
		TTL MFW Heat						-
		36,637,020) BTU/hr					R
	· · · · ·		-					
		36,644,221	BTU/hr at rated cor	nditions				R
		Error						
		(7,201	1) BTU/hr at rated CF	RD flow			<i>i</i> .	R
		the second second						-
	<u>I</u>	Incertainty in Rated	MWt					
	· ·	CRDhp	= -0.00005%	Aller .		· • • •	_ ·	R
							. ~	

(N	C.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCULATION CONTINUATION SHEET				
CALC NO.:	SC-BB-0525 Attachment 6	REV:	5	REF:	CONT'D ON SHEE	r: <u>17</u>	
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	DATE:	
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A	N/A	

7.2.4 Reactor Water Cleanup Uncertainty(ies)

Referring to the schematic drawing in section 4.0, it can be seen that RWCU flow is measured and mass calculated by a "NUMAC" process unit. Differential pressure, temperature, by dedicated thermocouples, and reactor pressure are an input to the instrument. Therefore, the RWCU contributed heat is affected by the following parameters:

a) Mass Flow Measurement affected by: 1) flow, 2) temperature, and 3) pressure induced factors/instrumentation loops errors

b) The RWCU Enthalpy determination is affected by: 1) temperature instrumentation loop error (see discussion for pressure)

The flow formula is derived from the ASME (Ref. 3.4.9) as follows:

Flow = C*K*(DP)^0.5

where K is:

K = Calib Flow / [C*(Calib inWC)^0.5]

-	(NC.E	DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		SHEET:	17			
	CALC NO.: SC-BB-0525 Attachment 6		REV:	5	REF:(CONT'D ON SHEET:	18
	ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
	Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A	_	N/A

7.2.4.1 RWCU Inlet/Outlet Flow Heat Error due to Flow Element Expansion deviation from Calibration (RWCUFa)

The Numac computer calculating the mass flow has a built-in Fa constant different than the flow element Fa provided at the calculated venturi rated temperature of 533F. This induces a bias error. Furthermore, the plant NUMAC normalizes the flow mass signal to a specific weight of 47.0 lbm/cuft for pressure and temperature conditions, back calculated below; therefore, the rated conditions are set at 530.8F.

Pressure Density Compensated to :	48.00 lb/cuft	517.9 F	<u>908 psia</u>
The Fa used in the calculation is fixed to:		1.0045	
The correct Fa at rated 533 F is:		1.0087	

Based on the Fa differences the induced flow error is calculated below:

Fa = FE Thermal Expansion

Ref.: 3.4.10

Flow+err = C x Fa+err / Fa x K x (DP)^0.5

			K = 9	448.61			
			Calib Flow = 1	89797.2 lb/hr	<u>500 GPM</u>	(Note)	
Fa Error			Calib inWC = 4	03.5			
Rated 533F	1.0087	Assun	ned Calib Temp = 5	30.8			
Calibrated	1.0045	Assun	ned Calib Press = 1	114.7			
			r = 4	7.326			
* *		Assur	ned Rated Flow = 1	48000 lb/hr	389 GPM		
1			Rated h = 5	10 A	, algebraider zu ersteret, febr		
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	T+err
1.0000	1.0000	245.3519	245.3519	1.0087	1.0045	530.8	3 530.8
0.00%	÷ 0	0.00%	÷ 0				0
	· · ·				,		·
P Rtd	P+err	r	h Rtd	Flow+err			
1114.7	1114.7	47.3259	524.95	147,384			
	0						
and an an an an an an an an an an an an an		Uncertainty RWCUFa -6	5 16.2 lb/hr T	his a bias and the a	actual contributed Heat	is Higher than indicat	ed
· · · · · · · · · · · · · · · · ·							

(NC	(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)			ULATION CONTINUATION SHEE	ET SH	EET:	18
CALC NO.:	CALC NO.: SC-BB-0525 Attachment 6		5	REF:	CONT'D O N SI	EET:	19
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	DATE:	
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A	N/A	

7.2.4.2 RWCU Inlet/Outlet Flow Heat Error due to Fluid Specific Weight deviation (RWCUPMA)

This error is the combination of several uncertainties calculated below:

7.2.4.2.1 RWCU Inlet/Outlet Flow Error due to Fluid Specific Weight Numac Lookup Tables Error (RWCUPMA1)

The Numac performs the fluid specific weight determination with an error of 0.1 specific weight, this effect in the flow is calculated below.

r = Fluid Specific Weight

Ref.: 3.4.10

Flow+err = $C \times K \times (DP \times r+err / r)^{0.5}$

The flow error is the difference between the rated flow at rated specific weight minus the flow at specific weight plus error:

RWCUPMA1 = Flowrated - Flowrated+error

			K = 9	9448.61					
			Calib Flow = 1	189797.2 lb/hr	500 GPM	(Note)			
Fa Error		Calib in WC = 403.5							
Rated 533F	1.0087	Assur	Assumed Calib Temp = 530.8						
Calibrated	1.0045	Assumed Calib Press = 1114.7							
			r = 4						
		Assur	med Rated Flow = 1	Rated Flow = 148000 lb/hr					
			Rated hout = 5	524.95 btu/lb					
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err		T Rtd		
1.0000	1.0000	245.3519	245.3519	1.0087		1.0087		530.8	
0.00%	0	0.00%	\$ 0						

	P Rtd	P+err	r	Numac err	r+perr+Numac	h Rtd	Flow
ļ	1114.7	1114.7 psi	47.32		47.426	524.95	148,157
		0 psi					

Uncertainty	
RWCUPMA1 = 1	56.3 lb/hr

(N	C.DE-AP_ZZ-0002(Q), Rev. 12, Form 2)		CALCULATION CONTINUATION SHEET				
CALC NO.:	SC-BB-0525 Attachment 6	REV:	5	REF:		CONT'D ON SHEET: 2	20
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	DATE:	
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A	N/A	

7.2.4.2.2 RWCU Inlet/Outlet Flow Error due to Fluid Specific Weight Numac 0.75 Factor Pressure Correction Factor Error (RWCUPMA2)

The Numac computer introduces a 0.75 factor to the input pressure raw value and calculates the specific weight for saturated conditions, which bias the actual flow.

Ref.: 3.4.10

Flow+err = $C \times K \times (DP \times r + err / r)^{0.5}$

The flow error is the difference between the rated flow at rated specific weight minus the flow at specific weight plus error:

RWCUPMA2 = Flowrated - Flowrated+error

r = Fluid Specific Weight

			K = 94				
`			Calib Flow = 18	9797.2 lb/hr 5	500 GPM	(Note)	
Fa Error			Calib in WC = 40	3.5			
Rated 533F	1.0087	Assum	ed Calib Temp = 53	8.0			
Calibrated	1.0045	Assum	ed Calib Press = 11	14.7			
			r = 47	.326			
and the second second second second second second second second second second second second second second second		Assum	88.8 GPM				
			Rated = 52	4.95 btu/lb			
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	
1.0000	1.0000	245.3519	245.3519	1.0087	1.0087	53	30.8
0.00%	0	0.00%	• 0	· · ·			
	· · · · · · · · · · · · · · · · · · ·				•		

P Rtd	P+err	TSat	r+perr	Numac rerr	r+perr+Numac	h Rtdout	h Rtd return	Flow
1114.7	840 psi	523.8	47.5895	0	47.5895	524.95	396.90	148,412
	75%	75						

Uncertainty RWCUPMA2 = -412 lb/hr

This a bias and the actual contributed Heat is Higher than indicated

(NC	(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)			CALCULATION CONTINUATION SHEET				
CALC NO.:	SC-BB-0525 Attach	ment 6	REV:	5	REF:	co	NT'D ON SHEET:	21
ORIGINATOR:	Ĺ	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2	2/14/2017	John Wilkens		3/13/2017	N/A		N/A

7.2.4.2.3 RWCU Inlet/Outlet Flow Heat Error due to Fluid Specific Weight Pressure Loop Uncertainty (RWCUP_SW)

Pressure is utilized as an input to the Numac to determine the specific weight of the fluid. The pressure loop uncertainty combined with the Numac computer uncertainty introduces an error in the calculated specific weight.

The loop error is comprised of 1) pressure loop, PT, 2) NUMAC computer uncertainties. The combined uncertainties are:

RWCUpress error= 21 psi

Ref.: 3.4.10

Flow+err = $C \times K \times (DP \times r+err / r)^{0.5}$

The flow error is the difference between the rated flow at rated specific weight minus the flow at specific weight plus error:

 $RWCUp_SW = [Flowrated (h_in - h_out) - Flowrated+error (h_in - h_out)] \times 2.93E-07 / 3840 \times 100\%$

r =	Fluid Specific Weight		К=	9448.61		
			Calib Flow =	189797.2 lb/hr	500 GPM	(Note)
Fa Error			Calib inWC =	403.5		
Rated 533F	1.0087	Assi	med Calib Temp =	530.8		
Calibrated	1.0045	Assi	umed Calib Press =	1114.7		
			r =	47.326		
		Ass	umed Rated Flow =	148000 lb/hr	388.8 GPM	
			Rated h =	524.95 btu/lb		
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd in
1 0000	1 0000	245 3510	245 3510	1 0087	1 0087	530.8

C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd in	T Rtd out
1.0000	1.0000	245.3519	245.3519	1.0087	1.0087	530.8	419.4
0.00%	: 0	0.00%	• 0				

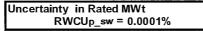
P Rtd	P+err	r+perr Num	ac rerr r+perr+Numac	h Rtd in	h Rtd out	Flow
1000.69	1022 psi	47.2624	0 47.2624	509.23	396.90	147,901

TTL MFW Heat 16,614,845 BTU/hr

16,626,013 BTU/hr at rated conditions

Error

11,168



(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		v. 12, Form 2) CALCULATION CONTINUATION SHEET				SHEET:	21
CALC NO.: SC-BB-0525 Attachment 6		REV:	5	REF:		CONT'D ON SHEET:	22
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	D	ATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A	N	/A

7.2.4.3 Reactor Water Cleanup Flow Error due to Flow Element Uncertainty (RWCUc)

The RWCU flow is affected by the FE error that is assigned to the flow element expansion coefficient.

С

The FE uncertainty is determined based in calculation:

Ref.: 3.4.10

. .

Flow+err = C+err x K x (DP)^0.5

The flow error is the difference between the rated flow minus the flow with the C coefficient error:

RWCUc = Flowrated - Flowrated+error

Fa Error			K = 94	48.61			
Rated 533F	1.0087		Calib Flow = 18		500 GPM	(Note)	
Calibrated	1.0045		Calib inWC = 40				
			ied Calib Temp = 53				
		Assum	ed Calib Press = 11	14.70			
			r = 47	7.33			
		Assun	ned Rated Flow = 14	8000 lb/hr 3	389 GPM		
			Rated h = 52	4.95 btu/lb			
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	T+err
1.0000	1.0150	245.3519	245.3519	1.0087	1.0087	530.8	530.8
1.50%	<u>: 150</u>	0.00%	; 0				• 0
P Rtd	r	h	Flow				
1114.7	47.3259	525.0	150,220				

Uncertainty RWCUc = 2220.0 lb/hr

(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCU	ILATION CONTINUATION	SHEET	SHEET:	22
CALC NO.:	SC-BB-0525 Attachment 6	REV:	5	REF:		CONT'D ON SHEET:	23
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFLER;	DA	TE:
Michael Miller	2/14/201	7 John Wilke	ens	3/13/2017	N/A	N	A

7.2.4.4 Reactor Water Cleanup Flow Error due to Differential Pressure (DP) Loop Uncertainty (RWCUdp)

This error is introduced by the differential pressure instrument loop. The uncertainties in the loop are found in: Ref.: 3.4.10

The loop is comprised of 1) flow transmitter, FT, 2) NUMAC computer. The uncertainties are in % DP span:

The flow error is the difference between the rated flow minus the flow with the C coefficient error:

RWCUdp = Flowrated - Flowrated+error

Accuracy:			Loop Drift:		
RWCU_AFT	RWCU_ANU_IE	RWCU_ANU_A/D	RWCU_VDFT	RWCU_VDNU_IE	RWCU_VDNU_A/D
0.503%	0.100%	0.233%	0.900%	0.127%	0.127%

Loop Calibration:

RWCU_CEFT	RWCU_CENU_A/D
0.139%	0.02%

The uncertainties are random and independent and combined by the SRSS method:

1.09% span DP

Flow+err = $C \times K \times (DP+err)^{0.5}$

Fa Error Rated 533F Calibrated	1.0087 1.0045	Assu	Calib Flow = Calib inWC = Imed Calib Temp = Imed Calib Press = r = Imed Rated Flow =	403.50 530.80 1114.70 47.326	500 GPM 389 GPM	(Note)	
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	T+err
1.0000	1.0000	245.3519	249.7337	1.0087	1.0087	530.8	530.8
0.00%	0						¢0
P Rtd	r	h	Flowrated+err				
1114.7	47.3259	524.95	149,316				
-	Г	Uncertainty					

RWCUdp = 1315.7 lb/hr

(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCULATION CONTINUATION SHEET				SHEET:	23	
CALC NO .:	SC-BB-0525 Attac	hment 6	REV:	5	REF:		CONT'D ON SHEET	24
ORIGINATOR:		DATE:	REVIEWER:		DATE:	VERIFIER:	······································	DATE:
Michael Miller		2/14/2017	John Wilkens		3/13/2017	N/A	•	N/A

7.2.4.5 Reactor Water Cleanup Flow Error due to Signal Conditioning/NSSS Computer Loop Uncertainty (RWCUNSSS_cptr)

The differential pressure is converted to flow by the Numac computer and retransmitted as flow signal to the plant computer for heat balance calculations.

This portion of the loop is comprised of 1) NUMAC computer output, 2) NSSS computer uncertainty. The uncertainties are in % flow span:

	Accuracy:						
1	RWCU_ANU_D/A	RWCU_AA/D	-				
	0.233%	0.188%					

Loop Drift:				
RWCU_VDNU_D/A	RWCU_VNA/D			
0.13%	0.000%			

Loop Calibration:

.188%
)

The uncertainties are random and independent and combined by the SRSS method:

0.38% span FLOW

0.3076|\$Pail1 EOW

The flow error is the difference between the rated flow at without loop error minus the flow plus loop error:

RWCUNSSS_cptr = Flowrated - Flowrated+error

Fa Error			K = 9	448.61			
Rated 533F	1.0087		Calib Flow = 1	89797.2 lb/hr 5	500 GPM	(Note)	
Calibrated	1.0045		Calib inWC = 4	03.50	, -	. ,	
		Assum	ed Calib Temp = 5	30.80			
		Assum	ed Calib Press = 1	114.70			
			r = 4	7.33			
	•	Assum	ed Rated Flow = 1	48000 lb/hr 3	389 GPM		
			Rated h = 5	24.95 btu/lb		с.	
C Rtd	C+err	DP Rtd	DP+err	Fa Rtd	Fa+err	T Rtd	T+err
1.000		245.3519	245.3519	1.0087	1.0087	530.8	530.8
0.00	6 🗧 0						0
		· · ·					<u>.</u>
P Rtd	r	h	Flow				
1114.	7 47.3259	524,95	148.714.0				

 III III III IIII		1 · · · · · · · · · · ·
	2	· .
· · · · · · · · · · · · · · · · · · ·	Uncertainty	1
R	WCUNSSS_cptr= 71	3.7 lb/hr

(NC	.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCU	LATION CONTINUATION S	HEET	SHEET:	24
CALC NO.:	SC-BB-0525 Attachment 6	REV:	5	REF:		CONT'D ON SHEET:	25
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:	C	ATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A	1	N/A

7.2.4.6 Reactor Water Cleanup Total Flow due to Flow Loop Uncertainties (RWCUf)

RWCU Inlet h - Outlet h.

The total RWCU Flow Uncertainty is calculated below:

RWCUfu =+/-SQRT(RWCUPMA1^2+RWCUc^2+RWCUdp^2+RWCUNSSS_cptr^2)-RWCUFa-RWCUPMA2

Notice that the bias PMAs are factored with both signs, since the negative uncertainty is the one that has impact in the heat balance calculations, that is, that (-) less indication means that power is higher; however, it will be factored in both directions for simplicity.

RWCUfu = 3710 lb/hr

Then, the heat error contribution is the calculated inlet flow heat error minus the outlet flow heat error:

RWCUh_in = 509.23 btu/lb RWCUh_out = 396.90 btu/lb

And the RWCU heat error contribution is calculated by the following expression:

RWCU = [RWCUfu (RWCUh_in - RWCUh_out) x MWt_BTU_hr (conversion factor)]/Rated MWt 100%

RWCUf = 0.0032%

This total error will be treated as bias in the total heat balance error

(N	C.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCULATION	CONTINUATION SHEE	T	SHEET:	25
CALC NO .:	SC-BB-0525 Attachment 6	REV:	5	REF:		CONT'D ON SHEET:	26
ORIGINATOR:	DATE	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017	N/A		N/A

7.2.4.7 Reactor Water Cleanup Flow Enthalpy Heat Error due to Temperature Uncertainty (RWCUht)

This error is the error resultant of temperature measurement errors by the inlet/outlet RWCU thermocouple loops factored into the fluid enthalpy determination. The thermocouples are instruments with good repeatability and stability. However, fabrication errors can amount to several farenheit degrees. The fabrication errors can be calibrated out, since essentially it is a bias, systematic error. The temperature loops for RWCU are not calibrated out. Finally, since most of the thermocouples loop error is a bias, the conservative and safe way to apply the error, is for the two temperature error to be set in the same direction; therefore, the effect is additive, bias. The temperature loops error is found in:

<u>Ref. 3.4.6</u>

The heat error is the difference between the inlet flow heat error minus the outlet flow heat error:

RWCUht = [Flow [(hin - hin+error) + (hout - hout+error)]] x 2.93E-07 / 3840 x 100%

 In flow heat
 TRtd
 T+err
 P Rtd
 h rated
 h+err
 Flow

 517.9
 528.8
 1000.69
 509.23
 522.62
 148,000

 Error (F)
 10.9
 10.9
 10.9
 10.9
 10.9
 10.9

Out flow heat

TRtd	T+err	P Rtd	h rated	h+err	Flow
419.4	430.3	1000.69	396.90	408.79	148,000
Error (F)	10.9				

Error 3,741,250 BTU/hr error at rated reactor water cleanup flow

Uncertainty in Rated MWt RWCUht = 0.0285%

This error is a bias

(NC.D	DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALC	ULATION CONTINUATION SHEET	SHEET:	26
CALC NO .:	SC-BB-0525 Attachment 6	REV:	5	REF:	CONT'D ON SHEET:	27
ORIGINATOR:	DATE:	REVIEWER:		DATE: VER	FIER:	DATE:
Michael Miller	2/14/2017	John Wilkens		3/13/2017 N/A		N/A

7.2.4.8 Reactor Water Cleanup Flow Enthalpy Heat Error due to Pressure Loop Uncertainty (RWCUhp)

The reactor water cleanup enthalpy determination is affected by the loop pressure error. The pressure has a very small effect in the water enthalpy, however, it is determined in this calculation. The loop uncertainty is documented in:

Ref.: 3.4.4

The heat error is the difference in the CRD flow heat content at rated flow conditions minus the heat error content at rated conditions plus error:

RWCUhp = [Flow [(hin - hin+error) - (hout - hout+error)]] x 2.93E-07 / 3840 x 100%

In flow heat

P Rtd	P+err	TRtd	h rated	h+err	Flow
1000.69	1020.89	517.9	509.23	509.22	148,000
Error (psi)	20.2				·

Out flow heat

P Rtd	P+err	TRtd	h rated	h+err	Flow
1000.69	1020.89	419.4	396.90	396.92	148,000
Error (psi)	20.2			-	

Error

5,768 BTU/hr at rated reactor water cleanup flow

Uncertainty in Rated MWt RWCUhp = 0.00004%

(NC	DE-AP.ZZ-0002(Q), Rev. 12, Form 2)	CALCULATION CONTINUATION SHEET SHEET:			
CALC NO .:	SC-BB-0525 Attachment 6	REV: 5	REF:	CONTO ON SHEET:	28
ORIGINATOR:	DATE	REVIEWER:	DATE: VERIFIER	: :	DATE:
Michael Miller	2/14/2017	John Wilkens	3/13/2017 N/A		N/A

7.2.5 Recirculation Pumps Heat Error due to Watts Loop Uncertainty (RRPw)

This section calculates the uncertainty due to RRP watts loop error, calculated in:

Ref.: 3.4.11

The rated power for the pump-motor and the motor efficiency (0.93) is from reference:

(Ref. 3.4.3)

There are two recirculation pumps, the calculated error below is per pump. The actual total MW for the 2 pumps is taken from above reference.

W 2 pump = 7.33

The Watt error contribution is calculated as follows:

RRPw = [(W Rtd/pump + MW Loop Span x Span err) x Mottor eff] - W Rtd/pump x Motor eff] / 3840 x 100%

W Rtd/pmp+err	Motor Eff	W+err
3.823	0.93	3.55
	Error =	1.50 % span
	Span =	10.5 Mwatt
1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1		TTL Mwatt
÷ +- +		341 N

Error

0.1465 Mwatt

Uncertainty in Rated MWT RRPw = 0.0038%

(NC	DE-AP.ZZ-0002(Q), Rev. 12, Form 2)		CALCU	JLATION CONTINUATION S	HEET	SHEET:	28
CALC NO.:	SC-BB-0525 Attachment 6	REV:	5	REF:		CONT'D ON SHEET:	29
ORIGINATOR:	DATE:	REVIEWER:		DATE:	VERIFIER:		DATE:
Michael Miller	2/14/2017	John Wilker	ıs	3/13/2017	N/A		N/A

7.2.6 Thermal Loses (TL)

This section calculates the uncertainty due to TL error. This error will be treated as a bias error since the estimated value is larger or smaller than assumed, i.e. it is a fixed error not a random error.

An assumed error equal to 20% of the specified loses is used.

The rated Heat Loss is from reference:

(Ref. 3.4.2)

W Rtd	W+err
1.1	1.32
Error =	20.00%

TTL Mwatt Heat	1
1.32	мw

1.10 MW at rated conditions

Error

0.2200 MW error at rated radiated loses

Uncertainty in Rated MWT	This error is treated as bias.
TL = 0.006%	

Note: The computer utilizes this value combined with Other System Loses (Section 7.2.7) as Radiative power loses, QRAD = 1.94

(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)				CALCULATION CONTINUATION SHEET			SHEET:	29
CALC NO .:	SC-BB-0525 Attac	nment 6	REV:	5	REF:		CONT'D ON SHEET:	30
ORIGINATOR:		DATE:	REVIEWER:		DATE:	VERIFIER:	C	DATE:
Michael Miller	· · · · ·	2/14/2017	John Wilkens		3/13/2017	N/A	1	N/A

7.2.7 Other System Loses (OSL)

The rated value includes Rod Drive seal purge flow to recirculation pumps. An assumed error equal to 20% of the specified loses is used. This error will be treated as a bias error since if the estimated value is larger or smaller than assumed, i.e. it is a fixed error not a random error.

The rated Losses figure is from reference:

(Ref. 3.4.2)

W Rtd W+err 1.18 1 Error = 20%	416	Rev 5
	TTL Mwatt Heat	
	1.42 MW	Rev 5
	1.18 MW at rated conditions	Rev 5
	Error 0.2360 MW error at rated radiated loses	Rev 5
	Uncertainty in Rated MWT OSL = 0.006% This error is treated as bias.	Rev 5

Note: The computer utilizes this value combined with Thermal Loses (Section 7.2.6) as Radiative power loses, QRAD = 1.94

(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)			CALCULATION CONTINUATION SHEET			Т	SHEET:	30
CALC NO.:	SC-BB-0525 Attachm	ent 6	RE :	5	REF:	CONT'D	ON SHEET:	31
ORIGINATOR:	DA	TE:	RE IEWER:		DATE:	VERIFIER:	10	DATE:
Michael Miller	2/	14/2017	John Wilkens		3/13/2017	N/A		N/A

7.2.8 Heat Balance Calculation Power Uncertainty (Power U)

The calculated heat balance uncertainty is the algebraic combination of the bias errors with the independent/random errors statistically combined, that contribute into the heat balance calculation, in accordance with the heat balance formula:

Power = MFW(MSh-FWh)-CRDF(hin-hout)+RWCU(hout-hin)-RRP+HL+Miscellaneous

Summary of Heat Balance Calculation Contributing Errors:

Random Errors:	FWm = 0.3548% FWht = 0.1775% MSm = 1.4017% MSmoist = 0.0000%	
	CRDc = 0.0054% CRDdp = 0.0062% RRPw = 0.0038% RWCUp sw = 0.0001%	
Dependent Errors:	Errors FWhp = 0.0012% MShp = 0.0253% CRDhp = -0.00005% RWCUhp = 0.00004%	<u>Variable</u> Rated MS pressure = 1001 psia
Bias Errors:	CRDt = -0.0012% CRDht = -0.0097% RWCUf = 0.0032% RWCUht = 0.0285% TL = 0.006% OSL = 0.006%	

Heat Balance Calculation Power Error (U):

Power Error = SQRT[(MSm-FWm)^2+(MShp-FWhp+CRDhp+RWCUhp)^2+FWht^2+MSmoist^2+CRDc^2+CRDdp^2+ +RWCUp_sw^2+RRPw^2x2]+CRDt+CRDht+RWCUf+RWCUft+TL+OSL

Power Error = 1.095%

To ensure operation margin exist, due to possible instrumentation loops miss-calibration, actual drift (to be determined by history), etc., a margin is added:

Power U = Power Error + Margin

where margin is defined as 2.0% (SET POWER U) - Power Error

and

Margin = 0.905%

Power U = 2.000%

Rev 5

Rev 5

(NC.DE-AP.ZZ-0002(Q), Rev. 12, Form 2)				CALCULATION CONTINUATION SHEET				SHEET:	31		
CALC NO.:	SC-BB-0525 Attach	nment 6	REV:	5		REF:			CONT'D ON SHEET:	N/A	4
ORIGINATOR:	- · ·	DATE:	REVIEWER:			DATE:	VERIFIEF	د		DATE:	
Michael Miller	14 . j.	2/14/2017	John Wilken	S		3/13/2017	N/A			N/A	

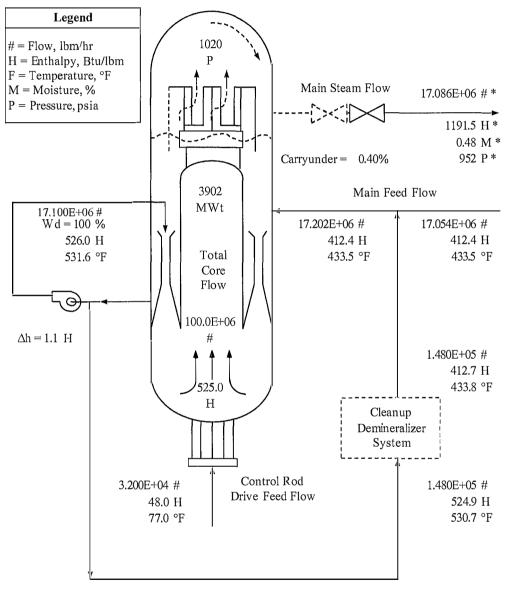
8.0 SUMMARY

The calculated Heat Balance Error performed in this calculation is applicable to the hand calculation error when determined process values and steam tables heat values are used with an accuracy of 3 decimal places. This results are applicable to hand calculated heat balance since less hardware errors are involved in the hand calculation, data collection. The Heat Balance calculation error (Section 7.0) is:

Power U = 2.000%

SC-BB-0525 Attachment 7 Page 1 of 1

Figure 3-2: Reactor Heat Balance – TLTP (101.6% of CLTP) $[T_{FW} = 433.5^{\circ}F / P_{DOME} = 1020 \text{ psia}]$



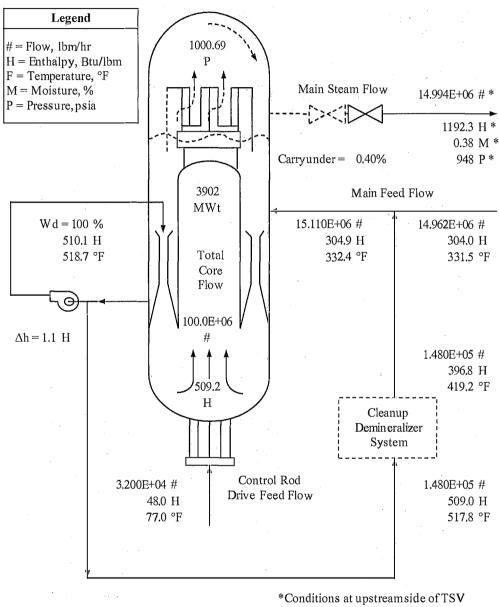
*Conditions at upstream side of TSV

з

Core Thermal Power	3902.0
Pump Heating	10.7
Cleanup Losses	-4.9
Other System Losses	-2.6
Turbine Cycle Use	3905.2 MWt

SC-BB-0525 Attachment 8 Page 1 of 1

Figure A-1 Reactor Heat Balance at 100%TLTP / 100%F Reduced FW Temperature



Core Thermal Power	3902.0	
Pump Heating	10.7	
Cleanup Losses	-4.9	
Other System Losses	-2.6	
Turbine Cycle Use	3905.2 MWt	