**CONSUMERS
ENERGY**

PALISADES NUCLEAR PLANT
EN GINEERING ANALYSIS COVER SHEET

EA- ELEC08-0001

Total Number of Sheets 20

Title Uncertainty Calculation r the Secondary Calorimetric Heat Balance

INITIATION AND REVIEW

Calculation Status Preliminary ☐ Pending ☐ Final ☒ Superseded ☐

Rev #	Description	Initiated		Init Appd By	Review Method			Technically Reviewed		Rev'r Appd By	Sup'v & S/DR Appd
		By	Date		Alt Calc	Detail Rev'w	Qual Test	By	Date		
0	Original Issue	.A. ischoff	3/21/02	RMB		✓		D.M. Kennedy	4/5/02		RMB 4/18/02
1	See Record Of Revision Sheet	M Hamm	7/15/02	RMB		✓		DM Kennedy	8/15/02		RMB 8/24/02
2	Revise Feedwater Error See Record of Revision	JM Hamm	4/12/05			✓		DM Kennedy	5/1/05		5/5/05

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RECORD OF REVISION

Revision Number	Description Of Change
1	EA-ELEC08-0004, "Uncertainty Calculation for UFM Corrected, Density Compensated, Total Feedwater Flow Measurement (PPC Only)" has been revised which resulted in an increase in the Total Loop Uncertainty used as an input to this calculation. The uncertainty of the temperature input to the heat balance changed due to the revision of EA-ELEC08-0004. The expected power uprate plant operating parameters are included in Section 4.1.1 as a major assumption. The indicated calculation status on the cover sheet has been changed to Pending. Section 1.0; Added reference to power uprate. Section 3.2.3; Changed dW_{FWC} to 28,614.9 lbm/hr Section 3.2.7; Changed T_{FW} to ±3.63°F and 3.4134°F to 3.6251°F Section 4.1.1; Added this section to provide plant parameters expected following the power uprate. Section 5.1; Changed Total Uncertainty (Uncorrected) to +1.13% Power -1.21% Power Section 5.2; Changed Total Uncertainty (Corrected) to +0.49% Power, -0.55% Power Section 7.0; Changed Total Uncertainty (Uncorrected) to +1.13% Power -1.21% Power Changed Total Uncertainty (Corrected) to +0.49% Power, -0.55% Power Section 9.9; Changed the revision level to Rev.1 Section 9.11; Changed to RI-24A Revision 0. Section 9.12; Added RI-24B Revision 0.
2	Revised Total Feedwater flow error, (dW_{FWC}) from 28.6149 Klbm/hr to 29.389 Klbm/hr based on EA-ELEC08-004, "Uncertainty Calculation for UFM Corrected, Density Compensated Total Feedwater Flow Measurement (PPC Only)." Error was changed based on a change in location of the UFM measuring the B feedwater loop flow.

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2	Revised Total Feedwater flow error, (dW_{FWC}) from 28.6149 Klbm/hr to 29.389 Klbm/hr based on EA-ELEC08-004, "Uncertainty Calculation for UFM Corrected, Density Compensated Totall Feedwater Flow Measurement (PPC Only)." Error was changes based on a change in ocation of the UFM measuring the B feedwater loop flow.

1.0 OBJECTIVE / SCOPE

This calculation will compute the uncertainty associated with the secondary calorimetric heat balance calculation with and without the Ultrasonic Flow Meter correction factor. Heat balance uncertainties are computed for the manual heat balance calculation performed through performance of DWO-1 with utilizing the power uprate values (Reference 9.10).

2.0 FUNCTIONAL DESCRIPTION

The Steam Generators (SG) serve to remove energy from the Primary Coolant System (PCS) and supply high quality steam to the main turbine and various auxiliary services. Steam exits the SGs through two 36" headers (Main Steam Lines). Each Main Steam Line (MSL) contains a Main Steam Isolation Valve which provides the ability to isolate the MSL from the remainder of the secondary system. An accurate calculation of Reactor power is obtained by performing a secondary heat balance.

The equation used to perform the Secondary Calorimetric power calculation is derived as follows:

Applying the 1st Law of Thermodynamics (Conservation of Energy) to the Primary Coolant System (PCS) yields the following energy equation:

$$\sum Energy_{IN} - \sum Energy_{OUT} = 0$$

Note: Steady state conditions are assumed.

For the PCS, it is reasonable to assume that no external work is performed and changes in kinetic energy are negligible. Therefore, only the heat sources and heat sinks in the PCS need to be considered. The following heat sources introduce energy (Q) into the Primary Coolant System:

- Reactor (Q_{RX})
- Primary Coolant Pumps (Q_{PCP})
- Pressurizer Heaters (Q_{PZR})
- Charging Flow (Q_{CH})

The following heat sinks remove energy (Q) from the Primary Coolant System:

- Steam Generators (Q_{SG})
- Letdown Flow (Q_{LD})
- Fixed Insulation Losses (Q_{FL})

Substituting the heat sources and heat sinks into the energy equation and solving for Q_{RX} yields the following equation:

$$Q_{RX} = Q_{SG} + Q_{LD} + Q_{FL} - Q_{PCP} - Q_{PZR} - Q_{CH}$$

Note: Energy removed from the Primary Coolant System due to PCS leakage is considered to be negligible and is not included in the Reactor Power equation.

Per Reference 9.7, the energy terms associated with the primary coolant pumps, letdown flow, charging flow, fixed insulation losses, and the pressurizer heaters are combined into one constant value (C). Therefore, the energy equation is simplified as follows:

$$Q_{RX} = Q_{SG} - C$$

Per Reference 9.7, the value of C will vary depending on the number of charging pumps / letdown orifices in service (up to 3 total). Reference 9.7 determines a conservatively low value of C for each combination with the following results:

C = 9.72 MWth (one orifice)
C = 8.52 MWth (two orifices)
C = 7.14 MWth (three orifices)

DWO-1 is utilized to compute the value of Q_{SG} given in the equation presented above.

The determination of the Steam Generator term (Q_{SG}) requires the application of the energy equation with the Steam Generator considered as the control volume.

The following heat sources introduce energy into the Steam Generators:

- Energy from the PCS (Q_{SG})
- Feedwater Flow (Q_{FW})

The following heat sinks remove energy from the Steam Generators:

- Blowdown Flow (Q_{BD})
- Steam Flow (Q_{ST})

Substituting the heat sources and heat sinks into the energy equation and solving for Q_{SG} yields the following equation:

$$Q_{SG} = Q_{ST} + Q_{BD} - Q_{FW}$$

3.0 ANALYSIS INPUTS

3.1 HEAT BALANCE UNCERTAINTY EQUATION

Per Reference 9.4, the following equation represents the heat balance calculation as computed by DWO-1:

$$Q_{SG} = \left(435.8\text{[illegible]}4 + 0.1753\,P_{SG} - 1.1045\,T_{FW} + X\left(851.789 - 0.20257\,P_{SG}\right)\right)W_{FW} - X\left(851.789 - 0.20257\,P_{SG}\right)W_{BD}$$

where,

Q_{SG} = Heat removed from the PCS by the Steam Generators (btu / hr)
P_{SG} = Steam Generator Pressure (psia)
T_{FW} = Feedwater Temperature (°F)
X = Steam quality (unit-less)
W_{FW} = Feedwater flow (lbm / hr)
W_{BD} = Blowdown flow (lbm / hr)

Note: The equation given above is simplified in DWO-1 and broken down into multiple steps. Steam quality is not measured when performing the heat balance.

The effects of instrument uncertainties on the heat balance are computed by taking the total derivative of the overall energy equation given above as follows:

$$dQ_{SG} = \frac{\partial Q_{SG}}{\partial W_{FW}}dW_{FW} + \frac{\partial Q_{SG}}{\partial W_{BD}}dW_{BD} + \frac{\partial Q_{SG}}{\partial P_{SG}}dP_{SG} + \frac{\partial Q_{SG}}{\partial T_{FW}}dT_{FW} + \frac{\partial Q_{SG}}{\partial X}dX$$

Using the methodology described in References 9.1 and 9.2, the individual random uncertainty terms are combined using the Square Root Sum of Squares method as follows:

$$dQ_{SG} = \sqrt{\left(\frac{\partial Q_{SG}}{\partial W_{FW}}dW_{FW}\right)^2 + \left(\frac{\partial Q_{SG}}{\partial W_{BD}}dW_{BD}\right)^2 + \left(\frac{\partial Q_{SG}}{\partial P_{SG}}dP_{SG}\right)^2 + \left(\frac{\partial Q_{SG}}{\partial T_{FW}}dT_{FW}\right)^2 + \left(\frac{\partial Q_{SG}}{\partial X}dX\right)^2}$$

The partial derivatives in the equation given above represent the weighting factor of each parameter used for the heat balance calculation. The differentials in the equation given above represent the uncertainty associated with each parameter.

The partial derivatives are as follows:

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$$\frac{\partial Q_{SG}}{\partial W_{FW}} = 435.804 + 0.1753\,P_{SG} - 1.1045\,T_{FW} + X\left(851.789 - 0.20257\,P_{SG}\right)$$

$$\frac{\partial Q_{SG}}{\partial W_{BD}} = -X\left(851.789 - 0.20257\,P_{SG}\right)$$

$$\frac{\partial Q_{SG}}{\partial T_{FW}} = -1.1045\,W_{FW}$$

$$\frac{\partial Q_{SG}}{\partial P_{SG}} = 0.1753\,W_{FW} + X\left(0.20257\right)\left(W_{BD} - W_{FW}\right)$$

$$\frac{\partial Q_{SG}}{\partial X} = \left(851.789 - 0.20257\,P_{SG}\right)\left(W_{FW} - W_{BD}\right)$$

The following nominal full power values are used to compute the value of each partial derivative:

W_{FW}	= 5,678,500 lbm / hr	[Reference 9.10]
W_{BD}	= 30,000 lbm / hr	[Reference 9.4]
T_{FW}	= 440.7°F	[Reference 9.10]
P_{SG}	= 765.8 psia	[Reference 9.10]
X	= 0.9989	[Average of SG A value and SG B value from Reference 9.4]

Substituting these values into each partial derivative yields the following weighting factors for each parameter used in the heat balance calculation:

$$\frac{\partial Q_{SG}}{\partial W_{FW}} = 779.190 \text{ btu / lbm}$$

$$\frac{\partial Q_{SG}}{\partial W_{BD}} = -695.895 \text{ btu / lbm}$$

$$\frac{\partial Q_{SG}}{\partial T_{FW}} = -6{,}271{,}903 \text{ btu / (hr - °F)}$$

$$\frac{\partial Q_{SG}}{\partial P_{SG}} = -147{,}517 \text{ btu / (hr - psia)}$$

$$\frac{\partial Q_{SG}}{\partial X} = 3{,}935{,}089{,}059 \text{ btu / hr}$$

3.2 HEAT BALANCE INPUT UNCERTAINTIES

3.2.1 Per Reference 9.5, the uncertainty associated with the blowdown flow (W_{BD}) input to the heat balance uncertainty calculation is as follows:

dW_{BD} = ±2,500 lbm / hr

3.2.2 Per Reference 9.4, the uncertainty associated with the steam quality (dX) measurement which is used in the heat balance calculation is as follows:

dX = ±0.00016

3.2.3 Per Reference 9.3, the feedwater flow input to the heat balance is obtained by reading PPC points FEEDWTR_FLOW_SGA_AVE and FEEDWTR_FLOW_SGB_AVG. If these points are not available, alternate computer points (FT-0701 and FT-0703) are used to measure feedwater flow. Per Reference 9.6, the Ultrasonic Flow Meter (UFM) corrected uncertainty (dW_{FWc}) associated with the PPC feedwater flow for each loop reading consists of the uncertainty associated with the flow transmitter and the PPC A/D uncertainty:

dW_{FWc} = ±29.389 Klbm / hr

Per Reference 9.10, the nominal post power uprate feedwater flow rate is 5,678,500 lbm / hr. Therefore,

dW_{FWc} = ±0.51 % Flow

3.2.4 Per Reference 9.11, the random uncertainty of the PPC feedwater flow reading (without UFM correction) consists of the uncertainty associated with the flow element, the flow transmitter, the temperature loop error, and the PPC A/D uncertainty:

dW_{FW} = ±0.24% Flow

Using the post uprate feedwater flow value per steam generator from Reference 9.10, 5,678,500 lbm / hr, yields the following uncertainty expressed in units of lbm / hr:

dW_{FW} = ±13,628.4 lbm / hr @ 100% Power

3.2.5 Per Reference 9.11, the bias uncertainty associated with the feedwater flow measurement (without UFM correction) consists of the bias uncertainty associated with the flow element and the As-Left tolerance of the transmitter. Therefore, the total bias uncertainty is treated as a bi-directional bias as follows:

Bias = (±0. 50% ±0.25%) Flow @ 100% Power
Bias = ±0.75% Flow @ 100% Power

Using the post uprate feedwater flow value from Reference 9.10, 5,678,500 lbm / hr, yields the following uncertainty expressed in units of lbm / hr:

dW_{FVB} = ±42,588 lbm / hr @ 100% Power

3.2.6 At the present time, per Reference 9.3, PPC points PT_0751B and PT_0752B are used to obtain Steam Generator pressure. If these points are unavailable, Steam Generator pressure (P_{SG}) indicators PIC-0751A, 0751B, 0751C, and 0751D are averaged to obtain Steam Generator A pressure, and PIC-0752A, 0752B, 0752C, and 0752D are averaged to obtain Steam Generator B pressure. Per Assumption 4.1, the procedure will require the average of at least 3 Steam Generator Pressure readings per Steam Generator when the heat balance is performed in the future. Per Reference 9.8, the uncertainty associated with PIC-0751A, 0751B, 0751C, 0751D and PIC-0752A, 0752B, 0752C, and 0752D is as follows:

eP_{SG} = +27.48 psia -28.44 psia

For conservatism, the Steam Generator pressure indicator uncertainty is rounded to ±29 psia, and one steam generator pressure channel is assumed to be out of service. Therefore, the uncertainty associated with the averaging of three pressure inputs is computed as follows:

$$dP_{SG} = \pm\sqrt{\left(\frac{29\text{ psia}}{3}\right)^2 + \left(\frac{29\text{ psia}}{3}\right)^2 + \left(\frac{29\text{ psia}}{3}\right)^2}$$

$$dP_{SG} = \pm 16.74\text{ psia}$$

3.2.7 Per Reference 9.3, the feedwater temperature input to the heat balance is obtained by reading PPC points HB_TEMP_STEADY_SGA and HB_TEMP_STEADY_SGB. If these points are not available, alternate computer points (TT_0706A and TT_0708A) are used to measure feedwater temperature. Reference 9.5 provides a PPC Feedwater Temperature uncertainty value of
± 1.3°F. However, Reference 9.6 calculates a more conservative uncertainty associated with the PPC feedwater temperature reading of ± 3.63°F (rounded up from 3.6251°F). Though the results of Reference 9.6 (stated in Section 8.0) are valid for restricted use, this value is used as it bounds the value from Reference 9.5. Therefore:

$$dT_{FW} = \pm 3.63° F$$

NOTE: *Temperature input uncertainties are calculated for single point real time FW Temperature measurements. Any time averaging of FW Temperature values prior to use in calorimetric calculations would provide FW Temperature (and uncertainty) values bounded by the single point real time FW Temperature measurements.*

3.2.8 Per Reference 9.4, the Heat Balance Uncertainty equation (stated in Section 3.1) has, as part of its basis, enthalpy calculation equations. Differences between steam enthalpies determined by using these equations and those determined using the ASME Steam Tables could impart a bias uncertainty into the calculation of overall uncertainty for the secondary calorimetric. This additional bias term is computed below by determining steam and feedwater enthalpy errors at various points and choosing a representative bias from the calculated errors.

Attachment A show the determination of bounding values for enthalpy errors in Feedwater and Steam. ASME Steam enthalpies were determined for saturated steam conditions, while feedwater enthalpies were determined for compressed liquid at 830 psia. Minor differences between the assumed feedwater pressure and actual feedwater pressure would result in negligible enthalpy bias differences. Feedwater enthalpy Delta h error is bounded by +0.17 btu / lbm. In other words, calculated hFW is larger than actual hFW. Steam (mixture enthalpy Delta h error is bounded by –0.08 btu / lbm. In the calculation of secondary calorimetric uncertainty, these errors would result in thermal power calculations that are lower than actual thermal power which is non conservative. These errors can be added to yield an overall enthalpy bias term, as follows:

$$hb = -(|hsb| + |hfb|)$$

where:
hb = total enthalpy bias uncertainty
hsb = steam enthalpy bias uncertainty
hfb = feedwater enthalpy bias uncertainty

Therefore:
$hb = -(0.08 + 0.17)$ btu/lbm
$hb = -0.25$ btu / lbm

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3.3 HEAT BALANCE INPUTS

3.3.1 Per Reference 9.7, a conservatively determined constant value (C) is used to account for the energy terms associated with the primary coolant pumps, letdown flow, charging flow, fixed insulation losses, and the pressurizer heaters. The constant C varies depending on the number of charging pump / letdown flow orifices in service (up to three total). Parameters such as charging flow, letdown flow, etc. are relatively constant during the performance of the heat balance, and treating these parameters as constants simplifies the heat balance. Reference 9.7 demonstrates that the calculated C values are lower than actual, which would tend to compensate for any actual variations in the parameters that make up the C constant. The following equation from Section 2.0 demonstrates that using a lower than actual C value is conservative.

$$Q_{RX} = Q_{SG} - C$$

This equation shows that using a smaller value of "C" would result in a higher calculated "Q_{RX}". As nuclear instrumentation is calibrated to the heat balance results, this would cause indicated power to be greater than actual, which is conservative.

3.3.2 The following plant parameters are used for the heat balance uncertainty calculation:

P_{SG} = Steam Generator Pressure (psia) [Reference 9.10]
P_{SG} = 765.8 psia

T_{FW} = Feedwater Temperature (°F) [Reference 9.10]
T_{FW} = 440.7°F

X = Steam quality (unit-less) [Reference 9.4]
X = 0.9989

W_{BD} = Blowdown flow (lbm / hr) [Reference 9.4]
W_{BD} = 30,000 lbm / hr

4.0 ASSUMPTIONS

4.1 MAJOR ASSUMPTIONS

4.1.1 None

4.2 MINOR ASSUMPTIONS

4.2.1 Per Reference 9.3 the manual heat balance calculation, without the PPC Steam Generator pressure values available, will use the average of at least three pressure indications per Steam Generator each time the Secondary Heat Balance is performed.

4.2.2 All uncertainties associated with the ultrasonic flow meter are random and independent.

4.2.3 Per Reference 9.10, the following plant parameters are anticipated after the power uprate project. If actual plant conditions are similar to these, this calculation remains valid.

Q_R = Reactor 100% Power
Q_R = 2565.4 MWt

P_{SG} = Steam Generator Pressure (psia)
P_{SG} = 765.8 psia

T_{FW} = Feedwater Temperature (°F)
T_{FW} = 440.7°F

F_{FW} = Feedwater Flow (Mlb_m / hr)
F_{FW} = 11.357 Mlb_m / hr

5.0 ANALYSIS

Computations are performed to an accuracy of several significant digits, but presented in this calculation rounded to two decimal places in most cases. Hand verification of this calculation utilizing the rounded values may result in slightly different results due to round off errors.

5.1 SECONDARY HEAT BALANCE UNCERTAINTY (Without UFM Correction)

Random Uncertainties

Per Analysis Input 3.1, the following equation is used to compute the random uncertainties associated with the heat balance:

$$dQ_{SG} = \sqrt{\left(\frac{\partial Q_{SG}}{\partial W_{FW}} dW_{FW}\right)^2 + \left(\frac{\partial Q_{SG}}{\partial W_{BD}} dW_{BD}\right)^2 + \left(\frac{\partial Q_{SG}}{\partial P_{SG}} dP_{SG}\right)^2 + \left(\frac{\partial Q_{SG}}{\partial T_{FW}} dT_{FW}\right)^2 + \left(\frac{\partial Q_{SG}}{\partial X} dX\right)^2}$$

The uncertainties associated with each input parameter (differentials) are as follows:

dW_{FWL} = feedwater flow (random) = ±13,628 lbm / hr [Analysis Input 3.2.4]
dW_{FWL} = feedwater flow (bias) = ± 42,588 lbm / hr [Analysis Input 3.2.5]
dW_{BD} = blowdown flow = ±2,500 lbm / hr [Analysis Input 3.2.1]
dT_{FW} = feedwater temperature = ±3.63 ° F [Analysis Input 3.2.7]
dP_{SG} = Steam Generator pressure = ±16.74 psia [Analysis Input 3.2.6]
dX = steam quality = ±0.00016 [Analysis Input 3.2.2]

Per Analysis Input 3.1, the partial derivatives are as follows:

$$\frac{\partial Q_{SG}}{\partial W_{FW}} = 779.190 \text{ btu / lbm}$$

$$\frac{\partial Q_{SG}}{\partial W_{BD}} = -695.895 \text{ btu / lbm}$$

$$\frac{\partial Q_{SG}}{\partial T_{FW}} = -6{,}271{,}903 \text{ btu / (hr - °F)}$$

$$\frac{\partial Q_{SG}}{\partial P_{SG}} = -147{,}517 \text{ btu / (hr - psia)}$$

$$\frac{\partial Q_{SG}}{\partial X} = 3{,}935{,}089{,}059 \text{ btu / hr}$$

Therefore, the random uncertainty associated with the heat balance calculation is as follows:

$$dQ_{SG} = \pm 25{,}310{,}409 \text{ btu / hr}$$

Per Reference 9.4, the conversion from btu / hr to Wt is performed by multiplying by a factor of 0.29293 Wt – hr/btu. Per Reference 9.10, 100% Power equates to 2,565.4 MWt. Therefore, the random heat balance uncertainty is converted to % Power with the following equation:

$$dQ_{SG}(\%\ Power) = dQ_{SG}(btu/hr)\left(0.29293\frac{Wt}{btu/hr}\right)\left(\frac{100\%\ Power}{2{,}565{,}400{,}000\ Wt}\right)$$

Therefore,

$$dQ_{SG} = \pm 0.29\ \%\ Power\ (Single\ Steam\ Generator)$$

The total random uncertainty associated with the heat balance calculation is computed with the following equation:

$$dQ_{SG} = \sqrt{dQ_{SG}^{2} + dQ_{SG}^{2}}\ \ (Both\ Steam\ Generators)$$

$$dQ_{SG} = \pm 0.41\ \%\ Power\ (Both\ Steam\ Generators)$$

Bias Uncertainties

There are two bias uncertainties that must be considered, Feedwater Flow Measurement bias (FWb) and enthalpy bias (hb). These bias terms are calculated below, then combined to yield the total bias uncertainty for one steam generator. This result can be multiplied by 2 to yield total bias uncertainty for both steam generators.

Feedwater Flow Measurement Bias Uncertainty

Per Section 3.2.5, the following bi-directional bias uncertainty is associated with the feedwater flow measurement for one Steam Generator:

$$FWb\ (lbm/hr) = \pm 42{,}588\ lbm/hr$$

Per Analysis Input 3.1, the weighting factor (partial derivative) associated with the feedwater flow heat balance input is as follows:

$$\frac{\partial Q_{SG}}{\partial W_{FW}} = 779.190\ btu/lbm$$

The feedwater flow measurement bias term is converted to btu / hr with the following equation:

$$FWb\ (btu/hr) = FWb\ (lbm/hr)\left(\frac{\partial Q_{SG}}{\partial W_{FW}}\right)$$

$$FWb\ (btu/hr) = \pm 33{,}184{,}144\ btu/hr$$

Enthalpy Bias Uncertainty

Per Section 3.2.8, the following enthalpy bias is associated with the feedwater flow to each steam generator which is 5,678,500 lbm/hr:

$hb = 0.25$ btu / lbm
hb (btu / hr) = hb (btu / lbm) * W_{FW}

hb (btu/hr) = -0.25 btu / lbm * 5,678,500 lbm / hr
hb (btu / hr) = -1,419,625 btu / hr

Total Bias Uncertainty

Total bias uncertainty ($Bias_T$) is the sum of the Feedwater Flow Measurement uncertainty bias and the enthalpy bias. Therefore:

$Bias_T$ = FWb + hb
$Bias_T$ = ±33,184,144 btu / hr -1,419,625 btu / hr
$Bias_T$ = +31,764,519 btu / hr - 34,603,769 btu / hr

Per Reference 9.4, the conversion from btu / hr to Wt is performed by multiplying by a factor of 0.29293 Wt – hr/btu. Per Reference 9.10, 100% Power equates to 2,565.4 MWt. Therefore, the bias term is converted to % Power utilizing the following equation:

$$Bias_T\,(\%\,Power) = Bias\,(btu/hr)\left(0.29293\frac{Wt}{btu/hr}\right)\left(\frac{100\%\,Power}{2{,}565{,}400{,}000\,Wt}\right)$$

$Bias_T$ (% Power) = +0.36% Power -0.40 % Power (One Steam Generator)

The total bias uncertainty associated with the feedwater flow to both Steam Generators is obtained by multiplying the bias uncertainties for a single Steam Generator by "2". Therefore,

$Bias_T$ (% Power) = + 0.72% -0.80% Power (Both Steam Generators)

Secondary Heat Balance Total Uncertainty (Uncorrected Feedwater Flow)

Total Uncertainty (Uncorrected) = ±0.41% Power + 0.72% Power –0.80% Power
Total Uncertainty (Uncorrected) = +1.13% Power – 1.21% Power

+ .41% + .72% = 1.13%

− .41% − .80% = −1.2%

5.2 SECONDARY HEAT BALANCE UNCERTAINTY (With UFM Correction)

Random Uncertainties

Per Analysis Input 3.1, the following equation is used to compute the random uncertainties associated with the heat balance:

$$dQ_{SG} = \sqrt{\left(\frac{\partial Q_{SG}}{\partial W_{FW}} dW_{FW}\right)^2 + \left(\frac{\partial Q_{SG}}{\partial W_{BD}} dW_{BD}\right)^2 + \left(\frac{\partial Q_{SG}}{\partial P_{SG}} dP_{SG}\right)^2 + \left(\frac{\partial Q_{SG}}{\partial T_{FW}} dT_{FW}\right)^2 + \left(\frac{\partial Q_{SG}}{\partial X} dX\right)^2}$$

The uncertainties associated with each input parameter (differentials) are as follows:

dW_{FW}	= UFM corrected feedwater flow	= ±29,389 lbm / hr	[Analysis Input 3.2.3]
dW_{BD}	= blowdown flow	= ±2,500 lbm / hr	[Analysis Input 3.2.1]
dT_{FW}	= feedwater temperature	= ±3.63°F	[Analysis Input 3.2.7]
dP_{SG}	= Steam Generator pressure	= ±16.74 psia	[Analysis Input 3.2.6]
dX	= steam quality	= ±0.00016	[Analysis Input 3.2.2]

Per Analysis Input 3.1, the partial derivatives are as follows:

$$\frac{\partial Q_{SG}}{\partial W_{FW}} = 779.190 \text{ btu / lbm}$$

$$\frac{\partial Q_{SG}}{\partial W_{BD}} = -695.895 \text{ btu / lbm}$$

$$\frac{\partial Q_{SG}}{\partial T_{FW}} = -6{,}271{,}903 \text{ btu / (hr - °F)}$$

$$\frac{\partial Q_{SG}}{\partial P_{SG}} = -147{,}517 \text{ btu / (hr - psia)}$$

$$\frac{\partial Q_{SG}}{\partial X} = 3{,}935{,}089{,}059 \text{ btu / hr}$$

Therefore, the random uncertainty associated with the heat balance calculation is as follows:

$$dQ_{SG} = \pm 32{,}438{,}841 \text{ btu / hr}$$

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Per Reference 9.4, the conversion from btu / hr to Wt is performed by multiplying by a factor of 0.29293 Wt – hr/btu. Per Reference 9.10, 100% Power equates to 2,565.4 MWt. Therefore, the random heat balance uncertainty is converted to % Power with the following equation:

$$dQ_{SG}\ (\%\ \text{Power}) = dQ_{SG}(\text{btu}/\text{hr})\left(0.29293\,\frac{\text{Wt}}{\text{btu}/\text{hr}}\right)\left(\frac{100\%\ \text{Power}}{2{,}565{,}400{,}000\ \text{Wt}}\right)$$

Therefore,

$dQ_{SG} = \pm 0.3704\%$ Power (Single Steam Generator)

The total random uncertainty associated with the heat balance calculation is computed with the following equation:

$$dQ_{SG} = \sqrt{dQ_{SG}^{\,2} + dQ_{SG}^{\,2}}\ \text{(Both Steam Generators)}$$

$dQ_{SG} = \pm 0.5238\%$ Power (Both Steam Generators)

Bias Uncertainties

Per Section 3.1.3, there are no feedwater flow measurement bias terms associated with the heat balance when UFM corrected feedwater flow is utilized as an input. Per Section 3.2.8, there is an enthalpy bias term that must be considered.

Enthalpy Bias Uncertainty

Not uncertainty [illegible] 6/15

Per Section 3.2.8, the following enthalpy bias is associated with the feedwater flow to each steam generator which is 5,678,500 lbm/hr:

$hb = -0.25$ btu / lbm
$hb\ (\text{btu}/\text{hr}) = hb\ (\text{btu}/\text{lbm}) * W_{FW}$

$hb\ (\text{btu}/\text{hr}) = -0.25\ \text{btu}/\text{lbm} * 5{,}678{,}500\ \text{lbm}/\text{hr}$
$hb\ (\text{btu}/\text{hr}) = -1{,}419{,}625\ \text{btu}/\text{hr}$

Per Reference 9.4, the conversion from btu / hr to Wt is performed by multiplying by a factor of 0.29293 Wt – hr/btu. Per Reference 9.10, 100% Power equates to 2,565.4 MWt. Therefore, the bias term is converted to % Power utilizing the following equation:

$$\text{Bias}\ (\%\ \text{Power}) = \mathit{Bias}\,(\mathit{btu}/\mathit{hr})\left(0.29293\,\frac{\text{Wt}}{\text{btu}/\text{hr}}\right)\left(\frac{100\%\ \text{Power}}{2{,}565{,}400{,}000\ \text{Wt}}\right)$$

Bias (% Power) = $\boxed{-0.0162}$ % Power (One Steam Generator)

.032

0.3

8.0 CONCLUSION

This calculation computed the uncertainty associated with the secondary calorimetric heat balance calculation with and without the Ultrasonic Flow Meter correction factor. Heat balance uncertainties were computed for the manual heat balance calculation performed through performance of DWO-1. See Section 7.0 for results. The results of this calculation are subject to the following limitations:

- This calculation assumes that Reference 9.3 will be revised to use the average of PIC-0751A, 0751B, 0751C, and 0751D to obtain Steam Generator A pressure, and the average of PIC-0752A, 0752B, 0752C, and 0752D will be used to obtain Steam Generator B pressure every time the Secondary Heat Balance is performed. The results of this calculation are based on the use of at least 3 Steam Generator Pressure indications per steam generator.

- Per Reference 9.3, the feedwater flow control room indicators (FI-0701 and FI-0703) may also be used as the feedwater flow input to the heat balance. The uncertainty associated with the control room feedwater flow indicators is larger than the uncertainty associated with the PPC computer point indications of feedwater flow. Reference 9.6 does not compute the uncertainties associated with the feedwater flow control room indicators. The results of this calculation are based on the use of the PPC computer points for the feedwater flow measurement.

- Per Reference 9.3, the feedwater temperature control room indicators (TI-0706 and TI-0708) or recorder TR-0706 may also be used as the feedwater temperature input to the heat balance. The uncertainties associated with the control room indicators and the recorder are larger than the uncertainty associated with the PPC computer point indications of feedwater temperature. Reference 9.6 does not compute the uncertainties associated with the analog indications of feedwater temperature. The results of this calculation are based on the use of the PPC computer points for the feedwater temperature measurement.

9.0 REFERENCES

9.1 NUREG/CR-3659, "A Mathematical Model for Assessing the Uncertainties of Instrumentation Measurements for Power and Flow of PWR Reactors", Dated February 1985.

9.2 ISA-RP67.04, Part II - 1994, "Methodologies for the Determination of Setpoints for Nuclear Safety Related Instrumentation", May 1995.

9.3 DWO-1, "Operator's Daily / Weekly Items, Modes 1, 2, 3, and 4", Revision 70.

9.4 EA-HAR-91-10, "Heat Balance Adjustment for Moisture Content of Steam", Revision 0.

9.5 EA-AFZ-96-01, "Analysis of Various Heat Balance Input Inaccuracies", Revision 2.

9.6 EA-ELEC08-0004, " Uncertainty Calculation for UFM Corrected, Density Compensated Total Feedwater Flow Measurement (PPC Only)", Revision 2.

9.7 EA-BWB-96-01, "Heat Balance Calculation Using the Ultrasonic Flowmeter Measurement Device", Revision 5.

9.8 EA-ELEC08-97-04, "Uncertainty Calculation Steam Generator Pressure Loops", Revision 2.

9.9 Deleted

9.10 EA-RCH-01-05, "Calculation of Chapter 14 Safety Analysis Parameter Changes Due to FC-977 Power Uprate," Revision 0.

9.11 RI-24A, "Steam Generator Feedwater Temperature Instrument Loop Calibration, " Procedure, Revision 0.

9.12 RI-24B, "Steam Generator Feedwater Flow Instrument Loop Calibration," Procedure, Revision 0.

ATTACHMENT A

The following table establishes bounding differences between steam and feedwater enthalpy taken from ASME Steam Tables and calculated using approximations from Reference 9.4.

STEAM ENTHALPY (Saturated Conditions)

(SGA) hm = 1220.36-.02709*PSG

(SGB) hm = 1219.97-.02700*PSG

XA = 0.999135
XB = 0.998668

PSG	ASME			Calc.		ASME	Calc.	
(psia)	hg	hf	hmA	hmA	Delta h	hmB	hmB	Delta h
760	1200.44	502.7	1199.836	1199.772	**-0.065**	1199.511	1199.45	**-0.061**
765.8	1200.29	503.75	1199.687	1199.614	**-0.073**	1199.362	1199.293	**-0.069**
770	1200.18	504.5	1199.578	1199.501	**-0.078**	1199.253	1199.18	**-0.073**

FEEDWATER ENTHALPY (Compressed liquid at 830 psia)

hFW = 1.1045*TFW - 66.493

TFW	ASME	Calc.	
deg. F	hFW	hFW	Delta h
442.7	422.32	422.47	**0.150**
440.7	420.11	420.26	**0.150**
438.7	417.89	418.05	**0.160**

PALISADES NUCLEAR PLANT
ENGINEERING ANALYSIS CHECKLIST

Attachment 4
Revision 12
Page 1 of 1

EA - ELEC08-0001 REV. ~~1~~ 2 | R2

SECTION I Items Affected By This EA	Affected Yes	Affected No	Revision Required	Identify*	Closeout
1.0 Other EAs	☐	☒	~~NO~~	~~EA-GPI-98-02 Rev 1~~	
2.0 Design Documents Electrical E-38 through E-49	☐	☒			
3.0 Design Documents Mechanical M240-M246, M257-M261, M[illegible]64-M666, M1600	☐	☒			
4.0 LICENSING DOCUMENTS					
4.1 Final Safety Analysis Report (FSAR)	☐	☒			
4.2 Technical Specifications	☐	☒			
4.3 Operating Requirements Manual	☐	☒			
5.0 PROCEDURES					
5.1 Administrative Procedures	☐	☒			
5.2 Operating Procedures (SOP, EOP, ONP, etc)	☐	☒			
5.3 Working Procedures	☐	☒			
5.4 Tech Spec Surveillance Test Procedures	☐	☒			
6.0 OTHER DOCUMENTS					
6.1 Q-List	☐	☒			
6.2 Plant Drawings	☐	☒			
6.3 Equipment Data Base	☐	☒			
6.4 Spare Parts (Stock/MMS)	☐	☒			
6.5 Fire Protection Program Report (FPPR)	☐	☒			
6.6 Design Basis Documents	☐	☒			
6.7 Operating Checklists	☐	☒			
6.8 SPCC/PIPP Oil and Hazardous Material Spill Prevention Plan	☐	☒			
6.9 EQ Documents	☐	☒			
6.10 MOV/AOV Program Documents (Voltage, thrust, weak link, etc)	☐	☒			
6.11 Work Instructions	☐	☒			
6.12 Other 50.59 SCREEN DMK	☑	~~☒~~	No	SDR 02-230	

R2

SECTION II

Do any of the following documents need to be generated as a result of the conclusions reached in this EA:

	Yes	No	
1. Corrective Action Document?	☐	☒	Reference
2. EQ Evaluation Sheet?	☐	☒	Reference
3. Safety Evaluation?	☐	☒	Reference ~~02-230~~ DMK
4. Design Basis Document Change Request?	☐	☒	Reference
5. FSAR Change Request?	☐	☒	Reference
6. Verification Test Procedure (for changes to the Design Basis)?	☐	☒	Reference

Robert M. Hagman 4/18/2006 | R2

Completed By Richard A. Bischoff Richard A. Bischoff Date July 15, 2002

Technical Reviewed By DMKennedy DMKennedy Date 8/15/02 5/1/05

*Identify Section, No, Drawing, Document, etc

Note Rev 2 only changed input. Methodology and conclusions not changed. | R2
RMH
4/19/2006

Proc No 9.11
Attachment 5
Revision 13
Page 1 of 1

TECHNICAL REVIEW CHECKLIST

EA - ELEC08 - 0001 REV. 1 & REV 2

This checklist provides guidance for the review of engineering analyses. Answer questions Yes or No, or N/A if they do not apply. Document all comments on a EA Review Sheet. Satisfactory resolution of comments and completion of this checklist is noted by the Technical Review signature at the bottom of this sheet.

		(Y, N, N/A)
1.	Have the proper input codes, standards and design principles been specified?	Y
2.	Have the input codes, standards and design principles been properly applied?	Y
3.	Are all inputs and assumptions valid and the basis for their use documented?	Y
4.	Is Vendor information used as input addressed correctly in the analysis?	Y
5.	If the analysis argument departs from Vendor Information/ Recommendations, is the departure justification documented?	Y
6.	Are assumptions accurately described and reasonable?	Y
7.	Are the design basis changes permitted by this EA bounded by the applicable 50.59 Review?	Y
8.	Are all constants, variables and formulas correct and properly applied?	Y
9.	Have all comments been documented on an EA Review Sheet and resolved, or have any minor (insignificant) errors been identified and their insignificance justified? (Indicate "No Comments," if none were made.)	No Comments
10.	If the analysis involves welding, is the following information accurately represented on the analysis drawing (Output document)? ● Type of Weld ● Size of Weld ● Material Being Joined ● Thickness of Material Being Joined ● Location of Weld(s) ● Appropriate Weld Symbology	N/A
11.	Has the objective of the analysis been met?	Y
12.	Have administrative requirements such as numbering, format, and indexing been satisfied?	Y

DMKennedy Rev 2
Technical Reviewer DMKennedy Date 5/1/05 8/15/02

50.59 SCREEN

Page 1 of 1

SDR Log No 02-230
05-370

I. **Activity/Document N** EA - ELEC08 - 0001 **Revision No** ~~0~~ 2 (R2

Title Unceratinty Cal altion for the Secondary Calorimetric Heat Balance

Brief Description of ctivity (What Is Being Changed and Why) FC-977 is performing a power uprate for the reactor power level. ncertainties associated with the Secondary Calorimetric must be determined. This analysis determines t total uncertainty of the secondary calorimetric heat balance calculation with and without the Ultra Sonic Flow eter correction factor. With the lower uncertainty values, the reactor could operate at a power level closer to e license value with assurance of not exceeding the license value. Continued [ ]

II. **50.59 Screening Qu tions (Check Correct Response)**
(See Attachment 6 f Guidance)

List the documents (U SAR, Technical Specifications, and other documents) reviewed where relevant information was found including section numbers: FSAR 7.5.3.3, Operating Requirements Manual section 3.17.6.3, Technical S ecifications Basis SR3.3.1.3 & SR 3.1.4.3 NRC Regulatory Issue Summary 2002-03 Sections I.1.F and I.2, 1996 Annual report of Facility Changes, Tests and Experiments item 96-1362.

Identify relevant UFS R design functions: This Engineering Analysis only addresses the uncertainty of the Secondary calorimetr heat balance with and without the UFM correction factor. The reactor power level is determined during th performance of DWO-1 on a daily basis. This is not a modification to an existing system or equipment. This e gineering analysis only evaluates the uncertainty of the secondary calorimetric heat balance calculation.

1. Does the prop ed activity involve a change to an SSC that adversely affects an UFSAR descri ed design function? ___Yes ✓ No
2. Does the prop ed activity involve a change to a procedure that adversely affects how UF AR described SSC design functions are performed or controlled? ___Yes ✓ No
3. Does the prop ed activity involve revising or replacing an UFSAR described evaluation me odology that is used in establishing the design bases or used in the safety ana ses? ___Yes ✓ No
4. Does the prop ed activity involve a test or experiment not described in the UFSAR, where n SSC is utilized or controlled in a manner that is outside the reference boun s of the design for that SSC or is inconsistent with analyses or descriptions in e UFSAR? ___Yes ✓ No
5. Does the prop ed activity require a change to the Technical Specifications? ___Yes ✓ No

III. If all questions are an wered NO, **then** implement the activity without performing a 50.59 Evaluation or obtaining NRC approv l.
If question 5 is answe d YES, **then** a License Amendment must be obtained from the NRC prior to implementation of the ctivity.
If question 5 is answe d NO and question 1, 2, 3 or 4 is answered YES, **then** a 50.59 Evaluation shall be performed.

IV. Provide an overall jus cation for the answers to the screening questions.

This engineering analysis a resses the secondary calorimetric heat balance uncertainty. The results will be used for the power uprate progra evaluation. This engineering analysis only evaluates existing equipment and does not perform any changes or mod ications.
Continued [ ]

4/19/2005 (R2

V. **Screen Signoffs** Screen Preparer: Ricahrd A. Bischoff Richard A Bischoff Date: 3/25/02

Screen Reviewer: DL Kennedy Date: 4/5/02

DL Kennedy 5/1/05