ATTACHMENT 3
Exelon Generation Company, LLC Calculation LE-0113, Rev. 1, "Reactor Core Thermal Power Uncertainty Calculation Unit 1"

Exelon.

Design Analysis Major Revision Cover Sheet

Design Analysis (Major Revision)

Last Page No.: [6] 94

Analysis No.: [1] LE-0113 **Revision:** [2] 1

Title: [3] Reactor Core Thermal Power Uncertainty Calculation Unit 1

EC/ECR No.: [4] LG 09-00096 **Revision:** [5] 1

Station(s): [7] Limerick

Unit No.: [8] 1

Discipline: [9] LEDE

Descrip. Code/Keyword: [10] N/A

Safety/QA Class: [11] N

System Code: [12] 006,041,042,043,044,047

Structure: [13] N/A

Component(s): [14]

CONTROLLED DOCUMENT REFERENCES [15]

Document No.:	From/To	Document No.:	From/To
LEAE-MUR-0001	From	LM-562	From
LM-0552	From	L-S-15	From
LM-553	From	L-S-19	From
LE-0116	From	L-S-36	From
LEAM-MUR-0038	To	LEAM-MUR-0046	To
LEAM-MUR-0039	To	LEAM-MUR-0041	To
LEAM-MUR-0048	To		

Is this Design Analysis Safeguards Information? [16] Yes ☐ No ☒ If yes, see SY-AA-101-106

Does this Design Analysis contain Unverified Assumptions? [17] Yes ☐ No ☒ If yes, ATI/AR#:

This Design Analysis SUPERCEDES: [18] **LE-0113 Revision 0** **In its entirety.**

Description of Revision (list affected pages for partials): [19] This revision incorporates the revised uncertainty number from LEAE-MUR-0001 (Caldon ER-739) and the revised parameter values at MUR rated power from GEH task report T0100. Although this is a major revision, the changes themselves are not significant with regard to the final result. This calculation is prepared to support a License Amendment Request for an increase in licensed power so there is no effect on any operating margin. All pages reformatted and reprinted. Changes to text on pages 1-2, 4-8, 18, 21-22, 24-25, 33-34, 40, 43-44, 48-49, 52-58, 60-61. Replaced Att. 5 (p. 70-75) & Att. 6 (p. 76).

Preparer: [20] Patricia A. Ugorcak (Print Name) Patricia A. Ugorcak (Sign Name) 3-3-2010 (Date)

Method of Review: [21] **Detailed Review** ☒ **Alternate Calculations (attached)** ☐ **Testing** ☐

Reviewer: [22] John Pehush (Print Name) John Pehush (Sign Name) 3-3-2010 (Date)

Review Notes: [23] Independent review ☒ Peer review ☐

Performed a line by line review of the calculation and verified revised design input were correctly incorporated. All comments were resolved to the satisfaction of the reviewer. This calculation supports the MUR by reducing the measurement uncertainty of Core Thermal Power from 2.0 % to 0.35 %.

(For External Analyses Only)

External Approver: [24] Richard Brusato (Print Name) John Pehush. for Richard Brusato (Sign Name) 3-4-2010 (Date)

Exelon Reviewer: [25] Niranjan Roy (Print Name) (Sign Name) 3-12-10 (Date)

Independent 3rd Party Review Reqd? [26] ~~Yes ☒~~ No ☒ No ITPR for R1 ATG

Exelon Approver: [27] Raymond George (Print Name) (Sign Name) 3/16/2010 (Date)

CC-AA-309
Revision 9

ATTACHMENT 1
Owners Acceptance Review Checklist for External Design Analysis

DESIGN ANALYSIS NO. LE-0113 **REV.** 1

		Yes	No	N/A
1.	Do assumptions have sufficient rationale?	☑	☐	☐
2.	Are assumptions compatible with the way the plant is operated and with the licensing basis?	☑	☐	☐
3.	Do the design inputs have sufficient rationale?	☑	☐	☐
4.	Are design inputs correct and reasonable with critical parameters identified, if appropriate?	☑	☐	☐
5.	Are design inputs compatible with the way the plant is operated and with the licensing basis?	☑	☐	☐
6.	Are Engineering Judgments clearly documented and justified?	☑	☐	☐
7.	Are Engineering Judgments compatible with the way the plant is operated and with the licensing basis?	☑	☐	☐
8.	Do the results and conclusions satisfy the purpose and objective of the Design Analysis?	☑	☐	☐
9.	Are the results and conclusions compatible with the way the plant is operated and with the licensing basis?	☑	☐	☐
10.	Does the Design Analysis include the applicable design basis documentation?	☑	☐	☐
11.	Have any limitations on the use of the results been identified and transmitted to the appropriate organizations?	☐	☐	☑
12.	Are there any unverified assumptions?	☐	☑	☐
13.	Do all unverified assumptions have a tracking and closure mechanism in place?	☐	☐	☑
14.	Have all affected design analyses been documented on the Affected Documents List (ADL) for the associated Configuration Change?	☑	☐	☐
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)	☑	☐	☐
16.	Have vendor supporting technical documents and references (including GE DRFs) been reviewed when necessary?	☑	☐	☐
17.	Have margin impacts been identified and documented appropriately for any negative impacts (Reference ER-AA-2007)?	☐	☐	☑

EXELON REVIEWER: NIRANJAN ROY / **DATE:** 3-12-10
Print / Sign

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1.0 PURPOSE

The purpose of this calculation is to determine the uncertainty in the reactor core thermal power (heat balance) calculation performed by the Plant Process Computer (PPC). This calculation will evaluate the contribution of the different instrument channel loop uncertainties to the uncertainty of the Core Thermal Power (CTP) value using the reactor heat balance relationship when the plant is operating at 100% rated power under steady state conditions.

This calculation is being performed in support of the licensing amendment for Measurement Uncertainty Recapture (MUR) power uprate. The calculation provides the uncertainty in the value of CTP calculated by the Plant Process Computer at MUR rated conditions for use in requesting an increase in the CTP licensing limit for Limerick Generating Station Unit 1. Therefore, there are no acceptance criteria. The number is simply stated for use in preparation of the License Amendment Request.

1.1 FUNCTIONAL DESCRIPTION AND CONFIGURATION

Limerick Generation Station (LGS) Unit 1 will be installing highly accurate ultrasonic feedwater flow meters per Engineering Change Request (ECR) LG 09-00096. This calculation will determine the uncertainty in Core Thermal Power calculation when the reactor heat balance is performed using the process computer with the feedwater flow and temperature measurement input supplied by the Caldon® Leading Edge Flow Meters Check Plus (LEFM✓+) System Ultrasonic Flow Meters (UFM).

2.0 DESIGN BASIS

Various plant parameters are monitored by the NSSS computer to develop the reactor core thermal power calculation. On June 1, 2000 Appendix K to Part 50 of Title 10 of the Code of Federal Regulations was changed to allow licensees to use a power uncertainty of less than 2 % in their LOCA analysis. The change allowed licenses to recapture power by using state-of-art devices to more precisely measure feedwater flow. Feedwater flow inaccuracy is a large contributor in the uncertainty determination of reactor power. This calculation is being performed in the support of a License Amendment Request (LAR) for a MUR power uprate.

2.1 INPUTS

Table 2-1 lists the parameters which specify input to the core thermal power calculation, their uncertainty values, and the source of these values.

The values for Feedwater Flow, Feedwater Temperature, and Reactor Narrow Range Dome Pressure are specified by separate calculations as follows (Ref. 4.8.6 thru 4.8.8):

- LEAE-MUR-0001, Bounding Uncertainty Analysis for Thermal Power determination
- LE-0116, Reactor Dome Narrow Range Pressure Measurement Uncertainty

The uncertainties for Reactor Water Clean-up (RWCU) Flow Rate, RWCU Inlet Temperature Thermocouple, Control Rod Drive (CRD) Flow Rate, and Recirculation Pump Power are calculated in individual sections of this calculation. Recirculation Pump Efficiency is given in calculation LM-0552 (Ref. 4.8.2). The thermal loss due to radiated heat loss to the drywell is specified by separate calculation LM-553 (Ref. 4.8.3) for calculating the reactor heat balance by hand.

Other inputs and the related source references are listed in the Table 2-1.

Table 2-1.
Design Inputs

Description	Inst. Tag No.	Computer Point	Nominal Value	Uncertainty	Uncertainty Basis
CRD Enthalpy	N/A	N/A	68.00 Btu/lbm (Ref. 4.9.10)	± 0.005 Btu/lbm	(Ref. 4.9.3)
CRD Water Flow Discharge Temperature	TE-046-103	A1201	97.2 °F (Ref. 4.9.10)	± 0.7 °F	(Ref. Attachment 1)
CRD Water Flow Rate	FT-046-1N004	A1711	Nominal Flow 0.0320 Mlbm/hr (Ref. 4.9.10)	± 0.0017 Mlbm/hr	(Section 7.5.6)
Feedwater Enthalpy	N/A	N/A	405.30 Btu/lbm (Ref. 4.9.10)	± 0.005 Btu/lbm	(Ref. 4.9.3)
Feedwater Mass Flow Rate (LEFM ✓+ System)	10-C986	N/A	15.255 Mlbm/hr (Ref. 4.9.10)	± 0.28 %	(Ref. 4.8.6)
Feedwater Pressure	N/A	N/A	1155 PSIG (Ref.4.4.1)	± 10 psi	(Section 3.11)
Feedwater Temperature	TE-006-1N041A-F	A1744 thru A1750	427.1 °F (Ref. 4.9.10)	± 0.57 °F	(Ref. 4.8.6)
Radiated Reactor Pressure Vessel (RPV) Heat Loss	N/A	N/A	0.89 MW (Ref. 4.8.3, Sec. 2.0)	± 10 %	(Section 3.12)
Reactor Dome Pressure	PT-042-1N008	E1234	1060 PSIA (Ref. 4.9.10)	± 20 psi	(Ref. 4.8.8)
Saturated Steam Enthalpy	N/A	N/A	1190.0 Btu/lbm (Ref. 4.9.10)	± 0.85 Btu/lbm	(Section 7.7.2.2)
Recirculation Pump Motor efficiency	1A(B)-P201	N/A	94.8 % (Attachment 10 & Ref. 4.8.2)	N/A	N/A
Recirculation Pump Motor Power	1A(B)-P201	N/A	7700 Hp (5.74 MW) (Ref. 4.3.3)	± 1.4 %	(Section 7.6.8)
RWCU Discharge Enthalpy	N/A	N/A	418.40 Btu/lbm (Ref. 4.9.10)	± 0.005 Btu/lbm	(Ref. 4.9.3)

Table 2-1.
Design Inputs

Description	**Inst. Tag No.**	**Computer Point**	**Nominal Value**	**Uncertainty**	**Uncertainty Basis**
RWCU Discharge Temperature	TE-044-1N015	A1742	439 °F (Ref. 4.9.10)	± 4.37	(Section 7.4.6)
RWCU Inlet Flow Rate	FT-044-1N036A	A1718	0.1540 Mlbm/hr Ref. 4.9.10)	± 0.0035 Mlbm/hr	(Section 7.3.6)
RWCU Regen Heat Exchanger Inlet Temperature	TE-044-1N004	A1741	535.3 °F (Ref. 4.9.10)	± 4.37 °F	(Section 7.4.6)
RWCU Suction Enthalpy	N/A	N/A	530.6 Btu/lbm (Ref. 4.9.10)	± 0.005 Btu/lbm	(Ref. 4.9.3)

2.2 REACTOR WATER CLEANUP (RWCU) FLOW LOOP UNCERTAINTY

2.2.1 Reactor Water Cleanup System Equipment Design Data (Ref. 4.3.4)

System flow rate (lbm/hr)

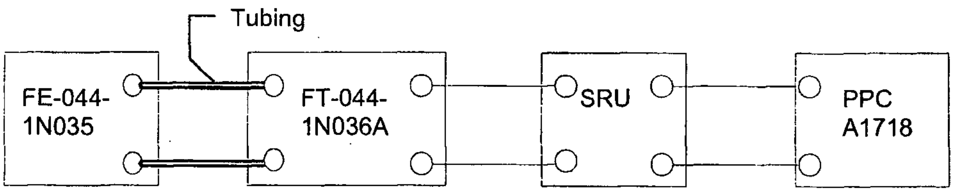
Normal operation "A" pump	154,000
Normal operation "B" plus "C" pump	133,000

Main Cleanup Recirculation Pumps	"A" Pump	"B" & "C" Pumps
Number required	1	2
Capacity, % (each)	100	50

"A" pump capacity is greater that the combined capacity of the "B" and "C" pumps

2.2.2 RWCU Flow Measurement Loop Diagram

RWCU flow is measured by an orifice plate (FE-044-1N035) located on the suction side of the RWCU Recirculation Pumps, which provides a ΔP signal to a Rosemount transmitter (FT-044-1N036A). The transmitter supplies a milliamp signal to the PPC for display in the Control Room. The instrument loop consists of the following: flow element, flow transmitter, a signal resistance unit and a PPC input/output (I/O) module. The loop configuration is shown below (Ref. 4.5.10):



The loop components evaluated in this document (the applicable performance specifications and process parameter data):

2.2.3 RWCU System Inlet Flow (Ref. 4.4.1, 4.5.6, 4.5.7, 4.5.10, 4.5.11, 4.5.16, 4.6.4, and 4.9.1)

Table 2-2.
RWCU System Inlet Flow Element – Unit 1

Component I.D.:	FE-044-1N035 "RWCU SUCTION FLANGE UPSTREAM OF VALVE HV-44-1F001"
Device Type:	Orifice Plate
Manufacturer/Model No.:	Vickery Simms Inc./145C3227P037
Reference Accuracy (A1):	±1.50% of actual flow rate
Installation Accuracy:	± 0.5%
Environmental Conditions (Temp.):	40°F (min.) to 156°F (max.)
Environmental Conditions (Press.):	(-) 1.0 (min.) to (+) 7.0 inches H_2O (max.)

Table 2-2.
RWCU System Inlet Flow Element – Unit 1

Environmental Conditions (RH %):	20 (min.) to 90 (max.)
Pipe Size:	6 inch schedule 80
Flange Rating:	600#
Pipe Class Service No.:	DCA-101 "RWCU from Recirc. Pump Suction Valve F004
Normal Operating Temperature:	539 °F
Design Temperature:	582 °F
Maximum Operating Temperature:	582 °F
Normal Operating Pressure:	1060 psig
Design Pressure:	1250 psig
Maximum Operating Pressure:	1360 psig
Normal flow Rate:	360 gpm
Maximum Flow Rate:	477 gpm
ΔP @ Max. Flow Rate:	200 inches H_2O, nameplate data: 1178 psig & 545 °F

2.2.4 RWCU System Inlet Flow (Ref. 4.2.1, 4.2.2, 4.5.6, 4.5.10, 4.5.19, 4.5.20, 4.6.4, 4.7.2, 4.7.6, 4.7.7, 4.9.5, and 4.9.7)

Table 2-3.
RWCU System Inlet Flow Differential Pressure Transmitter

Component I.D.:	FT-044-1N036A "REACTOR WATER CLEANUP INLET"
Location (AREA / EVEL / RM):	016 / 283' / 506
Device Type:	Differential Pressure Transmitter
Manufacturer/Model No.:	Rosemount/1153DB5RCN0039
Quality Classification:	Q (Not Required)
Accident Service:	N/A
Seismic Category:	N/A
Tech Spec Requirement:	N/A
Upper Range Limit @ 68 °F:	750 inches H_2O
Lower Range Limit @ 68 °F:	0–125 inches H_2O
Calibrated Range:	0 to 218.3 inches H_2O - static pressure corrected
Operating Range:	0 to 220 inches H_2O at 1060psig
Calibration Span:	218.3 inches H_2O

Table 2-3.
RWCU System Inlet Flow Differential Pressure Transmitter

Output Signal:	4 – 20 mA
Setpoint:	N/A
Calibration Period:	24 months
Accuracy (A2):	± 0.25 % calibrated span (see note)
Calibration Accuracy:	± 0.5 %
Stability (Drift, D2):	± 0.2 % URL for 30 months [2σ]
Temperature Effect (DTE1), per 100°F	± (0.75 % of upper range limit + 0.5 % span)
Temperature Normal Operating Limits:	40 to 200 °F
Overpressure Effect:	Maximum zero shift of ± 1.0 % URL above 2000 psig
Static Pressure Zero Effect:	±0.2 % of upper range limit
Static Pressure Span Effect (SPNE2):	± 0.5 % input reading per 1,000 psi.
Seismic (vibration) Effect (SEIS2):	Accuracy within ±0.5 % of upper range limit during and after a seismic disturbance defined by a required response spectrum with a ZPA of 4 g's.
Power Supply Effect (PSE2):	< 0.005 % of calibrated span per volt
Mounting Position Effect:	No span effect. Zero shift of up to 1.5 inH_2O
EMI/RFI Effect:	Not Specified
Response time (damping):	Code N - Adjustable damping; max. 0.8 seconds
Harsh temperature effect (HTE2):	Accuracy within ± 5.0 % of URL during and after exposure to 265 °F (129.5 °C), 24 psig, for 35 hours.
Humidity limits:	0 to 100 % Relative Humidity (RH)
Safety Classification:	Application - Non-safety-Related
Radiation Effect (e2R):	Accuracy within ± 4.0 % of URL during and after exposure to 2.2 x10^7 rads, TID of gamma
Note: Includes combined effects of linearity, hysteresis, and repeatability	

2.2.5 RWCU System Signal Resistor Unit (Ref. 4.1.1, 4.5.10, 4.5.17, and 4.7.3):

Table 2-4.
RWCU System PPC Precision Signal Resistor Unit

Dwg. Designation:	SRU-1
Device Type:	Precision signal resistor unit
Manufacturer/Model No.:	Bailey Type 766
Selected Range:	250 Ohm

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Table 2-4.
RWCU System PPC Precision Signal Resistor Unit

Accuracy:	± 0.1 %, (± 0.25 ohm)
Safety Classification:	N/A
Temperature Effect:	± 0.5 % for 40 – 120°F
Input Signal Range:	4 to 20 mAdc

2.2.6 RWCU System Computer Point – Plant Process Computer (PPC) (Ref. 4.5.10 and Attachment 4):

The PPC calculates Core Thermal Power based in part on the measurement of Reactor Water Cleanup flow. The PPC uses an analog input card, which read the voltage drop across a precision 250 ohm resistor.

Table 2-5.
RWCU System PPC Analog Input Card Unit 1

Component I.D.:	A1718
Location:	10-C603 (H12-P603)
Device Type:	PPC - Potentiometer (Analog) Input Card
Manufacturer/Model No.:	Analogic/ANDS5500
Quality Classification:	N/A
Accident Service:	N/A
Seismic Category:	N
Tech Spec Requirement:	N/A
Selected Full Scale Span:	± 5 VDC
Calibration Span:	(-) 5 VDC to (+) 5 VDC
Calibration Period:	24 months
Accuracy (A3):	± 0.5 % of full scale span
Input Impedance (resistance):	10 Meg Ohms
Analog to Digital Converter:	Not Specified
Power Supply Effect (PSE3):	N/A
EMI/RFI Effect:	N/A
Response time (damping):	N/A
Operating Temperature Limits:	32 to 122 °F (0 to 50 °C)
Humidity limits:	Not Specified
Safety Classification:	Non Safety-Related

2.2.7 RWCU System Local Service Environments (Ref. 4.4.2):

Table 2-6.
RWCU System Local Service Environments

	Flow Transmitter	Plant Process Computer
Area / Room.	Area 016	Area 008 – Control Room
Location	506C – Cont. H2 Recombiner	Control Room (Comp. Rm. 553)
Normal Temp. Range (°F)	65 min / 106 max / 85 norm	65 min / 78 max / norm N/A
Normal Pressure	(-) 0.25 inches WG	+ 0.25 inches WG
Normal Humidity (RH %)	50 average / 90 maximum	50 average / 90 maximum
Radiation	2.50E-03 Rads/hr, 8.78E+02 TID	N/A

2.3 REACTOR CLEANUP SYSTEM TEMPERATURE

2.3.1 RWCU System Regenerative Heat Exchanger Inlet Temperature (Ref. 4.4.1, 4.5.6, 4.5.11, 4.5.16, 4.5.18, 4.5.19, 4.6.4, 4.9.5, and 4.9.7)

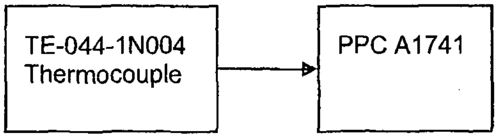


Table 2-7.
RWCU System Inlet Thermocouple

Component Numbers:	TE-044-1N004 "REACTOR WATER CLEANUP SYSTEM REGEN HEAT EXCH INLET TEMP"
Device Type:	Type T Copper – Constantan (CU/CN)
Manufacturer/Model No.:	California Alloy Co/Model 117C3485P073
Element Range:	(-)200° to (+)700 °F
Calibrated Range	0° - 600°F
Rated Accuracy:	± 0.75°F
Output Signal:	(-) 0.674 mV to (+)15.769 mV
Safety Classification:	N/A
Pipe Class Service No.:	DCC-101 "RWCU pump discharge thru Regen HXs
Normal Operating Temperature	530 °F (See Note 1)
Normal Operating Temperature Spec:	535 °F
Design Temperature:	582 °F
Maximum Operating Temperature:	582 °F

Table 2-7.
RWCU System Inlet Thermocouple

Normal Operating Pressure:	1235 psig
Design Pressure:	1290 psig
Maximum Operating Pressure:	1542 psig
Normal flow Rate:	360 gpm

Note 1: Reactor Engineering provided normal operating temperature based on 100% power operation for both Units. Data was retrieved once per hour for one week. Unit 2's value of 530 °F is more conservative than Unit 1's value of 528 °F. Per the GEH task report the value of 535.5 °F will be used (Ref. 4.9.10).

2.3.2 RWCU System Regenerative Heat Exchanger Outlet Temperature (Ref. 4.1.1, 4.5.6, 4.5.16, 4.5.18, 4.5.19, 4.6.4, 4.5.11, 4.9.5, and 4.9.7)

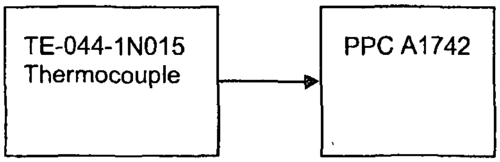


Table 2-8.
RWCU System Outlet Thermocouple

Component Numbers:	TE-044-1N015 "REACTOR WATER CLEANUP SYSTEM REGEN HEAT EXCH OUTLET TEMP"
Device Type:	Type T Copper – Constantan (CU/CN)
Manufacturer/Model No.:	California Alloy Co/Model 117C3485P073
Element Range:	(-)200° to (+)700 °F
Input Range	0° - 600°F
Rated Accuracy:	± 0.75°F
Output Range	(-) 0.674 mV to (+)15.769 mV
Safety Classification:	N/A
Pipe Class Service No.:	ECC-105 "RWCU Regen HX to HV-1F042
Normal Operating Temperature based on actual plant data	440 °F (See Note 2)
Normal Operating Temperature:	438 °F
Design Temperature:	434 °F
Maximum Operating Temperature:	434 °F
Normal Operating Pressure:	1168 psig
Design Pressure:	1290 psig
Maximum Operating Pressure:	1542 psig
Normal flow Rate:	360 gpm

Note 2: Reactor Engineering provided normal operating temperature based on 100% power operation

for both Units. Data was retrieved once per hour for one week. However, the value of 439 °F from the GEH Task Report will be used (Ref. 4.9.10).

2.3.3 RWCU System Plant Process Computer (PPC) (Ref. 4.5.6, 4.5.16, and Attachment 4):

Table 2-9.
RWCU System Thermocouple PPC Analog Input Card Unit 1

Component I.D.:	A1718 and A1742
Location:	10-C603 (H12-P603)
Device Type:	PPC - Potentiometer (Analog) Input Card
Manufacturer/Model No.:	Analogic/ANDS5500
Quality Classification:	N/A
Accident Service:	N/A
Seismic Category:	N
Tech Spec Requirement:	N/A
Selected Range:	Upper: -25 mV to + 25mV
Calibration Span:	(-) 0.674 mV to (+)15.769 mV
Calibration Period:	24 months
Accuracy (A2):	± 0.5 % of full scale span
Input Impedance (resistance):	10 Meg Ohms
Analog to Digital Converter:	Not Specified
Signal Source Resistance:	2800 Ω maximum
Power Supply Effect (PSE2):	N/A
EMI/RFI Effect:	N/A
Response time (damping):	N/A
Operating Temperature Limits:	32 to 122 °F (0 to 50 °C)
Humidity limits:	Not Specified
Safety Classification:	Non Safety-Related

2.3.4 RWCU System Local Service Environments (Ref. 4.4.2):

Table 2-10.
RWCU System Thermocouple Local Service Environments

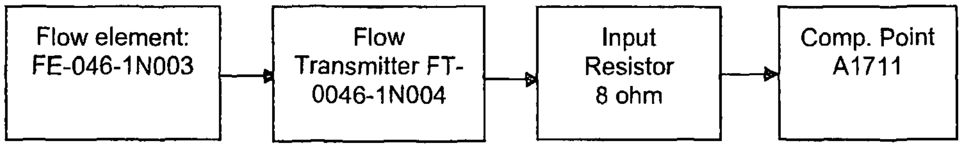
	Thermocouple	Plant Process Computer
Area / Room.	Area 016	Area 008 – Control Room
Location	506C – Cont. H2 Recombiner	Control Room (Comp. Rm. 553)
Normal Temp. Range (°F)	65 min / 112 max / 104 norm	65 min / 78 max / norm N/A

Normal Pressure	(-) 0.25 inches WG	+ 0.25 inches WG
Normal Humidity (RH %)	50 average / 90 maximum	50 average / 90 maximum
Radiation	2.50E-03 Rads/hr, 8.78E+02 TID	N/A

2.4 CRD FLOW RATE UNCERTAINTY

2.4.1 CRD Hydraulic System Flow Loop Diagram

Each analyzed instrument loop consists of a flow element supplying a differential pressure to a pressure transmitter, and a *PPC input/output (I/O) module with a precision resistor (8 Ω) across the input. The* loop is shown as follows:



The loop components evaluated in this document (and the applicable performance specification and process parameter data):

2.4.2 CRD Hydraulic System Flow Element (Ref. 4.4.1, 4.5.8, 4.5.12, 4.6.2, 4.6.3, 4.8.5, and 4.9.5)

Table 2-11.
CRD Hydraulic System Flow Element – Unit 1

Component I.D.:	FE-046-1N003 "CRD HYDRAULIC SYS DRIVE WTR FLOW CONT"
Device Type:	Flow Nozzle
Manufacturer/Model No.:	GE - Vickery Simms Inc./ 158B7077AP016
Reference Accuracy (A1):	± 1.0 % flow
Design Temperature:	150°F
Design Pressure:	2000 psig
Pipe Size:	2 inch schedule 80
Material	Stainless Steel
Maximum Flow	100 gpm
Pipe Class Service No.:	DCD-112, "Control Rod Drive Hyd. from DBD-I 08 to Hydraulic Control Units
Normal Operating Temperature:	100 °F (See Note 1)
Design Temperature:	150 °F
Maximum Operating Temperature:	150 °F
Normal Operating Pressure:	1448 psig
Design Pressure:	1750 psig
Maximum Operating Pressure:	1750 psig

Table 2-11.
CRD Hydraulic System Flow Element – Unit 1

Normal flow Rate:	105 gpm @ 1515.8 psig
ΔP @ Max. Flow Rate:	200 inches H_2O @ 100 gpm

Note 1: The value of 97.2 °F will be used based on the GEH Task Report (Ref. 4.9.10).

2.4.3 CRD Hydraulic System Flow Transmitter (Ref. 4.5.8, 4.5.12, 4.6.2, 4.6.3, 4.7.4 and 4.9.5)

Table 2-12.
CRD Hydraulic System Differential Pressure Transmitter

Component I.D.:	FT-046-1N004 "CRD HYDRAULIC SYS DRIVE WTR FLOW CONT"
Location (AREA / EVEL / RM):	015 / 253' / 402
Device Type:	Differential Pressure Transmitter
Manufacturer/Model No.:	Rosemount/ 1151DP5D22PB
Quality Assurance Classification:	N
Accident Service & Seismic Category:	N/A
Tech Spec Requirement:	N/A
Upper Range Limit:	750 inches H_2O
Lower Range Limit:	0–125 inches H_2O
Calibrated Span:	0 to 197.5 inches H_2O - static pressure corrected
Operating Span:	0 to 200 inches H_2O at 100 gpm
Output Signal:	4 – 20 mA, Corresponding to 0 – 100 gpm
Calibration Period:	24 months
Accuracy (A2):	± 0.25 % calibrated span
Calibration Accuracy:	± 0.5 %
Stability (Drift, D2):	± 0.25 % of URL for 6 months [2σ]
Temperature Effect (DTE1), per 100°F	± 1.5% of URL per 100 °F ± 2.5 % for low range (URL/6) This taken to be equal to 2.4 % at 197.5 inches H_2O span
Temperature Normal Operating Limits:	(-)40 to 150 °F (Amplifier)
Overpressure Effect:	Zero shift of less than ± 2.0 %
Static Pressure Zero Effect:	± 0.5 % of upper range limit for 2000 psi
Static Pressure Span Effect (SPNE2):	(-) 0.5 % ± 0.1% input reading per 1,000 psi. This is a systematic error which can be calibrated out for a particular pressure before installation.

Table 2-12.
CRD Hydraulic System Differential Pressure Transmitter

Seismic (vibration) Effect (SEIS2):	± 0.05 % of URL per g at 200 Hz in any axis.
Power Supply Effect (PSE2):	< 0.005 % of calibrated span per volt.
Mounting Position Effect:	No span effect. Zero-shift can be calibrated out.
EMI/RFI Effect:	Not Specified
Response time (damping):	Not Specified
Harsh temperature effect (HTE2):	Not Applicable
Humidity limits:	0 to 100 % RH
Safety Classification:	Non-safety related
Radiation Effect (e2R):	Not Specified

2.4.4 CRD Hydraulic System Flow Signal Resistor Unit (Ref. 4.1.1, 4.5.12, Attachment 12, and 4.7.3):

Table 2-13.
CRD Hydraulic System PPC Precision Signal Resistor Unit

Dwg. Designation:	8 Ω
Device Type:	Precision signal resistor unit (wire-wound).
Manufacturer/Model No.:	Bailey Type 766
Selected Range:	8 Ohm
Accuracy:	± 0.008 ohm (± 0.1 %)
Safety Classification:	N/A
Temperature Effect:	± 0.5 % for 40 – 120°F
Input Signal Range:	4 to 20 mAdc

2.4.5 CRD Hydraulic System Flow PPC I/O (Refs. 4.5.8, 4.5.12, and Attachment 4):

Table 2-14.
CRD Hydraulic System PPC Analog Input Card Unit 1

Component I.D.:	A1711
Location:	10-C603 (H12-P603)
Device Type:	PPC - Potentiometer (Analog) Input Card
Manufacturer/Model No.:	Analogic/ANDS5500
Quality Classification:	N/A
Accident Service & Seismic Category:	N/A
Tech Spec Requirement:	N/A
Selected Full Scale Span:	± 160 mV

Table 2-14.
CRD Hydraulic System PPC Analog Input Card Unit 1

Calibration Span:	(-) 160 mV to (+) 160 mV
Calibration Period:	24 months
Accuracy (A3):	± 0.5 % of full scale span
Calibration Accuracy:	N/A
Input Impedance (resistance):	10 Meg Ohms
Analog to Digital Converter:	Not Specified
Power Supply Effect (PSE3):	N/A
EMI/RFI Effect:	N/A
Operating Temperature Limits:	32 to 122 °F (0 to 50 °C)
Humidity limits:	Not Specified
Safety Classification:	Non Safety-Related

2.4.6 CRD Hydraulic System Flow Process Parameters (Refs. 4.3.2 and 4.8.5):

Process Temp Maximum: 150 °F Process Temp Minimum: 45°F

The minimum water temperature is based on the CST being outside and exposed to winter elements. The maximum temperature is based on 140°F of the condensate and condenser system plus 10°F nominal heat addition from the CRD Water pump. (Ref. 4.3.2)

2.4.7 CRD Hydraulic System Local Service Environments (Ref. 4.4.2):

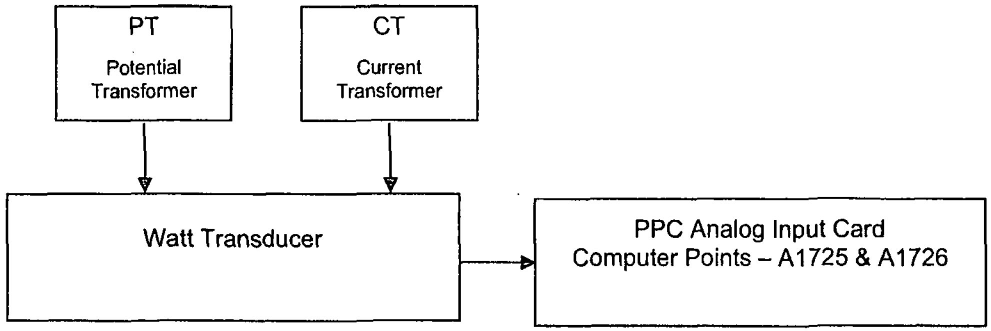
Table 2-15.
CRD Hydraulic System Local Service Environments

	Flow Transmitter	Plant Process Computer
Area / Room.	Area 015 / Room 402	Area 008 – Control Room
Location	Room 402	Control Room (Comp. Rm. 553)
Normal Temp. Range (°F)	65 min / 106 max / 90 norm	65 min / 78 max / norm N/A
Normal Pressure	(-) 0.25 inches WG	+ 0.25 inches WG
Normal Humidity (RH %)	50 average / 90 maximum	50 average / 90 maximum
Radiation	1.00E-01 Rads/hr, 3.51E+04 TID	N/A

2.5 RECIRCULATION PUMP MOTOR UNCERTAINTY

2.5.1 Recirculation Pump Motor Loop Diagram

Each analyzed instrument loop consists of a Watt Transducer, and a PPC input/output (I/O) module. The uncertainty magnitude of the CT and PT is negligible for this calculation.



2.5.2 Recirculation Pump Motor Watt Transducer (Ref. 4.5.13 to 4.5.15, 4.6.6, Attachment 9, 4.9.5, and 4.9.7)

Table 2-16.
Recirculation Pump Motor Watt Transducer

Component I.D.:	MT1A and MT1B
Location:	10-C603 (H12-P603)
Device Type:	Watt Transducer
Manufacturer/Model No.:	Ametek Power Systems / XL3-1K5A2-25
Quality Classification:	N/A
Accident Service & Seismic Category:	N/A
Tech Spec Requirement:	N/A
Rated Output (RO)	10.5 MW
Current Input (Current Transformer):	0 – 5 Amps (1500/5)
Voltage Input (Potential Transformer):	0 - 120 V (4160/120)
Output Range:	0 - 1 mAdc
Calibration Period:	24 months
Accuracy (A1):	± (0.2% Reading + 0.01% Rated Output) at 0-200% Rated Output
Stability (Drift, D1) per year:	± 0.1% RO, Non-cumulative
Temperature Effect:	± 0.005 % / ° C
PF Effect on Accuracy	± 0.1% VA (maximum)
EMI/RFI Effect:	N/A

Table 2-16.
Recirculation Pump Motor Watt Transducer

Operating Temperature Limits:	(-)4°F to 158 °F (-20° C to +70° C)
Operating Humidity:	0 to 95 % RH non condensing
Safety Classification:	Non Safety-Related

2.5.3 Recirculation Pump Motor Watt Meter Transducer Precision Signal Resistor (Ref. 4.5.13 to 4.5.15, and 4.9.7):

Table 2-17.
Recirculation Pump Motor Watt Transducer PPC Precision Signal Resistor Unit

Dwg. Designation:	R3A & R3B
Device Type:	Precision signal resistor unit (wire-wound)
Manufacturer/Model No.:	GE / Type HR41D5B
Selected Rating:	160 Ohm
Accuracy:	± 0.1% of input signal range, 0.1 watt
Safety Classification:	N/A
Temperature Effect:	N/A
Input Signal Range:	0 - 1 mAdc

2.5.4 Recirculation Pump Motor Watt Transducer PPC Analog Input Card (Ref. Attachment 4):

Table 2-18.
Recirculation Pump Motor Watt Transducer PPC Analog Input Card Unit 1

Component I.D.:	A1725 and A1726
Location:	10-C603 (H12-P603)
Device Type:	PPC - Potentiometer (Analog) Input Card
Manufacturer/Model No.:	Analogic/ANDS5500
Quality Classification:	N/A
Accident Service & Seismic Category:	N/A
Tech Spec Requirement:	N/A
Selected Full Scale Span:	± 160 mV
Calibration Span:	(-) 160 mV to (+) 160 mV
Calibration Period:	24 months
Accuracy (A2):	± 0.5 % of full scale span

Table 2-18.
Recirculation Pump Motor Watt Transducer PPC Analog Input Card Unit 1

Input Impedance (resistance):	10 Meg Ohms
Analog to Digital Converter:	Not Specified
Power Supply Effect (PSE2):	N/A
EMI/RFI Effect:	N/A
Operating Temperature Limits:	32 to 122 °F (0 to 50 °C)
Humidity limits:	Not Specified
Safety Classification:	Non Safety-Related

3.0 ASSUMPTIONS AND LIMITATIONS

3.1 Standard practice is to specify calibration uncertainty in calculations equal to the uncertainty associated with the instruments under test (Ref. 4.1.1).

3.2 Instrumentation uncertainty caused by the operating environment's temperature, humidity, and pressure variations are evaluated when these error sources are specified by the instrument's vendor. If the instrument's operating environment specifications bound the in-service environmental conditions where the equipment is located and separate temperature, humidity, and pressure uncertainty terms are not specified for the instrument, then these uncertainties are assumed to be included in the manufacturer's reference accuracy specification.

3.4 Published instrument vendor specifications are considered to be based on sufficiently large samples so that the probability and confidence level meets the 2σ criteria, unless stated otherwise by the vendor.

3.5 Seismic effects are considered negligible or capable of being calibrated out unless the instrumentation is required to operate during and following a seismic event.

3.6 The insulation resistance error is considered negligible unless the instrumentation is required to operate in an abnormal or harsh environment.

3.7 Regulated instrument power supplies are assumed to function within specified voltage limits; therefore, power supply error is considered negligible with respect to other error terms unless the vendor specifically specifies a power supply effect.

3.8 Measurement of CRD hydraulic system purge water temperature is found to be accurate within ± 0.7 °F per Attachment 1. The enthalpy of water at the CRD normal operating pressure of 1448 psig as listed in P-300 (reference 4.4.1) and normal operating temperature of 97.2 °F (Table 2-1) are used to determine uncertainty of the CRD hydraulic system enthalpy because this is more conservative than using the higher temperatures normally found during operation.

3.9 The CRD system uses a Rosemount 1151 differential pressure transmitter (Section 2.4.3), which is mounted in a radiation exposure area. A radiation exposure effect is not specified for the Model 1151 transmitter; therefore the radiation effect applicable to this transmitter is assumed to be 10 % of span. This assumption is considered conservative based on three factors: (1) periodic surveillance is performed on this transmitter and it is required to operate within 0.5 % of span or maintenance activities must be performed. Existing calibration records did not indicate anything unusual occurring with the calibration of these transmitters in this service. (2) A Rosemount Model 1153 series B transmitter is rated for radiation exposure and may be expected to have a radiation effect of ± 4 % of upper range limit (URL) during and after exposure to 2.2 x 10^7 rad (Section 7.3.1.16). However, this exposure is over a 1000 times the expected exposure for the CRD system flow transmitter s during normal service. The estimated TID during normal service for the CRD flow transmitter is 3.51 x 10^4 rad (Section 4.4.2). The 10 % span estimated effect is more than an order of magnitude greater than the threshold for maintenance activity and of the same order of magnitude of the effect on a similar transmitter with 1000 times the exposure.

3.10 Interim results are rounded to the level of significance of the input data to avoid implying that a higher level of precision exists in the calculated values. For example, uncertainty may be specified by a supplier to one significant figure (e.g., 0.5 %). This value says that the level of significance associated with this uncertainty is one part in two hundred. The results are rounded when the numeric value of a result implies a higher level of significance than what the input data suggests.

3.11 An uncertainty of ± 10 psig is assumed for the feedwater pressure and the CRD outlet pressure to conservatively cover the variations in the actual steam dome or reactor vessel pressure. The variation in pressure has a negligible effect on the enthalpy of the feedwater.

3.12 An uncertainty of 10 % is assumed for the RPV thermal radiation heat loss term, Q_{RAD}, based on a review of calculation LM-0553 (Reference 4.8.3). LM-0553 determined the RPV heat loss by calculating the actual heat load in the drywell, subtracting the heat load attributed to any operating equipment in the drywell, and proportioning the heat load based on the shared chilled water system design flows assigned to Unit 1 drywell and Unit 2 drywell on a percentage basis. LM-0553 assumes Unit 1 and Unit 2 are operating at 100 percent power and the drywell air cooling fans are aligned as designed.

3.13 Steam table excerpts have been provided for convenience as Attachment 6, National Institute for Standards and Technology (NIST) Thermophysical Properties of Water, as extracted from the NIST fluid properties WebBook (Reference 4.9.3). For conservatism, factors of one-half the least significant figure in the tables are used for the interpolation error. The factors are 0.05 Btu/lbm for vapor and 0.005 Btu/lbm for liquid.

4.0 REFERENCES

4.1 METHODOLOGY

4.1.1 CC-MA-103-2001, Rev 0, "Setpoint Methodology for Peach Bottom Atomic Power Station and Limerick Generating Station

4.1.2 IC-11-00001, Rev. 4, Calibration of Plant Instrumentation and Equipment

4.2 PROCEDURES

4.2.1 ST-2-044-400-1, Rev. 23, Reactor Water Cleanup High Differential Flow Isolation Calibration

4.2.2 IC-C-11-00307, Rev. 5, Calibration of Rosemount Model 1153 and 1154 Transmitters

4.3 DESIGN BASIS DOCUMENTS

4.3.1 L-S-11, Rev. 15, DBD Feedwater System

4.3.2 L-S-15, Rev. 10, DBD Control Rod Drive System

4.3.3 L-S-19, Rev. 10, DBD Recirculation System

4.3.4 L-S-36, Rev. 10, DBD Reactor Water Makeup System

4.3.5 L-S-42, Rev. 09, DBD Nuclear Boiler System

4.4 SPECIFICATIONS, CODES, & STANDARDS

4.4.1 P-300, Rev. 45, Specification "Piping Materials and Instrument Piping Standards"

4.4.2 M-171, Rev. 16, Specification for Environmental Service Condition LGS Units 1 & 2

4.5 LIMERICK STATION DRAWINGS

4.5.1 M-06 Sheet 3, Rev. 58, P&ID Feedwater

4.5.2 M-23 Sheet 4, Rev. 33, P&ID Process Sampling

4.5.3 M-41 Sheets 1/2, Rev. 46/62, P&ID Nuclear Boiler

4.5.4 M-42 Sheets 1/2, Rev. 41/34, P&ID Nuclear Boiler Vessel Instrumentation

4.5.5 M-43 Sheets 1/2, Rev. 48/39, P&ID Reactor Recirculation Pump

4.5.6 M-44 Sheets 1/2, Rev. 56/47, P&ID Reactor Water Clean-up

4.5.7 M-45 Sheet 1, Rev. 30, P&ID Cleanup Filter and Demineralizer

4.5.8 M-46 Sheet 1, Rev. 51, P&ID Control Rod Drive Hydraulic-Part A

4.5.9 M-47 Sheet 1, Rev. 45, P&ID Control Rod Drive Hydraulic-Part B

4.5.10 B21-1050-E-008, Rev. 13, Elem. Diagram Steam Leak Detection Schematic

4.5.11 G31-N011-C-003, Rev 002, Purchased PT. ORF. PLT. SH 1

4.5.12 C11-1060-E-002, Rev. 23, Elem. Diagram CRD Hydraulic System, LGS U1

4.5.13 B32-1030-E-050, Sheet 18, Rev. 5, Elem. Diag. Reactor "A" Recirc Pump an MG Set, Unit 1

4.5.14 B32-1030-E-050, Sheet 19, Rev. 4, Elem. Diag. Reactor "B" Recirc Pump an MG Set, Unit 1

4.5.15 B32-1030-E-050, Sheet 3, Rev. 7, Elem. Diag. Reactor "A" & "B" Recirc Pump an MG Set, Parts List, Unit 1

4.5.16 G31-1040-E-003, Rev. 28, Elementary Diag. Reactor Water Cleanup System, Unit 1

4.5.17 C32-1020-E-003, Rev. 33, Elem. Diag. Feedwater Control System, Unit 1

4.5.18 B21-1040-E-003, Rev. 21, Elem. Diag. Nuclear Boiler Process

4.5.19 E-0701, Sheets 6/16, Rev. 9/8, Schematic & Connection Diagram NSSS/BOP Computer Analog Inputs, Unit 1

4.5.20 G31-1030-G-001, Rev. 20, Process Diagram Reactor Water Clean-Up System (High Pressure)

4.5.21 B32-C-001-J-023, Rev. 1, Recirculation Pump Curve (Attachment 10)

4.6 GENERAL ELECTRIC (GE) DOCUMENTS

4.6.1 C11-4010-H-004, Rev. 13, Control Rod Drive System

4.6.2 C11-N003-C-001 Rev 002 PPD-Flow Nozzle

4.6.3 C11-3050-H-001, Rev. 14, CRD Instrumentation System

4.6.4 G31-3050-H-001, Rev. 26, Reactor Water Clean-Up System

4.6.5 B21-3050-H-001, Rev. 27, Nuclear Boiler System

4.6.6 B32-3050-H-001, Rev. 6, Reactor Recirculation System

4.7 VENDOR INFORMATION

4.7.1 M-1-B32-C001-K7, Recirculation Pump Vendor Manual

4.7.2 Rosemount Product Data Sheet 00809-0100-4302, Rev BA, January 2008, Rosemount 1153 Series B Alphaline® Nuclear Pressure Transmitter

4.7.3 A41-8010-K-018.6 - Bailey Signal Resistor Unit (SRU) Type 766 (Attachment 12)

4.7.4 Rosemount Inc., Instruction Manual 4259, Model 1151 Alphaline® $\sqrt{\Delta P}$ Flow Transmitter, 1977 (Attachment 11)

4.7.5 C95-0000-K-002(1).2 - ANDS4810 - Data Acquisition System Instruction Manual

4.7.6 Rosemount Specification Drawing 01153-2734, "N0039 Option – Combination N0016 & N0037" (Attachment 13)

4.7.7 Rosemount Product Data Sheet 00813-0100-2655, Rev. AA June 1999 "N–Options for Use with the Model 1153 &I 1154 Alphaline® Nuclear Pressure Transmitters" (Attachment 14)

4.7.8 Fluke 8050A - Digital Multimeter Measurement P/N 530907 Rev 2 1984, Instruction Manual

4.7.9 Ametek Power Instruments, Digital & Analog Transducers, Power Measurement Catalog, Scientific Columbus Exceltronic AC Watt Transducer Specification (Attachment 9)

4.8 CALCULATIONS AND ENGINEERING ANALYSIS

4.8.1 LM-547, Rev. 2, Reactor Core Thermal Power Calculation Correction for Unaccounted Flow to Reactor Vessel

4.8.2 LM-552, Rev. 7, Reactor Heat Balance Calculation for Limerick Units 1 & 2

4.8.3 LM-553, Rev. 0, Determination of the Reactor Pressure Vessel (RPV) Heat Loss

4.8.4 EE-94LGS, Rev. 16, Proper Calibration of Feedwater Elements FE-006-1(2)N001A, B, C (GE SIL 452)

4.8.5 LM-562, Rev. 2, CRD Flow Rates and System Pressures

4.8.6 LEAE-MUR-0001, Rev. 1, Bounding Uncertainty Analysis for Thermal Power determination at Limerick Unit 1 Using the LEFM ✓+ System

4.8.7 Deleted

4.8.8 LE-0116, Rev. 0, Reactor Dome Narrow Range Pressure Measurement Uncertainty

4.8.9 Deleted

4.9 OTHER REFERENCES

4.9.1 ASME, "Fluid Meters Their Theory and Application" Sixth Edition, 1971.

4.9.2 Limerick Updated Final Safety Analysis Report, R14

4.9.3 Lemmon, E.W., McLinden, M.O., and Friend, D.G., "Thermophysical Properties of Fluid Systems", in NIST Chemistry WebBook, NIST Standard Reference Database Number 69, Eds. P.J. Linstrom and W.G. Mallard, National Institute of Standards and Technology, Gaithersburg MD, 20899, http://webbook.nist.gov, (retrieved January 22, 2010) (Attachment 6)

4.9.4 NUREG/CR-3659, Dated January 1985, NRC Guidance, A Mathematical Model for Assessing the Uncertainties of Instrumentation Measurements for Power and Flow of PWR Reactors

4.9.5 Plant Information Management System (PIMS) Data

4.9.6 TODI Tracking No: SEAG #09-000167, Plant Process Computer Data of various plant parameters, to support Core Thermal Power Uncertainty Calculations, Station/Unit(s) U1/U2, 9/3/09

4.9.7 IISCP (Improved Instrument Setpoint Control Program) Datasheets) Version 7.5

4.9.8 Edwards, Jerry L. Rosemount Nuclear Instruments letter in reference to "Grand Gulf Nuclear Station message on INPO plant reports, subject Rosemount Instrument Setpoint Methodology, dated March 9, 2000". Letter dated 04/04/2000. (Attachment 3)

4.9.9 TODI A169446-80, Source Document "Steam Carryover Fraction on Process Computer Heat Balance Calculations" (Attachment 2)

4.9.10 TODI A1695446-87, Source Document "GE Task Report T0100, December 2009, Revision 1" (Attachment 5)

5.0 IDENTIFICATION OF COMPUTER PROGRAMS

The results of calculations by special computer programs were not directly used in this design analysis. Microsoft® Office Excel 2003 SP 3 was used to confirm the arithmetic results.

6.0 METHOD OF ANALYSIS

6.1 METHODOLOGY

The methodology used to calculate Section 6 is based on CC-MA-103-2001, "Setpoint Methodology for Peach Bottom Power Station and Limerick Generating Station" (Ref. 4.1.1).

These are non-safety-related indication loops, but the indication is used to calculate Core Thermal Power, which is a licensing limit. This analysis will use the Square Root of the Sum of the Squares (SRSS) methodology for combining the random and independent uncertainties. The dependent uncertainties will be combined according to their dependency relationships and biases will be algebraically summed in accordance with the Reference 4.1.1. The level of confidence for each uncertainty will be normalized to a 2σ confidence level.

6.2 CORE THERMAL POWER (CTP) CALCULATION:

The process computer provides a calculation of the CTP based on a system heat balance, where CTP is the difference between the energy leaving the system and the energy input into the system from energy sources external to the core. The process computer steady state reactor heat balance equation is based on a summation of all heat sources raising the inlet feedwater and other cold water to steam exiting the pressure vessel. Figure 5-1 shows the Limerick heat balance control volume.

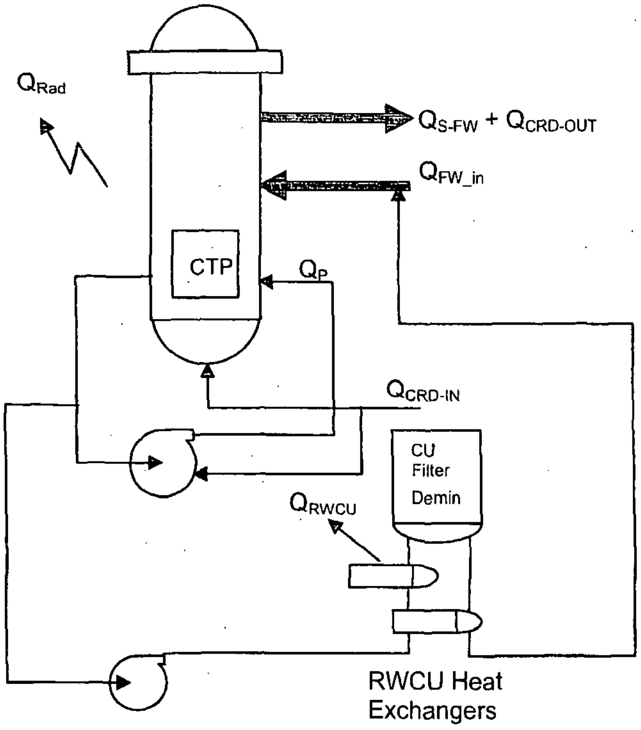


Figure 5-1, Limerick Heat Balance Control Volume Diagram

CTP = Energy out – Energy in (Equation 1)

Energy in = $Q_{FW\text{-}IN} + Q_{CRD\text{-}IN} + Q_P$ (Equation 2)

Energy out = $Q_{S\text{-}FW} + Q_{CRD\text{-}OUT} + Q_{RAD} + Q_{RWCU}$ (Equation 3)

Where,

CTP	Core Thermal Power generated by nuclear fuel
$Q_{FW\text{-}IN}$	Energy of feedwater required to raise inlet FW to Steam
$Q_{CRD\text{-}IN}$	Energy of CRD purge water and recirculation pump seal purge water going to feedwater
Q_P	Heat added by the recirculation pumps
$Q_{S\text{-}FW}$	Energy of steam from feedwater supply
$Q_{CRD\text{-}OUT}$	Energy of CRD purge water and recirculation pump seal purge water going to steam
Q_{RAD}	Radiative heat losses from the reactor pressure vessel
Q_{RWCU}	Heat removed by the RWCU system regenerative heat exchangers (includes both a heat removal term and a heat additions term)

6.2.1 Energy In

Each of the above heat contributors are individually evaluated as follows:

6.2.1.1 Energy of feedwater ($Q_{FW\text{-}IN}$) is equal to the feedwater mass flow rate (w_{FW}) multiplied by the enthalpy of the water at the bulk temperature of the feedwater ($h_{FW}(T_{FW})$) entering the reactor. Changes to the bulk temperature of the feedwater due to the influx of recirculation water and RWCU water are ignored because these mass flows represent less than 1 % of the total mass flow and the temperature change caused by their influx negligible.

$Q_{FW\text{-}IN} = w_{FW} \cdot h_F(T_{FW})$ (Equation 4)

6.2.1.2 Energy of Control Rod Drive purge water and recirculation pump seal purge water ($Q_{CRD\text{-}IN}$) is taken to be fixed at the enthalpy of water for a given temperature and pressure.

$Q_{CRD\text{-}IN} = w_{CRD} \cdot h_F(T_{CRD})$ (Equation 5)

6.2.1.3 Energy of recirculation pumps (Q_P)

Energy of recirculation pumps (Q_P) is taken as the number of pump motors (n) multiplied by the efficiency of the pump motors (η_m) multiplied by the power of the pump motors (W_E). This is a conservative value because the combined net energy of the two recirculation pump motors contributes to the energy of the recirculation water. This estimate is fixed relative to CTP because relatively large random variations in Q_P will be negligible compared to Q_{FW}.

$Q_P = n \cdot \eta_m \cdot W_E$ (Equation 6)

6.2.2 Energy out

6.2.2.1 Energy of Steam

Energy of steam from feedwater ($Q_{S\text{-}FW}$) is equal to the feedwater mass flow rate (W_{FW}) multiplied by the enthalpy ($h_G(P_S)$) of the steam (h_G) at the steam dome pressure (P_S). The moisture carryover mass fraction is conservatively set to 0 (See Attachment 2).

$$Q_{S\text{-}FW} = w_{FW} \cdot h_G(P_S) \qquad \text{(Equation 7)}$$

6.2.2.2 Energy of CRD Purge Water

In a Boiling Water Reactor (BWR), the energy of CRD purge water and recirculation pump seal purge water going to steam ($Q_{CRD\text{-}OUT}$) is equal to the mass flow rate of control rod drive and recirculation pump seal purge water (w_{CRD}) multiplied by its enthalpy. However, the Feedwater mass flow rate will makes up greater than 99 % of the steam mass flow rate; therefore, W_{CRD} will be quantified as a fixed number because relatively large random variations in W_{CRD} will be negligible in determining Q_S.

$$Q_{CRD\text{-}OUT} = w_{CRD} \cdot h_G(P_S) \qquad \text{(Equation 8)}$$

6.2.2.3 Energy of Reactor Pressure Vessel Radiative Heat Loss

Energy of reactor pressure vessel radiative heat loss (Q_{RAD}) includes both heat loss due to thermal radiation as well as heat loss through convection. This value is fixed relative to CTP because relatively large random variations in Q_{RAD} will be negligible in determining Q_S.

6.2.2.4 Energy of Reactor Water Clean-up

Energy of reactor water clean up (Q_{RWCU}) is based on the net heat removed by the non-regenerative heat exchanges from the recirculated water stream bypassed from Recirculation Loop B to the RWCU. The actual contribution to the heat removed from the reactor pressure vessel is negligible because the non-regenerative heat exchangers cool the stream going to the cleanup filters and demineralizers and the regenerative heat exchangers use the incoming stream to reheat the RWCU flow back up to the feedwater temperature. The mass flow rate is equal to the nominal pump flow rate the higher of Pump A or the combination of Pump B & C. The pump flow rate is fixed relative to CTP because relatively large random variations in Q_{RWCU} will be negligible in determining Q_S. The net heat removed is equal to the mass flow rate (W_{RWCU}) multiplied by difference of enthalpies across the RWCU.

$$Q_{RWCU} = w_{RWCU} \cdot [h_F(T_{RPV}) - h_F(T_{FW})] \qquad \text{(Equation 9)}$$

6.2.3 Heat Balance Equation

The reactor heat balance is based on the principle that heat input to the reactor water equals heat out. Substituting Equations 2 and 3 into Equation 1 yields:

$$(Q_{S\text{-}FW} + Q_{CRD\text{-}OUT} + Q_{RAD} + Q_{RWCU}) = CTP + (Q_{FW\text{-}IN} + Q_{CRD\text{-}IN} + Q_P) \qquad \text{(Equation 10)}$$

Solving for CTP yields,

$$CTP = (Q_{S\text{-}FW} + Q_{CRD\text{-}OUT} + Q_{RAD} + Q_{RWCU}) - (Q_{FW\text{-}IN} + Q_{CRD\text{-}IN} + Q_P)$$

$$= [w_{FW} \cdot h_G(P_S) + w_{CRD} \cdot h_G(P_S) + Q_{RAD} + w_{RWCU} \cdot [h_F(T_{RPV}) - h_F(T_{FW})]$$
$$- [w_{FW} \cdot h_F(T_{FW}) + w_{CRD} \cdot h_F(T_{CRD}) + n \cdot \eta_m \cdot W_E] \qquad \text{(Equation 11)}$$

Combining like terms,

$$CTP = [[w_{FW} \cdot h_G(P_S) - w_{FW} \cdot h_F(T_{FW})] + [w_{CRD} \cdot h_G(P_S) - w_{CRD} \cdot h_F(T_{CRD})] + Q_{RAD} + w_{RWCU} \cdot [h_F(T_{RPV}) - h_F(T_{FW})] - n \cdot \eta_m \cdot W_E] \qquad \text{(Equation 12)}$$

$$CTP = w_{FW} \cdot [h_G(P_S) - h_F(T_{FW})] + w_{CRD} \cdot [h_G(P_S) - h_F(T_{CRD})] + Q_{RAD} + w_{RWCU} \cdot [h_F(T_{RPV}) - h_F(T_{FW})] - n \cdot \eta_m \cdot W_E \qquad \text{(Equation 13)}$$

Equation 13 is the form of the equation used by the Plant Process Computer (PPC) to calculate CTP (Reference 4.8.2). The CTP can now be expressed as a function of W_{FW}, $h_G(P_S)$, $Q_{CRD\text{-}OUT}$, Q_{RAD}, Q_{RWCU}, $h_F(T_{FW})$, $Q_{CRD\text{-}IN}$, Q_P.

$$CTP = f\,(w_{FW}, h_G(P_S), Q_{CRD\text{-}OUT}, Q_{RAD}, Q_{RWCU}, h_F(T_{FW}), Q_{CRD\text{-}IN}, Q_P) \qquad \text{(Equation 14)}$$

Further simplification of Equation 14 can be made by setting variables with negligible input into the uncertainty of the CTP to constant values. The variables that have negligible contribution to the determination of the uncertainty of the heat from CTP are $Q_{CRD\text{-}OUT}$, Q_{RAD}, Q_{RWCU}, $Q_{CRD\text{-}IN}$, and Q_P as discussed above (Sections 6.2.2.2, 6.2.2.3, 6.2.2.4, 6.2.1.2, and 6.2.1.3).

$$CTP = [w_{FW} * h_G(P_S) + Q_{CRD\text{-}OUT} + Q_{RAD} + Q_{RWCU}] - [w_{FW} * h_F(T_{FW}) + Q_{CRD\text{-}IN} + Q_P]$$

$$= w_{FW} * [h_G(P_S) - h_F(T_{FW})] + (Q_{CRD\text{-}OUT} - Q_{CRD\text{-}IN}) + Q_{RAD} + Q_{RWCU} - Q_P \qquad \text{(Equation 15)}$$

6.2.4 Uncertainty Determination

From NUREG/CR-3659 (Ref. 4.9.4), the standard uncertainty (uc) of a function (y) containing multiple statistically independent terms may be expressed as follows:

$$y = f(x_1, x_2, \ldots, x_N)$$

$$u_c = \sqrt{\left(\sum_{i=1}^{N} [c_i u(x_i)]^2\right)} = \sqrt{\left(\sum_{i=1}^{N} u_i^2(y)\right)} \qquad \text{(Equation 16)}$$

Where,

$$c_i = \frac{\partial f}{\partial X_i} \text{ and } u_i(y) = \text{I } c_i \text{ I } u(x_i) \qquad \text{(Equation 17)}$$

The standard uncertainty, u_c, is multiplied by a coverage factor, k, which is equivalent to the number of standard deviations for a given confidence level to arrive at the measurement uncertainty U and the expected value of y, Y, is taken as y plus or minus the measurement uncertainty.

$$U = ku_c(y) \text{ and } Y = y \pm U \qquad \text{(Equation 18)}$$

6.2.4.1 Standard Uncertainty for CTP

The standard uncertainty for CTP can be determined by taking the square root of the sum of the squares of the partial derivatives of each subcomponent of CTP multiplied by the square of the uncertainties of the subcomponents as shown in Equation 19 (Reference 4.9.4).

$$u_{CTP} = \sqrt{\begin{aligned} &\left[\left(\left|\frac{\partial CTP}{\partial w_{FW}}\right|\right)^2 * \left(\sigma_{w_{FW}}\right)^2\right] + \left[\left(\left|\frac{\partial CTP}{\partial h_G(P_S)}\right|\right)^2 * \left(\sigma_{h_G(P_S)}\right)^2\right] + \\ &\left[\left(\left|\frac{\partial CTP}{\partial h_F(T_{FW})}\right|\right)^2 * \left(\sigma_{h_F(T_{FW})}\right)^2\right] + \left[\left(\left|\frac{\partial CTP}{\partial Q_{CRD\_OUT}}\right|\right)^2 * \left(\sigma_{Q_{CRD\_OUT}}\right)^2\right] + \\ &\left[\left(\left|\frac{\partial CTP}{\partial Q_{CRD\_IN}}\right|\right)^2 * \left(\sigma_{Q_{CRD\_IN}}\right)^2\right] + \left[\left(\left|\frac{\partial CTP}{\partial Q_{RAD}}\right|\right)^2 * \left(\sigma_{Q_{RAD}}\right)^2\right] + \\ &\left[\left(\left|\frac{\partial CTP}{\partial Q_{RWCU}}\right|\right)^2 * \left(\sigma_{Q_{RWCU}}\right)^2\right] + \left[\left(\left|\frac{\partial CTP}{\partial Q_P}\right|\right)^2 * \left(\sigma_{Q_P}\right)^2\right] \end{aligned}} \quad \text{(Equation 19)}$$

The partial derivative terms can be solved for by recalling CTP from Equation 15.

$$CTP = w_{FW} \cdot (h_G(P_S) - h_F(T_{FW})) + (Q_{CRD\text{-}OUT} - Q_{CRD\text{-}IN}) + Q_{RAD} + Q_{RWCU} - Q_P$$

The partial derivatives are determined from Equation 15 and shown below, remembering that the terms $Q_{CRD\text{-}OUT}$, $Q_{CRD\text{-}IN}$, Q_{RAD}, Q_{RWCU}, and Q_P are fixed relative to the determination of the uncertainty of CTP.

$$\frac{\partial CTP}{\partial w_{FW}} = \left(h_G(P_S) - h_F(T_{FW})\right) \quad \text{(Equation 20)}$$

$$\frac{\partial CTP}{\partial h_G(P_S)} = w_{FW} \quad \text{(Equation 21)}$$

$$\frac{\partial CTP}{\partial h_F(T_{FW})} = -w_{FW} \quad \text{(Equation 22)}$$

$$\frac{\partial CTP}{\partial Q_{CRD\_OUT}} = 1 \quad \text{(Equation 23)}$$

$$\frac{\partial CTP}{\partial Q_{CRD\_IN}} = -1 \quad \text{(Equation 24)}$$

$$\frac{\partial CTP}{\partial Q_{RAD}} = 1 \quad \text{(Equation 25)}$$

$$\frac{\partial CTP}{\partial Q_{RWCU}} = 1 \quad \text{(Equation 26)}$$

$$\frac{\partial CTP}{\partial Q_P} = -1 \quad \text{(Equation 27)}$$

The Feedwater mass flowrate uncertainty, σ_{WFW}, is equal to the measurement uncertainty as shown in Equation 28.

$$\sigma_{W_{FW}} = u_{FW} \cdot w_{FW} \qquad \text{(Equation 28)}$$

The steam enthalpy uncertainty, σ_{hG}, is determined by Equation 29.

$$\sigma_{h_G}(P_S, T_S, I_o) = \sqrt{\left(\frac{\partial h_G}{\partial T}\right)^2 \cdot \sigma_T^2 + \left(\frac{\partial h_G}{\partial P}\right)^2 \cdot \sigma_P^2 + \left(\frac{\partial h_G}{\partial I_O}\right)^2 \cdot \sigma_{I_o}^2} \qquad \text{(Equation 29)}$$

Substituting finite differences for the partial derivatives:

$$= \sqrt{\left(\frac{\Delta h_G}{\Delta T}\right)^2 \cdot \sigma_T^2 + \left(\frac{\Delta h_G}{\Delta P}\right)^2 \cdot \sigma_P^2 + \left(\frac{\Delta h_G}{\Delta I_O}\right)^2 \cdot \sigma_{I_o}^2} \qquad \text{(Equation 30)}$$

Noting that for saturated steam, pressure determines the temperature of the steam; thus, $\sigma_T = 0$. In addition, the steam tables used were derived from NIST Chemistry WebBook (Reference 4.9.3). The interpolation error for steam enthalpy, σ_{I_o} = ± 0.05 Btu/lbm.

$$\sigma_{h_G}(P_S, I_o) = \sqrt{\left(\frac{\Delta h_G(P_S)}{\Delta P_S}\right)^2 * \sigma_P^2 + \left(\frac{\Delta h_G(I_o)}{\Delta I_o}\right)^2 * \sigma_{I_o}^2} \qquad \text{(Equation 31)}$$

The Feedwater enthalpy uncertainty, σ_{hF}, is determined by Equation 32.

$$\sigma_{h_F}(T_{FW}, P_{FW}, I_o) = \sqrt{\left(\frac{\partial h_F}{\partial T}\right)^2 * \sigma_T^2 + \left(\frac{\partial h_F}{\partial P}\right)^2 * \sigma_P^2 + \left(\frac{\partial h_F}{\partial I_O}\right)^2 * \sigma_{I_o}^2} \qquad \text{(Equation 32)}$$

Substituting finite differences for the partial derivatives yields

$$= \sqrt{\left(\frac{\Delta h_F}{\Delta T}\right)^2 * \sigma_T^2 + \left(\frac{\Delta h_F}{\Delta P}\right)^2 * \sigma_P^2 + \left(\frac{\Delta h_F}{\Delta I_O}\right)^2 * \sigma_{I_o}^2}$$

The interpolation error for liquid enthalpy, σ_{I_o} = ± 0.005 BTU/lb, and that the enthalpy of subcooled water varies with temperature and slightly with pressure; thus,

$$\sigma_{h_F}(T_{FW}, P_{FW}, I_o) = \sqrt{\left(\frac{\Delta h_F(T)}{\Delta T}\right)^2 * \sigma_T^2 + \left(\frac{\Delta h_F(P)}{\Delta P}\right)^2 * \sigma_P^2 + \left(\frac{\Delta h_F}{\Delta I_O}\right)^2 * \sigma_{I_o}^2} \qquad \text{(Equation 33)}$$

The following uncertainty terms are relatively insignificant in the determination of CTP uncertainty; therefore, it is only necessary to quantify the uncertainty to within a reasonably conservative value. Refinement of the uncertainty of these items after this initial determination is not required given that the uncertainty is within the tolerances shown in the sensitivity analysis (See Attachment 7).

The Control Rod Drive (CRD) outlet energy uncertainty, σ_{QCRD_OUT}, is determined by Equation 34, where x_{CRD} is the uncertainty calculated for the CRD flow stream.

$$\sigma_{Q_{CRD\_OUT}} = x_{CRD}\,\% \cdot Q_{CRD\_OUT} \qquad \text{(Equation 34)}$$

The CRD inlet energy uncertainty, σ_{QCRD_IN}, is determined by Equation 35, where x_{CRD} is the uncertainty calculated for the CRD flow stream.

$$\sigma_{Q_{CRD\_IN}} = x_{CRD}\ \% \cdot Q_{CRD\_IN} \qquad \text{(Equation 35)}$$

The reactor pressure vessel heat loss uncertainty, σ_{QRAD}, is determined by Equation 36, where x_{RAD} is the uncertainty assigned to the heat loss value calculated by LM-0553 (Reference 4.8.3).

$$\sigma_{Q_{RAD}} = x_{RAD}\ \% \cdot Q_{RAD} \qquad \text{(Equation 36)}$$

The RWCU heat removal uncertainty, σ_{QRWCU}, is determined by Equation 37, where x_{RWCU} is the uncertainty calculated for the RWCU heat balance terms.

$$\sigma_{Q_{RWCU}} = x_{RWCU}\ \% \cdot Q_{RWCU} \qquad \text{(Equation 37)}$$

The Recirculation Pump heat addition uncertainty, σ_{QP}, is determined by Equation 38, where x_P is the uncertainty calculated for measurement of the recirculation pump motor power.

$$\sigma_{Q_P} = x_P\ \% \cdot Q_P \qquad \text{(Equation 38)}$$

6.2.5 Extended Instrument Drift

Instrument drift specifications are usually published for a defined period of time. The instrument drift for one period of time is independent from the instrument drift of any other equivalent period of time. Therefore, the drift specification D for a period of X months can be expanded to n·X months (where n is the station surveillance interval divided by the vendor drift interval and n is an integer greater than zero) by the SRSS method. Instrument drift for surveillance intervals exceeding the instrument suppliers' specified drift interval is calculated using Equation 39 (Section 4.1.1 of reference 4.1.1,).

$$D_n = [n \cdot (D_x)^2]^{1/2} \qquad \text{(Equation 39)}$$

7.0 NUMERIC ANALYSIS

7.1 FEEDWATER FLOW UNCERTAINTY

The uncertainty of the feedwater mass flow rate measurement for the Caldon® Ultrasonics Leading Edge Flow Meter Check Plus (LEFM✓+) system is taken from Reference 4.8.6, Section 2.0, using Equation 28.

$$\sigma_{W_{FW}} = U_{FW\ measurement} * W_{FW} = 0.28\% * W_{FW}$$

$$= 0.0028 * 15{,}255{,}000 \text{ lbm/hr}$$

$$= 42{,}714 \text{ lbm/hr}$$

7.2 STEAM DOME PRESSURE MEASUREMENT UNCERTAINTY

The uncertainty of the steam dome pressure measurement is taken from Reference 4.8.8.

$$\sigma_{P_S} = \pm 20 \text{psig}$$

7.3 REACTOR WATER CLEAN-UP (RWCU) FLOW LOOP UNCERTAINTY

7.3.1 RWCU Flow Loop Accuracy (LA_{RWCU_Flow})

7.3.1.1 RWCU Flow Element Reference Accuracy (A1)

Reference Accuracy is specified as ± 1.50% of actual rate of flow (Section 2.2.3).

$A1_{2\sigma}$ = ± 1.50% Flow

7.3.1.2 RWCU Flow Element Installation Effect (IE1)

The flow elements meet the installation requirements of Ref. 4.6.5. Therefore,

IE1 = ± 0.50% Flow

7.3.1.3 RWCU Flow Element Temperature Effect on Flow Element Expansion (TN1)

Per section 2.2.3, the maximum temperature of the water passing through the flow element is 582 °F and the normal temperature is 539 °F with the flow elements located just upstream of the RWCU Recirculation Pumps. Since the system temperature operation band is small, there is a minor change in the flow element expansion factor. The change is in order of 0.003 inches or less for the temperature range of 515 °F to 560 °F. Therefore the temperature effect on flow element expansion can be neglected.

TN1 = ± 0% Flow

7.3.1.4 RWCU Flow Element Temperature Effect on Density (TD1)

During normal operations the temperature of the fluid passing through the flow element at the inlet of the RWCU system is approximately 535.3 °F. The effect temperature has on density will be evaluated at ± 4.37 °F (Section 7.4.6) from the base condition of 535.3 °F at 1060 psig (1074.7 psia) at the flow element (Section 2.2.3). Density is relatively constant at 1060 psig; however, for conservatism a variation of ± 10 psig is used to show that the pressure effect is negligible even at four times the nominally specified transmitter reference accuracy of 0.25 %. The uncertainty in the density, $\sigma_P(T,P)$, as a function of temperature and pressure will follow Equation 33. Density values are from Reference 4.9.3 (printout included as Attachment 6).

$$\sigma_{\rho}(T_{RWCU}) = \sqrt{\left(\frac{\rho(539.7)-\rho(530.9)}{539.7-530.9}\right)^2 \left(\frac{\frac{lbm}{ft^3}}{psi}\right)^2 * (4.4\,°F)^2 + \left(\frac{\rho(1070)-\rho(1050)}{1070-1050}\right)^2 \left(\frac{\frac{lbm}{ft^3}}{psi}\right)^2 * (10\,psi)^2}$$

$$= \sqrt{\left(\frac{46.693-47.275}{539.7-530.9}\right)^2 \left(\frac{\frac{lbm}{ft^3}}{°F}\right)^2 * (4.4\,°F)^2 + \left(\frac{46.994-46.980}{1070-1050}\right)^2 \left(\frac{\frac{lbm}{ft^3}}{psi}\right)^2 * (10\,psi)^2}$$

$$\sigma_{\rho}(T_{FW}) = 0.29108\ \frac{lbm}{ft^3}$$

Divide by the base density at 535.3°F and 1060 psig to convert to a percentage value:

$$\sigma_{\rho}(T_{RWCU}, P_{10}) = \frac{0.291\,(lbm/ft^3)}{46.987\,(lbm/ft^3)} @ 535.3\,°F = 0.00619 = 0.619\,\%$$

The percent change in density, σ_x, as a function of the percent change in flow, σ_1, is given by the following equation (Reference Attachment 8, Equation A8-10):

$$\sigma_x \approx 2 * \sigma_1$$

Rearranging Equation A8-10 and substituting σ_ρ for σ_x to solve for the unknown flow uncertainty, σ_1:

$$\begin{aligned} TD1_{\%flow} &= \frac{1}{2} \cdot TD1_{\%density} \\ &= \frac{1}{2} \cdot 0.619\,\% \\ &= 0.309\,\% \end{aligned}$$

$$TD1_{\%flow} = 0.3\,\%\ \text{of flow}$$

7.3.1.5 RWCU Flow Element Humidity Error (e1H)

The flow element is a mechanical device installed within the process. Therefore, humidity effects are not applicable.

e1H = 0

7.3.1.6 RWCU Flow Element Radiation Error (e1R)

The flow element is a mechanical device installed within the process. Therefore, radiation effects are not applicable.

e1R = 0

7.3.1.7 RWCU Flow Element Seismic Error (e1S)

For normal error analysis, normal vibrations and seismic effects are considered negligible or capable of being calibrated out. Therefore, there is no seismic error for normal operating conditions (Section 3.5).

e1S = 0

7.3.1.8 RWCU Flow Element Static Pressure Offset Error (e1SP)

The flow element is a mechanical device installed within the process. Therefore, static pressure effects are not applicable.

e1SP = 0

7.3.1.9 RWCU Flow Element Ambient Pressure Error (e1P)

The flow element is a mechanical device installed within the process. Therefore, therefore the flow element is not subject to ambient pressure variations.

e1P = 0

7.3.1.10 RWCU Flow Element Process Error (e1Pr)

Any process errors have been accounted for as errors associated with Temperature Effect on Density. Therefore,

e1Pr = 0

7.3.1.11 RWCU Flow Element Temperature Error (e1T)

Temperature error is considered to be a random variable for the flow elements and is addressed under Temperature Effect on Flow Element Expansion (Section 7.3.1.3). Therefore,

e1T = 0

7.3.1.12 RWCU Flow Transmitter Reference Accuracy (A2)

Reference Accuracy is specified as ± 0.25 % of span considered to be a 3σ value (Section 2.2.4). The reference accuracy is set to the calibration accuracy per plant procedure (Reference 4.1.1).

$A2_{3\sigma} = \pm 0.50\ \%\ [3\sigma]$

Converting to a 2σ value

$A2_{2\sigma} = \pm 0.50\ \% * 2 / 3$

$A2_{2\sigma} = \pm 0.3333\ \%$ of span

Converting % span to % flow

Rearranging Equation A8-10, $\sigma_{\Delta P} = 2 * \sigma_{FLOW}$, to solve for flow (Reference Attachment 8):

$A2_{2\sigma\%Flow} = A2_{\%Span} / 2$

$= \pm 0.3333\ \%$ of span / 2

$= \pm 0.1667\ \%$ of Flow

$A2_{2\sigma\%Flow} = \pm 0.1667\ \%$ of Flow

7.3.1.13 RWCU Flow Transmitter Power Supply Effects (σ2PS2)

Power supply effects are considered to be negligible (Section 3.7). Therefore,

$\sigma 2PS2 = \pm 0$

7.3.1.14 RWCU Flow Transmitter Ambient Temperature Error ($\sigma 2T$)

The temperature effect is ± (0.75 % URL + 0.5 % span)/100°F [3σ] (Section 2.2.4). The maximum temperature at the transmitter location is 106 °F, and minimum temperature during calibration could be 65 °F, so the maximum difference = 106 – 65 °F = 41 °F (Section 2.3.4)

$\sigma 2T_{3\sigma}$ = ± [(0.0075 * 750 INWC + 0.005 * 220 INWC) * 41 °F/ 100 °F]

= ± [(5.625 INWC + 1.1 INWC) * 0.41]

$\sigma 2T_{3\sigma}$ = ± 2.76 INWC [3σ], rounded to level of significance

Converting to a 2σ value

$\sigma 2T_{2\sigma}$ = ± 2.76 INWC * 2 / 3

$\sigma 2T_{2\sigma}$ = ± 1.8382 INWC

Converting to % span

$\sigma 2T_{2\sigma}$ = ± 1.8382 INWC / 220 INWC

= ± 0.008355 = 0.8355 %

Converting % span to % flow

Rearranging Equation A8-10, $\sigma_{\Delta P} = 2 * \sigma_{FLOW}$, to solve for flow (Reference Attachment 8):

$\sigma 2T_{2\sigma\%Flow}$ = $\sigma 2T_{2\sigma\%Span} / 2$

= ± 0.8355 % / 2

= ± 0.4178 %

$\sigma 2T_{2\sigma\%Flow}$ = ± 0.418 %

7.3.1.15 RWCU Flow Transmitter Humidity Error (e2H)

The manufacturer specifies the transmitter operating humidity limits between 0 and 100 % RH (Section 2.2.4). The transmitter is located in Containment H2 Recombiner Room 506C, Area 16 where humidity may vary from 50 to 90% RH (Reference 4.4.2). Humidity errors are set to zero because they are considered to be included within the reference accuracy specification under these conditions. (Section 3.2)

e2H = 0

7.3.1.16 RWCU Flow Transmitter Radiation Error (e2R)

The manufacturer specifies the transmitter operating radiation effect during and after exposure to 2.2 x 10^7 rads TID (Section 2.2.4). The transmitter is located in Containment H2 Recombiner Room 506C, Area 16, where total integrated dose (TID) could be as high as 8.78 x 10^2 rad (Reference Section 4.4.2). Therefore,

e2R = ± (4.0 % of URL) * dose / rated dose

= ± (0.04 · 750 INWC) * 8.78 x 10^2 / 2.2 x 10^7

= ± 30 INWC * 3.99 x 10^{-5}

e2R = ± 1.20 x 10^{-3} INWC

Converting to % span

$e2R_{\%Span}$ = ± 1.20 x 10^{-3}INWC / 220 INWC

= ± 5.44 x 10^{-6} = 5.44 x 10^{-4} %

Converting % span to % flow

Rearranging Equation A8-10, $\sigma_{\Delta P} = 2 * \sigma_{FLOW}$, to solve for flow (Reference Attachment 8):

$e2R_{\%Flow} = e2R_{\%Span} / 2$

$= \pm 5.44 \times 10^{-4} \% / 2$

$= \pm 2.72 \times 10^{-4} \%$

$= \pm 2.72 \times 10^{-4} \%$, which is negligible

$e2R_{\%Flow} = 0$

7.3.1.17 RWCU Flow Transmitter Seismic Error (e2S)

The transmitter's accuracy is within ± 0.5% of URL (upper range limit) during and after a seismic disturbance defined by a required response spectrum with a ZPA of 4 g's. A seismic event defines a particular type of accident condition. Therefore, there is no seismic error for normal operating conditions (Section 3.5)

$e2S = 0$

7.3.1.18 RWCU Flow Transmitter Ambient Pressure Error (e2P)

The flow transmitter is an electrical device and therefore not affected by ambient pressure.

$e2P = 0$

7.3.1.19 RWCU Flow Transmitter Temperature Error (e2T)

Temperature error is considered to be a random variable for a Rosemount transmitter. Therefore

$e2T = 0$

7.3.1.20 RWCU PPC I/O Module and SRU Reference Accuracy (A3)

Reference accuracy of the computer input is taken to be the SRSS of the reference accuracies of the SRU and the I/O module. The reference accuracy of the SRU is 0.1 % of span (Section 2.2.5). Reference Accuracy for the I/O module is specified as ± 0.5 % of span (Section 2.2.6).

$A3_{2\sigma} = \sqrt{0.1^2 + 0.5^2} = 0.5099 = 0.51$ % span

Converting % span to % flow

Rearranging Equation A8-10, $\sigma_{\Delta P} = 2 * \sigma_{FLOW}$, to solve for flow (Reference Attachment 8):

$A3_{\%Flow} = A3_{\%Span} / 2$

$= \pm 0.51\% / 2$

$A3_{\%Flow} = \pm 0.255 \%$

7.3.1.21 RWCU PPC I/O Module Humidity Error (e3H)

The manufacturer specifies the I/O module operating humidity limits between 0 and 95 % RH (Section 2.2.6). The I/O module is located in the Control Room 533, where humidity may vary from 50 to 90% RH (Reference 4.4.2). Humidity errors are set to zero because they are considered to be included within the reference accuracy specification under these conditions (Section 3.2).

$e3H = 0$

7.3.1.22 RWCU PPC I/O Module Radiation Error (e3R)

No radiation errors are specified in the manufacturer's specifications. The instrument is located in the Control Room 533, a mild environment (Section 4.4.2). Therefore, it is reasonable to consider the normal radiation effect as being included in the reference accuracy.

$e3R = 0$

7.3.1.23 RWCU PPC I/O Module Seismic Error (e3S)

No seismic effect errors are specified in the manufacturer's specifications. A seismic event defines a particular type of accident condition. Therefore, there is no seismic error for normal operating conditions (Section 3.5).

$e3S = 0$

7.3.1.24 RWCU PPC I/O Module Static Pressure Offset Error (e3SP)

The I/O module is an electrical device and therefore not affected by static pressure.

$e3SP = 0$

7.3.1.25 RWCU PPC I/O Module Ambient Pressure Error (e3P)

The I/O module is an electrical device and therefore not affected by ambient pressure.

$e3P = 0$

7.3.1.26 RWCU PPC I/O Module Process Error (e3Pr)

The I/O module receives an analog current input from the flow transmitter proportional to the pressure sensed. Any process errors associated with the conversion of pressure to a current signal have been accounted for as errors associated with Flow Element. Therefore,

$e3Pr = 0$

7.3.1.27 RWCU Flow Loop Accuracy (LA_{RWCU_Flow})

$$LA_{RWCU\_Flow} = \pm [(A1)^2 + (IE1)^2 + (TN1)^2 + (TD1)^2 + (e1H)^2 + (e1R)^2 + (e1S)^2 + (e1SP)^2 + (e1P)^2 + (e1Pr)^2 + (e1T)^2 + (A2)^2 + (s2PS2)^2 + (s2T)^2 + (e2H)^2 + (e2R)^2 + (e2S)^2 + (e2P)^2 + (e2T)^2 + (A3)^2 + (e3H)^2 + (e3R)^2 + (e3S)^2 + (e3SP)^2 + (e3P)^2 + (e3Pr)^2]^{1/2}$$

$$= \pm [(1.5)^2 + (0.5)^2 + (0)^2 + (0.3)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0.1667)^2 + (0)^2 + (0.418)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0.255)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2]^{1/2}$$

$$= \pm 1.690425\ \%$$

$$LA_{RWCU\_Flow} = \pm 1.7\ \%$$

7.3.2 RWCU Flow Loop Drift (LD_{RWCU_Flow})

7.3.2.1 RWCU Flow Element Drift Error (D1)

The flow element is a mechanical device; drift error is not applicable for the flow elements. Therefore,

$D1 = \pm 0.00\%$ Flow

7.3.2.2 RWCU Flow Transmitter Drift Error (D2)

Drift error for the transmitter is ± 0.2% of URL / 30 months, taken as a random 2σ value (Section 2.2.4). The calibration frequency is 2 years, with a late factor of 6 months.

$D2_{2\sigma} = \pm (0.2\% * URL)$

Drift is applied to the surveillance interval (SI) using Equation 39 (Section 6.2.5) as follows

$D2_{2\sigma} = \pm [n \cdot (D_x)^2]^{1/2}$,

$= \pm ([(24 \text{ months} + 6 \text{ months}) / 30 \text{ months}] \cdot [0.002 \text{ URL}]^2)^{1/2}$

$= \pm ([(30 / 30)] \cdot [1.5 \text{ INWC}]^2)^{1/2}$

$D2_{2\sigma} = \pm 1.50$ INWC

Converting to % span

$D2_{\%Span} = \pm 1.5 \text{ INWC} / 219.8 \text{ INWC}$

$= \pm 0.00682439 = 0.682439 \%$

Converting % span to % flow

Rearranging Equation A8-10, $\sigma_{\Delta P} = 2 * \sigma_{FLOW}$, to solve for flow (Reference Attachment 8):

$D2_{\%Flow} = D2_{\%Span} / 2$

$= \pm 0.682439\% / 2$

$= \pm 0.341219 \%$

$D2_{\%Flow} = \pm 0.34 \%$

7.3.2.3 RWCU Flow PPC I/O Module Drift Error (D3)

The vendor does not specify a drift error for the I/O module. Therefore, per Ref. 4.1.1 Section I, it is considered to be included in the reference accuracy.

$D3 = \pm 0$

7.3.2.4 RWCU Flow Loop Drift (LD_{RWCU_Flow})

$LD_{RWCU\_Flow} = [(D1)^2 + (D2)^2 + (D3)^2]^{1/2}$

$= [(0)^2 + (0.34)^2 + (0)^2]^{1/2}$

$= \pm 0.341219 \%$

$LD_{RWCU\_Flow} = \pm 0.34 \%$

7.3.3 RWCU Flow Loop Process Measurement Accuracy (PMA_{RWCU_Flow})

No additional PMA effects beyond the effects specified in the calculation of loop accuracy.

$PMA_{RWCU\_Flow} = 0$

7.3.4 RWCU Flow Loop Primary Element Accuracy (PEA_{RWCU_Flow})

No additional PEM effects beyond the effects specified in the calculation of loop accuracy.

$PEA_{RWCU\_Flow} = 0$

7.3.5 RWCU Flow Loop Calibration Accuracy (CA_{RWCU_Flow})

Standard practice is to specify calibration uncertainty in calculations equal to the uncertainty associated with the instruments under test (Reference 4.1.1).

Therefore,

$CA_{RWCU\_Flow} = [(A1)^2 + (A2)^2 + (A3)^2]^{1/2}$

$= [(1.5 \%)^2 + (0.1667 \%)^2 + (0.255 \%)^2]^{1/2}$

$CA_{RWCU\_Flow} = 1.5 \%$

7.3.6 Total Uncertainty RWCU Flow Loop (TU_{RWCU_Flow}).

$$TU_{RWCU\_Flow} = \pm [(LA)^2 + (LD)^2 + (PMA)^2 + (PEA)^2 + (CA)^2]^{1/2}$$

$$= \pm [(1.7)^2 + (0.34)^2 + (0)^2 + (0)^2 + (1.5)^2]^{1/2}$$

$$= \pm 2.29251\%$$

$$TU_{RWCU\_Flow} = \pm 2.3 \text{ \% of flow}$$

To convert 2.3% flow error to lbm/hr rated flow of flow 0.1540 Mlbm/hr (Table 2-1):

Converting to lbm/hr for water at rated conditions:

$$TE_{MASS} = \pm (2.3 \%)*(0.1540 \text{ Mlbm/hr})$$

$$TE_{MASS} = \pm 3542 \text{ lbm/hr, or } \pm 0.0035 \text{ Mlbm/hr}$$

This value is entered into Table 2-1 for the uncertainty associated with RWCU flow.

7.4 RWCU TEMPERATURE LOOP UNCERTAINTY

7.4.1 RWCU Temperature Loop Accuracy (LA_{RWCU_T})

7.4.1.1 RWCU Temperature Element Reference Accuracy (A1)

RWCU Temperature Element Reference Accuracy is provided in Section 2.3.1.

$A1 = \pm 0.75$ °F

7.4.1.2 RWCU Temperature Element Power Supply Effects (σ1PS)

Power supply effects are considered to be negligible (Section 3.7). Therefore,

$\sigma 1PS = 0$

7.4.1.3 RWCU Temperature Element Ambient Temperature Error (σ1T)

All thermocouple extension wire junctions are on adjacent terminals and are assumed to be at the same temperature. Therefore, for the thermocouple,

$\sigma 1T_{1\sigma} = 0$

7.4.1.4 RWCU Temperature Element Humidity Error (e1H)

The manufacturer does not specify the thermocouple operating humidity limits (Section 2.3.1). The thermocouple is located in the RWCU System Room 506, where humidity may vary from 50 to 90% RH (Reference 4.4.2). Humidity errors are set to zero because they are considered to be included within the reference accuracy specification under these conditions (Section 3.2).

$e1H = 0$

7.4.1.5 RWCU Temperature Element Radiation Error (e1R)

No radiation errors are specified in the manufacturer's specifications. The instrument is located in the Control Room 533, a mild environment (Reference 4.4.2). Therefore, it is reasonable to consider the normal radiation effect as being included in the reference accuracy. Therefore,

$e1R = 0$

7.4.1.6 RWCU Temperature Element Seismic Error (e1S)

No seismic effect errors are specified in the manufacturer's specifications. A seismic event defines a particular type of accident condition. Therefore, there is no seismic error for normal operating conditions (Section 3.5).

$e1S = 0$

7.4.1.7 RWCU Temperature Element Vibration Effect (e1V)

The error due to vibration is considered to be negligible because it is small and unaffected by vibrations in the system.

$e1V = 0$

7.4.1.8 RWCU Temperature Element Static Pressure Error (e1SP)

The thermocouple output is not subject to pressure variations.

$e1SP_{1\sigma} = 0$

7.4.1.9 RWCU Temperature Element Ambient Pressure Error (e1P)

The thermocouple is an electrical device and therefore not affected by ambient pressure.

$e1P = 0$

7.4.1.10 RWCU Temperature Element Temperature Error (e1T)

The temperature error is assumed to be included in the reference accuracy (Reference 4.1.1). Therefore,

$e1T = 0$

7.4.1.11 RWCU Temperature Loop PPC I/O Module Reference Accuracy (A2)

Reference Accuracy is specified as ± 3.0 °F (Section 2.3.3) and considered to be a 2σ value (Section 3.4)

$A2_{2\sigma} = \pm 3.0\ °F$

7.4.1.12 RWCU Temperature Loop PPC I/O Module Humidity Error (e2H)

The manufacturer specifies the I/O module operating humidity limits between 0 and 95 % RH (Section 2.3.3). The I/O module is located in the Control Room 533, where humidity may vary from 50 to 90% RH (Reference Section 4.4.2). Humidity errors are set to zero because they are considered to be included within the reference accuracy specification under these conditions. (Section 3.2)

$e2H = 0$

7.4.1.13 RWCU Temperature Loop PPC I/O Module Radiation Error (e2R)

No radiation errors are specified in the manufacturer's specifications. The instrument is located in the Control Room 533, a mild environment [Section 4.4.2]. Therefore, it is reasonable to consider the normal radiation effect as being included in the reference accuracy. Therefore,

$e2R = 0$

7.4.1.14 RWCU Temperature Loop PPC I/O Module Seismic Error (e2S)

No seismic effect errors are specified in the manufacturer's specifications. A seismic event defines a particular type of accident condition. Therefore, there is no seismic error for normal operating conditions (Section 2.8).

$e2S = 0$

7.4.1.15 RWCU Temperature Loop PPC I/O Module Static Pressure Offset Error (e2SP)

The I/O module is an electrical device installed in the control room and is not subject to pressure effects.

$e2SP = 0$

7.4.1.16 RWCU Temperature Loop PPC I/O Module Ambient Pressure Error (e2P)

The I/O module is an electrical device and therefore not affected by ambient pressure.

$e2P = 0$

7.4.1.17 RWCU Temperature Loop Accuracy (LA_{RWCU_Flow})

$$LA_{RWCU\_T} = \pm [(A1)^2 + (\sigma 1PS)^2 + (\sigma 1T)^2 + (e1H)^2 + (e1R)^2 + (e1S)^2 + (e1V)^2 + (e1SP)^2 + (e1P)^2 + (e1T)^2 + (A2)^2 + (e2H)^2 + (e2R)^2 + (e2S)^2 + (e2SP)^2 + (e2P)^2]^{1/2}$$

$$= \pm [(0.75)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (3.0)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2]^{1/2}\ °F$$

$$= \pm [0.5625 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 9.0 + 0 + 0 + 0 + 0 + 0]^{1/2}\ °F$$

$$= \pm [9.5625\ °F^2]^{1/2}$$

$$LA_{RWCU\_T} = \pm 3.09\ °F$$

7.4.2 RWCU Temperature Loop Drift

7.4.2.1 RWCU Temperature Element Drift Error (D1)

The error associated with the thermocouple is already included in the reference accuracy (Section 3.2). Therefore, for the thermocouple,

$D1 = \pm 0$

7.4.2.2 RWCU Temperature Loop PPC I/O Module Drift Error (D2)

The vendors do not specify drift errors for the SRU and I/O module. Therefore, per Section 3.2, it is considered to be included in the reference accuracy.

$D2 = \pm 0$

7.4.2.3 RWCU Temperature Loop Drift (LD_{RWCU_T})

$$LD_{RWCU\_T} = [(D1)^2 + (D2)^2]^{1/2}$$

$$= [(0)^2 + (0)^2]^{1/2}$$

$$= \pm 0.0\ \%$$

$$LD_{RWCU\_T} = \pm 0\ \%$$

7.4.3 RWCU Temperature Loop (PMA_{RWCU_T})

No additional PMA effects beyond the effects specified in the calculation of loop accuracy.

$PMA_{RWCU\_T} = \pm 0$

7.4.4 RWCU Temperature Loop (PEA_{RWCU_T})

No additional PMA effects beyond the effects specified in the calculation of loop accuracy.

$PEA_{RWCU\_T} = 0$

7.4.5 RWCU Temperature Loop Calibration Accuracy (CA_{RWCU_T})

Standard practice is to specify calibration uncertainty in calculations equal to the uncertainty associated with the instruments under test (Reference 4.1.1).

Therefore,

$$CA_{RWCU\_T} = [(A1)^2 + (A2)^2 + (A3)^2]^{1/2}$$

$$= [(\pm 0.75\ °F)^2 + (\pm 3.0\ °F)^2]^{1/2}$$

$$CA_{RWCU\_T} = \pm 3.09\ °F$$

7.4.6 Total Uncertainty RWCU Temperature Loop (TU_{RWCU_T})

$$TU_{RWCU\_T} = \pm [(LA)^2 + (LD)^2 + (PMA)^2 + (PEA)^2 + (CA)^2]^{1/2}$$

$$= \pm [(3.09)^2 + (0)^2 + (0)^2 + (0)^2 + (3.09)^2]^{1/2}$$

$$= \pm 4.370 \text{ °F}$$

$$TU_{RWCU\_T} = \pm 4.37 \text{ °F}$$

7.5 CRD FLOW RATE UNCERTAINTY

7.5.1 CRD Flow Rate Loop Accuracy (LA_{CRD_Flow})

7.5.1.1 CRD Flow Element Reference Accuracy (A1)

The accuracy of the flow element is ± 1% of actual rate of flow (Section 2.4.2).

Therefore,

A1 = ± 1 % flow

7.5.1.2 CRD Flow Element Humidity, Radiation, Pressure, and Temperature Errors (e1H, e1R, e1P, e1T)

The flow element is a mechanical device mounted in the process and its output is not subject to environmental or vibration effects. Therefore;

e1H = e1R = e1P = e1T = 0

7.5.1.3 CRD Flow Element Seismic Error (e1S)

A seismic event is an abnormal operating condition and is not addressed by this calculation (Section 3.5). Therefore;

e1S = 0

7.5.1.4 CRD Flow Element Static Pressure Error (e1SP)

The flow element is constructed of stainless steel and is not affected by process pressure. Therefore,

e1SP = 0

7.5.1.5 CRD Flow Transmitter Reference Accuracy (A2)

Reference Accuracy is ± 0.25 % of span (Section 2.4.3). The reference accuracy is set to the calibration accuracy per plant procedure (Reference 4.1.1).

A2 = ± 0.50 %

Converting % span to % flow

Rearranging Equation A8-10, $\sigma_{\Delta P} = 2 * \sigma_{FLOW}$, to solve for flow (Reference Attachment 8):

$$A2_{\%Flow} = A2_{\%Span} / 2$$

$$= \pm 0.50 \text{ \% of span} / 2$$

$$= \pm 0.25 \text{ \% of Flow}$$

$$A2_{\%Flow} = \pm 0.25 \text{ \% of Flow}$$

7.5.1.6 CRD Flow Transmitter Power Supply Effects ($\sigma 2PS$)

Power supply effects are considered to be negligible (Section 3.7). Therefore,

$\sigma 2PS = \pm 0$

7.5.1.7 CRD Flow Transmitter Ambient Temperature Error ($\sigma 2T$)

The temperature effect is ± 2.4 % of span per 100 °F at 197.5 INWC span (Section 2.4.3). The calibrated span is 197.5 INWC. The maximum temperature at the transmitter location is 106 °F, and minimum temperature during calibration could be 65 °F, so the maximum difference = 106 - 65 °F = 41 °F (Section 2.3.4).

$\sigma 2T = \pm [(0.024 \cdot 197.5 \text{ INWC}) / 100 \text{ °F}] \cdot 41 \text{ °F}$ [3σ]

$= \pm [(4.74 \text{ INWC})/100 \text{ °F}] \cdot 41 \text{ °F}$

$= \pm 1.943 \text{ INWC}$

Converting to % span

$\sigma 2T_{2\sigma} = \pm 1.943 \text{ INWC} / 197.5 \text{ INWC}$

$= \pm 0.0098$

Converting % span to % flow

Rearranging Equation A8-10, $\sigma_{\Delta P} = 2 * \sigma_{FLOW}$, to solve for flow (Reference Attachment 8):

$\sigma 2T_{2\sigma\%Flow} = \sigma 2T_{2\sigma\%Span} / 2$

$= \pm 0.98 \% / 2$

$= \pm 0.49 \%$

$\sigma 2T_{2\sigma\%Flow} = \pm 0.49 \%$

7.5.1.8 CRD Flow Transmitter Humidity Error (e2H)

The manufacturer specifies the transmitter operating humidity limits between 0 and 100 % RH (Section 2.4.3). The transmitter is located in the CRD Equipment Area, Room 402, where humidity may vary from 50 to 90% RH (Reference 4.4.2). Humidity errors are set to zero because they are considered to be included within the reference accuracy specification under these conditions. (Section 3.2)

$e2H = 0$

7.5.1.9 CRD Flow Transmitter Radiation Error (e2R)

Radiation error is assumed to be 10 % of span (Section 3.9).

$e2R = 10 \% \text{ of Span}$

$= 10 \% \cdot 197.5 \text{ INWC}$

$e2R = 19.75 \text{ INWC}$

Converting to % span

$\sigma 2R = \pm 19.75 \text{ INWC} / 197.5 \text{ INWC}$

$= \pm 0.10 = 10 \%$

Converting % span to % flow

Rearranging Equation A8-10, $\sigma_{\Delta P} = 2 * \sigma_{FLOW}$, to solve for flow (Reference Attachment 8):

$\sigma 2R_{\%Flow} = \sigma 2R_{2\sigma\%Span} / 2$

$= \pm 10.0\% / 2$

$= \pm 5.00\%$

$\sigma 2R_{\%Flow} = \pm 5.0\%$

7.5.1.10 CRD Flow Transmitter Seismic Error (e2S)

No seismic effect errors are specified in the manufacturer's specifications. A seismic event defines a particular type of accident condition. Therefore, there is no seismic error for normal operating conditions (Section 3.5)

$e2S = 0$

7.5.1.11 CRD Flow Transmitter Vibration Effect (e2V)

The error due to vibration is considered to be negligible because it is small and unaffected by vibrations in the system.

$e2V = 0$

7.5.1.12 CRD Flow Transmitter Static Pressure Zero Error (e2SP)

The transmitter has a Zero Error of ± 0.5 % of URL for 2000 psi (Section 2.4.3). The calibrated range shown in Table 2-12 shows the static pressure adjustment made to account for the span error effect. Therefore, the total Static Pressure Error is

$e2SP = \pm 0.5\ \%$ of URL for 2000 psi

The normal operating pressure (Table 2-11) is 1448 psig. Therefore,

$$e2SP = \pm 0.5\ \% \cdot 750\ \text{INWC} \cdot 1448\ \text{psig} / 2000\ \text{psi}$$

$$= \pm 2.715\ \text{INWC}$$

$$e2SP = \pm 2.72\ \text{INWC, rounded}$$

Converting to % span

$$\sigma 2SP = \pm 2.72\ \text{INWC} / 200\ \text{INWC}$$

$$= \pm 0.01316 = 1.32\ \%$$

Converting % span to % flow

Rearranging Equation A8-10, $\sigma_{\Delta P} = 2 * \sigma_{FLOW}$, to solve for flow (Reference Attachment 8):

$$\sigma 2SP_{\%Flow} = \sigma 2SP_{2\sigma\%Span} / 2$$

$$= \pm 1.32\ \% / 2$$

$$\sigma 2SP_{\%Flow} = \pm 0.66\ \%$$

7.5.1.13 CRD Flow Transmitter Ambient Pressure Error (e2P)

The flow transmitter is an electrical device and therefore not affected by ambient pressure.

$e2P = 0$

7.5.1.14 CRD Flow Transmitter Temperature Error (e2T)

Temperature error is considered to be a random variable for a Rosemount transmitter. Therefore

$e2T = 0$

7.5.1.15 CRD Flow Loop PPC I/O Module Reference Accuracy (A3)

Reference accuracy of the computer input is taken to be the SRSS of the reference accuracies of the SRU and the I/O module. The reference accuracy of the SRU is 0.1 % of span. Reference Accuracy for the I/O module is specified as ± 0.5 % of span (Sections 2.4.4 and 2.4.5).

$$A3_{2\sigma} = \sqrt{0.1^2 + 0.5^2} = 0.5099 = 0.51\ \%\ \text{span}$$

Converting % span to % flow

Rearranging Equation A8-10, $\sigma_{\Delta P} = 2 * \sigma_{FLOW}$, to solve for flow (Reference Attachment 8):

$A3_{\%Flow}$ = $A3_{\%Span} / 2$

= ± 0.51% / 2

$A3_{\%Flow}$ = ± 0.255 %

7.5.1.16 CRD Flow Loop PPC I/O Module Humidity Error (e3H)

The manufacturer specifies the I/O module operating humidity limits between 0 and 95 % RH (Section 2.4.4). The I/O module is located in the Control Room 533, where humidity may vary from 50 to 90 % RH (Reference 4.4.2). Humidity errors are set to zero because they are considered to be included within the reference accuracy specification under these conditions. (Section 3.2)

e3H = 0

7.5.1.17 CRD Flow Loop PPC I/O Module Radiation Error (e3R)

No radiation errors are specified in the manufacturer's specifications. The instrument is located in the Control Room 533, a mild environment [Reference 4.4.2]. Therefore, it is reasonable to consider the normal radiation effect as being included in the reference accuracy. Therefore,

e3R = 0

7.5.1.18 CRD Flow Loop PPC I/O Module Seismic Error (e3S)

No seismic effect errors are specified in the manufacturer's specifications. A seismic event defines a particular type of accident condition. Therefore, there is no seismic error for normal operating conditions (Section 3.5).

e3S = 0

7.5.1.19 CRD Flow Loop PPC I/O Module Static Pressure Offset Error (e3SP)

The I/O module is an electrical device and therefore not affected by static pressure.

e3SP = 0

7.5.1.20 CRD Flow Loop PPC I/O Module Ambient Pressure Error (e3P)

The I/O module is an electrical device and therefore not affected by ambient pressure.

e3P = 0

7.5.1.21 CRD Flow Loop PPC I/O Module Process Error (e3Pr)

The I/O module receives an analog current input from the flow transmitter proportional to the pressure sensed. Any process errors associated with the conversion of pressure to a current signal have been accounted for as errors associated with flow transmitter. Therefore,

e3Pr = 0

7.5.1.22 CRD Flow Loop Accuracy (LA_{CRD_Flow})

$$LA_{CRD\_Flow} = [(A1)^2 + (e1H)^2 + (e1R)^2 + (e1P)^2 + (e1T)^2 + (e1S)^2 + (e1SP)^2 + (A2)^2 + (\sigma 2PS2)^2 + (\sigma 2T)^2 + (e2H)^2 + (e2R)^2 + (e2S)^2 + (e2V)^2 + (e2SP)^2 + (e2P)^2 + (e2T)^2 + (A3)^2 + (e3H)^2 + (e3R)^2 + (e3S)^2 + (e3SP)^2 + (e3P)^2 + (e3Pr)^2]^{1/2}$$

$$= [(1)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0.25)^2 + (0)^2 + (0.49)^2 + (0)^2 + (5.0)^2 + (0)^2 + (0)^2 + (0.66)^2 + (0)^2 + (0)^2 + (0.255)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2]^{1/2}$$

$$= \pm 5.177183 \%$$

$$LA_{CRD\_Flow} = \pm 5.2 \%$$

7.5.2 CRD Flow Loop Drift (LD_{CRD_Flow})

7.5.2.1 CRD Flow Element Drift Error (D1)

The flow element is a mechanical device; drift error is not applicable for the flow elements. Therefore,

$D1 = \pm 0.00\%$ Flow

7.5.2.2 CRD Flow Loop Transmitter Drift Error (D2)

7.5.2.3 CRD Flow Loop Drift Error (D2)

Drift error for the transmitter is ± 0.25 % of URL / 6 months, taken as a random 2σ value (Section 3.4). The calibration frequency is 2 years, with a late factor of 6 months.

$D2_{2\sigma} = \pm (0.25\ \% * \text{URL})$

Drift is applied to the surveillance interval as follows (Section 6.2.5):

$D2_{2\sigma} = \pm ([(24 \text{ months} + 6 \text{ months}) / 6 \text{ months}] * [0.0025 \text{ URL}]^2)^{1/2}$

$= \pm ([30/6][0.0025 * 750 \text{ INWC}]^2)^{1/2}$

$= \pm [17.578125]^{1/2}$

$= \pm 4.192627458$ INWC

$D2_{2\sigma} = \pm 4.19$ INWC, rounded to level of significance

Converting to % span

$D2_{\%Span} = \pm 4.19 \text{ INWC} / 197.5 \text{ INWC}$

$= \pm 0.02121 = 2.121\ \%$

Converting % span to % flow

Rearranging Equation A8-10, $\sigma_{\Delta P} = 2 * \sigma_{FLOW}$, to solve for flow (Reference Attachment 8):

$D2_{\%Flow} = D2_{\%Span} / 2$

$= \pm 2.121\ \% / 2$

$= \pm 1.0608\ \%$

$D2_{\%Flow} = \pm 1.0\ \%$

7.5.2.4 CRD Flow Loop PPC I/O Module Drift Error (D3)

The vendor does not specify a drift error for the I/O module. Therefore, per Ref. 4.1.1 Section I, it is considered to be included in the reference accuracy.

$D3 = \pm 0$

7.5.2.5 CRD Flow Loop Drift (LD_{RWCU_Flow})

$LD_{CRD\_Flow} = \pm [(D1)^2 + (D2)^2 + (D3)^2]^{1/2}$

$= \pm [(0)^2 + (1.0)^2 + (0)^2]^{1/2}$

$= \pm [1]^{1/2}$

$LD_{CRD\_Flow} = \pm 1.0\ \%$

7.5.3 CRD Flow Loop Process Measurement Accuracy (PMA_{CRD_Flow})

No additional PMA effects beyond the effects specified in the calculation of loop accuracy.

$PMA_{RWCU\_Flow} = 0$

7.5.4 CRD Flow Loop Primary Element Accuracy (PEA_{CRD_Flow})

No additional PEM effects beyond the effects specified in the calculation of loop accuracy.

$PEA_{RWCU\_Flow} = 0$

7.5.5 CRD Flow Loop Calibration Accuracy (CA_{CRD_Flow})

Standard practice is to specify calibration uncertainty in calculations equal to the uncertainty associated with the instruments under test (Section 4.1.1).

Therefore,

$$CA_{RWCU\_Flow} = [(A1)^2 + (A2)^2 + (A3)^2]^{1/2}$$

$$= [(1\ \%)^2 + (0.25\ \%)^2 + (0.255\ \%)^2]^{1/2}$$

$$= 1.06185\ \%$$

$$CA_{RWCU\_Flow} = 1.06185\ \% = \text{rounded to } 1.1$$

7.5.6 Total Uncertainty CRD Flow Loop (TU_{CRD_Flow})

$$TU_{CRD\_Flow} = [(LA)^2 + (LD)^2 + (PMA)^2 + (PEA)^2 + (CA)^2]^{1/2}$$

$$= [(5.2)^2 + (1.0)^2 + (0)^2 + (0)^2 + (1.1)^2]^{1/2}$$

$$= \pm 5.4083\ \%$$

$$TU_{CRD\_Flow} = \pm 5.4\ \% \text{ of flow}$$

To convert to lbm/hr, at rated flow of 0.0320 Mlbm/hr (Table 2-1):

$$TE_{CRD\_MASS} = \pm (5.4\ \%)*(32000\ \text{lbm/hr})$$

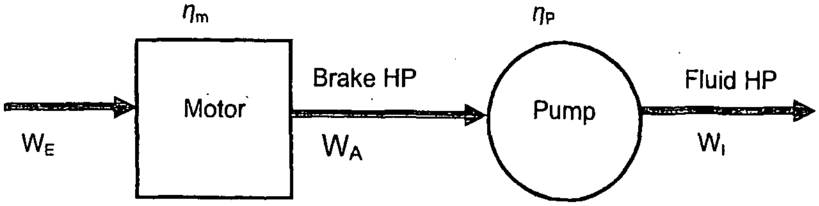
$$TE_{CRD\_MASS} = \pm 0.0017\ \text{Mlbm/hr}$$

This value is entered into Table 2-1 for the uncertainty associated with CRD flow.

7.6 RECIRCULATION PUMP HEAT UNCERTAINTY

7.6.1.1 Recirculation Pump Motor Power (Q_P)

The recirculation pump system consists of two parallel pumps that maintain forced circulation flow loops in the reactor core. The water originates in the core and returns to the core at a higher pressure. The work performed by the recirculation pumps includes the specific work of the pump plus the pump inefficiency. This energy can be estimated by measuring the power consumed by the pump motor and multiplying the pump motor power by the motor efficiency. The maximum design output of the recirculation motor M-G set is 7700 HP, which is monitored by the watts transducer. The 7700 HP is conservatively used in lieu of the motor 7500 HP rated in determining the recirculation pump heat uncertainty.



$\eta_m = \dfrac{W_A}{W_E}$, motor efficiency;

where $W_A = \eta_m \cdot W_E$, motor output to pump (brake horsepower (HP))

$\eta_P = \dfrac{W_I}{W_A}$, pump efficiency

W_I = ideal work energy input to fluid system (fluid HP)

W_E = electric power input to motor (measured power, Watts)

The difference between the input (actual pump power) and the output (ideal) pump power is the power lost to friction in the pump. The heat added to the pump is due to inefficiency.

$$\text{Heat Added by Pump} = \left(\left(1 - \eta_P \middle/ 100 \right) \right) \cdot W_A$$

The calculation of the total recirculation pump heat input, Q_p, is taken from Equation 6 (Section 6.2.1.3).

$Q_P \quad = \quad 2 \cdot \eta_m \cdot W_E$ (Equation 40)

Motor Efficiency, η_m, is 94.8% at maximum speed of 1690 rpm (Reference 4.8.2)

= 2 * 0.948 * 5.74 MW (based on 7,700 Hp motor (Table 2-1)

= 10.8866 MW

Multiply by 3,412,000 Btu/hr per MW to convert to Btu/hr

= 10.8866 MW * 3,412,000 Btu/hr/MW

= 37,145,079 Btu/hr

Q_P = 37,145,000 Btu/hr, rounded to level of significance

Where, standard conversion factors are:

1 HP = 550 ft-lb$_f$/s

1 ft^3 = 7.48 gal

1 W = 3.412 Btu/hr

1 HP = 0.7457 kW

1HP = 2544.43 Btu/hr

7.6.2 Recirculation Pump Motor Watt Transducer Loop Uncertainty

7.6.2.1 Recirculation Pump Motor Watt Transducer Reference Accuracy (A1)

The accuracy of the transducer is ± 0.2 % of Reading + 0.01 % Rated Output at 0 to 200% of the Rated Output (reference Section 2.5.2).

Maximum error is when the reading is equal to the recirculation pump motor power rating in MW, i.e., 7700 HP (5.74 MW, Reference 4.3.3).

$A1_{2\sigma}$ = ± (0.2% * 5.74 MW + 0.01% * 10.5 MW)

= ± 0.01253 MW

$A1_{2\sigma}$ = ± 0.013 MW, rounded to level of significance

7.6.2.2 Recirculation Pump Motor Watt Transducer Power Supply Effects (σ1PS)

Power supply effects are considered to be negligible (Section 3.7). Therefore,

$\sigma 1PS = 0$

7.6.2.3 Recirculation Pump Motor Watt Transducer Ambient Temperature Error (σ1T)

The Watt Transducer is located in the auxiliary electrical room. This is a controlled environment; therefore, temperature error can be neglected.

$\sigma 1T = 0$

7.6.3 Watt Transducer Humidity, Radiation, Pressure, and Temperature Errors (e1H, e1R, e1P, e1T)

The watt transducer is an electrical device and the output is not subject to environmental or vibration effects. Therefore;

e1H = e1R = e1P = e1T = 0

7.6.3.1 Recirculation Pump Motor Watt Transducer Seismic Error (e1S)

A seismic event is an abnormal operating condition and is not addressed by this calculation. Therefore;

e1S = 0

7.6.3.2 Recirculation Pump Motor Watt Transducer Static Pressure Error (e1SP)

The watt transducer is an electrical device not affected by process pressure. Therefore;

e1SP = 0

7.6.3.3 Recirculation Pump Motor Watt Transducer PPC I/O Module Reference Accuracy (A2)

Reference accuracy of the computer input is taken to be the SRSS of the reference accuracies of the SRU and the I/O module. The reference accuracy of the SRU is 0.1 % of span as given in Section 2.5.3. Reference Accuracy for the I/O module is specified as ± 0.5 % of span (Section 2.5.4) and considered to be a 2σ value (Section 3.4).

$A2_{2\sigma} = \sqrt{0.1^2 + 0.5^2} = 0.509901951 = 0.51\ \%$

$A2_{2\sigma} = \pm\ 0.51\% * \text{range}$

$A2_{2\sigma} = \pm\ 0.0051 * 10.5\ \text{MW} = 0.05355\ \text{MW}$

7.6.3.4 Recirculation Pump Motor Watt Transducer PPC I/O Module Humidity Error (e2H)

The manufacturer specifies the I/O module operating humidity limits between 0 and 95 % RH (Section 2.4.4). The I/O module is located in the Control Room 533, where humidity may vary from 50 to 90 % RH (Reference 4.4.2). Humidity errors are set to zero because they are considered to be included within the reference accuracy specification under these conditions. (Section 3.2)

e2H = 0

7.6.3.5 Recirculation Pump Motor Watt Transducer PPC I/O Module Radiation Error (e2R)

No radiation errors are specified in the manufacturer's specifications. The instrument is located in the Control Room 533, a mild environment (Section 4.4.2). Therefore, it is reasonable to consider the normal radiation effect as being included in the reference accuracy. Therefore,

e2R = 0

7.6.3.6 Recirculation Pump Motor Watt Transducer PPC I/O Module Seismic Error (e2S)

No seismic effect errors are specified in the manufacturer's specifications. A seismic event defines a particular type of accident condition. Therefore, there is no seismic error for normal operating conditions (Section 3.5).

e2S = 0

7.6.3.7 Recirculation Pump Motor Watt Transducer PPC I/O Module Static Pressure Offset Error (e2SP)

The I/O module is an electrical device and therefore not affected by static pressure.

e2SP = 0

7.6.3.8 Recirculation Pump Motor Watt Transducer PPC I/O Module Ambient Pressure Error (e2P)

The I/O module is an electrical device and therefore not affected by ambient pressure.

e2P = 0

7.6.3.9 Recirculation Pump Motor Watt Transducer PPC I/O Module Process Error (e2P)r

Any process errors associated with the conversion of pressure to a current signal have been accounted for as errors associated with Watt Transducer. Therefore,

e2Pr = 0

7.6.3.10 Recirculation Pump Motor Watt Transducer Loop Accuracy (LA_P)

$$LA_P = \pm\ [(A1)^2 + (\sigma1PS)^2 + (\sigma1T)^2 + (e1H)^2 + (e1R)^2 + (e1P)^2 + (e1T)^2 + (e1S)^2 + (e1SP)^2 + (A2)^2 + (e2H)^2 + (e2R)^2 + (e2S)^2 + (e2SP)^2 + (e2P)^2 + (e2Pr)^2]^{1/2}$$

$$= \pm\ [(0.013)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0.05355)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0)^2 + (0)]^{1/2}$$

$$= \pm\ 0.05511\ \text{MW}$$

$$LA_P = \pm\ 0.055\ \text{MW}$$

7.6.4 Recirculation Pump Motor Watt Transducer Loop Drift (LD_P)

7.6.4.1 Recirculation Pump Motor Watt Transducer Drift Error (D1)

The drift will be considered random and independent over time. The surveillance frequency is 30 months; therefore, drift error follows Equation 39 (Section 6.2.5 and reference 2.5.2).

D1 = ± 0.1% of RO per year

= $[(30/12) \cdot (\pm 0.1\% \text{ RO})^2]^{1/2}$

= $[2.5 \cdot 0.00011025 \text{ MW}^2]^{1/2}$

= 0.016601958 MW

D1 = 0.017 MW, rounded to level of significance

7.6.4.2 Recirculation Pump Motor Watt Transducer PPC I/O Module Drift Error (D2)

The vendor does not specify a drift error for the I/O module. Therefore, per Ref. 4.1.1 Section I, it is considered to be included in the reference accuracy.

D2 = ± 0

7.6.4.3 Recirculation Pump Motor Watt Transducer Loop Drift (LD_{RWCU_Flow})

$LD_P = \pm [(D1)^2 + (D2)^2]^{1/2}$

$= \pm [(0.017)^2 + (0)^2]^{1/2}$

$LD_P = \pm 0.017$ MW

7.6.5 Recirculation Pump Motor Watt Transducer Process Measurement Accuracy (PMA_P)

No additional PMA effects beyond the effects specified in the calculation of loop accuracy.

$PMA_P = 0$

7.6.6 Recirculation Pump Motor Watt Transducer Primary Element Accuracy (PEA_P)

No additional PEM effects beyond the effects specified in the calculation of loop accuracy.

$PEA_P = 0$

7.6.7 Recirculation Pump Motor Watt Transducer Loop Calibration Accuracy (CA_P)

Standard practice is to specify calibration uncertainty in calculations equal to the uncertainty associated with the instruments under test.

Therefore,

$CA_P = \pm [(A1)^2 + (A2)^2]^{1/2}$

$= \pm [(0.013)^2 + (0.05355)^2]^{1/2}$

$= \pm 0.05511$

$CA_P = \pm 0.055$ MW

7.6.8 Total Uncertainty Recirculation Pump Motor Watt Transducer Loop (TU_P)

$TU_P = \pm [(LA)^2 + (LD)^2 + (PMA)^2 + (PEA)^2 + (CA)^2]^{1/2}$

$= \pm [(0.055)^2 + (0.017)^2 + (0)^2 + (0)^2 + (0.055)^2]^{1/2}$

= ± 0.079618 MW, round to ± 0.08 MW

Converting to % motor power

TU_P = ± 0.08 MW / 5.74 MW

= ± 0.013937

= ± 1.4 %

7.7 DETERMINATION OF CTP UNCERTAINTY

7.7.1 Numerical Solutions for the Partial Derivative Terms

Solutions are found in two parts by first substituting values from Table 2-1 into Equations 20 through 27, as shown.

$$\frac{\partial \mathrm{CTP}}{\partial W_{FW}} = \left(h_G\left(P_S\right) - h_F\left(T_{FW}\right)\right)$$

$$= \left(h_G\left(P_S\right) - h_F\left(427.1\ ^\circ\mathrm{F}\right)\right)\ \mathrm{Btu/lbm}$$

(Reference Equation 20)

$$= (1190.0 - 405.30)\ \mathrm{Btu/lbm}$$

$$= 784.70\ \mathrm{Btu/lbm}$$

$$\frac{\partial CTP}{\partial h_G(P_S)} = W_{FW} = 15{,}255{,}000\ \mathrm{lbm/hr}$$ (Reference Equation 21)

$$\frac{\partial CTP}{\partial h_F(T_{FW})} = -W_{FW} = -15{,}255{,}000\ \mathrm{lbm/hr}$$ (Reference Equation 22)

$$\frac{\partial \mathrm{CTP}}{\partial Q_{\mathrm{CRD\_OUT}}} = 1$$ (Reference Equation 23)

$$\frac{\partial \mathrm{CTP}}{\partial Q_{\mathrm{CRD\_IN}}} = -1$$ (Reference Equation 24)

$$\frac{\partial \mathrm{CTP}}{\partial Q_{\mathrm{RAD}}} = 1$$ (Reference Equation 25)

$$\frac{\partial \mathrm{CTP}}{\partial Q_{\mathrm{RWCU}}} = 1$$ (Reference Equation 26)

$$\frac{\partial \mathrm{CTP}}{\partial Q_{\mathrm{P}}} = -1$$ (Reference Equation 27)

7.7.2 Component Uncertainty Terms

The component uncertainty terms, u_c, are found by substituting values into Equations 31, 33 through 37, as shown.

7.7.2.1 Feedwater Mass Flowrate Uncertainty

$\sigma_{w_{FW}}$ = 42,714 lbm/hr (Section 7.1)

7.7.2.2 Steam Enthalpy Uncertainty

$$\sigma_{h_G}(P_S,I_o) = \left(\frac{\Delta h_G(P_S)}{\Delta P_S}\right)^2 * \sigma_P^{\,2} + \left(\frac{\Delta h_G(I_o)}{\Delta I_o}\right)^2 * \sigma_{I_o}^{\,2} \qquad \text{(Reference Equation 31)}$$

The nominal steam dome pressure is evaluated for saturated steam at 1060 psia (Reference 4.9.10) with an uncertainty of ± 20 psig (Section 7.2). Steam table interpolation error is taken to be one-half of the least significant figure shown, i.e., ± 0.05 Btu/lbm for 1190.0 Btu/lbm. In Equation 31, the partial derivative with respect to interpolation of the enthalpy value from the steam table $(\Delta h_G(I_0)/\Delta I_0) = 1$, because this represents the enthalpy as read from the steam/pressure curve divided by the enthalpy as read from the steam/pressure curve. Enthalpy values are from Reference 4.9.3.

$$\sigma_{h_G}(P_S,I_o) = \sqrt{\left(\frac{h_G(1080) - h_G(1040)}{1080 - 1040}\right)^2 \left(\frac{Btu\,/\,lbm}{psi}\right)^2 * (20\ psi)^2 + (1)^2 \left(\frac{Btu\,/\,lbm}{Btu\,/\,lbm}\right)^2 * \left(0.05\frac{Btu}{lbm}\right)^2}$$

$$= \sqrt{\left(\frac{1190.2 - 1191.9}{1080 - 1040}\right)^2 \left(\frac{Btu\,/\,lbm}{psi}\right)^2 * (20\ psi)^2 + (1)^2 \left(\frac{Btu\,/\,lbm}{Btu\,/\,lbm}\right)^2 * \left(0.05\frac{Btu}{lbm}\right)^2}$$

$$= 0.85147\ Btu\,/\,lbm$$

σ_{hG} (P_S, I_0) = 0.85 Btu/lbm, rounded to the inherent uncertainty of the steam table.

7.7.2.3 Feedwater Enthalpy Uncertainty

$$\sigma_{h_F}(T_{FW},P_{FW},I_o) = \sqrt{\left(\frac{\Delta h_F(T)}{\Delta T}\right)^2 \cdot \sigma_T{}^2 + \left(\frac{\Delta h_F(P)}{\Delta P}\right)^2 * \sigma_P{}^2 + \left(\frac{\Delta h_F}{\Delta I_O}\right)^2 \cdot \sigma_{I_o}{}^2} \quad \text{(Reference Equation 33)}$$

From Table 2-1, feedwater pressure is given as 1155 psig (1169.7 psia) ± 10 psi and feedwater temperature is given as 427.1 ± 0.57 °F. Enthalpy of water is from Attachment 6. Steam table interpolation error is taken to be one-half of the least significant figure shown, i.e., ± 0.005 Btu/lbm. In Equation 33, the partial derivative with respect to interpolation of the enthalpy value from the steam table ($\Delta h_F(I_0)/\Delta I_0$) = 1, because this represents the enthalpy as read from the steam/pressure curve divided by the enthalpy as read from the steam/pressure curve.

$$\sigma_{h_F}(T_{FW},P_{FW},I_o) = \sqrt{\begin{aligned}&\left(\frac{h_F(427.67) - h_F(426.53)}{427.67 - 426.53}\right)^2 \left(\frac{Btu/lbm}{°F}\right)^2 * (0.57\,°F)^2 + \\ &\left(\frac{h_F(1179.7) - h_F(1159.7)}{1179.7 - 1159.7}\right)^2 \left(\frac{Btu/lbm}{psi}\right)^2 * (10\,psi)^2 + \\ &(1)^2\left(\frac{Btu/lbm}{Btu/lbm}\right)^2 * \left(0.005\frac{Btu}{lbm}\right)^2\end{aligned}}$$

$$= \sqrt{\begin{aligned}&\left(\frac{406.28 - 405.04}{427.67 - 426.53}\right)^2 \left(\frac{Btu/lbm}{°F}\right)^2 * (0.57\,°F)^2 + \\ &\left(\frac{405.67 - 405.65}{1179.7 - 1159.7}\right)^2 \left(\frac{Btu/lbm}{psi}\right)^2 * (10\ psi)^2 + (1)^2\left(\frac{Btu/lbm}{Btu/lbm}\right)^2 * \left(0.005\ \frac{Btu}{lbm}\right)^2\end{aligned}}$$

$$= 0.6201\frac{\text{Btu}}{\text{lbm}}$$

$\sigma_{h_F}(T_{FW},P_{FW},I_o) = 0.620\ \frac{\text{Btu}}{\text{lbm}}$, rounded to the inherent uncertainty of the steam table.

The accuracy of the temperature measurement determines the feedwater enthalpy uncertainty. Variations in pressure and steam table interpolation are negligible.

7.7.2.4 Control Rod Drive Outlet Energy Uncertainty

The control rod drive outlet energy uncertainty is dominated by the uncertainty of the mass flow rate. The steam table interpolation error is negligible and is not used in the following computation. CRD mass flow rate uncertainty, x_{CRD}, is 5.4 % of flow (Section 7.5.6). The uncertainty is determined for a temperature of 97.2 °F ± 0.7 °F (Table 2-1) and a pressure of 1448 psig (1462.7 psia) ± 10 psi (Sections 2.4.2 and 3.11). Enthalpy values are from Reference 4.9.3.

The variation in h_f is shown below.

$$\sigma_{hf}\left(T_{CRD}\right) = \sqrt{\left(\frac{hf(97.9) - hf(96.5)}{97.9 - 96.5}\right)^2 \left(\frac{Btu\ /\ lbm}{°F}\right)^2 * (0.7°F)^2 + \left(\frac{hf(1472.7) - hf(1452.7)}{1472.7 - 1452.7}\right)^2 \left(\frac{Btu\ /\ lbm}{°F}\right) * (10psi)^2}$$

$$= \sqrt{\left(\frac{(69.848) - (68.458)}{97.9 - 96.5}\right)^2 \left(\frac{\text{Btu / lbm}}{°\text{F}}\right)^2 * (0.7°\text{F})^2 + \left(\frac{(69.180) - (69.127)}{1472.7 - 1452.7}\right)^2 \left(\frac{\text{Btu / lbm}}{°\text{F}}\right) * (10\,\text{psi})^2}$$

$$= 0.696 \text{ Btu/lbm}$$

Converting σ_{hf} to % of h_f

$= \pm$ 0.696 Btu/lbm / 69.153 Btu/lbm

$= \pm$ 0.01006 = ±1.01 %

The SRSS method is used to combine the mass flow rate and enthalpy uncertainty terms.

$$x_{CRD\_OUT}\,\% = \sqrt{5.4^2 + 1.01^2} = 5.5\,\% = 6\,\%, \text{ conservatively rounded up}$$

$$\sigma_{Q_{CRD\_OUT}} = x_{CRD\_OUT}\,\% \cdot Q_{CRD\_OUT} \qquad \text{(Reference Equation 34)}$$

Using steam enthalpy (1190.0 Btu/lbm) and CRD mass flow rate (0.0320 Mlbm/hr) from Table 2-1:

$$\sigma_{Q_{CRD\_OUT}} = \pm 6\,\% * h_G(P_S) * w_{CRD}$$

$= \pm$ 6 % * (1190.0 Btu/lbm) * (0.0320 Mlb/hr)

$= \pm$ 2,284,800 Btu/hr

$= \pm$ 2,285,000 Btu/hr, rounded to level of significance

7.7.2.5 Control Rod Drive Inlet Energy Uncertainty

The control rod drive inlet energy uncertainty is dominated by the uncertainty of the mass flow rate. CRD mass flow rate uncertainty, x_{CRD}, is taken at ± 6 % of mass flow, conservatively rounded up from the ± 5.5% mass flow uncertainty in Section 7.7.2.4). The CRD mass flow (0.0320 Mlb/hr) and enthalpy (68.0 Btu/lbm) are from Table 2-1.

$\sigma_{Q_{CRD\_IN}} = x_{CRD\_IN} \% \cdot Q_{CRD\_IN}$ (Reference Equation 35)

$= \pm 6 \% * h_f(CRD) * w_{CRD}$

$= \pm 6 \% *$ (68.00 Btu/lbm) * (0.0320 Mlbm/hr)

= ± 130,560 Btu/hr

= ± 131,000 Btu/hr, rounded to level of significance

7.7.2.6 Reactor Pressure Vessel Heat Loss Uncertainty

Reference 4.8.3 determines the Unit 1 reactor heat loss as 0.89 MWt. A conservative variance of 10 % of the heat loss rate is used to estimate the heat loss uncertainty.

$\sigma_{Q_{RAD}} = x_{RAD} \% \cdot Q_{RAD}$ (Reference Equation 36)

= ± 10 % * 0.89 MWt * 3,412,000 Btu/hr / MWt

= ± 303,668 Btu/hr

7.7.2.7 RWCU Heat Removal Uncertainty

The RWCU flow loop uncertainty is ± 2.3 % of mass flow (Section 7.3.6). The RWCU temperature measurement uncertainty is ± 4.37 °F (Section 7.4.6). The variation in enthalpy over the range of temperatures in this loop of about 0.5 % is negligible compared to the ~2.3 % flow variation. From Table 2-1, the RWCU suction and discharge enthalpies are:

$h_F(T_{RWCU\text{-}S}) = 530.6$ Btu/lbm $h_F(T_{RWCU\text{-}D}) = 418.4$ Btu/lbm

$\sigma_{Q_{RWCU}} = x_{RWCU} \% \cdot Q_{RWCU}$ (Reference Equation 37)

x_{RWCU} is set ± 2.3 % based on the mass flow uncertainty

Remembering that $Q_{RWCU} = w_{RWCU} * [h_F(T_{RWCU\text{-}S}) - h_F(T_{RWCU\text{-}D})]$ (See Equation 9)

$$w_{RWCU} = 154{,}000\frac{\text{lbm}}{\text{hr}}(\text{Pump A}) \text{ and } 133{,}000\frac{\text{lbm}}{\text{hr}}(\text{Pump B and C})$$ (Section 2.2.1)

Maximum heat removal occurs with Pump A running, therefore, W_{RWCU} = 154,000 lbm/hr.

$\sigma_{Q_{RWCU}} = \pm 2.3 \% \cdot w_{RWCU} \cdot [h_f(T_{RWCU\text{-}S}) - h_f(T_{RWCU\text{-}D})]$

$\sigma_{Q\text{-}RWCU} = \pm 2.3\% *$ (154,000 lbm/hr) * (530.6 – 418.4) (Btu/lbm)

$\sigma_{Q\text{-}RWCU} = \pm 397{,}412$ Btu/hr

= ± 397,400 Btu/hr, rounded to level of significance

7.7.2.8 Recirculation Pump Heat Addition Uncertainty

The power of the recirculation pumps (W_E) is measured by a watt-meter with a calculated uncertainty of 1.4 % (Section 7.6.8).

$$x_P = \pm 1.4\ \%$$

The uncertainty of the power measurement multiplied by the pump power, Q_P, is the uncertainty of the pump power, σ_{QP}. Q_P is 37,145,000 Btu/hr (Section 7.6.1.1).

$$\begin{aligned}\sigma_{Q_P} &= \pm x_P\ \% \cdot Q_P \qquad \text{(See Equation 38)}\\ &= \pm 1.4\% * 37{,}145{,}000 \text{ Btu/hr}\\ &= \pm 520{,}030 \text{ Btu/hr}\end{aligned}$$

$$\sigma_{Q_P} = \pm 520{,}000 \text{ Btu/hr, rounded to level of significance}$$

7.8 TOTAL CTP UNCERTAINTY CALCULATION

Total CTP uncertainty, U_{CTP}, is calculated by using Equations 19, 20 through 27, 28, 31, 33, and 34 through 37.

(Reference Equation 19)

$$u_{CTP} = \sqrt{\begin{array}{l} \left[\left(\left|\frac{\partial CTP}{\partial w_{FW}}\right|\right)^2 * \left(\sigma_{w_{FW}}\right)^2\right] + \left[\left(\left|\frac{\partial CTP}{\partial h_G(P_S)}\right|\right)^2 * \left(\sigma_{h_G(P_S)}\right)^2\right] + \\ \left[\left(\left|\frac{\partial CTP}{\partial h_F(T_{FW})}\right|\right)^2 * \left(\sigma_{h_F(T_{FW})}\right)^2\right] + \left[\left(\left|\frac{\partial CTP}{\partial Q_{CRD\_OUT}}\right|\right)^2 * \left(\sigma_{Q_{CRD\_OUT}}\right)^2\right] + \\ \left[\left(\left|\frac{\partial CTP}{\partial Q_{CRD\_IN}}\right|\right)^2 * \left(\sigma_{Q_{CRD\_IN}}\right)^2\right] + \left[\left(\left|\frac{\partial CTP}{\partial Q_{RAD}}\right|\right)^2 * \left(\sigma_{Q_{RAD}}\right)^2\right] + \\ \left[\left(\left|\frac{\partial CTP}{\partial Q_{RWCU}}\right|\right)^2 * \left(\sigma_{Q_{RWCU}}\right)^2\right] + \left[\left(\left|\frac{\partial CTP}{\partial Q_P}\right|\right)^2 * \left(\sigma_{Q_P}\right)^2\right] \end{array}}$$

$$\frac{\partial CTP}{\partial w_{FW}} = \left(h_G(P_S) - h_F(T_{FW})\right) \qquad \text{(Reference Equation 20)}$$

$$\frac{\partial CTP}{\partial h_G(P_S)} = w_{FW} \qquad \text{(Reference Equation 21)}$$

$$\frac{\partial CTP}{\partial h_F(T_{FW})} = -w_{FW} \qquad \text{(Reference Equation 22)}$$

$$\frac{\partial CTP}{\partial Q_{CRD\_OUT}} = 1 \qquad \text{(Reference Equation 23)}$$

$$\frac{\partial CTP}{\partial Q_{CRD\_IN}} = -1 \qquad \text{(Reference Equation 24)}$$

$$\frac{\partial CTP}{\partial Q_{RAD}} = 1$$ (Reference Equation 25)

$$\frac{\partial CTP}{\partial Q_{RWCU}} = 1$$ (Reference Equation 26)

$$\frac{\partial CTP}{\partial Q_{P}} = -1$$ (Reference Equation 27)

Substituting the previously determined values for the variables shown gives:

$$u_{CTP} = \sqrt{\begin{array}{l} \left(\left(\left|784.70\,\frac{Btu}{lbm}\right|\right)^2 * \left(42{,}714\;\frac{lbm}{hr}\right)^2\right) + \left(\left(\left|15{,}255{,}000\,\frac{lbm}{hr}\right|\right)^2 * \left(0.85\;\frac{Btu}{lbm}\right)^2\right) + \\ \left(\left(\left|-15{,}255{,}000\,\frac{lbm}{hr}\right|\right)^2 * \left(0.620\,\frac{Btu}{lbm}\right)^2\right) + \left(\left(\left|1\right|\right)^2 * \left(2{,}285{,}000\,\frac{Btu}{hr}\right)^2\right) + \\ \left(\left(\left|-1\right|\right)^2 * \left(131{,}000\,\frac{Btu}{hr}\right)^2\right) + \left(\left(\left|1\right|\right)^2 * \left(303{,}668\,\frac{Btu}{hr}\right)^2\right) + \\ \left(\left(\left|1\right|\right)^2 * \left(397{,}400\,\frac{Btu}{hr}\right)^2\right) + \left(\left(\left|1\right|\right)^2 * \left(520{,}000\,\frac{Btu}{hr}\right)^2\right) \end{array}}$$

U_{CTP} = 37,239,573 Btu/hr

U_{CTP} = 37,240,000 Btu/hr rounded to level of significance

Divide U_{CTP} by 3,412,000 Btu/hr to convert units to megawatts thermal (MWt)

U_{CTP} = (37,240,000 Btu/hr)/(3,412,000 (Btu/hr)/MWt)

U_{CTP} = 10.91442 MWt = 10.914 MWt, rounded

Limerick MUR rated thermal power megawatts = 3515 MWTH

The uncertainty in the CTP calculation performed by the Plant Process Computer as a percentage of MUR rated thermal power is:

$U_{CTP\text{-}2\sigma}$ = 10.914 MWTH / 3515 MWTH = 0.00310 = 0.310%

The determination of total CTP uncertainty is sensitive to two measured parameters, feedwater mass flow rate measurement uncertainty and feedwater temperature measurement uncertainty.

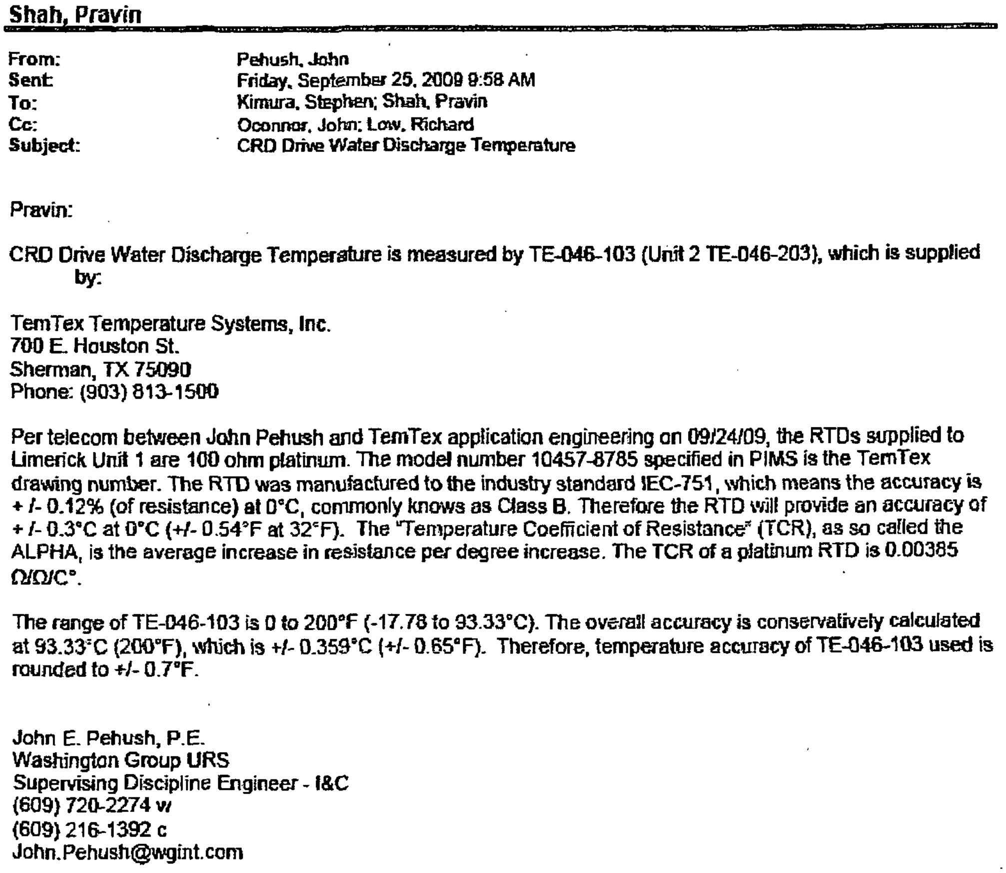
8.0 CONCLUSIONS

The total uncertainty associated with reactor thermal power (heat balance) calculation performed by the Plant Process Computer is 10.914 MWTH or 0.310 % of the MUR rated reactor thermal power limit of 3515 MWTH. This is a 2σ value.

9.0 ATTACHMENTS

Attachment 1

Telecon URS and TemTex Accuracy of RTDs for TE-046-103



Shah, Pravin

From: Pehush, John
Sent: Friday, September 25, 2009 9:58 AM
To: Kimura, Stephen; Shah, Pravin
Cc: Oconnor, John; Low, Richard
Subject: CRD Drive Water Discharge Temperature

Pravin:

CRD Drive Water Discharge Temperature is measured by TE-046-103 (Unit 2 TE-046-203), which is supplied by:

TemTex Temperature Systems, Inc.
700 E. Houston St.
Sherman, TX 75090
Phone: (903) 813-1500

Per telecom between John Pehush and TemTex application engineering on 09/24/09, the RTDs supplied to Limerick Unit 1 are 100 ohm platinum. The model number 10457-8785 specified in PIMS is the TemTex drawing number. The RTD was manufactured to the industry standard IEC-751, which means the accuracy is + /- 0.12% (of resistance) at 0°C, commonly knows as Class B. Therefore the RTD will provide an accuracy of + /- 0.3°C at 0°C (+/- 0.54°F at 32°F). The "Temperature Coefficient of Resistance" (TCR), as so called the ALPHA, is the average increase in resistance per degree increase. The TCR of a platinum RTD is 0.00385 Ω/Ω/C°.

The range of TE-046-103 is 0 to 200°F (-17.78 to 93.33°C). The overall accuracy is conservatively calculated at 93.33°C (200°F), which is +/- 0.359°C (+/- 0.65°F). Therefore, temperature accuracy of TE-046-103 used is rounded to +/- 0.7°F.

John E. Pehush, P.E.
Washington Group URS
Supervising Discipline Engineer - I&C
(609) 720-2274 w
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John.Pehush@wgint.com

Attachment 2

TODI A1695446-80I - Steam Carryover Fraction Design Input (1 page)

EXELON TRANSMITTAL OF DESIGN INFORMATION

☐SAFETY-RELATED ☒NON-SAFETY-RELATED ☐REGULATORY RELATED	Originating Organization ☒Exelon ☐Other (specify)	Tracking No: A1695446-80
Station/Unit(s) Limerick Units 1 & 2		Page 1 of 1
		To: John Pehush WGI - Mid Atlantic

Subject: Transmittal of information.

Steve Dragovich — Steve Dragovich — 11/25/09
Preparer — Preparer's Signature — Date

Chris Wiegand — 11/25/09
Approver — Approver's Signature — Date

Chris Wiegand
for MUR Project Reviewer For Quality/Completeness — for MUR Project Signature — 11/25/09 Date

Status of Information: ☒Approved for Use ☐Unverified

Description of Information:

The following information was requested by URS Washington Division (WGI) for input to Limerick's core thermal power (CTP) uncertainty calculations (units 1 & 2).

The steam carryover fraction that should be used as design input to the calculations is zero.

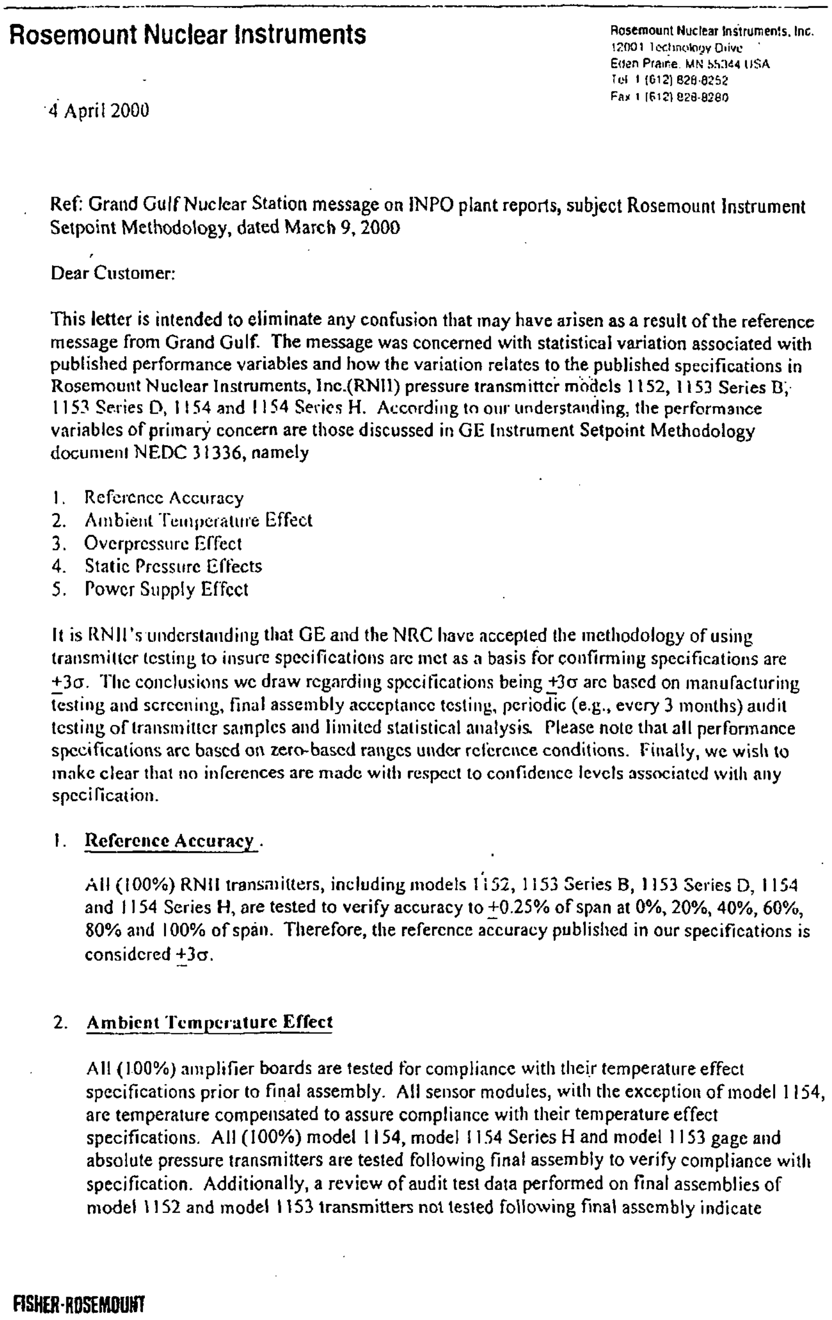
Purpose of Issuance and Limitations on Use: This information is being supplied solely for the use as design input for the Limerick CTP uncertainty calculations (units 1 & 2).

Source Documents:
G.E. Document "Impact of Steam Carryover Fraction on Process Computer Heat Balance Calculations", September 2001.

Distribution:
Original: Limerick file
CC: Ray George, Electrical Design Manager, Limerick
John Pehush, I&C Lead, WGI – Mid Atlantic

Attachment 3

Rosemount Nuclear Instruments customer letter to Grand Gulf (2 pages)



Rosemount Nuclear Instruments

Rosemount Nuclear Instruments, Inc.
12001 Technology Drive
Eden Prairie, MN 55344 USA
Tel 1 (612) 828-8252
Fax 1 (612) 828-8280

4 April 2000

Ref: Grand Gulf Nuclear Station message on INPO plant reports, subject Rosemount Instrument Setpoint Methodology, dated March 9, 2000

Dear Customer:

This letter is intended to eliminate any confusion that may have arisen as a result of the reference message from Grand Gulf. The message was concerned with statistical variation associated with published performance variables and how the variation relates to the published specifications in Rosemount Nuclear Instruments, Inc.(RNII) pressure transmitter models 1152, 1153 Series B, 1153 Series D, 1154 and 1154 Series H. According to our understanding, the performance variables of primary concern are those discussed in GE Instrument Setpoint Methodology document NEDC 31336, namely

1. Reference Accuracy
2. Ambient Temperature Effect
3. Overpressure Effect
4. Static Pressure Effects
5. Power Supply Effect

It is RNII's understanding that GE and the NRC have accepted the methodology of using transmitter testing to insure specifications are met as a basis for confirming specifications are $\pm 3\sigma$. The conclusions we draw regarding specifications being $\pm 3\sigma$ are based on manufacturing testing and screening, final assembly acceptance testing, periodic (e.g., every 3 months) audit testing of transmitter samples and limited statistical analysis. Please note that all performance specifications are based on zero-based ranges under reference conditions. Finally, we wish to make clear that no inferences are made with respect to confidence levels associated with any specification.

1. **Reference Accuracy**

   All (100%) RNII transmitters, including models 1152, 1153 Series B, 1153 Series D, 1154 and 1154 Series H, are tested to verify accuracy to ±0.25% of span at 0%, 20%, 40%, 60%, 80% and 100% of span. Therefore, the reference accuracy published in our specifications is considered $\pm 3\sigma$.

2. **Ambient Temperature Effect**

   All (100%) amplifier boards are tested for compliance with their temperature effect specifications prior to final assembly. All sensor modules, with the exception of model 1154, are temperature compensated to assure compliance with their temperature effect specifications. All (100%) model 1154, model 1154 Series H and model 1153 gage and absolute pressure transmitters are tested following final assembly to verify compliance with specification. Additionally, a review of audit test data performed on final assemblies of model 1152 and model 1153 transmitters not tested following final assembly indicate conformance to specification. Therefore, the ambient temperature effect published in our specifications is considered $\underline{+}3\sigma$.

3. **Overpressure Effect**

   Testing of this variable is done at the module stage. All (100%) range 3 through 8 sensor modules are tested for compliance to specifications. We do not test range 9 or 10 modules for overpressure for safety reasons. However, design similarity permits us to conclude that statements made for ranges 3 through 8 would also apply to ranges 9 and 10. Therefore, the overpressure effect published in our specifications is considered $\underline{+}3\sigma$.

4. **Static Pressure Effects**

   All (100%) differential pressure sensor modules are tested for compliance with static pressure zero errors. Additionally, Models 1153 and 1154 Ranges 3, 6,7 and 8 are 100% tested after final assembly for added assurance of specification compliance. Audit testing performed on ranges 4 and 5 have shown compliance to the specification. Therefore, static pressure effects published in our specifications are considered $\underline{+}3\sigma$.

5. **Power Supply Effect**

   Testing for conformance to this specification is performed on all transmitters undergoing sample (audit) testing. This variable has historically exhibited extremely small performance errors and small standard deviation (essentially a mean error of zero with a standard deviation typically less than 10% of the specification). All transmitters tested were found in compliance with the specification. Therefore, power supply effect published in our specifications is considered $\underline{+}3\sigma$.

Should you have any further questions, please contact Jerry Edwards at (612) 828-3951.

Sincerely,

Jerry Edwards

Jerry L. Edwards
Manager, Sales, Marketing and Contracts
Rosemount Nuclear Instruments, Inc.

FISHER-ROSEMOUNT

Attachment 4
Analogic Analog Input Card ANDS5500 (4 pages)

PEABODY, MA 01960

POTENTIOMETER INPUT CARD ANDS5500 SPECIFICATION

2-15227 REV 01

First Used On: ANDS5500
Code Ident: 1BM00 File Name: 2-15227rev01.doc
Page 1 of 8
Printed: April 4, 2003

REVISION HISTORY

REV	DESCRIPTION	DWN	APVD	DATE
01	SEE E.C.O	K.Q	RWA	08/25/83

Approvals for Release:

Richard Lane 2/13/03
Originator Date

Richard Lane 3/31/03
Engineer Date

ANDS5500

POTENTIOMETER INPUT CARD

SPECIFICATION

2-15227

RELATED DOCUMENTS:

Schematic	D5-8814
Theory of Operation	A2-5568

I. GENERAL DESCRIPTION

The Potentiometer Card is a user card for the ANDS 5500 Data Acquisition System. It consists of a power supply and voltage *reference*, an output multiplexer and four identical signal conditioning channels. There are two 44-pin edge-card connectors (male) on the PC board, one is connected internally to the system and the other is for user connection.

Each signal channel consists of an excitation output section and a signal input section. The latter can be preset to accept a variety of valtage ranges and types via jumpers. It provides a DC voltage to, and permits low frequency and DC measurement of the signals from, appropriate external devices such as piezoelectric accelerometers.

II. SPECIFICATIONS

1. GENERAL

Number of Channels:	4
Size and Shape:	Approximately 7 ½" x 4 ½" x ½" (similar to Analogic D4-7443)
Operating Temperature:	0 – 50 Degrees C.
Storage Temperature:	-40 – 85 Degrees C.
Input & Output Connection:	EDGECARD, gold plated

2. ELECTRICAL

a) Power Requirement:	+5v (+/-5%) at 100mA +15v (+/-5%) at 100mA -15v (+/-5%) at 100mA

b) Excitation Voltage Output (1 per channel)

Voltage Level:	+5v and –5v
Voltage Accuracy:	+/- 0.2% over operating temperature range
Output Current:	10mA max.
Output Impedance:	< 0.1 ohm
Protection:	Tolerate direct short circuit or short to +/-30vdc protected up to 250v by a thermistor

c) Signal Input (1 per channel)

Input Impedence:	10Meg ohm
Input Signal Ranges:	+/-5v, +/-2.5v, +/-1.25v, +/-500mv, +/-250mv, +/-125mv Jumper selected (see Table 1) and fine adjustment by trimpot
Primary Frequency Content:	DC to 100Hz
Signal Source Resistance:	2800 ohm max.
Overall Accurancy: (includes excitation accurancy)	+/- 0.5% over operating temperature range
Protection:	Input protected up to 250v continuous
Amplifier Upper Bandwidth:	10Hz, 45Hz and 100Hz (2-pole filter) Jumper selected (see Table 2)
Input Coupling	Jumper selected for either, AC OR DC. Lower AC bandwidth is 0.5Hz (see Table 2).

INPUT RANGE (F.S)	GAIN	JUMPER 2	JUMPER 3
+/- 5v	2	6 to 7	9 to 10
+/- 2.5v	4	5 to 7	9 to 10
+/- 1.5v	8	4 to 6	9 to 10

+/- 500mv	20	6 to 7	8 to 9
+/- 250mv	40	5 to 7	8 to 9
+/- 125mv	80	4 to 6	8 to 9

TABLE 1.

INPUT RANGE (CHANNEL GAIN) VS. JUMPER POSITION

BANDWIDTH	JUMPER 1	JUMPER 4	JUMPER 5
DC to 10Hz	2 to 3	12 to 13	16 to 17
DC to 45Hz	2 to 3	13 to 14	11 to 12
DC to 100Hz	2 to 3	17 to 18	15 to 16
0.5 to 10Hz	1 to 2	12 to 13	16 to 17
0.5 to 45Hz	1 to 2	13 to 14	11 to 12
0.5 to 100Hz	1 to 2	17 to 18	15 to 16

TABLE 2.

CHANNEL BANDWIDTH VS. JUMPER POSITION

d) Analog Signal Output to Bus

Analog Output Signal: Ch.1, Ch.2, Ch.3, Ch.4 or Hiz (high impedance state), digitally selected

Output Offset: +/- 5mv over operating temperature Range, adjustable to zero by trimpot

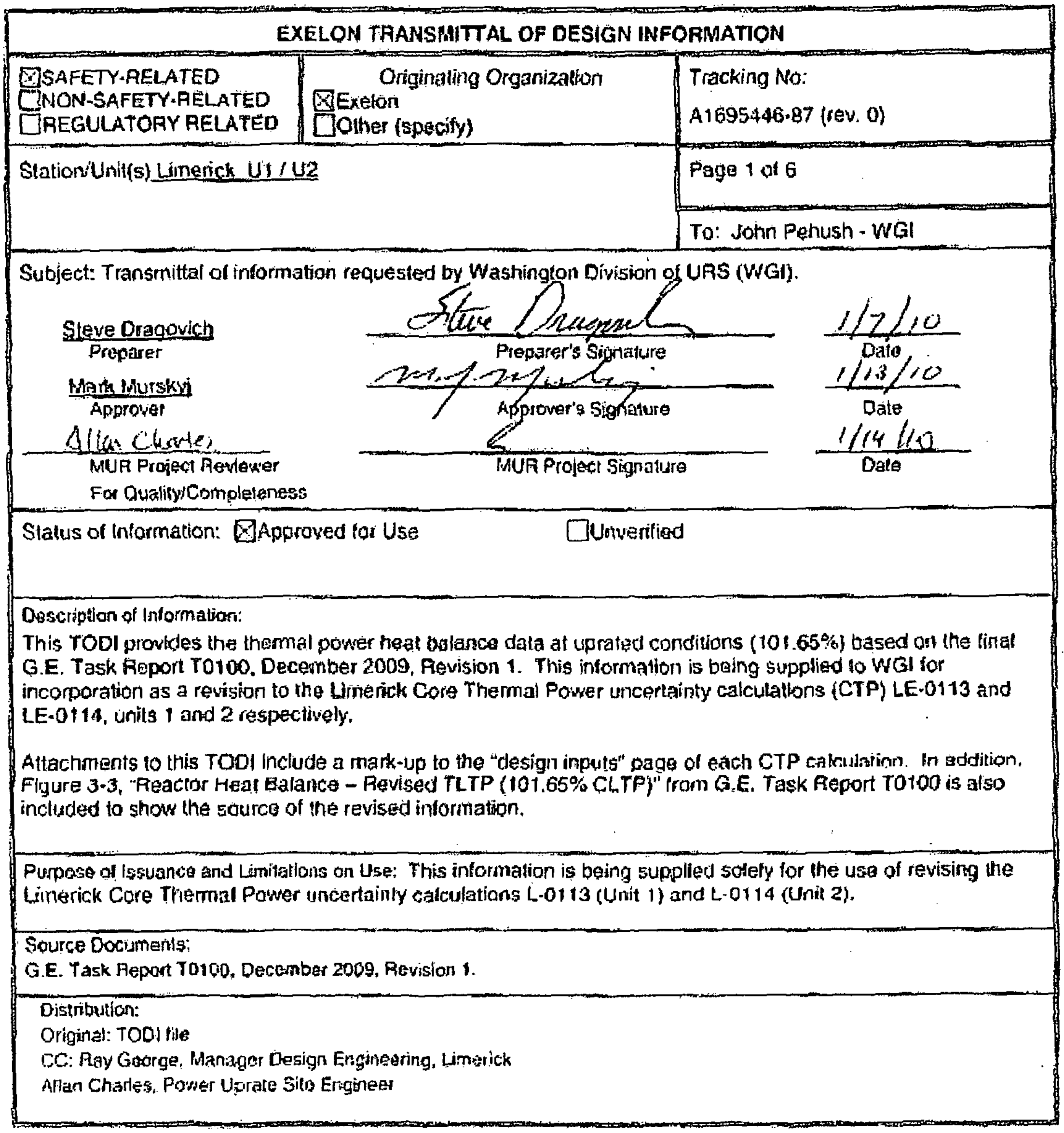
Full Scale Output Range: +/- 10v (+/-0.5%) with full scale input

Maximum Output Voltage in Hiz state: +/- 15v

e) Digital Signal Input From Bus: Channel select (see Table 3)

Attachment 5

TODI A1695446087 Source Document "GE Task Report T0100 December 2009 Revision 001" (6 Pages)



EXELON TRANSMITTAL OF DESIGN INFORMATION

☒SAFETY-RELATED ☐NON-SAFETY-RELATED ☐REGULATORY RELATED	*Originating Organization* ☒Exelon ☐Other (specify)	*Tracking No:* A1695446-87 (rev. 0)
Station/Unit(s) Limerick U1 / U2		Page 1 of 6 To: John Pehush - WGI

Subject: Transmittal of information requested by Washington Division of URS (WGI).

Steve Dragovich — Preparer — Steve Dragovich — Preparer's Signature — 1/7/10 — Date

Mark Murskyj — Approver — Approver's Signature — 1/13/10 — Date

Allan Charles — MUR Project Reviewer For Quality/Completeness — MUR Project Signature — 1/14/10 — Date

Status of Information: ☒Approved for Use ☐Unverified

Description of Information:
This TODI provides the thermal power heat balance data at uprated conditions (101.65%) based on the final G.E. Task Report T0100, December 2009, Revision 1. This information is being supplied to WGI for incorporation as a revision to the Limerick Core Thermal Power uncertainty calculations (CTP) LE-0113 and LE-0114, units 1 and 2 respectively.

Attachments to this TODI include a mark-up to the "design inputs" page of each CTP calculation. In addition, Figure 3-3, "Reactor Heat Balance – Revised TLTP (101.65% CLTP)" from G.E. Task Report T0100 is also included to show the source of the revised information.

Purpose of Issuance and Limitations on Use: This information is being supplied solely for the use of revising the Limerick Core Thermal Power uncertainty calculations L-0113 (Unit 1) and L-0114 (Unit 2).

Source Documents:
G.E. Task Report T0100, December 2009, Revision 1.

Distribution:
Original: TODI file
CC: Ray George, Manager Design Engineering, Limerick
Allan Charles, Power Uprate Site Engineer

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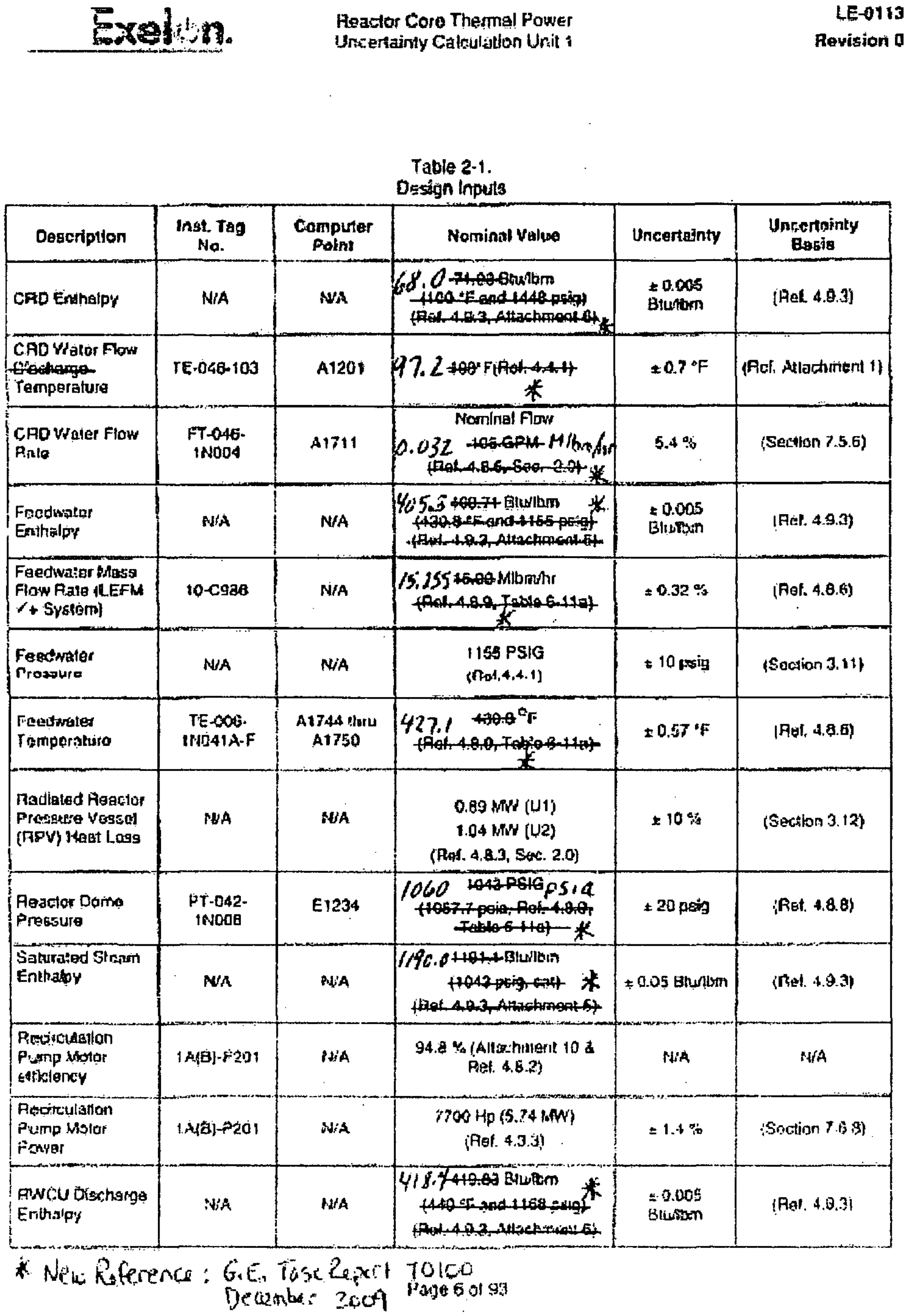

Table 2-1.
Design Inputs

Description	Inst. Tag No.	Computer Point	Nominal Value	Uncertainty	Uncertainty Basis
CRD Enthalpy	N/A	N/A	68.0 ~~71.09~~ Btu/lbm ~~(100 °F and 1448 psig)~~ ~~(Ref. 4.9.3, Attachment 6)~~ *	± 0.005 Btu/lbm	(Ref. 4.9.3)
CRD Water Flow ~~Discharge~~ Temperature	TE-046-103	A1201	97.2 ~~100°~~ F ~~(Ref. 4.4.1)~~ *	± 0.7 °F	(Ref. Attachment 1)
CRD Water Flow Rate	FT-046-1N004	A1711	Nominal Flow 0.032 ~~105 GPM~~ Mlbm/hr ~~(Ref. 4.8.6, Sec. 2.0)~~ *	5.4 %	(Section 7.5.6)
Feedwater Enthalpy	N/A	N/A	405.5 ~~409.71~~ Btu/lbm * ~~(430.8 °F and 1155 psig)~~ ~~(Ref. 4.9.3, Attachment 6)~~	± 0.005 Btu/lbm	(Ref. 4.9.3)
Feedwater Mass Flow Rate (LEFM ✓+ System)	10-C986	N/A	15.155 ~~15.00~~ Mlbm/hr ~~(Ref. 4.8.9, Table 6-11a)~~ *	± 0.32 %	(Ref. 4.8.6)
Feedwater Pressure	N/A	N/A	1155 PSIG (Ref. 4.4.1)	± 10 psig	(Section 3.11)
Feedwater Temperature	TE-006-1N041A-F	A1744 thru A1750	427.1 ~~430.8~~ °F ~~(Ref. 4.8.9, Table 6-11a)~~ *	± 0.57 °F	(Ref. 4.8.6)
Radiated Reactor Pressure Vessel (RPV) Heat Loss	N/A	N/A	0.89 MW (U1) 1.04 MW (U2) (Ref. 4.8.3, Sec. 2.0)	± 10 %	(Section 3.12)
Reactor Dome Pressure	PT-042-1N008	E1234	1060 ~~1043 PSIG~~ psia ~~(1057.7 psia, Ref. 4.8.9, Table 6-11a)~~ *	± 20 psig	(Ref. 4.8.8)
Saturated Steam Enthalpy	N/A	N/A	1190.0 ~~1191.4~~ Btu/lbm ~~(1043 psig, sat)~~ * ~~(Ref. 4.9.3, Attachment 6)~~	± 0.05 Btu/lbm	(Ref. 4.9.3)
Recirculation Pump Motor efficiency	1A(B)-P201	N/A	94.8 % (Attachment 10 & Ref. 4.8.2)	N/A	N/A
Recirculation Pump Motor Power	1A(B)-P201	N/A	7700 Hp (5.74 MW) (Ref. 4.3.3)	± 1.4 %	(Section 7.6.8)
RWCU Discharge Enthalpy	N/A	N/A	418.7 ~~419.83~~ Btu/lbm * ~~(440 °F and 1168 psig)~~ ~~(Ref. 4.9.3, Attachment 6)~~	± 0.005 Btu/lbm	(Ref. 4.9.3)

* New Reference : G.E. Task Report T0100
December 2009

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Exelon.
Reactor Core Thermal Power Uncertainty Calculation Unit 1
LE-0113
Revision 0

Table 2-1.
Design Inputs

Description	Inst. Tag No.	Computer Point	Nominal Value	Uncertainty	Uncertainty Basis
RWCU Discharge Temperature	TE-044-1N015	A1742	439 ~~440 °F~~ ~~(Section 2.3.2)~~ *	± 4.37	(Section 7.4.6)
RWCU Inlet Flow Rate	FT-044-1N036A	A1718	360 GPM (Max) Ref. 4.5.11)	± 2.3 %	(Section 7.3.6)
RWCU Regen Heat Exchanger Inlet Temperature	TE-044-1N004	A1741	535.3 ~~530 °F~~ ~~(Section 2.3.1)~~ *	4.37 °F	(Section 7.4.6)
RWCU Suction Enthalpy	N/A	N/A	530.6 ~~524.09~~ Btu/lbm ~~(530 °F and 1060 psig)~~ *	± 0.005 Btu/lbm	(Ref. 4.9.3)

* New Reference: GE Task Report T0100
December 2009

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Exelon. Reactor Core Thermal Power Uncertainty Calculation Unit 2 LE-0114 Revision 0

Table 2-1.
Design Inputs

Description	Inst. Tag No.	Computer Point	Nominal Value	Uncertainty	Uncertainty Basis
CRD Enthalpy	N/A	N/A	68.0 ~~71.93~~ Btu/lbm ~~(100 °F and 1448 psig)~~ ~~(Ref. 4.9.3, Attachment 6)~~ *	± 0.005 Btu/lbm	(Ref. 4.9.3)
CRD Water Flow ~~Discharge~~ Temperature	TE-046-203	A2201	97.2 ~~100°F (Ref. 4.4.1)~~ *	± 0.7 °F	(Ref. Attachment 1)
CRD Water Flow Rate	FT-046-2N004	A2711	Nominal Flow 0.032 ~~166 GPM~~ Mlbm/hr ~~(Ref. 4.8.6, Sec. 3.0)~~ *	5.4 %	(Section 7.5.6)
Feedwater Enthalpy	N/A	N/A	405.3 ~~409.71~~ Btu/lbm * ~~(430.8 °F and 1155 psig)~~ ~~(Ref. 4.9.3, Attachment 6)~~	± 0.005 Btu/lbm	(Ref. 4.9.3)
Feedwater Mass Flow Rate (LEFM ✓+ System)	20-C986	N/A	15.255 ~~16.09~~ Mlbm/hr ~~(Ref. 4.8.9, Table 6-11a)~~ *	± 0.32 %	(Ref. 4.8.6)
Feedwater Pressure	N/A	N/A	1155 PSIG (Ref.4.4.1)	± 10 psig	(Section 3.11)
Feedwater Temperature	TE-006-2N041A-F	A2744 thru A2750	427.1 ~~430.8~~ °F ~~(Ref. 4.8.9, Table 6-11a)~~ *	± 0.57 °F	(Ref. 4.8.6)
Radiated Reactor Pressure Vessel (RPV) Heat Loss	N/A	N/A	0.89 MW (U1) 1.04 MW (U2) (Ref. 4.8.3, Sec. 2.0)	± 10 %	(Section 3.12)
Reactor Dome Pressure	PT-042-2N008	E2234	1060 ~~1043 PSIG~~ psia ~~(1057.7 psia, Ref. 4.8.9, Table 6-11a)~~ *	± 20 psig	(Ref. 4.8.8)
Saturated Steam Enthalpy	N/A	N/A	1190.2 ~~1191.1~~ Btu/lbm ~~(1043 psig, sat)~~ * ~~(Ref. 4.9.3, Attachment 6)~~	± 0.05 Btu/lbm	(Ref. 4.9.3)
Recirculation Pump Motor efficiency	2A(B)-P201	N/A	94.8 % (Attachment 10 & Ref. 4.8.2)	N/A	N/A
Recirculation Pump Motor Power	2A(B)-P201	N/A	7700 Hp (5.74 MW) (Ref. 4.3.3)	± 1.4 %	(Section 7.5.8)
RWCU Discharge Enthalpy	N/A	N/A	418.1 ~~419.83~~ Btu/lbm * ~~(440 °F and 1159 psig)~~ ~~(Ref. 4.9.3, Attachment 6)~~	± 0.005 Btu/lbm	(Ref. 4.9.3)

* New Reference: GE Task Report T0100
December 2009

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Exelon.

Reactor Core Thermal Power
Uncertainty Calculation Unit 2

LE-0114
Revision 0

Table 2-1.
Design Inputs

Description	Inst. Tag No.	Computer Point	Nominal Value	Uncertainty	Uncertainty Basis
RWCU Discharge Temperature	TE-044-2N015	A2742	439 ~~440~~ °F ~~(Section 2.3.2)~~	± 4.37 °F	(Section 7.4.6)
RWCU Inlet Flow Rate	FT-044-2N036A	A2718	360 GPM (Max) Ref. 4.9.11)	± 2.3 %	(Section 7.3.8)
RWCU Regen Heat Exchanger Inlet Temperature	TE-044-2N004	A2741	535.3 ~~520~~ °F ~~(Section 2.3.4)~~	4.37 °F	(Section 7.4.6)
RWCU Suction Enthalpy	N/A	N/A	530.6 ~~524.30 Btu/lbm~~ ~~(530 °F and 1060 psig)~~	± 0.005 Btu/lbm	(Ref. 4.9.3)

* New Reference: G.E. Test Report T0100
December 2009

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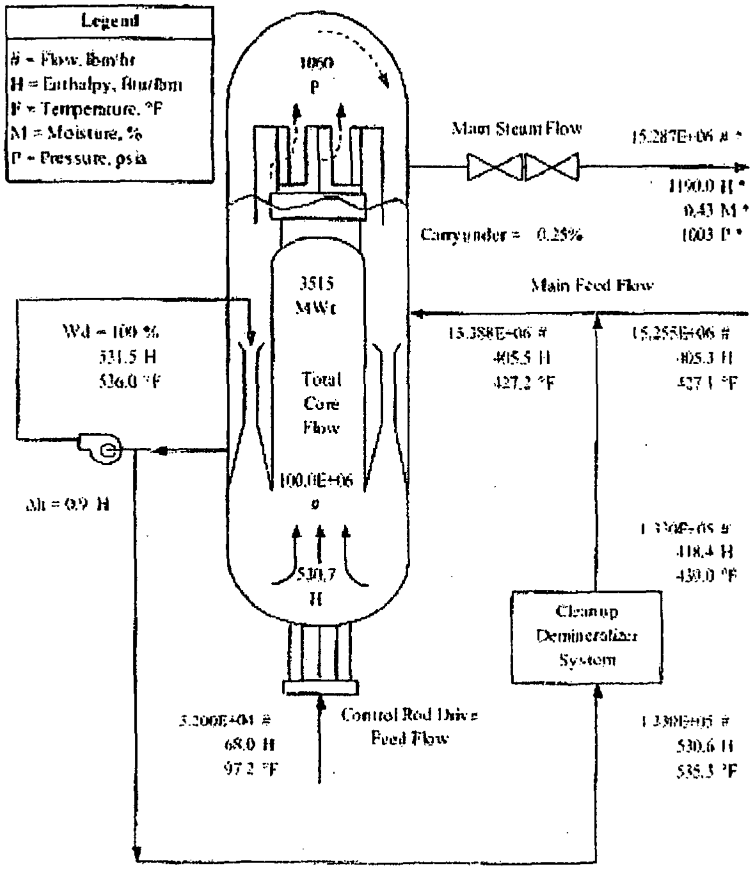
Figure 3-3: Reactor Heat Balance - Revised TLTP (~101.65% CLTP)

$[T_{FW} = 427.1°F / P_{DOME} = 1060 \text{ psia}]$



*Conditions at upstream side of TSV

Core Thermal Power	3515.0
Pump Heating	9.0
Cleanup Losses	-4.4
Other System Losses	-1.1
Turbine Cycle Use	3518.5 MWt

Attachment 6

NIST Thermophysical Properties of Water

Isobaric and Isothermal Properties of Water

Temperature (F)	Pressure (psia)	Density (lbm/ft3)	Volume (ft3/lbm)	Enthalpy (Btu/lbm)	Phase
97.200	1452.7	62.299	0.016052	69.127	liquid
97.200	1462.7	62.301	0.016051	69.153	liquid
97.200	1472.7	62.303	0.016051	69.180	liquid
96.500	1462.7	62.309	0.016049	68.458	liquid
97.200	1462.7	62.301	0.016051	69.153	liquid
97.900	1462.7	62.292	0.016053	69.848	liquid
530.90	1074.7	47.275	0.021153	525.50	liquid
535.30	1074.7	46.987	0.021282	531.00	liquid
539.70	1074.7	46.693	0.021416	536.56	liquid
535.30	1064.7	46.980	0.021286	531.02	liquid
535.30	1074.7	46.987	0.021282	531.00	liquid
535.30	1084.7	46.994	0.021279	530.99	liquid
427.10	1159.7	52.801	0.018939	405.65	liquid
427.10	1169.7	52.804	0.018938	405.66	liquid
427.10	1179.7	52.808	0.018936	405.67	liquid
426.53	1169.7	52.830	0.018929	405.04	liquid
427.10	1169.7	52.804	0.018938	405.66	liquid
427.67	1169.7	52.779	0.018947	406.28	liquid

Saturated Steam (Water Vapor) Properties

Temperature (F)	Pressure (psia)	Density lbm/ft3)	Volume (ft3/lbm)	Enthalpy Btu/lbm)	Phase
549.43	1040.0	2.3426	0.42688	1191.9	vapor
551.77	1060.0	2.3934	0.41781	1191.1	vapor
554.08	1080.0	2.4446	0.40907	1190.2	vapor

"Thermophysical Properties of Fluid Systems" by E.W. Lemmon, M.O. McLinden and D.G. Friend in **NIST Chemistry WebBook, NIST Standard Reference Database Number 69**, Eds. P.J. Linstrom and W.G. Mallard, National Institute of Standards and Technology, Gaithersburg MD, 20899, http://webbook.nist.gov, (retrieved January 22, 2010).

Attachment 7
CTP Calculation Results Sensitivity Analysis

The sensitivity of the calculation of core thermal power to variations in the energy terms is determined using estimated values for the energy out, energy in, and CTP.

Table A7-1 shows the results from Cases 1, 2 and 3. For this analysis, the error rate assumed for Q_S is set equal to a predicted error for the measurement of feedwater flow.

In Case 1 and Case 2, the Q_S error is kept the same; even though, the errors for the Q_{RAD}, Q_{RWCU}, Q_P, and Q_{CRD} terms are varied from 1 % to 19 % (29 % for Q_{crd}). Case 1 and Case 2 show that CTP is relatively insensitive to the accuracy of the Q_{RAD}, Q_{RWCU}, Q_P, and C_{CRD} terms, when the CTP error is rounded to level of significance.

Case 3 varied the error rate assumed for Q_S. A step change in the mass flow error rate of 0.01 % (from 0.31 % to 0.32 %) was found necessary to change the CTP error by 0.02 % (a change of 1 MW from 17 MWt to 18 MWt and 0.500 % to 0.520 %).

The step change error rate was calculated to determine how fine the parameters used to calculate Q_S and Q_{FW} need to be to effect the results. Parameter changes that would result in changes in the parameter's overall error rate less than 0.02 % were found to be negligible. Small variations in the flow measurement uncertainty were found to affect the CTP uncertainty.

For example, CTP is the difference between the energy leaving the reactor and the energy put into the reactor from other sources outside of the core. The enthalpy of saturated water varies with changes in pressure. For every 1 % change in pressure, the enthalpy of saturated water vapor (and by inference the energy of the flow) between 800 and 1,300 psig will vary by an average of 0.03 %. This change in enthalpy is less than the 0.04 % found necessary to cause a significant change in the CTP error rate. Thus, CTP can be said to be tolerant of the steam dome pressure measurement error specified the pressure measurement loop is shown to be accurate to about ~10 psig, which is approximately 1 % of the maximum allowable steam dome pressure.

Table A7-1. CTP Calculation Sensitivity Analysis

				Sensitivity Analysis Case 1		Case 2		Case 3	
			Energy in percent of CTP	Assumed error rate Case 1	Predicted error as Percent of CTP	Assumed error rate Case 2	Predicted error as Percent of CTP	Assumed error rate Case 3	Predicted error as Percent of CTP
	Energy Out								
Q_S	18,030,078,635	Btu/hr	152.70%	0.31%	0.473%	0.31%	0.473%	0.32%	0.489%
Q_{RAD}	3,754,300	Btu/hr	0.03%	1%	0.0003%	10%	0.003%	1%	0.000%
Qcu	16,407,160	Btu/hr	0.14%	1%	0.0014%	10%	0.014%	1%	0.001%
Q out	18,050,240,095	Btu/hr	152.87%						
	Energy In								
Q_{FW}	6,201,235,621	Btu/hr	52.52%	0.31%	0.163%	0.31%	0.163%	0.32%	0.168%
Qp	37,146,642	Btu/hr	0.31%	1%	0.0031%	10%	0.031%	1%	0.003%
Qcrd	4,578,000	Btu/hr	0.04%	1%	0.0004%	10%	0.004%	1%	0.000%
Q in	6,242,960,263	Btu/hr	52.87%						
	CTP								
Q_{CTP}	11,807,279,832	Btu/hr	SRSS all error terms‡		0.500%		0.500%		0.520%
			SRSS only Qs and Qfw error terms†		0.500%		0.500%		0.520%

†Error rounded to 3 significant figures

	Convert to MW				
Btu/hr per W	3.412				
Btu/hr per MW	3,412,000				
	In MWt			Relative errors MWt	
Q out	5,290	MWt			
Q in	1,830	MWt	Case 1	Case 2	Case 3
CTP	3,461	MWt	± 17.31 MWt	± 17.31 MWt	± 18.00 MWt

‡Error rounded to 2 significant figures

Attachment 8
Derivation of the relationship between flow, ΔP, and density

A8-1 Basic Flow Equation

Given that the basic flow equation (Reference A8.3-1) applicable to orifice plates, flow nozzles, and venturis is

$$Q = C \cdot \sqrt{\rho \cdot \Delta P}$$, where C is a constant (Equation A8-1).

Then the relationship between flow (Q) and differential pressure (ΔP) and density (ρ) can be derived.

A8-1.1. Relationship between Q, ΔP and ρ

For constant density, the flow can be shown to vary with the square root of ΔP such that,

$$\frac{Q_1}{Q_2} = \sqrt{\frac{\Delta P_1}{\Delta P_2}}$$

(Equation A8-2)

If the variation around some nominal flow, Q_0, is equal to some known uncertainty, σ_1, then

$$Q_1 = Q_0 * (1 - \sigma_1) \text{and } Q_2 = Q_0 * (1 + \sigma_1)$$ (Equation A8-3)

Similarly, if the variation around some nominal differential pressure, ΔP_0, is equal to some unknown ΔP uncertainty, σ_x, then

$$\Delta P_1 = P_0 * (1 - \sigma_x) \text{and } \Delta P_2 = P_0 * (1 + \sigma_x)$$ (Equation A8-4a)

For constant ΔP, if the variation around some nominal density, ρ_0, is equal to some unknown ρ uncertainty, σ_x, then

$$\rho_1 = \rho_0 * (1 - \sigma_x) \text{and } \rho_2 = \rho_0 * (1 + \sigma_x)$$ (Equation A8-4b)

These values can be substituted into Equation A8-2 and the equations manipulated to solve for σ_x.

$$\frac{Q_0 * (1 - \sigma_1)}{Q_0 * (1 + \sigma_1)} = \sqrt{\frac{P_0 * (1 - \sigma_x)}{P_0 * (1 + \sigma_x)}} \text{, } \Delta P$$ (Equation A8-5a)

$$\frac{Q_0 * (1 - \sigma_1)}{Q_0 * (1 + \sigma_1)} = \sqrt{\frac{\rho_0 * (1 - \sigma_x)}{\rho_0 * (1 + \sigma_x)}} \text{, for } \rho$$ (Equation A8-5b)

Crossing out like terms from the numerator and denominator, rearranging, and squaring both sides yields

$$\left[\frac{(1 - \sigma_1)}{(1 + \sigma_1)}\right]^2 = \frac{(1 - \sigma_x)}{(1 + \sigma_x)}$$

(Equation A8-6)

Equation A8-6 can be simplified by defining a new function of σ_1:

$$Y(\sigma_1) = \frac{(1-\sigma_1)}{(1+\sigma_1)}$$ (Equation A8-7)

Substituting Y(σ₁) into Equation A8-6 and rearranging, gives

$$Y(\sigma_1)^2 = \frac{(1-\sigma_x)}{(1+\sigma_x)}$$ (Equation A8-8)

$$(1+\sigma_x)\cdot Y(\sigma_1)^2 = (1-\sigma_x)$$

$$\left(Y(\sigma_1)^2 + Y(\sigma_1)^2\cdot\sigma_x\right) = (1-\sigma_x)$$

Solving for σ_x, gives the relationship between the uncertainty σ_x, for either ΔP or ρ, and the known uncertainty of flow, σ_1.

$$\sigma_x + Y(\sigma_1)^2\cdot\sigma_x = \left(1 - Y(\sigma_1)^2\right)$$

$$\sigma_x\cdot\left(1 + Y(\sigma_1)^2\right) = \left(1 - Y(\sigma_1)^2\right)$$

$$\sigma_x = \frac{\left(1 - Y(\sigma_1)^2\right)}{\left(1 + Y(\sigma_1)^2\right)}$$ (Equation A8-9)

Table A8-1 shows the relationship between the uncertainties in pressure or density, σ_x, and the uncertainty in flow, σ_1, to be essentially linear with a constant of proportionality equal to 2, see A8-1.2, provided σ_1 is small, which is taken to be less than or equal to 15 %.

Thus for small flow uncertainties, small σ_1, Equation A8-9 can be simplified as a linear function $f(\sigma_1)$, Equation A8-10, which says the uncertainty in differential pressure or the uncertainty in density is approximately equal to 2 times the flow uncertainty. The inverse is also true; given a differential pressure or density uncertainty, the uncertainty of the flow is one-half the differential pressure or density uncertainty.

$\sigma_x \approx n \cdot \sigma_1$, (Equation A8-10)

A8-1.2. The Limit of n

The limit of the constant of proportionality, n, in Equation A8-10 as σ_1 approaches zero is found to confirm that n can be considered as a constant within the range of σ_1 less than 15 % to 0.

$$\lim_{\sigma_1\to 0}(n) = \lim_{\sigma_1\to 0}\left(\frac{\sigma_x}{\sigma_1}\right) = \lim_{\sigma_1\to 0}\left(\frac{\left(\frac{1-Y(\sigma_1)^2}{1+Y(\sigma_1)^2}\right)}{\sigma_1}\right) = \lim_{\sigma_1\to 0}\left(\frac{1-Y(\sigma_1)^2}{\sigma_1\left(1+Y(\sigma_1)^2\right)}\right)$$

Recalling Y(σ₁) and expanding Y(σ₁)² in terms of σ₁

$$\lim_{\sigma_1\to 0}\left(\frac{1-Y(\sigma_1)^2}{\sigma_1\left(1+Y(\sigma_1)^2\right)}\right) = \lim_{\sigma_1\to 0}\left(\frac{1-\frac{\left(1-2\sigma_1+\sigma_1{}^2\right)}{\left(1+2\sigma_1+\sigma_1{}^2\right)}}{\sigma_1\left[1+\frac{\left(1-2\sigma_1+\sigma_1{}^2\right)}{\left(1+2\sigma_1+\sigma_1{}^2\right)}\right]}\right) =$$

$$\lim_{\sigma_1 \to 0}\left(\frac{\left(1+2\sigma_1+\sigma_1^2\right)-\left(1-2\sigma_1+\sigma_1^2\right)}{\sigma_1\left[\left(1+2\sigma_1+\sigma_1^2\right)+\left(1-2\sigma_1+\sigma_1^2\right)\right]}\right)=\lim_{\sigma_1 \to 0}\left(\frac{4\cdot\sigma_1}{\sigma_1\left(2+2\sigma_1^2\right)}\right)=$$

$$\lim_{\sigma_1 \to 0}\left(\frac{4}{\left(2+2\sigma_1^2\right)}\right)$$, which after substituting 0 for σ_1 gives

$$\lim_{\sigma_1 \to 0}(n)=2$$

A8-1.3. References

1. ASME PTC 19.5-2004, Flow Measurement, Performance Test Code, ASME International

Table A8-1.
Relationship between σ_1, $Y(\sigma_1)$, σ_x, and *n*

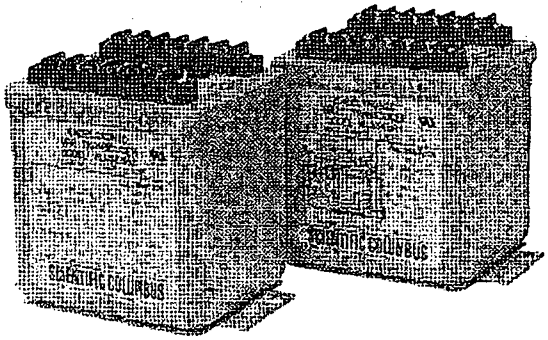
σ_1	$Y(\sigma_1)=\frac{(1-\sigma_1)}{(1+\sigma_1)}$	$\sigma_x=\frac{\left(1-Y(\sigma_1)^2\right)}{\left(1+Y(\sigma_1)^2\right)}$	$n=f(\sigma_x)=\frac{\sigma_x}{\sigma_1}$
0.0000001 %	99.9999998 %	2.0E-09	2.0000000585
0.001 %	99.998 %	2.0E-05	1.9999999998
0.4 %	99.2 %	0.008	2.0000000004
5.0 %	90.5 %	0.100	1.995
10.0 %	81.8 %	0.198	1.980
15.0 %	73.9 %	0.293	1.956
20.0 %	66.7 %	0.385	1.923
25.0 %	60.0 %	0.471	1.882
30.0 %	53.8 %	0.550	1.835
35.0 %	48.1 %	0.624	1.782
40.0 %	42.9 %	0.690	1.724
45.0 %	37.9 %	0.748	1.663
50.0 %	33.3 %	0.800	1.600
55.0 %	29.0 %	0.845	1.536
60.0 %	25.0 %	0.882	1.471
65.0 %	21.2 %	0.914	1.406
70.0 %	17.6 %	0.940	1.342
75.0 %	14.3 %	0.960	1.280
80.0 %	11.1 %	0.976	1.220
85.0 %	8.1 %	0.987	1.161
90.0 %	5.3 %	0.994	1.105
95.0 %	2.6 %	0.999	1.051
100.0 %	0.0 %	1.000	1.000

Attachment 9

Ametek Scientific Columbus Exceltronic AC Watt Transducer Specification (4 pages)

SCIENTIFIC COLUMBUS Exceltronic AC Watt or Var Transducers

Exceltronic watt and var transducers provide utility and industrial users with a high degree of accuracy for applications requiring precise measurements. These transducers provide a dc-output signal proportional to input watts or vars. All models are available with a wide range of input and output options.



Features

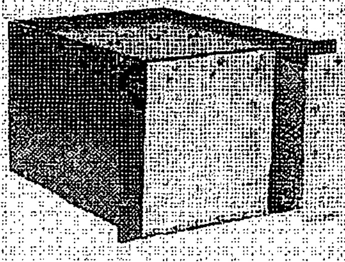
- Accuracy to 0.2% of reading
- Exceptional reliability
- Excellent long-term stability
- Self- or externally powered
- No zero adjustment required
- Most popular models are UL Recognized

Applications

- Substation monitoring
- SCADA
- Energy-management systems
- Distribution monitoring
- Process control

Outputs

- 0 to ±1 mAdc
- 1–5 or 1–3–5 mAdc
- 4–20 or 4–12–20 mAdc
- 10–50 or 10–30–50 mAdc



Also available in XLP modular, plug-in format for limited-space applications requiring large numbers of transducers.

- Two, four, or eight modules in one enclosure
- Easy to install, expand, or repair
- Convenient front-panel access for calibration and output-current jacks available

See pages 77–94 for more information.

SCIENTIFIC COLUMBUS Specifications

EXCELTRONIC AC WATT OR VAR TRANSDUCERS

Exceltronic

Specifications		0 to ±1 mAdc Watts (Watt Transducer)	P-Option* Watts (Watt Transducer)	0 to ±1 mAdc Vars (Var Transducer)	P-Option* Vars (Var Transducer)
Current Input	*Nominal* Range** Overload Continuous Overload 1 Second/Hour Burden/Element	5 A 0–10 A 20 A 250 A 0.2 VA (maximum) at 5 A			
Voltage Input	Nominal Range** Overload Continuous Burden/Element	120 V 0–150 V 200 V 0.035 VA (maximum) at 120 V			
External Auxiliary Power	Input Range Frequency Range Burden	85–135 Vac 50–500 Hz 3 VA Nominal	100–130 Vac 50–500 Hz 6 VA Nominal	85–135 Vac 50–500 Hz 3 VA Nominal	100–130 Vac 50–500 Hz 6 VA Nominal
Rated Output (RO) = 500 Watts or Vars/Element		±1 mAdc for Standard Calibration	5, 20, or 50 mAdc for Std. Calibration, depending on selected output range*	±1 mAdc for Standard Calibration	5, 20, or 50 mAdc for Std. Calibration, depending on selected output range*
Accuracy		±*(0.2% Reading + 0.01% RO)* at 0–200% RO	±*(0.2% Reading + 0.05% RO)* at 0–120% RO	±(0.2% Reading + 0.02% RO) at 0–200% RO	±(0.3% Reading + 0.05% RO) at 0–120% RO
Temperature Effect on Accuracy		±0.005% / ° C	±0.0075% / ° C	±0.009% / ° C	±0.012% / ° C
Operating Temperature Range		-20° C to +70° C	-20° C to +50° C	-20° C to +60° C	-20° C to +50° C
Compliance Voltage		10 Vdc	See Table 2 on page 40.	10 Vdc	See Table 2 on page 40.
Load		0–10,000 Ω		0–10,000 Ω	
Output Ripple Peak		< 0.5% RO	< 0.25% RO	< 0.5% RO	< 0.25% RO
Response Time		< 400 ms to 99%	< 1 Second to 99%	< 400 ms to 99%	< 1 Second to 99%
Power Factor		Any			
PF Effect on Accuracy		±0.1% VA (maximum)		±0.15% VA (maximum)	
Standard Calibration Adjustments	Gain Zero	±2% of Reading (minimum) None Required	±20% of Span (minimum) ±5% of Zero Point (minimum)	±2% of Reading (minimum) None Required	±20% of Span (minimum) ±5% of Zero Point (minimum)
Frequency Range		*58–62 Hz*		*60 Hz*	
Stability (per year)		±0.1% RO, Noncumulative	±0.15% of Span, Noncumulative	±0.2% RO, Noncumulative	±0.25% of Span, Noncumulative
Operating Humidity		0–95% Noncondensing			
Isolation		Complete (Input/Output/Power/Case)			
Dielectric Withstand		2500 VRMS*** at 60 Hz			
Surge Withstand		ANSI/IEEE C37.90.1			
Maximum Net Weight		3 lbs., 5 oz. (1.5 kg)	4 lbs., 8 oz. (2 kg)	3 lbs., 5 oz. (1.5 kg)	4 lbs., 8 oz. (2 kg)
Approximate Dimensions (excluding mounting plate)		*4.4" W x 3.9" D x 4.7" H* (112 mm x 99 mm x 119 mm) Style II Case, see page 122	*7.0" W x 3.7" D x 5.6" H* (178 mm x 94 mm x 142 mm) Style I Case, see page 122	*4.4" W x 3.9" D x 4.7" H* (112 mm x 99 mm x 119 mm) Style II Case, see page 122	*7.0" W x 3.7" D x 5.6" H* (178 mm x 94 mm x 142 mm) Style I Case, see page 122
Overrange with Linearity		500–1000 Watts/Element	500–600 Watts/Element	500–1000 Vars/Element	500–600 Vars/Element
		No additional error within voltage compliance. Reduce load resistance as required.			

* P-Option includes 1–5/1–3–5, 4–20/4–12–20, and 10–50/10–30–50 mAdc outputs.

** Total input not to exceed 200% of standard-calibration watts or vars on units with 0 to ±1 mAdc output.
Total input not to exceed 120% of standard-calibration watts or vars on units with P-Option outputs.

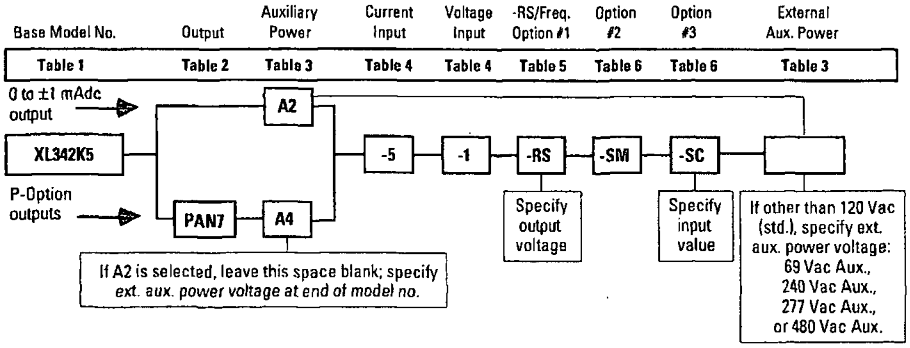
***Dielectric levels as indicated for UL Recognized models; levels may vary on non-UL Recognized models.

Specifications subject to change without notice.

Ordering Procedure
Exceltronic AC Watt or Var Transducers

ORDERING PROCEDURE

Specify by base model number and appropriate selection or option suffixes in the order shown in the following example.



EXAMPLES: XL342K5A2-5-1-RS-SM-SC

3-element, 0 to ±1 mAdc Watt Transducer; 120 Vac external auxiliary power; 10 A input; 240 V input; resistor scaling (converts current output to voltage output); seismic brace; special calibration (example: 7200 W).

XL342K5PAN7A4-5-1-RS-SM-SC

3-element, 4-20 mAdc Watt Transducer; internal auxiliary power; 10 A input; 240 V input; resistor scaling (converts current output to voltage output); seismic brace; special calibration (example: 7200 W).

Table 1 Base Model Number Selection

Element	Watt Model No.	Var Model No.	Connection	Calibration at Rated Output (5 A, 120 V Nominal Input)
1	XL5C5	XLV5C5	Single Phase	500 W or Vars
1½*	XL5C51½	XLV5C51½	3 Phase, 3 Wire	1000 W or Vars
2	XL31K5	XLV31K5	3 Phase, 3 Wire	1000 W or Vars
2½*	XL31K52½	XLV31K52½	3 Phase, 4 Wire	1500 W or Vars
3	XL342K5	XLV342K5	3 Phase, 4 Wire	1500 W or Vars

* 1½- and 2½-element units require a balanced voltage.

Table 2 Output Selection

0 to ±1 mAdc output is standard, and is specified by the Base Model Numbers. For outputs other than 0 to ±1 mAdc, indicate the appropriate P-Option in the "Output" position of the complete model number.

P-Option	Output Range	Compliance Voltage/ Maximum Load	Maximum Open Circuit Voltage
PAN6	1-5 mAdc	15 Vdc/3000 Ω	30 Vdc
PAN7	**4-20 mAdc**	**15 Vdc/750 Ω**	**30 Vdc**
PAN8	10-50 mAdc	15 Vdc/300 Ω	30 Vdc
PAN6-B	1-3-5 mAdc	15 Vdc/3000 Ω	30 Vdc
PAN7-B	4-12-20 mAdc	15 Vdc/750 Ω	30 Vdc
PAN8-B	10-30-50 mAdc	15 Vdc/300 Ω	30 Vdc
PA6	1-5 mAdc	40 Vdc/8000 Ω	70 Vdc
PA7	4-20 mAdc	40 Vdc/2000 Ω	70 Vdc
PA8	10-50 mAdc	30 Vdc/600 Ω	70 Vdc
PA6-B	1-3-5 mAdc	40 Vdc/8000 Ω	70 Vdc
PA7-B	4-12-20 mAdc	40 Vdc/2000 Ω	70 Vdc
PA8-B	10-30-50 mAdc	30 Vdc/600 Ω	70 Vdc

Ordering Procedure Exceltronic AC Watt or Var Transducers

Table 3 Auxiliary Power Supply Selection

Option	Description	Input Range	Frequency Range	Burden
(0 to ±1 mAdc Units)				
A2**	**External Auxiliary Power (120 Vac std.)**	**85-135 Vac**	**50-500 Hz**	**3 VA**
A4	Internal Auxiliary Power (self-powered)	70-112% of Nominal Aux. Power Voltage	Equals Input Frequency	3 VA
(P-Option Units)				
A2 (leave blank)**	**External Auxiliary Power (120 Vac std.)**	**100-130 Vac**	**50-500 Hz**	**6 VA**
A4	Internal Auxiliary Power (self-powered)	84-108% of Nominal Aux. Power Voltage	Equals Input Frequency	6 VA

** For external auxiliary power voltages other than 120 Vac, specify the voltage in the last position of the complete model number. (Example: 240 Vac Aux.)

DC external auxiliary power available; see Special Options on page 128.

Table 4 Input Selection

Current				Voltage			
Option	Nominal	Current Range w/ Accuracy	Calibration at Rated Output (5 A Nominal Input)	Option	Nominal	Voltage Range w/ Accuracy	Calibration at Rated Output (120 V Nominal Input)
-3	1 A	0-2 A	100 W or Vars/Element	-0	69 V	0-75 V	250 W or Vars/Element
-4	2.5 A	0-5 A	250 W or Vars/Element	**Std.*****	**120 V**	**0-150 V**	**500 W or Vars/Element**
Std.***	**5 A**	**0-10 A**	**500 W or Vars/Element**	-1	240 V	0-300 V	1000 W or Vars/Element
-11	7.5 A	0-15 A	750 W or Vars/Element	-9	277 V	0-340 V	1200 W or Vars/Element
-5	10 A	0-20 A	1000 W or Vars/Element	-2	480 V	0-600 V	2000 W or Vars/Element -7
15 A	*0-20 A1500 W or Vars/Element*						
-8****	25 A	0-30 A	2500 W or Vars/Element				

*** Leave "Input" positions blank in the model number.

**** Option -8 requires a Style I case. (See page 122 for case dimensions. Maximum height of terminal strip(s) is 1.07" for units with -8 option.)

Table 5 Scaling Resistor (-RS)/Frequency Options

Option	Description
-RS†	Scaling Resistor
-6	400 Hz
-12	50 Hz (not UL Recognized)
-6-RS†	400 Hz and Scaling Resistor
-12-RS†	50 Hz and Scaling Resistor

† You must specify the desired output voltage:
For 0 to ±1 mAdc units, specify range from 0 to ±10 Vdc. Load impedance is 1 MΩ/Vdc (minimum).
For P-Option units, specify range from 0-15 Vdc (PAN models) or 0-40 Vdc (PA models). Load impedance is 200, 50, or 20 (kΩ/Vdc) (minimum) for units with outputs of 5, 20, or 50 mAdc, respectively.

This information is not part of the model number, but must be provided to the factory when you place your order.

Table 6 Other Options

Option	Description
-20	50-200% Calibration Adjustment (current outputs)
-21	50-200% Calibration Adjustment (voltage outputs) (available only with 0 to ±1 mAdc units)
-24	24 Vdc Loop-Powered (PA7 and PA7-B models only) (consult factory for specifications)
-CE	Analog Output Shorting Relay (available only with 0 to ±1 mAdc units)
-SC††	Special Calibration
-SM	Seismic Brace (available with 0 to ±1 mAdc units) (consult factory if you desire this option with a P-Option unit)
-Z	Zero-Based Output Calibration (ex.: PA7-Z = 0-20 mAdc) (available only with P-Option units, except PAN-B models)

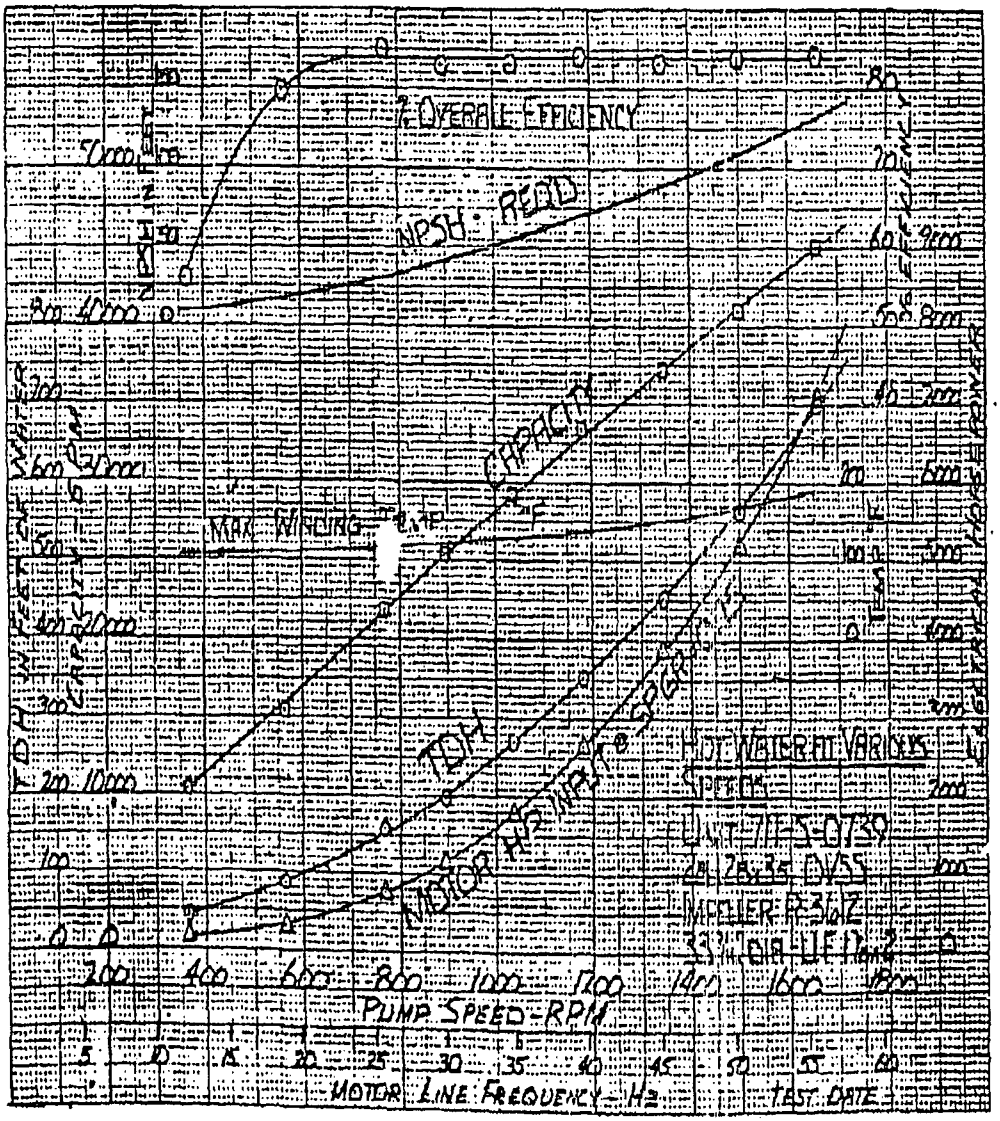
†† You must specify the desired input value:
0 to ±1 mAdc units can be calibrated within 90-180% of their standard-calibration input watts or vars. (Example: A 2-element watt transducer is calibrated to 1000 W standard. The -SC option can be added for input levels from 900 W (90%) to 1800 W (180%).) P-Option units can be calibrated within 60-180% of their standard-calibration input watts or vars.

This information is not part of the model number, but must be provided to the factory when you place your order.

If you require additional options not shown here, see Special Options on page 128. When ordering any special options, or more than three options, you must first consult the factory for pricing and delivery estimates.

Attachment 10

B32-C-001-J-023, Rev. 1, Recirculation Pump Curve (1 pages)



T-34081-3

Attachment 11

Rosemount Inc., Instruction Manual 4259, Model 1151 Alphaline® $\sqrt{\Delta P}$ Flow Transmitter, 1977 (PAGES 1, 6, 14, 24, AND 29)

INSTRUCTION MANUAL 4259

MODEL 1151DP
ALPHALINE®
$\sqrt{\Delta P}$
FLOW TRANSMITTER

CAUTION:
READ BEFORE ATTEMPTING
INSTALLATION OR MAINTENANCE
TO AVOID POSSIBLE
WARRANTY INVALIDATION

CONTENTS

'ALPHALINE' AND 'δ-CELL' are Rosemount Trademarks

Protected by one or more of the following U.S. Patents.
No. 3,271,669; 3,318,153; 3,618,390; 3,646,538; 3,793,885,
3,800,413; 3,854,039; 3,195,028; and 3,859,594.
Canada Patented 1968, 1974. Patente Mexicana No. 118,892.
Other U.S. and Foreign Patents issued or pending.

Rosemount Inc. POST OFFICE BOX 35129 MINNEAPOLIS, MINNESOTA 55435
PHONE: (612) 941-5560 TWX: 910-576-3103 TELEX: 29-0183 CABLE: ROSEMOUNT
Revised 11/77

Specifications - 1151DP $\sqrt{\Delta P}$ Flow Transmitter

Functional Specifications

Service

Liquid, gas or vapor.

Ranges

0-5/30 inches H_2O
0-25/150 inches H_2O
0-125/750 inches H_2O

Outputs

4-20 mADC, square root of input

Power Supply

External power supply required. Up to 45 VDC. Transmitter operates on 12 VDC with no load.

Load Limitations

See Figure 7.

Indication

Optional meter with 1-3/4" linear scale, 0-100%. Indication accuracy is ±2% of span.

Hazardous Locations

Explosion proof: Approved by Factory Mutual for Class I, Division 1, Groups B*, C and D; Class II, Division 1, Groups E, F and G; and Class III, Division 1. Certification by Canadian Standards Association (CSA) for Class I, Groups C and D available as an option. **Intrinsically safe:** FM certification optional for Class I, Division 1; Groups B, C and D when used with listed barrier systems.

Span and Zero

Continuously adjustable externally.

Zero Elevation and Suppression

Zero elevation or zero suppression up to 10% of calibrated span.

Temperature Limits

-20°F to +150°F Amplifier operating.
-40°F to +220°F Sensing element operating.
-60°F to +180°F Storage.

Static Pressure and Overpressure Limits

0 psia to 2000 psig on either side without damage to the transmitter. Operates within specifications between static line pressures of 1/2 psia and 2000 psig. 10,000 psig proof pressure on the flanges.

Humidity Limits

0-100% RH.

Volumetric Displacement

Less than 0.01 cubic inches.

Damping

Fixed response time of 1/3 second. (Corner frequency of 0.4 Hz)

Turn-on Time

10 seconds. No warmup required.

Performance Specifications

(ZERO BASED SPANS, REFERENCE CONDITIONS, 316SS ISOLATING DIAPHRAGMS. APPLIES FROM 25 TO 100% FLOW)

Accuracy
±0.25% of calibrated span for a range of 25% to 100% of flow (6% to 100% of input pressure). Includes combined effects of hysteresis, repeatability and conformity of the square root function.

Dead Band
None.

Stability
±0.25% of upper range limit for 6 months

Temperature Effect
The total effect including zero and span errors: ±1.5% of upper range limit per 100°F. (±2.5% for low range.)

Overpressure Effect
Zero shift of less than ±0.5% of upper range limit for 2000 psi (±2.0% for range 5).

Static Pressure Effect
Zero Error: ±0.5% of upper range limit for 2000 psi (±1.0% for range 3).

Span Error: -0.5±0.1% of reading per 1000 psi (-0.75±0.1% for range 3). This is a systematic error which can be calibrated out for a particular pressure before installation.

Vibration Effect
±0.05% of upper range limit per g to 200 Hz in any axis.

Power Supply Effect
Less than 0.005% of output span per volt.

Load Effect
No load effect other than the change in power supplied to the transmitter.

Mounting Position Effect
Zero shift of up to 1" H_2O which can be calibrated out. No span effect. No effect in plane of diaphragm.

Physical Specifications

Materials of Construction †

Isolating Diaphragms and Drain/Vent Valves:

316SS, HASTELLOY C or MONEL.

Process Flanges and Adapters:

Cadmium Plated Carbon Steel; 316SS, HASTELLOY C or MONEL.

Wetted O-Rings

VITON.

Fill Fluid:

Silicone Oil.

Bolts:

Cadmium Plated Carbon Steel.

Electronics Housing:

Low-copper aluminum (NEMA4).

Paint:

Polyester-Epoxy.

Process Connections

1/4-NPT on 2-1/8" centers on flanges. 1/2-NPT on 2", 2-1/8" or 2-1/4" centers with adapters.

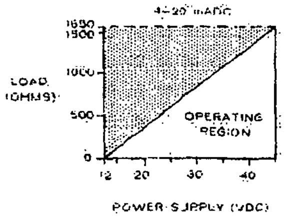
Electrical Connections

1/2-inch conduit with screw terminals and integral test jacks compatible with miniature banana plugs (Pomona 2944, 3690 or equal).

Weight

12 pounds excluding options.

FIGURE 7
LOAD LIMITATIONS



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*Optional meter not approved for Group B.

†MONEL is a trademark of International Nickel Co. HASTELLOY is a trademark of the Cabot Corp. VITON is a DuPont trademark
Terminology per SAMA Standard PMC20 1-1973.

PARTS LIST/DRAWINGS SECTION

Design Specifications

MODEL 1151DP	ALPHALINE $\sqrt{\Delta P}$ FLOW TRANSMITTER

CODE	RANGES
3	0-5 to 0-30 inches H_2O (0-127 to 0-762 mm H_2O)
4	0-25 to 0-150 inches H_2O (0-635 to 0-3810 mm H_2O)
5	0-125 to 0-750 inches H_2O (0-3175 to 0-19050 mm H_2O)

CODE	OUTPUT
C	4-20 mADC, square root of input

	MATERIALS OF CONSTRUCTION		
CODE	FLANGES AND ADAPTERS	DRAIN-VENT VALVES	ISOLATING DIAPHRAGMS
12	Cadmium Plated C.S.	316SS	316SS
13	Cadmium Plated C.S.	HASTELLOY C	HASTELLOY C-276
14	Cadmium Plated C.S.	MONEL	MONEL
22	316SS	316SS	316SS
23	316SS	316SS	HASTELLOY C-276
24	316SS	316SS	MONEL
33	HASTELLOY C	HASTELLOY C	HASTELLOY C-276
44	MONEL	MONEL	MONEL

CODE	OPTIONS
LM	Linear Meter, 0-100% scale
MB	Optional Mounting Bracket for Mounting to 2" Pipe
PB	Optional Mounting Bracket for Panel Mounting
FB	Optional Flat Mounting Bracket for Mounting to 2" Pipe
D1	Side Vent/Drain, Top
D2	Side Vent/Drain, Bottom
CE	Canadian Standards Association (CSA) Explosion Proof Certification for Class I, Groups C and D; Class II, Groups E, F and G; Class III; (Encl. IV).

INTRINSIC SAFETY APPROVAL (All Are Approved By Factory Mutual)

				CLASS I, DIV. 1, GROUPS		
	AGENCY	BARRIER MANUFACTURER	BARRIER MODEL	B	C	D
F1	FM	Foxboro	2AI-I2V-FGB, 2AI-I3V-FGB	X	X	Y
F2	FM	Taylor	124S1134, 124S1144	X	X	X
			124S931, 124S932		X	X
			124S1254, 124S1264		X	X
F3	FM	Westinghouse	75SB01	X	X	X
			56FC12		X	X
F4	FM	Leeds & Northrup	316569, 316747	X	X	X
F5	FM	Fischer & Porter	805H023U01, 805H027U01		X	X
			805H027U02	X	X	X
F6	FM	Fisher Controls	AC302		X	X
F7	FM	Honeywell	38545-XXXX-0110			
			-113-F5B5	X	X	X
			-111/112-F5B5		X	X

1151DP	4	C	12	LM, MB	← COMPLETED DESIGN SPECIFICATION

STANDARD ACCESSORIES All Models are shipped with flange adapter, vent/drain valves and one instruction manual per shipment.

OPTIONAL THREE-VALVE MANIFOLDS (Packaged Separately)

Part No. 1151-150-1: 3-Valve Manifold, Carbon Steel (Anderson, Greenwood & Co., M4AVC)
Part No. 1151-150-2: 3-Valve Manifold, 316SS (Anderson, Greenwood & Co., M4AVS)

TAGGING ALPHALINE Differential Pressure Transmitters will be tagged in accordance with customer requirements. All tags are stainless steel.

CALIBRATION Transmitters are factory calibrated to customer's specified span. If calibration is not specified, transmitters are calibrated at maximum range. Calibration is at ambient temperature and pressure.

Attachment 12
Bailey Signal Resistor Unit Type 766 (2 pages)

GEK-75733
VOLUME IV

TABLE OF CONTENTS

FIG. & INDEX NO.	PART NO.	REF. DES.	DESCRIPTION	UNITS PER/ASSY
3	6146K15P277	R3	RESISTOR, 250 OHMS, ±0.1% FIXED, WIRE-WOUND, 2.5 WATTS (V91637, TYPE RS-2C) (V00213, TYPE 1200S) (V12463, TYPE T-2C)	12
~~4~~	~~6146K15P280~~	~~R3~~	RESISTOR, 242 OHMS, ±0.1% FIXED, WIRE-WOUND, 2.5 WATTS (V91637, TYPE RS-2C) (V00213, TYPE 1200S) (V12463, TYPE T-2C)	6
4	6148K68P015	R4	RESISTOR, 8 OHMS, ±0.1% FIXED, WIRE-WOUND, 0.66 WATT, (V17870, TYPE R1375)	6
5	6149K92P303	R1	RESISTOR, 12100 OHMS, ±0.1% FIXED WIRE-WOUND, (V17870, TYPE R1391-0030), 0.25 WATT	6
5	6148K60P217	R2	RESISTOR, 400 OHMS, 0.1% FIXED, WIRE-WOUND, 0.66 WATT, (V17870, TYPE 1375)	6
6	6146K15P226	R3	RESISTOR, 100 OHMS, ±0.1% FIXED, WIRE-WOUND, 2.5 WATT, (V91637, TYPE RS-2C) (V00213, TYPE 1200S) (V12463, TYPE T-2C)	12
7	6146K15P271	R3	RESISTOR, 96.8 OHMS, ±0.1% FIXED, WIRE-WOUND, 2.5 WATTS	6
7	6148K68P522	R4	RESISTOR, 3.2 OHMS, ±0.1% FIXED, WIRE-WOUND, 0.66 WATT (V17870, TYPE R1375	6
8	6146K15P277	R3	RESISTOR, 250 OHMS, ±0.1% FIXED, WIRE-WOUND, 2.5 WATTS, (V91637, TYPE RS-2C) (V00213, TYPE 1200S) (V12463, TYPE T-2C)	6
9	6146K15P280	R3	RESISTOR, 242 OHMS, ±0.1% FIXED, WIRE-WOUND, 2.5 WATTS (V91637, TYPE RS-2C) (V00213, TYPE 1200S) (V12463, TYPE T-2C)	3
9	6148K68P015	R4	RESISTOR, 8 OHMS, ±0.1% FIXED, WIRE-WOUND, 0.66 WATT (V17870, TYPE R1375)	3
10	6146K15P226	R1	RESISTOR, 100 OHMS, ±0.1% FIXED, WIRE-WOUND, 2.5 WATT (V91637, TYPE RS-2C) (V00213, TYPE 1200S) (V12463, TYPE T-2C)	6
11	6146K15P271	R1	RESISTOR, 96.8 OHMS, ±0.1% FIXED, WIRE-WOUND, 2.5 WATTS, (V91637, TYPE RS-2C) (V00213, TYPE 1200S) (V12463, TYPE T-2C)	3
11	6148K68P522	R2	RESISTOR, 3.2 OHMS, ±0.1% FIXED, WIRE-WOUND, 0.66 WATT, (V17870, TYPE R1375)	3
12	6149K94P007	R1	RESISTOR, 150 OHMS, ±5% FIXED, WIRE-WOUND, 5 WATTS, (V44655, TYPE 995)	6

Attachment 13

Rosemount Specification Drawing 01153-2734, N0039 Option – Combination N0016 & N0037 (2 Pages)

N0039

LTR	DESCRIPTION	ECO NO.	APP'D	DATE
A	Original Release	626853	JmB	12/2/88

I. SCOPE

This specification defines a Model 1153 Series B pressure transmitter with combined options N0016 - a stainless steel 1/2 - 14 NPT pipe plug installed in one of the conduit hubs, and N0037 - a 4-20mA output signal with adjustable damping.

II. DETAILS

1. The pipe plug is to be assembled on the nameplate/vent valve side of the transmitter. The plug will be sealed with thread sealant and torqued to 150 in.-lbs.

2. The standard "R" calibration and amplifier boards are replaced with the special damping calibration and amplifier boards.

III. SPECIFICATIONS

Maximum damping for the electronics, measured at the 63% time constant is:

	Maximum Damping
Range 3	not applicable
Range 4	1.2 seconds
Range 5-9	0.8 seconds

The damping electronics are not intended for the range 3 because the slower response is not required for this transmitter pressure range.

IV. APPLICABILITY AND APPROVALS

This specification is limited to the Model 1153 Series B with "R" electronics. Qualification with the pipe plug was addressed in Rosemount Report 108026 (see paragraph 5.3.1). Qualification of the damping option was addressed in

CLASS IE USAGE

Rosemount Inc. MINNEAPOLIS, MINNESOTA

DR. BY: K. Hildebrandt
DATE: 11/16/88
APP'D: Ian Baldry
DATE: 12/2/88

TITLE: Specification Drawing
N0039 Option - Combination N0016 & N0037

SIZE: A
CODE IDENT. NO.: 04274
DRAWING NO.: 01153-2734
SHEET 1 OF 2

MASTER DRAWING

Form No. 60299-1, Rev. A

Rosemount Report D8800053. The damping option is qualified to the levels of the 1154 transmitter. However, when being used in the Model 1153 transmitter, the qualified requirements are those for the original Model 1153 transmitter. They are not altered because of the presence of the damping electronics.

MASTER DRAWING

CLASS IE USAGE	SIZE A	CODE IDENT. NO. 04274	DRAWING NO. 01153-2734
			SHEET 2 OF 2

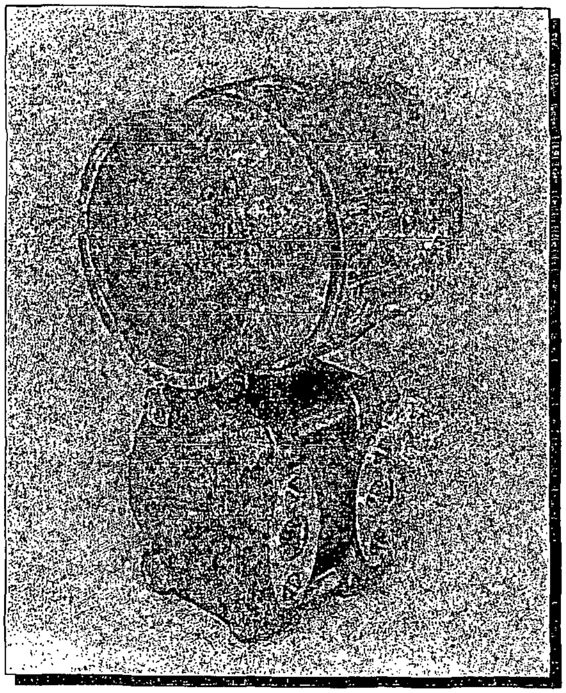
Form No. 60299-2, Rev. A

Attachment 14

Rosemount Product Data Sheet 00813-0100-2655, Rev. AA June 1999 "N-Options for Use with the Model 1153 & 1154 Alphaline® Nuclear Pressure Transmitters" (2 Pages)

00813-0100-2655
English
June 1999
Rev. AA

N–Options for Use with the Model 1153 and Model 1154 Alphaline® Nuclear Pressure Transmitters



ROSEMOUNT® NUCLEAR
FISHER-ROSEMOUNT Managing The Process Better.™

INTRODUCTION

Rosemount® Model 1153 and Model 1154 Alphaline® Nuclear Pressure Transmitters are designed for precise pressure measurements in nuclear applications which require reliable performance and safety over an extended service life. These transmitters have been qualified per IEEE Std 323-1974 and IEEE Std 344-1975 as documented in the corresponding Rosemount qualification reports.

Model 1153 and Model 1154 Transmitters are available in a variety of configurations for differential, flow, gage, absolute, and level measurements. To accommodate specific customer requirements, special N–Option features have been developed to provide greater application flexibility. For example, the N0010 option allows a transmitter to be calibrated up to 5% over its standard upper range limit. The N0026 option allows a Range Code 4 Transmitter to be calibrated up to 210 inH_2O rather than the standard Range Code 4 upper range limit of 150 inH_2O.

Following is a summary of selected N–Options. For additional information on these and other N–Options, contact Rosemount Nuclear Instruments, Inc.

SUMMARY OF N–OPTIONS

N0002	Specifies a reverse-acting gage pressure transmitter.
N0004	Specifies factory calibration of the transmitter at temperatures above or below room temperature. Transmitters may be calibrated at temperatures between 40 and 200 °F.
N0010	Allows the transmitter to be calibrated up to 5% above the standard upper range limit. For example, if the stated upper range limit of the transmitter is 1,000 psi, an N0010 transmitter may be calibrated up to 1,050 psi. This option is available on all ranges.
N0011	Allows 180° rotation of the electronics housing.
N0016	Specifies a stainless steel pipe plug installed on the nameplate/vent valve side of the 1153 Series B Transmitter.
N0018	Specifies a maximum static pressure rating of 3,200 psi rather than the standard 3,000 psi on any high-line differential pressure transmitter.
N0022	Specifies a welded ¼-in. Swagelok™ compression fitting on differential and high-line transmitters.
N0026	Allows an 1153 Series D or 1154 Range Code 4 transmitter to be calibrated up to 210 inH_2O rather than the standard Range Code 4 upper range limit of 150 inH_2O. The maximum and minimum span limits are 155 and 75 inH_2O, respectively.
N0029	Specifies factory calibration of the transmitter at a customer-specified elevated line pressure.
N0032	Specifies a Range Code 3 or 8 differential pressure transmitter with a maximum static pressure rating of 2,500 psi rather than the standard 2,000 psi. Applicable to Model 1153 Series Transmitters only.
N0033	Allows 90° clockwise rotation of the electronics housing. The terminal block lines up with the vent/drain valve side.
N0034	Specifies a Model 1153 Series D or Model 1154 Transmitter with a special mounting bracket that has no panel mounting holes.
N0037	Specifies adjustable damping on any Model 1153 or Model 1154 Transmitter.
N0077	Specifies a Model 1153 Series F with a SST electronics housing, SST housing covers and SST mounting bracket.
N0078	Allows 180° rotation of the process flanges
N0088	Allows 90° counterclockwise rotation of the electronics housing. The terminal block lines up with the process connections.

ORDERING INFORMATION

Consult the appropriate transmitter Product Data Sheet for a transmitter model number. Append the N–Option number to the end of the transmitter model number. An example of a typical model number with N–Option added is 1153DB5RAN0010.

Rosemount, the Rosemount logo, and Alphaline are registered trademarks of Rosemount Inc.
Swagelok is a registered trademark of Crawford Fitting Co.

May be protected by one or more of the following U.S. Patent Nos. 3,646,538; 3,793,865; 3,800,413; 3,975,719; Re. 30,603. Canada patented (Brevete) 1974, 1975, 1976, and 1979. May depend on model. Other foreign patents issued and pending.

Cover photo: 1153-001AB

CE Fisher-Rosemount satisfies all obligations coming from legislation to harmonize product requirements in the European Union.

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00813-0100-2655 Rev. AA