Westinghouse Electric Corporation

Water Reactor Divisions

Box 355
Pittsburgh Pennsylvania 15230-0355

August 30, 1985

CAW-85-057

Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commision
Washington, D.C. 20555

Attention: Mr. V.S. Noonan, Project Director
PWR Project Directorate #5

APPLICATION FOR WITHHOLDING PROPRIETARY
INFORMATION FROM PUBLIC DISCLOSURE

Subject: Justification of Reduced Flow Meter Measurement Uncertainties
Reference: Texas Utilities Generating Company Letter, Counsil to Denton, September - 1985

Dear Mr. Denton:

The proprietary material for which withholding is being requested in the reference letter by Texas Utilites Generating Company is further identified in an affidavit signed by the owner of the proprietary information, Westinghouse Electric Corporation. The affidavit, which accompanies this letter, sets forth the basis on which the information may be withheld from public disclosure by the Commission and addresses with specificity the considerations listed in paragraph (b) (4) of 10CFR Section 2.790 of the Commission's regulations.

The proprietary material for which withholding is being required is of the same technical type as that proprietary material previously submitted with Application for Withholding AW-76-60.

Accordingly, this letter authorizes the utilization of the accompanying affidavit by Texas Utilities Generating Company.

Correspondence with respect to the proprietary aspects of the application for withholding or the Westinghouse affidavit should reference this letter, CAW-85-057, and should be addressed to the undersigned.

Very truly yours,

Robert A. Wiesemann

Robert A. Wiesemann, Manager
Regulatory & Legislative Affairs

/lav
Enclosure(s)
cc: E. C. Shoemaker, Esq.
Office of the Executive Legal Director, NRC

PROPRIETARY INFORMATION NOTICE

TRANSMITTED HEREWITH ARE PROPRIETARY AND/OR NON-PROPRIETARY VERSIONS OF DOCUMENTS FURNISHED TO THE NRC IN CONNECTION WITH REQUESTS FOR GENERIC AND/OR PLANT SPECIFIC REVIEW AND APPROVAL.

IN ORDER TO CONFORM TO THE REQUIREMENTS OF 10CFR2.790 OF THE COMMISSION'S REGULATIONS CONCERNING THE PROTECTION OF PROPRIETARY INFORMATION SO SUBMITTED TO THE NRC, THE INFORMATION WHICH IS PROPRIETARY IN THE PROPRIETARY VERSIONS IS CONTAINED WITHIN BRACKETS AND WHERE THE PROPRIETARY INFORMATION HAS BEEN DELETED IN THE NON-PROPRIETARY VERSIONS ONLY THE BRACKETS REMAIN, THE INFORMATION THAT WAS CONTAINED WITHIN THE BRACKETS IN THE PROPRIETARY VERSIONS HAVING BEEN DELETED. THE JUSTIFICATION FOR CLAIMING THE INFORMATION SO DESIGNATED AS PROPRIETARY IS INDICATED IN BOTH VERSIONS BY MEANS OF LOWER CASE LETTERS (a) THROUGH (g) CONTAINED WITHIN PARENTHESES LOCATED AS A SUPERSCRIPT IMMEDIATELY FOLLOWING THE BRACKETS ENCLOSING EACH ITEM OF INFORMATION BEING IDENTIFIED AS PROPRIETARY OR IN THE MARGIN OPPOSITE SUCH INFORMATION. THESE LOWER CASE LETTERS REFER TO THE TYPES OF INFORMATION WESTINGHOUSE CUSTOMARILY HOLDS IN CONFIDENCE IDENTIFIED IN SECTIONS (4)(ii)(a) through (4)(ii)(g) OF THE AFFIDAVIT ACCOMPANYING THIS TRANSMITTAL PURSUANT TO 10CFR2.790(b)(1).

AW-76-60

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

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COUNTY OF ALLEGHENY:

Before me, the undersigned authority, personally appeared Robert A. Wiesemann, who, being by me duly sworn according to law, deposes and says that he is authorized to execute this Affidavit on behalf of Westinghouse Electric Corporation ("Westinghouse") and that the averments of fact set forth in this Affidavit are true and correct to the best of his knowledge, information, and belief:

Robert A. Wiesemann

Robert A. Wiesemann, Manager
Licensing Programs

Sworn to and subscribed before me this 2 day of December 1976.

Notary Public

(1) I am Manager, Licensing Programs, in the Pressurized Water Reactor Systems Division, of Westinghouse Electric Corporation and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing or rulemaking proceedings, and am authorized to apply for its withholding on behalf of the Westinghouse Water Reactor Divisions.

(2) I am making this Affidavit in conformance with the provisions of 10 CFR Section 2.790 of the Commission's regulations and in conjunction with the Westinghouse application for withholding accompanying this Affidavit.

(3) I have personal knowledge of the criteria and procedures utilized by Westinghouse Nuclear Energy Systems in designating information as a trade secret, privileged or as confidential commercial or financial information.

(4) Pursuant to the provisions of paragraph (b)(4) of Section 2.790 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

(i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse.

(ii) The information is of a type customarily held in confidence by Westinghouse and not customarily disclosed to the public. Westinghouse has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitutes Westinghouse policy and provides the rational basis required.

Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.

(e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

(f) It contains patentable ideas, for which patent protection may be desirable.

(g) It is not the property of Westinghouse, but must be treated as proprietary by Westinghouse according to agreements with the owner.

There are sound policy reasons behind the Westinghouse system which include the following:

(a) The use of such information by Westinghouse gives Westinghouse a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Westinghouse competitive position.

(b) It is information which is marketable in many ways. The extent to which such information is available to competitors diminishes the Westinghouse ability to sell products and services involving the use of the information.

(c) Use by our competitor would put Westinghouse at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Westinghouse of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Westinghouse in the world market, and thereby give a market advantage to the competition in those countries.

(f) The Westinghouse capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

(iii) The information is being transmitted to the Commission in confidence and, under the provisions of 10 CFR Section 2.790, it is to be received in confidence by the Commission.

(iv) The information is not available in public sources to the best of our knowledge and belief.

(v) The proprietary information sought to be withheld in this submittal is that which is appropriately marked in the attachment to Westinghouse letter number NS-CE-1298, Eicheldinger to Stolz, dated December 1, 1976, concerning information relating to NRC review of WCAP-8567-P and WCAP-8568 entitled, "Improved Thermal Design Procedure," defining the sensitivity of DNB ratio to various core parameters. The letter and attachment are being submitted in response to the NRC request at the October 29, 1976 NRC/Westinghouse meeting.

This information enables Westinghouse to:

(a) Justify the Westinghouse design.

(b) Assist its customers to obtain licenses.

(c) Meet warranties.

(d) Provide greater operational flexibility to customers assuring them of safe and reliable operation.

(e) Justify increased power capability or operating margin for plants while assuring safe and reliable operation.

(f) Optimize reactor design and performance while maintaining a high level of fuel integrity.

Further, the information gained from the improved thermal design procedure is of significant commercial value as follows:

(a) Westinghouse uses the information to perform and justify analyses which are sold to customers.

(b) Westinghouse sells analysis services based upon the experience gained and the methods developed.

Public disclosure of this information concerning design procedures is likely to cause substantial harm to the competitive position of Westinghouse because competitors could utilize this information to assess and justify their own designs without commensurate expense.

The parametric analyses performed and their evaluation represent a considerable amount of highly qualified development effort. This work was contingent upon a design method development program which has been underway during the past two years. Altogether, a substantial amount of money and effort has been expended by Westinghouse which could only be duplicated by a competitor if he were to invest similar sums of money and provided he had the appropriate talent available.

Further the deponent sayeth not.

Questions:

1. Provide and justify the variances and distributions for input parameters.

2. Justify that the nominal conditions used in the analyses bound all permitted modes of plant operation.

3. Provide a block diagram depicting sensor, processing equipment, computer, and readout devices for each parameter channel used in the uncertainty analysis. Within each element of the block diagram identify the accuracy, drift, range, span, operating limits, and setpoints. Identify the overall accuracy of each channel transmitter to final output and specify the minimum acceptable accuracy for use with the new procedure. Also identify the overall accuracy of the final output value and maximum accuracy requirements for each input channel for this final output device.

Response

I. INTRODUCTION

Four operating parameter uncertainties are used in the uncertainty analysis of the Improved Thermal Design Procedure (ITDP). These operating parameters are pressurizer pressure, primary coolant temperature (T_{avg}), reactor power, and reactor coolant system flow. These parameters are monitored on a regular basis and several are used for control purposes. The reactor power is monitored by the performance of a secondary side heat balance (power calorimetric measurement) at least once every 24 hours. The RCS flow is monitored by the performance of a precision flow measurement at the beginning of each cycle. The RCS loop elbow taps can then be normalized against the precision measurement and used for monthly surveillance (with a small increase in total uncertainty) or a precision flow measurement can be performed on the same surveillance schedule. Pressurizer pressure is a controlled parameter and the uncertainty for the Improved Thermal Design Procedure reflects the use of the control system. T_{avg} is a controlled parameter through the use of the temperature input to the Control Rod control system; the uncertainty presented here reflects the use of this control system.

Since 1978 Westinghouse has been deeply involved with the development of several techniques to treat instrumentation uncertainties, errors, and allowances. The earlier versions of these techniques have been documented for several plants; one approach uses 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. The other approach is based on the more realistic assumption that the uncertainties can be described with normal probability distributions. This assumption is also conservative in that the "tails" of the normal distribution are in reality "chopped" at the extremes of the range, i.e., the ranges for uncertainties are finite and thus, allowing for some probability in excess of the range limits is a conservative assumption. This approach has been used to substantiate the acceptability of the protection system setpoints for several plants with a Westinghouse NSSS, e.g., D. C. Cook II[4], North Anna Unit 1, Salem Unit 2, Sequoyah Unit 1, V. C. Summer, and McGuire Unit 1. Westinghouse believes that the latter approach can be used for the determination of the instrumentation errors and allowances for the ITDP parameters. The total instrumentation errors presented in this response are based on this approach.

II. METHODOLOGY

The methodology used to combine the error components for a channel is basically the appropriate statistical combination of those groups of components which are statistically independent, i.e., not interactive. Those errors which are not independent are combined arithmetically to form independent groups, which can then be systematically combined. The statistical combination technique used by Westinghouse is the [$]^{+a,c,e}$ of the instrumentation uncertainties. The instrumentation uncertainties are 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 staff[5,6] and various industry standards[8,9].

The relationship between the error components and the statistical instrumentation error allowance for a channel is defined as follows:

1. For parameter indication in the racks using a DVM;

$$\left[\qquad \right]^{+a,c}$$

Eq. 1

2. For parameter indication utilizing the plant process computer;

$$\left[\qquad \right]^{+a,c}$$

Eq. 2

3. For parameters which have control systems;

$$\left[\qquad \right]^{+a,c}$$

Eq. 3

where:

CSA = Channel Statistical Allowance
PMA = Process Measurement Accuracy
PEA = Primary Element Accuracy
SCA = Sensor Calibration Accuracy
SD = Sensor Drift
STE = Sensor Temperature Effects
SPE = Sensor Pressure Effects
RCA = Rack Calibration Accuracy
RD = Rack Drift
RTE = Rack Temperature Effects

DVM = Digital Voltmeter Accuracy
ID = Computer Isolator Drift
A/D = Analog to Digital Conversion Accuracy
CA = Controller Accuracy

The parameters above are as defined in reference 4 and are based on SAMA standard PMC-20-1973[10]. 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 metering devices, e.g., elbows, venturis, orifices,
- SCA - reference (calibration) accuracy for a sensor/transmitter,
- SD - change in input-output relationship over a period of time at reference conditions for a sensor/transmitter,
- STE - change in input-output relationship due to a change in ambient temperature for a sensor/transmitter,
- SPE - change in input-output relationship due to a change in static pressure for a Δp cell,
- RCA - reference (calibration) accuracy for all rack modules in loop or channel assuming the loop or channel is tuned to this accuracy. This assumption eliminates any bias that could be set up through calibration of individual modules in the loop or channel.
- RD - change in input-output relationship over a period of time at reference conditions for the rack modules,
- RTE - change in input-output relationship due to a change in ambient temperature for the rack modules,
- DVM - the measurement accuracy of a 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.

A more detailed explanation of the Westinghouse methodology noting the interaction of several parameters is provided in reference 4.

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). The uncertainties for both of these parameters are listed on Table 1, Comanche Peak Instrumentation Uncertainties.

1. Pressurizer Pressure

Pressurizer pressure is controlled by a system that compares the measured pressure against a reference value. The pressure is measured by a pressure cell connected to the vapor space of the pressurizer. Allowances are made as indicated on Table 1 for the transmitter and the process racks/controller. As noted, the CSA for this function is $[\quad]^{+a,c}$ with a bias of $[\quad]^{+a,c}$ which corresponds to a control accuracy of $[\quad]^{+a,c}$ with a bias of $[\quad]^{+a,c}$. The accuracy assumed in the ITDP analysis is $[\quad]^{+a,c}$ with a $[\quad]^{+a,c}$ bias. Being a controlled parameter, the nominal value of 2235 psig is reasonable and bounded by ITDP error analysis assumptions, i.e., assuming a normal, two sided distribution for CSA and a 95+% probability distribution for the noted CSA, σ equals $[\quad]^{+a,c}$ with a bias of $[\quad]^{+a,c}$. This corresponds to $\sigma = [\quad]^{+a,c}$ with a bias of $[\quad]^{+a,c}$.

2. T_{AVG}

T_{avg} is controlled by a system that compares the auctioneered high T_{avg} from the loops with a reference derived from the First Stage Turbine Impulse Pressure. T_{avg} is synthesized from ^{16}N Power and T_c. The highest loop T_{avg} is then used in the controller. Allowances are made as noted on Table 1 for the sensor/transmitters and the process racks/controller. As noted, the CSA for this function is $[\quad]^{+a,c}$ with a bias of $[\quad]^{+a,c}$

TABLE 1

COMANCHE PEAK INSTRUMENTATION UNCERTAINTIES

Control Systems: Pressurizer Pressure Control through 1st Stage Turbine Impulse Chamber Pressure
Rod Control: T_c through 1st Stage Turbine Impulse Chamber Pressure
Daily Power Calorimetric: Steamline Pressure Computer through Feedwater Venturi Δp Computer
Precision RCS Flow Measurement: Steamline Pressure Precision through RCS Flow Cold Leg Elbow Tap Computer

	Pressurizer Pressure Control (1)	T_c (1)	T_{avg} (1)	1st Stage Turbine Impulse Chamber Pressure (1)	Steamline Pressure Computer (1)	Feedwater Pressure Computer (1)	Feedwater Temperature Computer (1)	Feedwater Venturi Δp Computer (1)	Steamline Pressure Precision (1)	Feedwater Pressure Precision (1)	Feedwater Temperature Precision (1)	Feedwater Venturi Δp Precision(1)	Pressurizer Pressure Precision (1)	T_c Precision (1)	RCS Flow Cold Leg Elbow Tap Computer (1)
PMA	[														+a,c
PEA															
SCA															
SPE															
STE															
SD															
RCA															
RTE															
RD															
TR															
A/D															
DVM															
CA															
Readout															
CSA															]
Span	800 psi		100°F		1200 psi	2000 psi	500°F	100% Δp	1500 psi	1500 psi	500°F	100% Δp	800 psi	100°F	100% Δp

(1) % instrument span
(2) [
(3) [ ]+a,c]+a,c
(4) R/E converter [ ]+a,c
(5) T_c channel
(6) [ ]+a,c
(7) Power Calorimetric [ ]+a,c
(8) [
(9) [ ]+a,c
(10) R/E converter]+a,c

which corresponds to an instrumentation accuracy of [ ]$^{+a,c}$ with a bias of [ ]$^{+a,c}$. Assuming a normal, two sided distribution for CSA and a 95+% probability distribution results in a standard deviation, σ = [ ]$^{+a,c}$.

However, this does not include the controller deadband of ± 1.5°F. To determine the controller accuracy the instrumentation accuracy must be combined with the deadband. Westinghouse has determined that the probability distribution for the deadband is [ ].$^{+a,c}$

The variance for the deadband uncertainty is then:

[ ]$^{+a,c}$

and the standard deviation, $\sigma \approx$ [ ]$^{+a,c}$.

Combining statistically the standard deviations for instrumentation and deadband results in a controller standard deviation of:

$\sigma_T = (\sigma_1^2 + \sigma_2^2)^{1/2}$ = [ ]$^{+a,c}$

with a bias of [ ]$^{+a,c}$.

Therefore, the controller uncertainty for a 95+% normal probability distribution is [ ]$^{+a,c}$, with a bias of [ ]$^{+a,c}$. This is the uncertainty assumed for the ITDP error analysis and reasonably bounds the nominal value corresponding to the full power T_{avg}.

3. 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 and ^{16}N power 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:

$$RP = \left(\frac{\sum^{N} [Q_{SG} - Q_p] + Q_L}{H} \right) 100 \qquad \text{Eq. 4}$$

where;

RP	=	Core power (% RTP)
N	=	Number of primary side loops
Q_{SG}	=	Steam Generator thermal output (Btu/hr)
Q_p	=	RCP heat adder (Btu/hr)
Q_L	=	Primary system net heat losses (Btu/hr)
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 thermal output of the steam generator is determined by a calorimetric measurement defined as:

$$Q_{SG} = (h_s - h_f) W_f \qquad \text{Eq. 5}$$

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 the 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 a calculation based on the following:

$$W_f = (K)(F_a)\{(\rho_f)(\Delta p)\}^{1/2} \quad \text{Eq. 6}$$

where:

K	=	Feedwater venturi flow coefficient
F_a	=	Feedwater venturi correction for thermal expansion
ρ_f	=	Feedwater density (lb/ft^3)
Δp	=	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.

The RCP heat adder is determined by calculation, based on the best estimates 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 full power operation is used for these losses/heat inputs.

The core power measurement is based on the following plant measurements:

Steamline pressure (P_s)
Feedwater temperature (T_f)
Feedwater pressure (P_f)
Feedwater venturi differential pressure (Δp)
Steam generator blowdown (if not secured)

and on the following calculated values:

Feedwater venturi flow coefficient (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 adder (Q_p)

These measurements and calculations are presented schematically on Figure 1.

Starting off with the Equation 6 parameters, the detailed derivation of the measurement errors is noted below.

Feedwater Flow

Each of the feedwater venturis is calibrated by the vendor in a hydraulic laboratory under controlled conditions to an accuracy of [ ]$^{+a,b,c}$ of span. The calibration data which substantiates this accuracy is provided for all of the plant venturis by the respective vendors. An additional uncertainty factor of [ ]$^{+a,c}$ is included for installation effects, resulting in an overall flow coefficient (K) uncertainty of [ ]$^{+a,c}$. Since steam generator thermal output is proportional to feedwater flow, the flow coefficient uncertainty is expressed as [ ]$^{+a,c}$ power.

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 ± 2°F in the feedwater temperature range changes F_a by [ ]$^{+a,b,c}$ and the steam generator thermal output by the same amount. For this derivation, an uncertainty of [ ]$^{+a,c}$ in feedwater temperature was used (see Table 1) which results in a total uncertainty in F_a and steam generator output of [ ]$^{+a,c}$.

Based on data introduced into the ASME code, the uncertainty in F_a for 304 stainless steel is ±5 percent. This results in an additional uncertainty of [ ]$^{+a,c}$ in feedwater flow. A conservative value of [ ]$^{+a,c}$ is used in this analysis.

Using the ASME Steam Tables (1967) for compressed water, the effect of a [ ]$^{+a,c}$ error in feedwater temperature on the $(\rho_f)^{1/2}$ is $\simeq$ [ ]$^{+a,c}$ in steam generator thermal output. An error of [ ]$^{+a,c}$ in feedwater pressure, see Table 1, results in an uncertainty in $(\rho_f)^{1/2}$ of $\simeq$ [ ]$^{+a,c}$ in steam generator thermal output.

Table 1 provides a listing of the instrumentation errors for feedwater Δp assuming display on the process computer. The electronics errors are in percent Δp span and must be translated into percent feedwater flow at full power conditions. This is accomplished by multiplying the error in percent Δp span by the conversion factor noted below:

$$\left(\frac{1}{2}\right)\left(\frac{\text{span of feedwater flow transmitter in \% of nominal flow}}{100}\right)^2$$

For a feedwater flow transmitter span of [ ]+a,c nominal flow, the conversion factor is [ ]+a,c (which is the value used for this analysis).

Feedwater Enthalpy

The next major error component is the feedwater enthalpy used in Equation 5. For this parameter the major contributor to the error is the uncertainty in the feedwater temperature. Table 1 provides the detailed error breakdown for this temperature measurement assuming indication on the process computer. Statistically summing these errors (utilizing Eq. 2) results in a total temperature error of [ ]+a,c span. Using a span of 500°F results in a temperature error of [ ].+a,c Using the ASME steam tables (1967) for compressed water, the effect of a [ ]+a,c error in feedwater temperature on the feedwater enthalpy (h_f) is ≃ [ ]+a,c in steam generator thermal output. Using a [ ]+a,c error in feedwater pressure results in ≃ [ ]+a,c effect in h_f and steam generator thermal output.

Steam Enthalpy

The steam enthalpy has two contributors to the calorimetric error, steamline pressure and the moisture content. For steamline pressure the errors are as noted on Table 1, assuming display on the process computer. This results in a total instrumentation error (utilizing Eq. 2) of [ ]+a,c span with a bias of [ ]+a,c. Based on a 1300 psig span this equals [ ]+a,c with a bias value of [ ].+a,c The bias value is correctly carried through the calculation to its conclusion. Using the ASME Steam Tables (1967) for saturated water and steam, the effect of a [ ]+a,c error in steamline pressure on the steam enthalpy (h_s) is ≃ [ ]+a,c in steam generator thermal output. The bias value of [ ]+a,c has an effect equivalent to [ ]+a,c in steam generator thermal output.

The major contributor to h_s uncertainty is moisture content. The nominal or best estimate performance level is assumed to be [ ]$^{+a,c}$, which is the design limit to protect the high pressure turbine. The most conservative assumption that can be made in regards to maximizing steam generator thermal output is a steam moisture content of zero. This conservatism is introduced by assigning an uncertainty of [ ]$^{+a,c}$ to the moisture content, which is equivalent through enthalpy change to [ ]$^{+a,c}$ of thermal output.

Loop Power

The loop power uncertainty is obtained by statistically combining all of the error components noted for the steam generator thermal output (Q_{SG}) in terms of loop power. Within each loop these components are independent effects (or formed into independent quantities) since they are independent measurements. The feedwater temperature and pressure uncertainties are common to several of the error components, thus they are formed into independent quantities prior to the statistical combination. The bias for steamline pressure is appropriately treated as noted on Table 2.

Another effect which tends to be dependent, affecting all loops, is the accumulation of crud on the feedwater venturis, which can effect the Δp for a specified flow. Although it is conceivable that the crud accumulation could affect the static pressure distribution at the venturi throat pressure tap in a manner that would result in a higher flow for a specified Δp, the reduction in throat area resulting in a lower flow at the specified Δp is the stronger effect. All reported cases of venturi fouling have been associated with a significant loss in electrical output, indicating that the actual thermal power has been below the measured power rather than above it. Losses in net power generation which have been correlated with venturi fouling have occurred in about half of the Westinghouse pressurized water reactors operating in the United States. These power losses have been generally in the range of two to three percent. Power losses have also occurred in at least three, and possibly five Westinghouse plants operating abroad. In no case has venturi fouling been reported which resulted in a non-conservative feedwater flow measurement. Because the venturi crud formations have resulted in a conservative, reduced power condition, no uncertainty has been included in the analysis of power measurement error for this phenomenon.

The net pump heat uncertainty is derived in the following manner. The primary system net heat losses and pump heat adder for a four loop plant are summarized as follows:

Systems heat losses	- 2.0 MWt
Component conduction and convection losses	- 1.4
Pump heat adder	+18.0
Net Heat input to RCS	+14.6 MWt

The uncertainties for these quantities are as follows: The uncertainty on system heat losses, which are 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 the system hydraulics tests performed at Prairie Island II and by input power measurements from several plants, so the uncertainty for the pump heat adder 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 much less than [ ]$^{+a,c}$ of the total, which is equivalent to [ ]$^{+a,c}$ of core power.

The Total Loop Power uncertainty (noted in Table 2 as ≃ [ ]$^{+a,c}$ with a bias of [ ]$^{+a,c}$) is the statistical sum of the calorimetric uncertainties for a single loop. The Total Secondary Power uncertainty is the statistical combination of the Loop Power uncertainty and the number of primary side loops in the plant. As noted in Table 2, the Secondary Power uncertainty for Comanche Peak is ≃ ±2.0% with a bias of 0.04% RTP.

The Total Secondary Power uncertainty is less than or equal to the historically used value of ± 2% power. For ITDP, credit is taken for the increased knowledge of reactor power and the value noted above is used in the ITDP error analysis, i.e., the standard deviation for reactor power, at the 95+% probability level is,

σ = [ ]$^{+a,c}$ with a bias of [ ]$^{+a,c}$.

FIGURE 1
POWER CALORIMETRIC SCHEMATIC

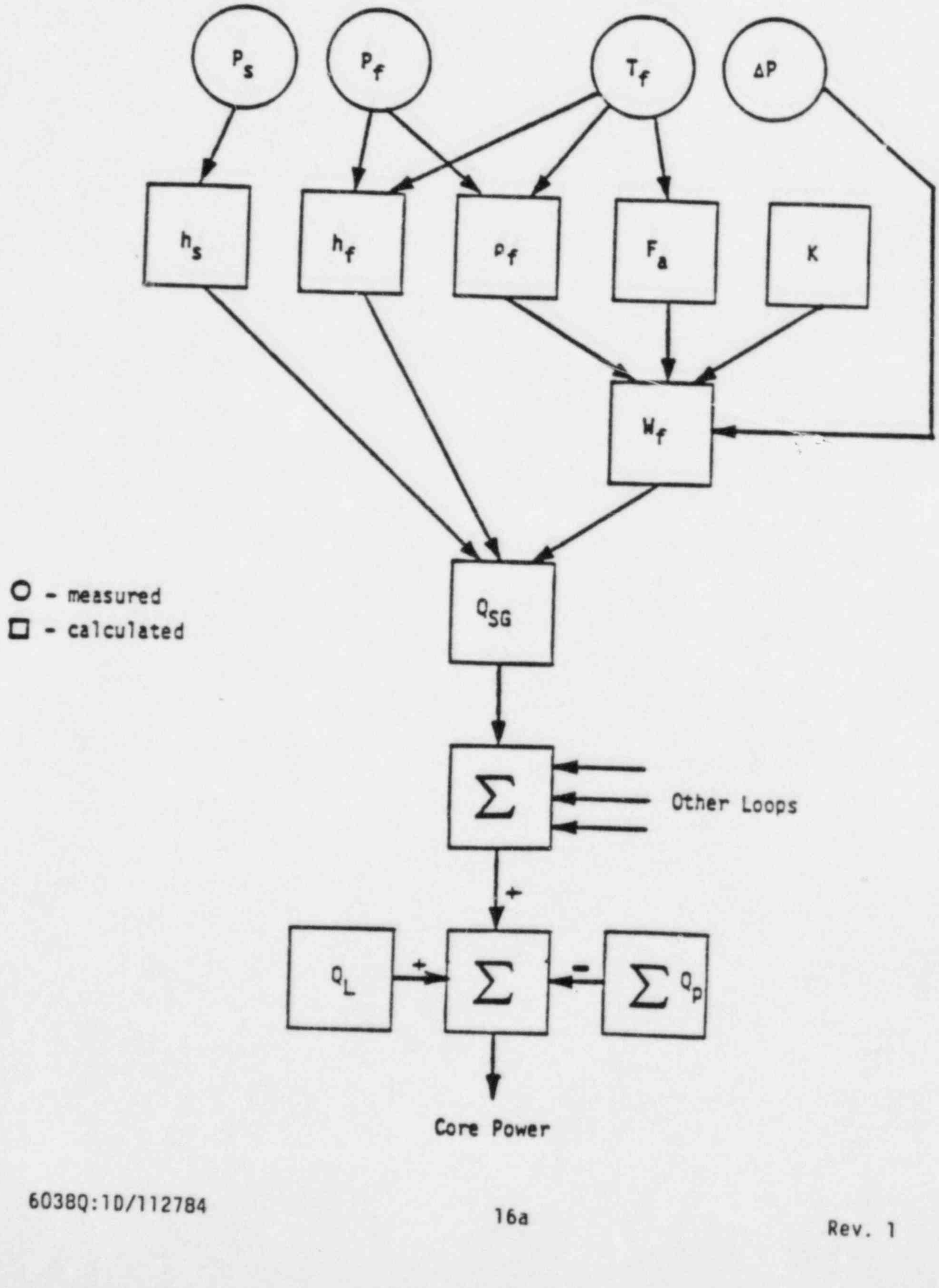

TABLE 2

SECONDARY POWER CALORIMETRIC MEASUREMENT UNCERTAINTIES

Component	Instrument Error	Power Uncertainty
Feedwater Flow	[	]+a,c
Venturi, K		
Thermal Expansion Coefficient		
Temperature		
Material		
Density		
Temperature		
Pressure		
Δp		
Feedwater Enthalpy		
Temperature		
Pressure		
Steam Enthalpy		
Pressure		
Random		
Bias		
Moisture Carryover		
Net Pump Heat Addition Uncertainty		]

[ ]+a,c

Loop Power Uncertainty = $\{\Sigma(e)^2\}^{1/2}$ =

[ ]+a,c

Total Secondary Power Uncertainty = $(\{\Sigma(e)^2\}/4)^{1/2}$ = [ ]+a,c

4. RCS FLOW

RCS flow is monitored by the performance of a precision flow measurement (through the use of the N-16 Transit Time Flow Meter and a secondary side power measurement) at the beginning of each cycle. The RCS cold leg elbow taps can then be normalized against the precision measurement and used for monthly surveillance (with a small increase in total uncertainty). The analysis presented in this report documents both measurements, i.e., the precision measurement and the elbow tap normalization uncertainties. It is assumed for this error analysis that the precision flow measurement is performed at the beginning of a cycle (thus eliminating allowances for feedwater venturi fouling) and within the calibration period (90 days) of the measurement instrumentation (thus reducing drift effects to the values noted on Table 1).

The flow measurement of the cold leg volumetric flow is performed by measuring the hot leg volumetric flow very accurately with the N-16 Transit Time Flow Meter (TTFM), determining the hot leg specific volume by the performance of a precision secondary side power calorimetric (to infer T_H) and then calculating the cold leg volumetric flow so the cold leg elbow taps can be normalized. The second two steps are necessary because the plant does not have RTD bypass loops with main coolant pipe scoops (thus, the T_H measurement is subject to large streaming errors) and because the safety analyses use cold leg volumetric flow as an initial condition parameter.

The TTFM is a set of detectors placed on each of the primary side hot legs that measures the time it takes for an N-16 noise spike to traverse a known distance. This allows a calculation of the hot leg coolant flow velocity and given the cross-sectional area of the hot leg piping, the volumetric flow rate. This flow rate can be measured quite accurately [$]^{+a,c}$ on an individual loop basis. WCAP-9172 (Proprietary) describes the measurement technique in more detail[11].

One of the reasons for measuring RCS flow accurately is to normalize the cold leg elbow taps, which measure the cold leg volumetric flow rate. Normally a precision flow calorimetric is performed to determine the flow rate. This involves performing a secondary side power calorimetric and measuring the primary side enthalpy rise (via T_H and T_C). However, as noted, this plant does not have scoops and RTD bypass loops to measure primary side temperatures. Instead it has RTDs in thermowells. This is reasonable for T_C where the coolant is well mixed after passing through the RCPs, but T_H indication may be in error due to streaming in the hot leg and the small cross-section seen by the thermowell. Therefore, it is not advisable to use measured T_H in the determination of the RCS flow. Instead, an iterative approach is used to infer T_H from measured secondary side loop power, T_C, and hot leg volumetric flow. The uncertainty analysis that follows is divided into four parts; TTFM, Power Calorimetric, Hot Leg to Cold Leg Conversion, and Elbow Tap Normalization.

A. Transit Time Flow Meter

The TTFM uncertainties are discussed in detail in Reference 11, however, to summarize, the major error components are due to detector placement and difference in fluid velocities as seen by the detector/collimator pairs. The refined uncertainties and the total system uncertainty is provided in Table 3.

[ ]+a,c

This is reflected in the calculations of Table 5a.

TABLE 3

TRANSIT TIME FLOWMETER UNCERTAINTIES

Component	Uncertainty[1]
Fluid Flow	[
Radial Velocity Profile	
Azimuthal Velocity Profile	
Cross Flow	
Mechanical	
Detector Spacing and Detector/Collimator Angle	
Pipe Internal Cross Sectional Area	
Data Collection Statistics	
Data Reduction	
System Timing	
Phase Shift	]+a,c

* [ ]+a,c

Total uncertainty for TTFM = [ ]+a,c

(1) Based on further refinement of data presented in WCAP-9172[11]

A meeting was held on October 11, 1984 between representatives of Texas Utilities Generating Company, Westinghouse, and the NRC to discuss the uncertainties noted in Table 3. As a result of these discussions it was agreed that the total TTFM uncertainty would be increased to [ ]$^{+a,c}$ on a single loop basis. This increase was deemed necessary by the staff to cover perceived uncertainties in the Azimuthal Velocity Profile. The result of this requirement is the addition of what is called an "NRC conservatism factor" of [ ]$^{+a,c}$ to the listing of Table 3. The uncertainties then calculated for the TTFM are:

[ ]$^{+a,c}$

These values are reflected in the calculations of Table 5b.

B. Power Calorimetric

The secondary side power calorimetric is performed in the same manner as described in Section III.3, except with more precision (via the use of special test instrumentation) and the gathering of multiple data sets, i.e., data is gathered at approximately five minute intervals over a one hour time period. The sensitivities noted in Section III.3 are also applicable to this calculation. The specific instrument uncertainties used in this calculation for the calorimetric are noted in Table 5 and are derived from the precision uncertainties noted in Table 1.

C. Hot Leg to Cold Leg Conversion

When a heat balance is performed on a plant in equilibrium, power is defined as:

$$Q = \dot{m} \Delta h \qquad \text{Eq. 7}$$

where;

$\dot{Q}$ = secondary side calorimetric power (Btu/min)
$\dot{m}$ = primary side mass flow rate (lb_m/min)
Δh = primary side enthalpy rise (Btu/lb_m)

Since the RCS is a closed system, the hot leg mass flow must equal the cold leg mass flow, or:

$$\dot{m} = (W_H/v_H) = (W_C/v_C) \qquad \text{Eq. 8}$$

where;

W_H = hot leg volumetric flow rate (ft^3/min)
v_H = hot leg coolant specific volume (ft^3/lb_m)
W_C = cold leg volumetric flow rate (ft^3/min)
v_C = cold leg coolant specific volume (ft^3/lb_m)

Therefore, it can be easily seen that the cold leg volumetric flow is the ratio of the specific volumes, times the hot leg volumetric flow:

$$W_C = W_H\ (v_C/v_H) \qquad \text{Eq. 9}$$

The plant can measure the following for equation 9:

W_H by use of the TTFM,
v_C by measurement of T_C and Pressurizer Pressure,
v_H by measurement of Pressurizer Pressure.

A starting point for T_H can be the measured value using the hot leg RTD, however there is still the streaming concern. Instead T_H is inferred by the use of secondary side calorimetric power, T_C, and hot leg flow, i.e., an iteration is performed by which the power determined by the secondary side calorimetric is compared against the power predicted for an assumed T_H. The predicted power is defined as:

$$q = W_H\,(h_H - h_c)/\nu_H \qquad \text{Eq. 10}$$

where;

- W_H = hot leg volumetric flow (ft^3/min)
- h_H = hot leg enthalpy $f(T_H, P)$
- h_c = cold leg enthalpy $f(T_c, P)$
- ν_H = hot leg specific volume $f(T_H, P)$.

The predicted versus actual power are compared and iterated until a maximum convergence error is reached.

Table 1 notes the uncertainty for the measurement of Pressurizer Pressure and T_c. Table 4 provides the sensitivity of ν_H, T_H, and ν_c to the noted parameters.

Using the results noted in Tables 1, 3, and 4, Table 5a lists the various components of the flow measurement uncertainty for cold leg volumetric flow calculated by equation 9. As can be seen on Table 5a several measurements are used twice, thus there are some dependent effects. The equation used to determine the loop flow measurement uncertainty is:

UNC W_c = [ ] +a,c (Eq. 11)

where:

- P_{ν_c} = Pressurizer Pressure for ν_c
- P_{ν_H} = Pressurizer Pressure for ν_H
- $T_{c_{\nu_c}}$ = T_c for ν_c
- $T_{c_{\nu_H}}$ = T_c for ν_H
- FM_{W_H} = TTFM for W_H
- FM_{ν_H} = TTFM for ν_H
- LP = Loop Calorimetric Power
- IC = Iteration Convergence Limit

Substituting the values of Table 5a into equation 11, UNC W_C = [
]$^{+a,c}$.

The uncertainty for total system flow for a four loop plant is defined as:

T UNC W_C = [ ]$^{+a,c}$ (Eq. 12)

where:

[ ]$^{+a,c}$

Substituting the values of Table 5a into equation 12, T UNC W_c = [
]$^{+a,c}$.

The above noted values for UNC W_c and T UNC W_c are based on use of the Westinghouse values for the TTFM uncertainty and do not include the "NRC conservatism factor". Table 5b notes the changed values for $FM_{W_{H_1}}$ and $FM_{v_{H_1}}$ that would result from the use of the conservatism factor. Substituting these values into equations 11 and 12 result in the following flow uncertainties:

UNC W_c = [

T UNC W_c =]$^{+a,c}$

D. <u>Normalized Elbow Taps for RCS Flow Measurement</u>

Based on the results of Equation 12, in order for a plant to assure operation within the analysis assumptions a precision RCS flow measurement would have to

be performed once every 31 EFPD. However, this is an involved procedure which requires considerable staff and setup time. Therefore, it is expected that the plant will perform one flow measurement at the beginning of the cycle and normalize the loop elbow taps. This allows the operator to quickly determine if there has been a significant reduction in loop flow on a shift basis and to avoid a long monthly procedure. The elbow taps are forced to read 1.0 in the process racks after performance of the precision flow measurement, thus, the elbow tap and its Δp cell are seeing normal operating conditions at the time of calibration/normalization and 1.0 corresponds to the measured loop flow at the time of the measurement.

For monthly surveillance to assure plant operation consistent with the analysis assumptions, two means of determining the RCS flow are available. One, to read the loop flows from the process computer, and two, to measure the output of the elbow tap Δp cells in the process racks with a DVM. The uncertainty for the use of the process computer and its convolution with the precision flow measurement uncertainty is presented as follows.

TABLE 4

ν_H, T_H, ν_c SENSITIVITY

Component	Sensitivity
ν_H	+a,c
Pressurizer Pressure	
T_H	
T_H	
Loop Power	
T_c	
W_H	
Convergence	
ν_c	
Pressurizer Pressure	
T_c	

FIGURE 2
PRECISION RCS MEASUREMENT SCHEMATIC

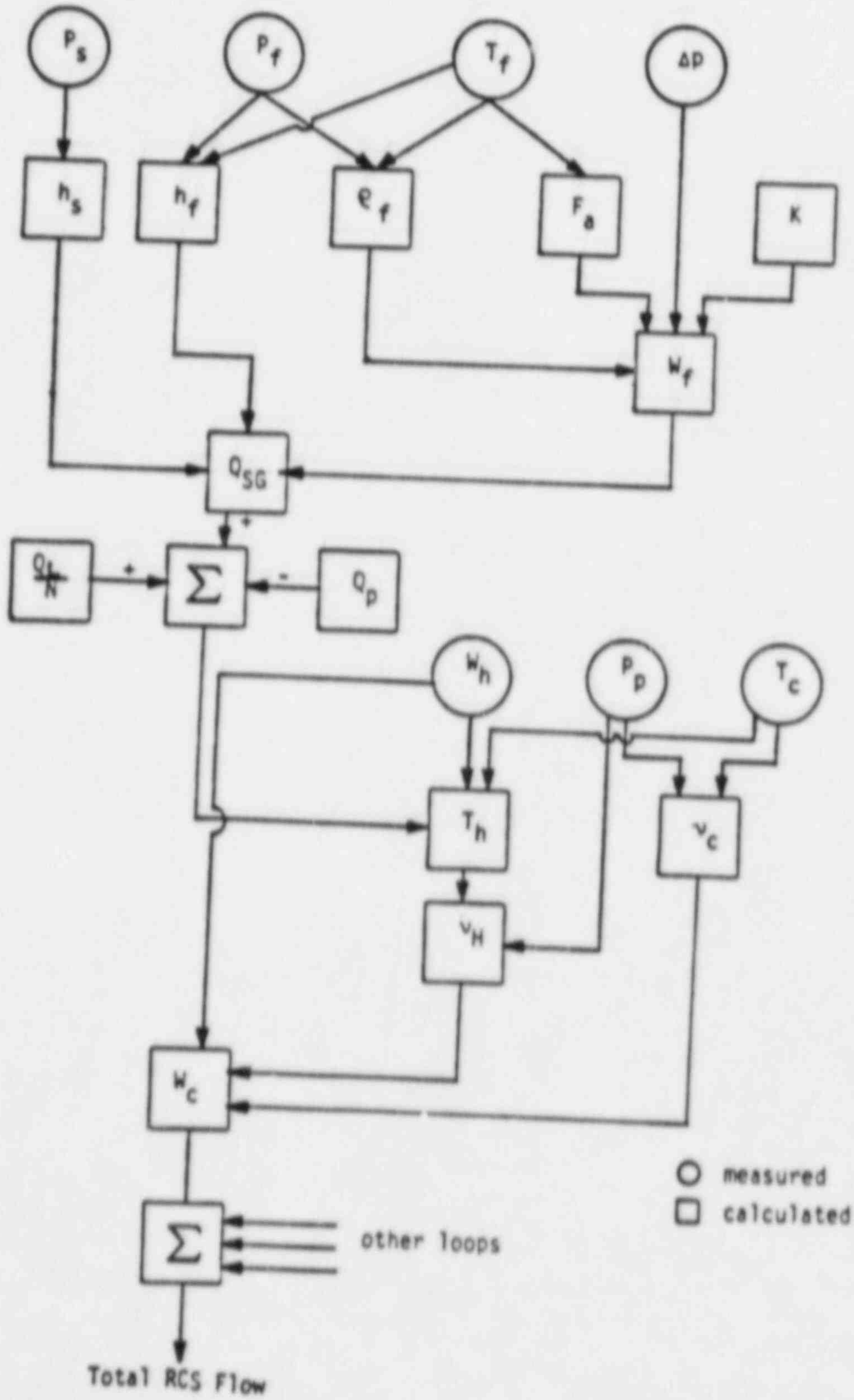

TABLE 5a

PRECISION RCS FLOW MEASUREMENT UNCERTAINTIES
(Without NRC conservatism factor in TTFM error)

Component	Instrument Error	Flow Uncertainty
Secondary Side Power Calorimetric		
Feedwater Flow		+a,c
Venturi, K		
Thermal Expansion Coefficient		
Temperature		
Material		
Density		
Temperature		
Pressure		
Δp		
Feedwater Enthalpy		
Temperature		
Pressure		
Steam Enthalpy		
Pressure		
Moisture Carryover		
Net Pump Heat Addition Uncertainty		
Primary Side Flow		
ν_c		
Temperature (T_c)		
Pressure		
Random		
Bias		

TABLE 5a (Continued)

PRECISION RCS FLOW MEASUREMENT UNCERTAINTIES

Component			Instrument Error	Flow Uncertainty
ν_H			[	]+a,c
	Pressure			
		Random		
		Bias		
	Temperature			
		Loop Power		
		T_c		
		W_H Random		
		Systematic		
		T_H Iteration Convergence		
TTFM		Random		
		Systematic		]

[ ]+a,c

Precision Secondary Side Loop Power Calorimetric Uncertainty =
$\{\Sigma(e)^2\}^{1/2}$ = [ ]+a,c

Loop Flow Uncertainty =
$\{\Sigma(e)^2\}^{1/2}$ = [ ]+a,c

Total RCS Flow Uncertainty =
$(\{\Sigma(e)^2\}/4)^{1/2}$ = [ ]+a,c

TABLE 5b

PRECISION RCS FLOW MEASUREMENT UNCERTAINTIES
(With NRC conservatism factor in TTFM error)

Component	Instrument Error	Flow Uncertainty
Secondary Side Power Calorimetric	Same as Table 5a.	
Primary Side Flow		
ν_c		+a,c
Temperature (T_c)		
Pressure		
Random		
Bias		
ν_H		
Pressure		
Random		
Bias		
Temperature		
Loop Power		
T_c		
W_H Random		
Systematic		
T_H Iteration Convergence		
TTFM		
Random		
Systematic		

TABLE 5b (Continued)

[ ]+a,c

Loop Flow Uncertainty =

$\{\Sigma (e)^2\}^{1/2}$ = [ ]+a,c

Total RCS flow Uncertainty =

$(\{\Sigma (e)^2\}/4)^{1/2}$ = [ ]+a,c

Assuming that only one elbow tap per loop is available to the process computer and using the uncertainties for the elbow tap noted in Table 1 results in the following elbow tap measurement uncertainty:

	% flow
PMA	[ ]$^{+a,c}$
PEA	
SCA	
SPE	
STE	
SD	

	% flow
RCA	[ ]$^{+a,c}$
RTE	
RD	
ID	
A/D	
Readout	

Where:

Readout = Allowance for variability of process signal, and all other parameters are as noted for Equation 2.

The Δp span of Table 1 is converted to flow on the basis the instrument span is [ ]$^{+a,c}$. The uncertainty for this flow measurement is:

UNC ET = [ ]$^{+a,c}$ Eq. 13

Using the values noted above, for one loop UNC ET = [$\pm$ 1.53% flow]$^{+a,c}$. The system flow measurement uncertainty for a four loop plant is defined as:

$$T\ UNC\ ET = UNC\ ET/(4)^{1/2}$$

$\simeq$ [ ]$^{+a,c}$ Eq. 14

If the plant process computer is inoperable at the time of required surveillance, readings can be taken in the process racks with a DVM. The accuracy of this measurement is equal to or better than the process computer measurement. It is therefore conservative to use the process computer uncertainty for this analysis.

When the elbow taps are normalized against the precision flow measurement, the combined uncertainty is defined as:

UNC FM = $\left[\qquad \right]^{+a,c}$ Eq. 15

For use in the ITDP calculations, UNC FM is calculated using T UNC W_c based on the Westinghouse TTFM uncertainties without the NRC conservatism factor. In this instance, UNC FM = $[\qquad]^{+a,c}$. The standard deviation used in the ITDP calculation is then:

$\sigma = [\qquad]^{+a,c}$

For the Unit 1 flow versus $F_{\Delta H}$ trade-off Technical Specification, UNC FM is calculated using T UNC W_c based on use of the NRC conservatism factor. In this instance, UNC FM = $[\qquad]^{+a,c}$, or ~ 1.8% flow. The flow measurement uncertainty used this value in the generation of Figure 3.2-3 (in the Comanche Peak Technical Specifications).

As noted earlier in this document, Westinghouse assumes no errors due to feedwater venturi fouling. When performing an RCS flow calorimetric this assumption requires some effort on the part of the plant staff to either verify there are no fouling characteristics exhibited, or inspect the venturis (and clean, if necessary), or determine the magnitude of the fouling effects because the flow calorimetric is very sensitive to fouling effects, i.e., a 1% fouling effect impacts the flow calorimetric by 1%. However, for Comanche Peak this is not the case. The secondary side power calorimetric is used only in the determination of a value for T_H. Therefore, the sensitivity to venturi fouling is considerably reduced, i.e., a 1% fouling effect impacts the flow measurement uncertainty for the cold leg volumetric flow only by $[\qquad]^{+a,c}$ (and does not impact the hot leg volumetric flow measurement at all). Thus, the need for elaborate or comprehensive means of detecting venturi fouling at the 0.1 to 0.2% flow range are unnecessary. Use of normal plant instrument and practices should be more than sufficient to ensure the detection of fouling at levels low enough to make a fouling allowance for Figure 3.2-3 unnecessary.

In summary, the instrument uncertainties determined in this document are:

Pressurizer Pressure

T_{avg}

Power

RCS Flow without NRC conservatism factor (ITDP)

RCS Flow with NRC conservatism factor (Tech Spec)

[ ]$^{+a,c}$

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6. NUREG-0717 Supplement No. 4, Safety Evaluation Report related to the operation of Virgil C. Summer Nuclear Station Unit No. 1, Docket 50-395, August, 1982.

7. NRC proposed Regulatory Guide 1.105 Rev. 2, "Instrument Setpoints", dated 11/83.

8. ANSI/ANS Standard 58.4-1979, "Criteria for Technical Specifications for Nuclear Power Stations".

9. ISA Standard S67.04, 1982, "Setpoints for Nuclear Safety-Related Instrumentation Used in Nuclear Power Plants".

10. Scientific Apparatus Manufacturers Association, Standard PMC-20-1-1973, "Process Measurement and Control Terminology".

11. Graham, K. F., Forker, J. M., "An N-16 Transit Time Flow Measurement System (TTFM) Description and Performance," WCAP-9172 (Proprietary), WCAP-9173 (Non-Proprietary), February 1978.