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WESTINGHOUSE IMPROVED THERMAL DESIGN PROCEDURE INSTRUMENT UNCERTAINTY METHODOLOGY FOR CAROLINA POWER AND LIGHT SHEARON HARRIS NUCLEAR POWER STATION

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I. INTRODUCTION

Four operating parameter uncertainties are used in the uncertainty analysis of the Improved Thermal Design Procedure (ITDP). These parameters are Pressurizer Pressure, Primary Coolant Temperature (T_{avg}), Reactor Power, and Reactor Coolant System Flow. They are frequently monitored and several are used for control purposes. Reactor power is monitored by the performance of a secondary side heat balance (power calorimetric) once every 24 hours. RCS flow is monitored by the performance of a precision flow calorimetric at the beginning of each cycle. The RCS Cold Leg elbow taps are normalized against the precision calorimetric and used for monthy surveillance (with a small increase in uncertainty). Pressurizer pressure is a controlled parameter and the uncertainty reflects the control system. T_{avg} is a controlled parameter via the temperature input to the rod control system and the uncertainty reflects this control system.

Westinghouse has been involved with the development of several techniques to treat instrumentation uncertainties. An early version (for D. C. Cook 2 and Trojan) used the methodology outlined in WCAP-8567 "Improved Thermal Design Procedure",[1,2,3] which is based on the conservative assumption that the uncertainties can be described with uniform probability distributions. Another approach (for McGuire and Catawba) is based on the more realistic assumption that the uncertainties can be described with random, normal, two sided probability distributions.[4] This approach is used to substantiate the acceptability of the protection system setpoints for many Westinghouse plants, e.g., D. C. Cook 2[5], V. C. Summer, Wolf Creek, Millstone Unit 3 and others. The second approach is now utilized for the determination of all instrumentation errors for both ITDP parameters and protection functions.

II. METHODOLOGY

The methodology used to combine the error components for a channel is the square root of the sum of the squares of those groups of components which are statistically independent. Those errors that are dependent are combined arithmetically into independent groups, which are then systematically combined. The uncertainties used are considered to be random, two sided distributions. The sum of both sides is equal to the range for that parameter, e.g., Rack Drift is typically [ ]$^{+a,c}$, the range for this parameter is [ ]$^{+a,c}$. This technique has been utilized before as noted above, and has been endorsed by the NRC staff(6,7,8,9) and various industry standards(10,11).

The relationships between the error components and the channel instrument error allowance are variations of the basic Westinghouse Setpoint Methodology(12) and are defined as follows:

1. For precision parameter indication using Special Test Equipment or a DVM at the input to the racks;

$$CSA = ((SCA + SMTE + SD)^2 + (SPE)^2 + (STE)^2 + (RDOUT)^2)^{1/2} + BIAS \qquad \text{Eq. 1}$$

2. For parameter indication utilizing the plant process computer;

$$CSA = ((SCA + SMTE + SD)^2 + (SPE)^2 + (STE)^2 + (RCA + RMTE + RD)^2 + (RTE)^2 + (ID)^2 + (A/D)^2)^{1/2} + BIAS \qquad \text{Eq. 2}$$

3. For parameters which have control systems;

$$CSA = ((PMA)^2 + (PEA)^2 + (SCA + SMTE + SD)^2 + (SPE)^2 + (STE)^2 + (RCA + RMTE + RD + CA)^2 + (RTE)^2)^{1/2} + BIAS \qquad \text{Eq. 3}$$

where:

CSA	=	Channel Allowance
PMA	=	Process Measurement Accuracy
PEA	=	Primary Element Accuracy
SCA	=	Sensor Calibration Accuracy
SMTE	=	Sensor Measurement and Test Equipment Accuracy
SPE	=	Sensor Pressure Effects
STE	=	Sensor Temperature Effects
SD	=	Sensor Drift
RCA	=	Rack Calibration Accuracy
RMTE	=	Rack Measurement and Test Equipment Accuracy
RTE	=	Rack Temperature Effects
RD	=	Rack Drift
RDOUT	=	Readout Device Accuracy (DVM or gauge)
ID	=	Computer Isolator Drift
A/D	=	Analog to Digital Conversion Accuracy
CA	=	Controller Accuracy

The parameters above are as defined in references 5 and 12 and are based on SAMA Standard PMC 20.1, 1973[13]. However, for ease in understanding they are paraphrased below:

- PMA - non-instrument related measurement errors, e.g., temperature stratification of a fluid in a pipe,
- PEA - errors due to a metering device, e.g., elbow, venturi, orifice,
- SCA - reference (calibration) accuracy for a sensor/transmitter,
- SPE - change in input-output relationship due to a change in static pressure for a d/p cell,
- STE - change in input-output relationship due to a change in ambient temperature for a sensor/transmitter,
- SD - change in input-output relationship over a period of time at reference conditions for a sensor/transmitter,
- RCA - reference (calibration) accuracy for all rack modules in loop or channel assuming the loop or channel is string calibrated, or tuned, to this accuracy.
- RTE - change in input-output relationship due to a change in ambient temperature for the rack modules,

RD - change in input-output relationship over a period of time at reference conditions for the rack modules,

RDOUT - the measurement accuracy of a special test local gauge, digital voltmeter or multimeter on it's most accurate applicable range for the parameter measured,

ID - change in input-output relationship over a period of time at reference conditions for a control/protection signal isolating device,

A/D - allowance for conversion accuracy of an analog signal to a digital signal for process computer use,

CA - allowance for the accuracy of a controller, not including deadband.

BIAS - a non-random uncertainty for a sensor/transmitter or a process parameter.

A more detailed explanation of the Westinghouse methodology noting the interaction of several parameters is provided in references 5 and 12.

III. Instrumentation Uncertainties

The instrumentation uncertainties will be discussed first for the two parameters which are controlled by automatic systems, Pressurizer Pressure, and T_{avg} (through Rod Control).

1. PRESSURIZER PRESSURE

Pressurizer Pressure is controlled by comparison of the measured vapor space pressure and a reference value. Allowances are made for the transmitter and the process racks/controller. As noted on Table 1, the electronics uncertainty for this function is [$]^{+a,c}$ which corresponds to an accuracy of [$]^{+a,c}$. In addition to the controller accuracy, an allowance is made for pressure overshoot or undershoot due to the interaction and thermal inertia of the heaters and spray. Based on an evaluation of plant operation, an allowance of [$]^{+a,c}$ was made for this effect. Therefore, a total control system uncertainty of [$]^{+a,c}$ is typically calculated, which results in a standard deviation of [$]^{+a,c}$ (assuming a normal, two sided probability distribution).

TABLE 1

PRESSURIZER PRESSURE CONTROL SYSTEM ACCURACY

+a,c

SCA =
SMTE=
STE =
SD =
BIAS=
RCA =
RMTE=
RTE =
RD =
CA =

+a,c

ELECTRONICS UNCERTAINTY =
PLUS

ELECTRONICS UNCERTAINTY =
PLUS

CONTROLLER UNCERTAINTY =

2. T_{AVG}

T_{avg} is controlled by a system that compares the auctioneered high T_{avg} from the loops with a reference, usually derived from the First Stage Turbine Impulse Chamber Pressure. T_{avg} is the average of the narrow range T_H and T_C values. The highest loop T_{avg} is then used in the controller. Allowances are made (as noted on Table 2) for the RTDs, transmitter and the process racks/controller. The CSA for this function is dependent on the type of RTD, pressure transmitter, and the location of the RTDs, i.e., in the RTD bypass manifold or in the Hot and Cold Legs. Based on the assumption that 1 T_H and 1 T_C cross-calibrated RdF RTDs are used to calculate T_{avg} and the RTDs are located in the RTD bypass manifold, the CSA for the electronics is [ ]$^{+a,c}$. Assuming a normal, two sided probability distribution results in an electronics standard deviation (s_1) of [ ]$^{+a,c}$.

However, this does not include the controller deadband of $\pm$ 1.5 ^{o}F. The controller accuracy is the combination of the instrumentation accuracy and the deadband. The probability distribution for the deadband has been determined to be [ ].$^{+a,c}$ The variance for the deadband uncertainty is then:

$$(s_2)^2 = [\quad]^{+a,c}.$$

Combining the variance for instrumentation and deadband results in a controller variance of:

$$(s_T)^2 = (s_1)^2 + (s_2)^2 = [\quad]^{+a,c}$$

The controller s_T = [ ]$^{+a,c}$ for a total uncertainty of [ ]$^{+a,c}$.

TABLE 2

ROD CONTROL SYSTEM ACCURACY

	Tavg	TURB PRES
PMA =		
SCA =		
SMTE=		
STE =		
SD =		
BIAS=		
RCA =		
RMTE=		
RMTE=		
RTE =		
RD =		
CA =		
BIAS=		

+a,c

RTDs USED - TH = 1 TC = 1

ELECTRONICS CSA =	
ELECTRONICS SIGMA =	
CONTROLLER SIGMA =	
CONTROLLER BIAS =	
CONTROLLER CSA =	

+a,c

3. RCS FLOW

ITDP, and some plant Technical Specifications, requires an RCS flow measurement with a high degree of accuracy. It is assumed for this error analysis that the flow measurement is performed within thirty days of calibrating the measurement instrumentation. Therefore, except where necessary due to sensor location, drift effects are not included. It is also assumed that the calorimetric flow measurement is performed at the beginning of a cycle, i.e., no allowances have been made for Feedwater venturi fouling. The minimum power level assumed for the measurement is 90% RTP.

The flow measurement is performed by determining the Steam Generator thermal output (corrected for the RCP heat input and the loop's share of primary system heat losses) and the enthalpy rise (Delta-h) of the primary coolant. Assuming that the primary and secondary sides are in equilibrium, the RCS total vessel flow is the sum of the individual primary loop flows, i.e.,

$$W_{RCS} = N(W_L). \qquad \text{Eq. 4}$$

The individual primary loop volumetric flows are determined by correcting the thermal output of the Steam Generator for Steam Generator blowdown (if not secured), subtracting the RCP heat addition, adding the loop's share of the primary side system losses, dividing by the primary side enthalpy rise and multiplying by the Cold Leg specific volume. The equation for this calculation is:

$$W_L = \frac{(A)(Q_{SG} - Q_P + (Q_L/N))(V_C)}{(h_H - h_C)} \qquad \text{Eq. 5}$$

where;

W_L	=	Loop flow (gpm)
A	=	0.1247 gpm/(ft^3/hr)
Q_{SG}	=	Steam Generator thermal output (Btu/hr)
Q_P	=	RCP heat addition (Btu/hr)
Q_L	=	Primary system net heat losses (Btu/hr)
V_C	=	Specific volume of the Cold Leg at T_C (ft^3/lb)

N	=	Number of primary side loops
h_H	=	Hot Leg enthalpy (Btu/lb)
h_C	=	Cold Leg enthalpy (Btu/lb).

The thermal output of the Steam Generator is determined by precision secondary side calorimetric measurement, which is defined as:

$$Q_{SG} = (h_s - h_f)W_f \qquad \text{Eq. 6}$$

where;	h_s	=	Steam enthalpy (Btu/lb)
	h_f	=	Feedwater enthalpy (Btu/lb)
	W_f	=	Feedwater flow (lb/hr).

The Steam enthalpy is based on measurement of Steam Generator outlet Steam pressure, assuming saturated conditions. The Feedwater enthalpy is based on the measurement of Feedwater temperature and Feedwater pressure. The Feedwater flow is determined by multiple measurements and the following calculation:

$$W_f = (K)(F_a)((\rho_f)(d/p))^{1/2} \qquad \text{Eq. 7}$$

where;	K	=	Feedwater venturi flow coefficient
	F_a	=	Feedwater venturi correction for thermal expansion
	ρ_f	=	Feedwater density (lb/ft^3)
	d/p	=	Feedwater venturi pressure drop (inches H_2O).

The Feedwater venturi flow coefficient is the product of a number of constants including as-built dimensions of the venturi and calibration tests performed by the vendor. The thermal expansion correction is based on the coefficient of expansion of the venturi material and the difference between Feedwater temperature and calibration temperature. Feedwater density is based on the measurement of Feedwater temperature and Feedwater pressure. The venturi pressure drop is obtained from the output of the differential pressure cell connected to the venturi.

RCP heat addition is determined by calculation, based on the best estimate of coolant flow, pump head, and pump hydraulic efficiency.

The primary system net heat losses are determined by calculation, considering the following system heat inputs and heat losses:

- Charging flow
- Letdown flow
- Seal injection flow
- RCP thermal barrier cooler heat removal
- Pressurizer spray flow
- Pressurizer surge line flow
- Component insulation heat losses
- Component support heat losses
- CRDM heat losses.

A single calculated sum for 100% RTP operation is used for these losses or heat inputs.

The Hot Leg and Cold Leg enthalpies are based on the measurement of the Hot Leg temperature, Cold Leg temperature and the Pressurizer pressure. The Cold Leg specific volume is based on measurement of the Cold Leg temperature and Pressurizer pressure.

The RCS flow measurement is thus based on the following plant measurements:

- Steamline pressure (P_s)
- Feedwater temperature (T_f)
- Feedwater pressure (P_f)
- Feedwater venturi differential pressure (d/p)
- Hot Leg temperature (T_H)
- Cold Leg temperature (T_C)
- Pressurizer pressure (P_p)
- Steam Generator blowdown (if not secured)

and on the following calculated values:

- Feedwater venturi flow coefficients (K)
- Feedwater venturi thermal expansion correction (F_a)
- Feedwater density (ρ_f)

Feedwater enthalpy (h_f)
Steam enthalpy (h_s)
Moisture carryover (impacts h_s)
Primary system net heat losses (Q_L)
RCP heat addition (Q_p)
Hot Leg enthalpy (h_H)
Cold Leg enthalpy (h_C).

These measurements and calculations are presented schematically on Figure 1.

The derivation of the measurement errors and flow uncertainties on Table 5 are noted below.

Secondary Side

The secondary side uncertainties are in four principal areas, Feedwater flow, Feedwater enthalpy, Steam enthalpy and RCP heat addition. These four areas are specifically identified on Table 5.

For the measurement of Feedwater flow, each Feedwater venturi is calibrated by the vendor in a hydraulics laboratory under controlled conditions to an accuracy of [ ]$^{+a,b,c}$. The calibration dat which substantiates this accuracy is provided to the plant by the vendor. An additional uncertainty factor of [ ]$^{+a,c}$ is included for installation effects, resulting in a conservative overall flow coefficient (K) uncertainty of [ ]$^{+a,c}$. Since RCS loop flow is proportional to Steam Generator thermal output which is proportional to Feedwater flow, the flow coefficient uncertainty is expressed as [ ]$^{+a,c}$. It should be noted that no allowance is made for venturi fouling. The venturis should be inspected, and cleaned if necessary, prior to performance of the precision measurement. If fouling is present but not removed, it's effects must be treated as a flow bias.

The uncertainty applied to the Feedwater venturi thermal expansion correction (F_a) is based on the uncertainties of the measured Feedwater temperature and the coefficient of thermal expansion for the venturi material, usually 304 stainless steel. For this material, a change of ± 1 °F in the nominal Feedwater temperature range changes F_a by ± 0.002 % and the Steam Generator thermal output by the same amount.

Based on data introduced into the ASME Code, the uncertainty in F_a for 304 stainless steel is ± 5 %. This results in an additional uncertainty of [ ]$^{+a,c}$ in Feedwater flow. Westinghouse uses the conservative value of [ ]$^{+a,c}$.

Using the 1967 ASME Steam Tables it is possible to determine the sensitivities of various parameters to changes in Feedwater temperature and pressure. Table 3 notes the instrument uncertainties for the hardware used to perform the measurements. Table 4 lists the various sensitivities. As can be seen on Table 4, Feedwater temperature uncertainties have an impact on venturi F_a, Feedwater density and Feedwater enthalpy. Feedwater pressure uncertainties impact Feedwater density and Feedwater enthalpy.

Feedwater venturi d/p uncertainties are converted to % Feedwater flow using the following conversion factor:

$$\% \text{ flow} = (\text{d/p uncertainty})(1/2)(\text{transmitter span}/100)^2$$

Typically, the Feedwater flow transmitter span is [ ]$^{+a,c}$ nominal flow.

Using the 1967 ASME Steam Tables again, it is possible to determine the sensitivity of Steam enthalpy to changes in Steam pressure and Steam quality. Table 3 notes the uncertainty in Steam pressure and Table 4 provides the sensitivity. For Steam quality, the Steam Tables were used to determine the sensitivity at a moisture content of [ ]$^{+a,c}$, this value is noted on Table 4.

The net pump heat uncertainty is derived from the combination of the primary system net heat losses and pump heat addition and are summarized for a three loop plant as follows:

System heat losses	-2.0 MWt
Component conduction and convection losses	-1.4
Pump heat adder	+13.5
Net Heat input to RCS	+10.1 MWt

The uncertainty on system heat losses, which is essentially all due to charging and letdown flows, has been estimated to be [ ]$^{+a,c}$ of the calculated value. Since direct measurements are not possible, the uncertainty on component conduction and convection losses has been assumed to be [ ]$^{+a,c}$ of the calculated value. Reactor coolant pump hydraulics are known to a relatively high confidence level, supported by system hydraulics tests performed at Prairie Island II and by input power measurements from several plants, therefore, the uncertainty for the pump heat addition is estimated to be [ ]$^{+a,c}$ of the best estimate value. Considering these parameters as one quantity, which is designated the net pump heat uncertainty, the combined uncertainties are less than [ ]$^{+a,c}$ of the total, which is [ ]$^{+a,c}$ of core power.

Primary Side

The primary side uncertainties are in three principal areas, Hot Leg enthalpy, Cold Leg enthalpy and Cold Leg specific volume. These are specifically noted on Table 5. Three primary side parameters are actually measured, T_H, T_C and Pressurizer pressure. Hot Leg enthalpy is influenced by T_H, Pressurizer pressure and Hot Leg temperature streaming. The uncertainties for the instrumentation are noted on Table 3, the sensitivities are provided on Table 4. The Hot Leg streaming is split into random and systematic components. For plants with direct immersion RTDs located in RTD bypass manifolds fed by scoops in the legs, the streaming uncertainty is [ ]$^{+a,c}$ for both random and systematic components.

The Cold Leg enthalpy and specific volume uncertainties are impacted by T_C and Pressurizer pressure. Table 3 notes the T_C instrument uncertainty and Table 4 provides the sensitivities.

Noted on Table 5 is the plant specific RTD cross-calibration systematic allowance. When necessary, an allowance is made for a systematic temperature error due to the RTD cross-calibration procedure. No allowance was necessary for this plant.

Parameter dependent effects are identified on Table 5. Westinghouse has determined the dependent sets in the calculation and the direction of interaction, i.e., whether components in a dependent set are additive or subtractive with respect to a conservative calculation of RCS flow. The same work was performed for the instrument bias values. As a result, the calculation explicitly accounts for dependent effects and biases with credit taken for sign (or direction of impact).

Using Table 5, the 3 loop uncertainty equation (with biases) is as follows:

[ ] +a,c

Based on the number of loops, number, type and measurement method of RTDs, and the vessel Delta-T, the flow uncertainty is:

# of loops	flow uncertainty (% flow)
	+a,c
3	[ ]

TABLE 3

FLOW CALORIMETRIC INSTRUMENTATION UNCERTAINTIES

(% SPAN)	FW TEMP	FW PRES	FW d/p	STM PRESS	T_H	T_C	PRZ PRESS	
SCA =	[						]	+a,c
SMTE=								
SPE =								
STE =								
SD =								
R/E =								
RDOT=								
BIAS=								
CSA =								
# OF INSTRUMENTS USED	1/loop			1/steam line	1/loop	1/loop	3 **	
	^oF	psia	% d/p	psia	^oF	^oF	psia	
INST SPAN =	568.	1500.	120.	2000.	100.	100.	800.	
INST UNC. (RANDOM) =	[						]	+a,c
INST UNC. (BIAS) =								
NOMINAL =	435.	1064.		964.	620.2	557.4	2250.	

+a,c

* [ ]

** Number of Hot Leg and Cold Leg RTDs used for measurement in each loop and the number of Pressurizer Pressure transmitters used overall, i.e., one per loop. Measuring and averaging more than one RTD per loop will provide greater accuracy on hot and cold leg temperature measurements.

TABLE 4

FLOW CALORIMETRIC SENSITIVITIES

FEEDWATER FLOW

F_a

TEMPERATURE =

MATERIAL =

DENSITY

TEMPERATURE =

PRESSURE =

DELTA P =

FEEDWATER ENTHALPY

TEMPERATURE =

PRESSURE =

[ ] +a,c

h_s = 1194.2 BTU/LBM

h_f = 414.0 BTU/LBM

Dh(SG) = 780.2 BTU/LBM

STEAM ENTHALPY

PRESSURE =

MOISTURE =

HOT LEG ENTHALPY

TEMPERATURE =

PRESSURE =

[ ] +a,c

h_H = 643.3 BTU/LBM

h_C = 556.4 BTU/LBM

Dh(VESS) = 86.9 BTU/LBM

$Cp(T_H)$ = 1.565 BTU/LBM-^oF

COLD LEG ENTHALPY

TEMPERATURE =

PRESSURE =

[ ] +a,c

$Cp(T_C)$ = 1.262 BTU/LBM-^oF

COLD LEG SPECIFIC VOLUME

TEMPERATURE =

PRESSURE =

[ ] +a,c

TABLE 5

CALORIMETRIC RCS FLOW MEASUREMENT UNCERTAINTIES

COMPONENT	INSTRUMENT ERROR	FLOW UNCERTAINTY
FEEDWATER FLOW		+a,c
VENTURI		
THERMAL EXPANSION COEFFICIENT		
TEMPERATURE		
MATERIAL		
DENSITY		
TEMPERATURE		
PRESSURE		
DELTA P		
FEEDWATER ENTHALPY		
TEMPERATURE		
PRESSURE		
STEAM ENTHALPY		
PRESSURE		
MOISTURE		
NET PUMP HEAT ADDITION		
HOT LEG ENTHALPY		
TEMPERATURE		
STREAMING, RANDOM		
STREAMING, SYSTEMATIC		
PRESSURE		
COLD LEG ENTHALPY		
TEMPERATURE		
PRESSURE		
COLD LEG SPECIFIC VOLUME		
TEMPERATURE		
PRESSURE		
RTD CROSS-CAL SYSTEMATIC ALLOWANCE		

*, **, +, ++ INDICATE SETS OF DEPENDENT PARAMETERS

TABLE 5 (CONTINUED)

CALORIMETRIC RCS FLOW MEASUREMENT UNCERTAINTIES

COMPONENT		FLOW UNCERTAINTY	
BIAS VALUES		[ ]	+a,c
FEEDWATER PRESSURE	DENSITY		
	ENTHALPY		
STEAM PRESSURE	ENTHALPY		
PRESSURIZER PRESSURE	ENTHALPY - HOT LEG		
	ENTHALPY - COLD LEG		
	SPECIFIC VOLUME - COLD LEG		
FLOW BIAS TOTAL VALUE			

SINGLE LOOP UNCERTAINTY	(WITHOUT BIAS VALUES)	[ ]	+a,c
N LOOP UNCERTAINTY	(WITHOUT BIAS VALUES)		
N LOOP UNCERTAINTY	(WITH BIAS VALUES)		

As noted earlier, the precision flow calorimetric is used as the reference for the normalization of the Cold Leg elbow taps. Assuming that the elbow tap d/p transmitters are used to feed the plant process computer, it is a simple matter to perform Technical Specification required surveillance. Table 6 notes the instrument uncertainties for normalization of the elbow taps, assuming one elbow tap per loop. The d/p transmitter uncertainties are converted to % flow on the same basis as the Feedwater venturi d/p. The elbow tap uncertainty is then combined with the precision flow calorimetric uncertainty. This combination of uncertainties results in the following total flow uncertainty:

# of loops	flow uncertainty (% flow)
3	± 2.0% with 0.06% flow bias

The corresponding value used in ITDP is:

# of loops	standard deviation (% flow)
3	[ ] +a,c

TABLE 6

COLD LEG ELBOW TAP FLOW UNCERTAINTY

INSTRUMENT UNCERTAINTIES

	% d/p SPAN	% FLOW	
PMA =			+a,c
PEA =			
SCA =			
SPE =			
STE =			
SD =			
RCA =			
RMTE=			
RTE =			
RD =			
ID =			
A/D =			
RDOT=			
BIAS=			
FLOW CALORIM. BIAS =			
FLOW CALORIMETRIC =			
INSTRUMENT SPAN =			

SINGLE LOOP ELBOW TAP FLOW UNC =		+a,c
N LOOP ELBOW TAP FLOW UNC =		
N LOOP RCS FLOW UNCERTAINTY (WITHOUT BIAS VALUES) =		
N LOOP RCS FLOW UNCERTAINTY (WITH BIAS VALUES) =	2.06	

4. Reactor Power

Generally a plant performs a primary/secondary side heat balance once every 24 hours when power is above 15% Rated Thermal Power. This heat balance is used to verify that the plant is operating within the limits of the Operating License and to adjust the Power Range Neutron Flux channels when the difference between the NIS and the heat balance is greater than that required by the plant Technical Specifications.

Assuming that the primary and secondary sides are in equilibrium; the core power is determined by summing the thermal output of the steam generators, correcting the total secondary power for Steam Generator blowdown (if not secured), subtracting the RCP heat addition, adding the primary side system losses, and dividing by the core rated Btu/hr at full power. The equation for this calculation is:

$$RP = \frac{((N)(Q_{SG} - Q_P + (Q_L/N)))(100)}{H} \qquad \text{Eq. 8}$$

where;

RP	=	Core power (% RTP)
N	=	Number of primary side loops
Q_{SG}	=	Steam Generator thermal output (BTU/hr) as defined in Eq. 6
Q_P	=	RCP heat adder (Btu/hr) as defined in Eq. 5
Q_L	=	Primary system net heat losses (Btu/hr) as defined in Eq. 5
H	=	Core rated Btu/hr at full power.

For the purposes of this uncertainty analysis (and based on H noted above) it is assumed that the plant is at 100% RTP when the measurement is taken. Measurements performed at lower power levels will result in different uncertainty values. However, operation at lower power levels results in increased margin to DNB far in excess of any margin losses due to increased measurement uncertainty.

The secondary side power calorimetric equations and effects are the same as those noted for the precision flow calorimetric (secondary side portion), equations 6 and 7. The measurements and calculations are presented schematically on Figure 2. Table 7 provides the instrument uncertainties for those measurements performed. Since it is necessary to make this determination daily, it has been assumed that the plant process computer will be used for the measurements. The sensitivities calculated are the same as those noted for the secondary side on Table 4. As noted on Table 8, Westinghouse has determined the dependent sets in the calculation and the direction of interaction. This is the same as that performed for the flow calorimetric, but applicable only to power. The same was performed for the bias values noted. It should be noted that Westinghouse does not include any allowance for Feedwater venturi fouling. The effect of fouling is to result in an indicated power higher than actual, which is conservative.

Using the power uncertainty values noted on Table 8, the 3 loop uncertainty (with bias values) equation is as follows:

[ ]+a,c

Based on the number of loops and the instrument uncertainties for the four parameters, the power measurement uncertainty for the secondary side power calorimetric is:

# of loops	power uncertainty (% RTP)
3	[ ]+a,c

IV. CONCLUSIONS

The preceding sections provide the methodology to account for instrument uncertainties for pressure, temperature, power and flow.

The plant-specific instrumentation has been reviewed for Shearon Harris and the uncertainty calculations are completed. These uncertainty values or more conservative values are used in the ITDP analysis.

TABLE 7

POWER CALORIMETRIC INSTRUMENTATION UNCERTAINTIES

(% SPAN)	FW TEMP	FW PRES	FW d/p	STM PRESS	
SCA =					+a,c
SMTE=					
SPE =					
STE =					
SD =					
BIAS=					
RCA =					
RMTE=					
RTE =					
RD =					
ID =					
A/D =					
CSA =					

	FW TEMP	FW PRES	FW d/p	STM PRESS	
	°F	psia	% d/p	psia	
INST SPAN =	430.	1200.	122.	1300.	
INST UNC (RANDOM) =					+a,c
INST UNC (BIAS) =					
NOMINAL =	435.	1064.		964.	

* Since Feedwater Pressure is calculated, this is an assumed, conservative value.

TABLE 8

SECONDARY SIDE POWER CALORIMETRIC MEASUREMENT UNCERTAINTIES

COMPONENT		INSTRUMENT ERROR	POWER UNCERTAINTY
			+a,c
FEEDWATER FLOW			
VENTURI			
THERMAL EXPANSION COEFFICIENT			
TEMPERATURE			
MATERIAL			
DENSITY			
TEMPERATURE			
PRESSURE			
DELTA P			
FEEDWATER ENTHALPY			
TEMPERATURE			
PRESSURE			
STEAM ENTHALPY			
PRESSURE			
MOISTURE			
NET PUMP HEAT ADDITION			
BIAS VALUES			
FEEDWATER DELTA P			
FEEDWATER PRESSURE	DENSITY		
	ENTHALPY		
STEAM PRESSURE	ENTHALPY		
POWER BIAS TOTAL VALUE			

*, ** INDICATE SETS OF DEPENDENT PARAMETERS

SINGLE LOOP UNCERTAINTY	(WITHOUT BIAS VALUES)		
N LOOP UNCERTAINTY	(WITHOUT BIAS VALUES)		
N LOOP UNCERTAINTY	(WITH BIAS VALUES)		

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4. Westinghouse letter NS-EPR-2577, E. P. Rahe Jr. to C. H. Berlinger, NRC, dated 3/31/82.

5. Westinghouse Letter NS-TMA-1835, T. M. Anderson to E. Case, NRC, dated 6/22/78.

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FIGURE 1

RCS FLOW CALORIMETRIC SCHEMATIC

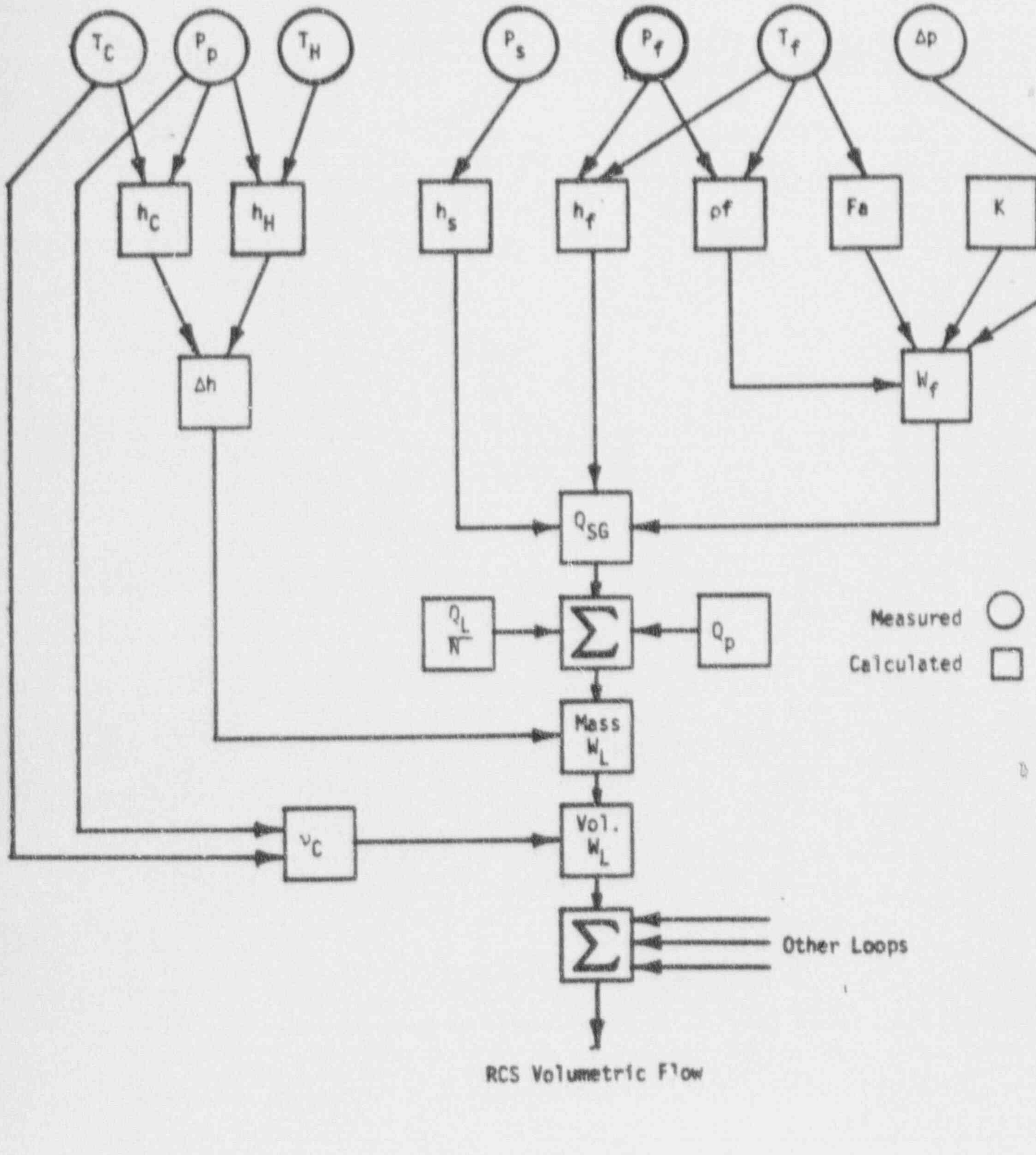

FIGURE 2

POWER CALORIMETRIC SCHEMATIC