Westinghouse Electric Company,
a division of CBS Corporation

Box 355
Pittsburgh Pennsylvania 15230-0355

January 25, 1999
CAW-99-1318

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Attention: Mr. Samuel J. Collins

APPLICATION FOR WITHHOLDING PROPRIETARY
INFORMATION FROM PUBLIC DISCLOSURE

Subject: Farley Nuclear Plant (Westinghouse Owners Group) Responses to NRC Request for Additional Information Related to WCAP-14750 "RCS Flow Verification Using Elbow Taps at Westinghouse 3-Loop PWRs," (Proprietary)

Dear Mr. Collins:

The proprietary information for which withholding is being requested in the above-referenced report is further identified in Affidavit CAW-99-1318 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 10 CFR Section 2.790 of the Commission's regulations.

Accordingly, this letter authorizes the utilization of the accompanying Affidavit by Southern Nuclear Operating Company.

Correspondence with respect to the proprietary aspects of the application for withholding or the Westinghouse affidavit should reference this letter, CAW-99-1318, and should be addressed to the undersigned.

Very truly yours,

H. A. Sepp, Manager
Regulatory and Licensing Engineering

Enclosures

cc: T. Carter/NRC (5E7)

9902090021 990202
PDR ADOCK 05000348
P PDR

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF ALLEGHENY:

Before me, the undersigned authority, personally appeared Henry A. Sepp, 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 Company, a division of CBS 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:

Henry A. Sepp
Henry A. Sepp, Manager
Regulatory and Licensing Engineering

Sworn to and subscribed
before me this 25th day
of January, 1999

Notarial Seal
Janet A. Schwab, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires May 22, 2000
Member, Pennsylvania Association of Notaries

Janet A. Schwab
Notary Public

(1) I am Manager, Regulatory and Licensing Engineering, in the Nuclear Services Division, of the Westinghouse Electric Company, a division of CBS Corporation ("Westinghouse"), 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 and rulemaking proceedings, and am authorized to apply for its withholding on behalf of the Westinghouse Energy Systems Business Unit.

(2) I am making this Affidavit in conformance with the provisions of 10CFR 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 the Westinghouse Energy Systems Business Unit 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.

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 of 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 10CFR Section 2.790, it is to be received in confidence by the Commission.

(iv) The information sought to be protected is not available in public sources or available information has not been previously employed in the same original manner or method 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 "Farley Nuclear Plant (Westinghouse Owners Group) Responses to NRC Request for Additional Information Related to WCAP-14750, "RCS Flow Verification Using Elbow Taps in Westinghouse 3-Loop PWRs," (Proprietary)," January, 1999 for Farley Units 1 and 2, being transmitted by Southern Nuclear Operating Company letter and Application for Withholding Proprietary Information from Public Disclosure, to the Document Control Desk, Attention Mr. Samuel J. Collins. The proprietary information as submitted for use by Southern Nuclear Operating Company for the Farley Unit 1 and 2 Nuclear Power Plants is expected to be applicable in other licensee submittals in response to certain NRC requirements for justification of use of RCS flow verification using elbow taps.

This information is part of that which will enable Westinghouse to:

(a) Provide elbow tap methodology.

(b) Establish appropriate instrument uncertainties associated with elbow tap measurements.

(c) Assist the customer to obtain NRC approval.

Further this information has substantial commercial value as follows:

(a) Westinghouse plans to sell the use of similar information to its customers for purposes of meeting NRC requirements for licensing documentation.

(b) Westinghouse can sell support and defense of RCS verification methodology using elbow taps to its customers in the licensing process.

Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Westinghouse because it would enhance the ability of competitors to provide similar licensing support documentation and licensing defense services for commercial power reactors without commensurate expenses. Also, public disclosure of the information would enable others to use the information to meet NRC requirements for licensing documentation without purchasing the right to use the information.

The development of the technology described in part by the information is the result of applying the results of many years of experience in an intensive Westinghouse effort and the expenditure of a considerable sum of money.

In order for competitors of Westinghouse to duplicate this information, similar technical programs would have to be performed and a significant manpower effort, having the requisite talent and experience, would have to be expended for developing testing and analytical methods and performing tests.

Further the deponent sayeth not.

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 10 CFR 2.790 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 (f) 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)(f) of the affidavit accompanying this transmittal pursuant to 10 CFR 2.790(b)(1).

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ATTACHMENT II

SNC Response To NRC
Request For Additional Information On WCAP-14750,
"RCS Flow Verification Using Elbow Taps At Westinghouse 3-Loop PWRs,"
Joseph M. Farley Nuclear Plant, Units 1 & 2

SAE/FSE-ALA-0597, Revision 0, "Farley Nuclear Plant (Westinghouse Owners Group) Responses to NRC Request for Additional Information Related to WCAP-14750, 'RCS Flow Verification Using Elbow Taps at Westinghouse 3-Loop PWRs,'" Westinghouse Proprietary Class 2C, January 25, 1999.

ATTACHMENT III

SNC Response To NRC
Request For Additional Information On WCAP-14750,
"RCS Flow Verification Using Elbow Taps At Westinghouse 3-Loop PWRs,"
Joseph M. Farley Nuclear Plant, Units 1 & 2

SAE/FSE-ALA-0598, Revision 0, "Farley Nuclear Plant (Westinghouse Owners Group) Responses to NRC Request for Additional Information Related to WCAP-14750, 'RCS Flow Verification Using Elbow Taps at Westinghouse 3-Loop PWRs,'" Westinghouse Class 3 Non-Proprietary, January 25, 1999.

FARLEY NUCLEAR PLANT (WESTINGHOUSE OWNERS GROUP) RESPONSES TO NRC REQUEST FOR ADDITIONAL INFORMATION RELATED TO WCAP-14750, "RCS FLOW VERIFICATION USING ELBOW TAPS AT WESTINGHOUSE 3-LOOP PLANTS"

RAI No. 1:

Section 4.2, Elbow Tap Flow Measurement Procedure, defines the baseline elbow tap flow coefficient (B) and the future cycle elbow tap flow coefficient (K) as the elbow tap ΔP (inches water) multiplied by the cold leg water specific volume (v).

NRC Question:

a. The use of the terminology "flow coefficient" to define the ΔP measurement values is confusing because the elbow tap "flow coefficient" normally refers to the constant C in the elbow tap equation, $Q = C\ (\Delta P)^{1/2}$, whereas ΔP is a variable as a function of flow rate. Why not use an alternate terminology, other than flow coefficient, for "$\Delta P \times v$"?

Farley (WOG) Response:

As shown in the publication "ASME Fluid Meters, Sixth Edition" the elbow tap volumetric flow equation includes a density term, i.e., $Q = C\ (\Delta P/\rho)^{1/2}$, where ΔP is at the fluid temperature, and ρ corrects for the change in elbow tap ΔP with temperature at a constant volumetric flow. The use of the term $(v\Delta P)^{1/2}$ in the Elbow Tap Flow Measurement Procedure is equivalent to the ASME elbow tap flow equation. In the Elbow Tap Flow Measurement Procedure, the square root of the ratio of the $(v\Delta P)$ terms (K for a future cycle and B for the baseline cycle) defines the change in flow from baseline to future cycle. The terminology "flow coefficient" for $(v\Delta P)$ is considered to be appropriate for these terms.

NRC Question:

b. Discuss the reasons for not directly using the equation $Q = C\ (\Delta P)^{1/2}$ for measuring reactor coolant system (RCS) flow rate with elbow tap meters, where the flow coefficient C should have a constant value for an elbow tap installation, and the elbow tap ΔP readings would be proportional to the square of the cold leg flow rates, independent of the plant hydraulic changes such as pump impeller smoothing, steam generator tube plugging, and fuel design change.

Farley (WOG) Response:

The equation in the Elbow Tap Flow Measurement Procedure for calculating future cycle flow, defined in WCAP-14750, is:

$$FCF = BCF \times ((v_f \Delta P_f) / (v_b \Delta P_b))^{1/2} = BCF \times (K / B)^{1/2},$$

where (FCF) = future cycle flow, (BCF) = baseline flow, (K) = future cycle flow coefficient, (B) = baseline cycle flow coefficient, and $(K / B)^{1/2}$ is the ratio of future cycle flow to baseline cycle flow. The terms (BCF) and $(v_b \Delta P_b)$ are constants which represent flow performance in the baseline cycle. If these terms were combined (i.e., $BCF / (v_b \Delta P_b)^{1/2}$), the combination would be equivalent to (C) in the "ASME Fluid Meters" equation ($Q = C (v\Delta P)^{1/2}$). Rather than defining the term ($BCF / (v_b \Delta P_b)^{1/2}$) to be (C), (BCF) is specified in gpm, and $(K / B)^{1/2}$ defines the change in flow, terms that are directly related to the performance of the plant. The equation in the Elbow Tap Flow Measurement Procedure is felt to be a better representation of the process.

NRC Question:

c. The definition in Equations 1 and 2 that B (or K) = $\Delta P \times v$ (where ΔP is in inches H_2O, and B and K are in inches $H_2O{*}ft^3/lb$) is not consistent with the basic elbow tap flow equation volumetric flow rate $Q = C \times (\Delta P)^{1/2}$.

   Explain why B and K are defined as they are. Please examine Equations 1 and 2 for whether B and K are defined correctly.

Farley (WOG) Response:

As shown in the publication "ASME Fluid Meters, Sixth Edition" the elbow tap volumetric flow equation includes a density term, i.e., $Q = C (\Delta P/\rho)^{1/2}$, where ΔP (psi) is at the fluid temperature, and ρ corrects for the change in elbow tap ΔP with temperature at a constant volumetric flow. The use of the term $(v\Delta P)^{1/2}$) is consistent with the ASME equation.

The elbow tap d/p transmitters are calibrated in inches of water at ambient temperature, which is equivalent to ΔP at any temperature. Since the Elbow Tap Flow Measurement Procedure uses elbow tap ΔP transmitter outputs in a ratio ($\Delta P / \Delta P$) to define change in flow rather than absolute flow, inches of water is equivalent to psi. Converting measurements to psi would not change the results. Both density (specific volume) and ΔP (inches, equivalent to psi at fluid temperature) are considered when determining volumetric flow.

RAI No. 2:

In the elbow tap flow measurement procedure in Section 4.2, the future cycle RCS flow will be calculated from the baseline calorimetric measured RCS flow multiplied by the "ratio of future cycle flow," R, which is defined in Equation 3 to be the square root of the ratio the average ΔP (times specific volume) of all elbow taps from the future cycle to that of the baseline cycle, i.e., $(K/B)^{1/2}$.

NRC Question:

a. Because of the variations in the elbow tap flow coefficients (note that the flow coefficient here is C in the basic elbow tap equation, not B or K as defined in Equations 1 and 2 of your report) and the Δp's for different elbow taps in the cold legs, what is the mathematical basis for the use of the average Δp of all elbow taps in defining the ratio of future cycle flow, R? Provide the mathematical derivation to show correctness of "R," "B," and "K" as defined in Section 4.2, using the average Δps.

Farley (WOG) Response:

No mathematical derivation is provided; however, the data presented in the response to question 2.b (see below) notes insignificant differences between the NRC proposed average of the ratios versus the Farley (WOG) presented ratio of the average. From the data presented, it can be concluded that the Farley (WOG) ratio of the average calculates a smaller magnitude R than the NRC proposed average of the ratio for nine out of 13 cycles and thus is considered the more conservative approach.

NRC Question:

b. As the flow coefficient (C) for each elbow tap should remain constant, the volumetric flow ratio should be equal to the square root of the Δp ratio between two cycles, which should be anticipated to be the same for all elbow taps. Would it be more appropriate, mathematically, to use the average value of the flow ratios (i.e., square root of Δp ratios) between the future cycle and the baseline cycle of all elbow taps to define the "ratio of future cycle flow," R? If not, why not?

Farley (WOG) Response:

Noted on the following tables are the Farley (WOG) Unit 1 and Unit 2 indicated transmitter Δp values for each cycle.

Tables 1 and 2 demonstrate that the difference between the two techniques in the determination of the system R value is insignificant. All of the % differences are less than [ ]$^{+a,c}$. The average difference when the NRC approach is used is [ ]$^{+a,c}$, (four positive differences), and the average difference when the Farley (WOG) approach is used is [ ]$^{+a,c}$, (nine negative differences). Therefore, it is concluded that the NRC average of the ratios (as suggested by the above question) is equivalent to the Farley (WOG) ratio of the averages (the method presented in the Farley (WOG) submittal). It should be noted that in a majority of the cases (nine of thirteen), the method presented in the Farley (WOG) submittal is more conservative (smaller in magnitude) than that suggested by the NRC.

TABLE 1 - UNIT 1 RCS FLOW TRANSMITTER ΔP AND R VALUES

Individual Transmitter Δp Values

Transmitter	Cycle 1	Cycle 8	Cycle 9	Cycle 10	Cycle 11	Cycle 12	Cycle 13	Cycle 14
FT414	286.50	285.73	284.70	281.10	284.69	284.69	283.04	277.99
FT415	295.00	278.24	277.20	278.70	277.18	276.12	274.95	269.11
FT416	333.00	316.47	314.10	318.30	309.28	315.27	314.31	312.87
FT424	300.10	292.75	289.50	290.80	294.91	294.91	294.80	290.16
FT425	305.50	300.23	299.10	296.60	295.83	302.43	295.94	295.72
FT426	332.50	312.42	311.20	309.30	310.02	308.83	309.07	303.80
FT434	304.00	304.27	304.30	298.80	303.18	303.18	300.22	295.30
FT435	335.00	338.89	335.30	333.90	329.24	329.24	326.71	325.14
FT436	349.25	345.74	349.50	345.20	340.72	344.49	343.61	334.18
Average Δp	315.65	308.30	307.21	305.86	305.01	306.57	304.74	300.47

+a,c

R value

Individual Transmitter R Values

Transmitter
FT414
FT415
FT416
FT424
FT425
FT426
FT434
FT435
FT436

Average R value

(R value) - (Average R value)

% Difference

% Difference = [(R value) - (Average R value)][100]/(R value)

TABLE 2 - UNIT 2 RCS FLOW TRANSMITTER ΔP AND R VALUES

Individual Transmitter Δp Values

Transmitter	Cycle 5	Cycle 6	Cycle 7	Cycle 8	Cycle 9	Cycle 10	Cycle 11
FT414	277.29	278.26	279.24	271.39	274.51	269.44	270.90
FT415	273.68	275.63	259.79	268.68	270.49	265.69	267.22
FT416	264.10	262.71	262.99	258.40	261.04	256.53	258.96
FT424	262.08	263.06	266.74	261.18	263.33	259.31	262.57
FT425	264.17	265.14	266.11	263.26	266.60	259.44	261.53
FT426	254.03	249.86	254.93	252.15	253.75	252.15	253.26
FT434	268.89	266.04	270.83	265.07	265.83	263.19	264.79
FT435	278.33	281.46	279.38	266.11	273.75	272.22	276.18
FT436	271.67	270.21	266.74	261.74	267.08	268.68	271.04
Average Δp	268.25	268.04	267.42	263.11	266.27	262.96	265.16
R value							

+a,c

Individual Transmitter R Values

Transmitter	
FT414	
FT415	
FT416	
FT424	
FT425	
FT426	
FT434	
FT435	
FT436	
Average R value	
(R value) - (Average R value)	
% Difference	

% Difference = [(R value) - (Average R value)][100]/(R value)

NRC Question:

c. FSAR Section 4.4.1.1 indicates there is to be at least a 95 percent probability at a 95 percent confidence level that departure from nuclear boiling (DNB) will not occur on the limiting fuel rods during normal operation and anticipated operational occurrences. Technical Specification 3.4.1 requires measurement of the DNB parameter of total RCS Flow rate.

To provide a 95/95 probability/confidence of the value of R, would it be more appropriate to adjust the "future cycle flow ratio," R, by taking into to account the uncertainty distribution of the Δp ratios among the elbow taps as the equation below? If not, why not?

$R = R_{avg} - K(95,95,N)\ \sigma$

where,

$R_{avg} = \Sigma\ R_i/N$

$R_i = (\Delta p_f/\Delta p_o)_i^{1/2}$, I = 1,2,....N
(Note that Δp's are in inch of water. If Δp's are in psi, then it will be multiplied by the specific volume of water)

N = total number of elbow taps = 3 x number of cold legs

σ = standard deviation of R_i's

K(95,95,N) = factor for one-sided tolerance limit for 95% probability at 95% confidence level for a sample size of N.

K(95,95,9) = 3.031

Farley (WOG) Response:

The basic presumption for use of the suggested approach is that all loops start with equal flow, experience equal mechanistic changes (equal impeller wear, equal steam generator tube plugging, equal steam generator tube sleeving, etc.); thus, the indicated Δp variation results from a random distribution of errors and uncertainties. However, [

]$^{+a,c}$. As part of the Cycle 1 startup process, plants scale the individual RCS flow channels to reflect 120 % flow at the indicated Δp values. Thus, the channels are normalized to reflect the same flow, [

]$^{+a,c}$.

As an example please note the Unit 1, Cycle 1 indicated Δp values from Table 1 in the response to Question 2.b (presented below).

Transmitter	Cycle 1
FT414	286.50
FT415	295.00
FT416	333.00
FT424	300.10
FT425	305.50
FT426	332.50
FT434	304.00
FT435	335.00
FT436	349.25

[

]+a,c.

As can be seen in the accompanying plot of [

]+a,c, where R equals the ratio of the average Δp values (Farley approach) and *R chan* equals the average of the ratios of the individual Δp values (NRC approach). The standard deviations for the individual R values for each of these cycles are presented below.

Cycle	σ
8	
9	
10	
11	
12	
13	
14	

+a,c

[

]+a,c

It is also suggested that application of a one-sided tolerance factor to the R values envelopes [

]$^{+a,c}$. Thus, it is concluded that application of the one-sided tolerance factor is not appropriate in this calculation.

NRC Question:

d. Alternatively, provide (1) statistical calculations that show that the 95/95 probability and confidence level can be met for RCS flow rate using your proposed measurement method utilizing the elbow tap flow meters, or (2) a justification for measures used to achieve an acceptable accuracy that bounds the 95/95 criteria such as by use of margins, conservative data, etc.

Farley (WOG) Response:

[

]$^{+a,c}$.

RAI No. 3:

The best estimate flow confirmation procedure described in Section 4.2 sets the upper bound of the future cycle RCS flow in accordance with Equation 6 by comparing the measured flow ratio to the flow ratio of best-estimate hydraulic calculations, which is indicated in Section 5.1 to have been developed and confirmed by numerous component flow resistance tests and analyses to be accurate to plus or minus 2 percent. The multiplier in Equation 6 is said to be an allowance for elbow tap flow measurement repeatability. It is indicated that since the elbow tap flow measurement uncertainty included this repeatability allowance, the measured flow ratio can be 0.4 percent higher than the estimated flow ratio and still define a conservative flow.

Section 4.1 discusses the elbow tap flow measurement repeatability with comparisons at the Prairie Island plant to the measurements of leading edge flow meter (LEFM), which is shown (in Section 5.2) to have an accuracy of plus or minus 0.67 percent established by a calibration test at Alden Laboratories. An average difference of less than 0.3 percent is shown in Table 4-1 between the elbow tap meter and the LEFM measurements on the RCS loop flows at full power and the flow ratios with one- and two-pump operation.

NRC Question:

a. Provide the definition of the terms "repeatability", "accuracy", and "uncertainty" as applied to the indicated RCS flow rate obtained by the elbow tap flow meters.

Farley (WOG) Response:

For the definition of Repeatability associated with instrumentation, Westinghouse uses the ISA S51.1-1979 definition, "The closeness of agreement among a number of consecutive measurements of the output for the same value of the input under the same operating conditions, approaching from the same direction, for full range traverses." In this specific instance, it is the potential uncertainty associated with the measurement of RCS flow on two different cycles using the same, or different, elbow tap Δp transmitters, process racks and indication.

For the definition of Accuracy associated with instrumentation, Westinghouse uses the ISA S51.1-1979 definition of accuracy rating, "In process instrumentation, a number or quantity that defines a limit that *errors* will not exceed when a *device* is used under specified *operating conditions*." and "Note 1: When operating conditions are not specified, *reference operating conditions* shall be assumed."

In the field of instrumentation, the term Uncertainty has been used interchangeably with the term error. It is the potential or allowed deviation from the ideal or "true" condition. In the specific instance of RCS flow measurements, it is the potential deviation of the indicated or measured flow from the "true" or actual system flow. This potential deviation is conservatively estimated by the combination of the various accuracy and error terms that could contribute to the indication deviation. These error terms are typically procedure limits [ ]$^{+a,c}$, vendor specified terms [ ]$^{+a,c}$, conservative allowances based on parameter observation [ ]$^{+a,c}$, data evaluation [ ]$^{+a,c}$ and/or control system accuracy.

NRC Question:

b. Provide the elbow tap measurement repeatability value, and describe how it is related to the data provided in Table 4-1, and explain how the elbow tap flow measurement uncertainty described in Appendix A of the report includes the repeatability allowance.

Farley (WOG) Response:

[ ]$^{+a,c}$. The uncertainties and parameters that could be present in an elbow tap flow measurement are noted and discussed below.

- RCS Flow Calorimetric
- hydraulic noise (PEA)
- sensor reference accuracy (SRA)
- sensor calibration accuracy (SCA)
- sensor measurement and test equipment accuracy (SMTE)
- sensor pressure effect (SPE)
- sensor temperature effect (STE)
- sensor drift (SD)
- rack calibration accuracy (for process computer indication) (RCA)
- rack measurement and test equipment accuracy (RMTE)
- rack drift (RD)
- rack temperature effect (RTE)

- [ ]$^{+a,c}$.

- Each elbow tap in a loop has one common tap and one independent tap; therefore, [ ]$^{+a,c}$.

- The sensor reference accuracy is the basic accuracy of the Δp transmitter and reflects the combined effects of hysteresis, linearity and repeatability of the device. When the device is calibrated in the manner described in ISA S51.1, this term can be ignored. When the device is calibrated in a different manner, e.g., using only a one up pass of four or five points, this term should be included in the calculation. [ ]$^{+a,c}$.

- The sensor calibration accuracy is the plant procedure as left calibration tolerance for the Δp transmitter. [ ]$^{+a,c}$.

- The sensor measurement and test equipment accuracy is the accuracy of equipment used to calibrate the transmitter, in this instance [ ]$^{+a,c}$.

- The sensor pressure effect accounts for the correction due to calibration at atmospheric pressure instead of operating pressure. [ ]$^{+a,c}$.

- The sensor temperature effect accounts for variation in ambient temperature. [

  ]$^{+a,c}$.

- The sensor drift is an allowance for transmitter drift. [

  ]$^{+a,c}$.

- The rack calibration accuracy is the plant procedure as left calibration tolerance for the input to the process computer. [
  ]$^{+a,c}$.

  The rack measurement and test equipment accuracy is the accuracy of the equipment used to calibrate the process racks, [

  ]$^{+a,c}$.

- The rack temperature effect accounts for variation in ambient temperature. [

  ]$^{+a,c}$.

- The rack drift is an allowance for process rack drift. [

  ]$^{+a,c}$.

The % Δp span uncertainties were converted to % flow span presuming an indication channel span of [ ]$^{+a,c}$. All uncertainties were then combined [

]$^{+a,c}$.

+a,c

[ ]

$$\varepsilon_T := \sqrt{\left(\frac{\varepsilon_1}{NT}\right)^2 + \left(\frac{\varepsilon_1}{NT}\right)^2}$$

[

]+a,c.

[

]+a,c.

NRC Question:

c. Describe or reference the best-estimate hydraulic calculation methodology used by Farley and other 3-loop plants, and describe how the plus or minus 2 percent accuracy of the hydraulic calculation is obtained and will be assured in the future hydraulic calculations.

Farley (WOG) Response:

The best-estimate hydraulic calculation methodology utilizes an analytical model to predict expected flow changes due to mechanistic changes performed to the RCS between cycles. Examples of such changes are steam generator tube plugging, fuel type changes, thimble plug removal or reinsertion, etc. A detailed description of the hydraulic flow model including a nodal network diagram (Figure 2) is provided below.

Reactor internals

The major flow path through the reactor internals from the vessel inlet nozzles to the vessel outlet nozzles, shown on Figure 2, is through the downcomer, lower plenum, reactor core and upper plenum. Figure 2 also shows small flow paths which bypass the reactor core; i.e., the core bypass flow through the control rod drive thimbles and the gap between the internals barrel and core baffle, the bypass flow through the vessel upper head, and the bypass flows through the vessel outlet nozzle gaps. These bypass flows for Farley Unit 1 and Unit 2 are conservatively estimated to be 4.5% of total flow in Cycle 1, so 95.5% of the total flow is the effective heat transfer flow through the reactor core.

The reactor internals flow resistance consists of three parts.

a. The reactor core flow resistance is calculated for the specific core configuration, power level, and coolant temperatures and pressure, using a flow coefficient based on a full size fuel assembly hydraulic test, and modified by an iteration to account for the effect of the calculated core flow velocity on the friction factor.

b. The vessel internals flow resistance accounts for the Δps at the calculated flow through the downcomer, lower plenum, and upper plenum. The flow resistances are determined from hydraulic model test data and analysis for the specific reactor internals design, based on Δp measurements within the model.

c. The small bypass flows are determined by applying a conservative margin to a best estimate of the flow fraction bypassing the main flow path. The effect of the bypass flows is applied by reducing the main flows by the appropriate bypass flow fraction and defining the main flow path flow resistance for the Δp at the slightly lower flow.

Reactor Coolant Loops

The reactor coolant loop flow passes through the reactor vessel outlet nozzle, hot leg pipe, steam generator, pump suction pipe, pump, cold leg pipe and reactor vessel inlet nozzle. There are no significant bypass flows in the Farley reactor coolant loops. The loop flow resistance is defined in three parts.

a. The reactor vessel nozzles are considered to be part of the coolant loops since the flow through nozzles is at loop flow. Separate nozzle Δps are calculated for the inlet and outlet nozzles to account for differences in coolant density and volumetric flow at the hot leg and cold leg temperatures. The best estimate flow analysis combines the Δps and converts them into a single flow resistance at the pump operating (cold leg) temperature.

b. The steam generator flow resistance is defined in five parts: inlet nozzle, tube inlet, tubes, tube outlet, and outlet nozzle. The tube flow resistance is over [ ]$^{+a,c}$ of the total. The analysis accounts for the number of plugged or sleeved tubes in each steam generator, so loop specific flows can be calculated when different numbers of tubes are plugged or sleeved in each loop. The tube flow resistance is calculated for the specific power level and coolant temperatures and pressure, using a flow coefficient modified by an iteration to account for the effect of the calculated tube velocity on friction factor. The analysis was confirmed by flow and Δp measurements at Prairie Island Unit 2, obtained over a temperature range of [ ]$^{+a,c}$

c. The reactor coolant piping flow resistance consists of the flow resistances for the hot leg, pump suction and cold leg piping. Hot leg flow resistance is adjusted to account for the higher volumetric flow at the hot leg temperature existing at full power. The flow resistance for each section is based on an analysis of the effect of upstream and downstream components on elbow loss coefficients, using the results of industry hydraulics tests. The piping flow resistance, which is less than [ ]$^{+a,c}$ of the system flow resistance, is consistent with the Δp measurements at Prairie Island Unit 2.

Reactor Coolant Pump Performance

The reactor coolant pump head-flow performance is based on a model test of the pump impeller, modified by analysis of as-built impeller dimensions. The methodology was confirmed by flow, Δp, speed and motor power measurements at Prairie Island Unit 2. Full flow tests of each impeller provide an approximate confirmation of pump performance. A polynomial equation is fit to the predicted pump head-flow performance and input to the best estimate flow analysis.

Best Estimate RCS Flow Calculations

The best estimate RCS flow analysis defines the Best Estimate Flow (BEF) and Future Cycle Estimated Flow (FEF) for the elbow tap flow measurement procedure. The calculation combines component flow resistances and pump performance predictions, and defines RCS loop flows at the desired power or temperature with any combination of pumps operating, with any fuel assembly design, and with different tube plugging in each steam generator. The calculated best estimated flows are in good agreement with calorimetric flow measurements from many plants before LLLPs were implemented. For the plants where the comparisons have been made, the calculated best estimate changes in flow from cycle to cycle have been in good agreement with changes measured by elbow taps.

Component head losses are calculated using the following form of the Bernoulli equation:

$$\Delta h = [K + fL/D] \times [v^2 / 2g],$$

where Δh = head loss, feet
K = form loss coefficient, e.g., entrance loss, elbow bend loss, etc.
f = friction factor from Moody diagram
L = length of flow path, feet
D = diameter of flow path, feet
v = fluid velocity in flow path, feet/second
g = acceleration of gravity, 32.18 feet/second^2

The $[K + fL/D]$ terms for a component are combined into a flow resistance term and converted for application in the following equation:

$$\Delta h = K_x \times Q^2,$$

where K_x = flow resistance for a component, E-10 feet/(gpm)^2
Q = volumetric flow through component, gpm

The Farley flows and flow resistances applied to Cycle 1 are summarized below.

Components		Flow resistances, E-10 feet/(gpm)^2 Unit 1	Unit 2
			+a,c
Reactor core	@ total flow		
	@ pump flow		
Reactor vessel internals	@ total flow		
	@ pump flow		
Reactor vessel nozzles			
Steam generator	inlet nozzle		
	tube inlet		
	tubes		
	tube outlet		
	outlet nozzle		
Reactor coolant piping			
Reactor coolant pump flow, gpm			
	dynamic head, feet		

With respect to the 2% uncertainty for the hydraulic model, the uncertainty is considered to apply to absolute flow and not relative flow changes as it is used in the elbow tap procedure. The model is used to determine relative flow changes from cycle to cycle resulting from mechanistic changes to the RCS as indicated above. The uncertainty of the flow resistance of a component is responsible for only a fraction of the 2% uncertainty on the prediction of the absolute flow, so the uncertainty in the relative change in flow resistance has a proportionally smaller impact on predicting the flow change. For example, the best estimate analysis would predict a flow decrease of approximately 1% for an increase in steam generator tube plugging of 5%. It is conservatively assumed that the uncertainty in predicting a flow resistance change is equal to or less than the flow resistance uncertainty for the component (10% for the steam generator), so the uncertainty of the flow change would be no more than 10% of the change, or 0.1% flow for the 5% increase in plugging. For the purposes of predicting flow changes from cycle to cycle, the analytical model is believed to have a maximum or bounding accuracy of 0.2%.

NRC Question:

d. The comparisons provided in Figures 6-1 and 6-2 of the RCS flows from the calorimetric measurements, elbow tap measurements, and best-estimate hydraulic calculations, show a difference of less than 0.5 percent between the elbow tap flow meter measured flow rates and the hydraulic calculation RCS flow rates. Explain how the use of Equation 6 defines a conservative flow, considering the hydraulic calculation accuracy, the elbow tap flow measurement repeatability and uncertainty.

Farley (WOG) Response:

The basic approach of the elbow tap flow measurement procedure is that the elbow tap transmitters will indicate changes in flow from the baseline cycle within the calculated uncertainty. The introduction of the hydraulic model to the procedure was to add an additional check to the procedure such that if one or more transmitters were to experience an unexpected error in a non-conservative direction, the procedure has a check or balance to allow for a correction. Equation 6 allows for a 0.4% difference in flow between the elbow tap prediction and the hydraulic model prediction for any mechanistic changes to the RCS. Although this term has been identified as a repeatability term, the 0.4% is used as an acceptance criterion and is considered to be a conservative allowance for the repeatability of all nine elbow tap transmitters as described in the response to 2b. If the elbow tap flow prediction is more than 0.4% greater than the best estimate flow prediction, Equation 6 requires that the procedure deviates from using the elbow tap data (R) by using the best estimate prediction (R') adjusted by the repeatability factor (0.4%). As stated in the response to 3c, the uncertainty associated with the hydraulic model is quite small (0.2% or less) due to the fact that the model is used to determine flow changes and not absolute flow. Depending on the magnitude of the difference between R and R', this check could also serve as an indication of operability of the transmitters which does not presently exist.

RAI No. 4:

Tables 6-1 and 6-2 provide calorimetric flow rates of all three loops for various cycles and baseline flow rates for Farley Units 1 and 2, respectively. The baseline flow rates for both units, which are shown to be the average of the loop flow rates of earlier cycles (before the transition to low leakage fuel core loading patterns) with hydraulic corrections and roundoff, are shown to be higher than any individual value from the three early cycles from which the baseline flow rates are obtained.

NRC Question:

a. With pump impeller smoothing, which was indicated by the Prairie Island LEFM data to cause a reduction of the RCS flow by 0.6 to 0.8 percent, and why are the baseline RCS flow rates higher than the first cycle flow rate? Provide the calculations to show how these baseline value flow rates are obtained and why they are higher than any individual value?

Farley (WOG) Response:

Measured flows differ from cycle to cycle, even without hydraulics changes, due to the imperfect repeatability of calorimetric flow measurements, so the baseline flow derived from the average of several cycle flows will always be higher than one or more of the measured flows, possibly including the baseline cycle.

The tables below show the development of baseline flows for Farley Units 1 and 2. The measured flows are the average loop flows appearing in WCAP-14750 Tables 6-1 and 6-2. Tube plugging corrections were obtained from WCAP-14750 Table 6-3. Measured flows after Cycle 1 were increased by the hydraulics corrections so the flows would be hydraulically equivalent to the flow in the baseline cycle. The differences between these corrected flows and their average is small. Also listed are the predicted cycle flows determined by applying hydraulics corrections to the baseline flows. Only in Cycle 1 of Unit 1 and Cycle 5 of Unit 2 are these flows greater than the measured flows. The flow in at least one cycle would be expected to be lower than the baseline when averaging flows from three cycles.

Cycle	Measured Flow, gpm	Smoothing Correction	Plugging Correction	Corrected Flow, gpm	Baseline Flow with Correction
			Farley Unit 1		
1	95628			95628	96000
4	95216	0.6%	0.56%	96320	94886
5	94948	0.6%	0.56%	96049	94886
Avg				95999	
			Farley Unit 2		
1					96167
2	95055	0.6%	0.57%	96167	95042
3	95080	0.6%	0.58%	96202	95032
5	94775	0.6%	0.76%	96064	94859
Avg				96144	

NRC Question:

b. In addition to the reasons provided in Sections 6.1 and 6.2 for excluding data of several cycles from Tables 6-1 and 6-2 for Farley Unit 1 and 2, respectively, provide the criteria and bases for the criteria that are used for Farley and will be used for other 3-loop plants such as V. C. Summer, Turkey Point 3 and 4, for excluding data from being used in deriving the baseline flow.

Farley (WOG) Response:

Section 4.2 in the report stated that calorimetric flows from the first few cycles are evaluated to define the baseline calorimetric flow, which can be based on one cycle or the average of multiple cycles. The response to NRC Question No. 4 in the attachment to the Southern Nuclear letter dated October 1, 1997 stated that the preferred procedure for determining baseline flow is to use only one calorimetric measurement, and if more than one measurement is used, the number should be limited to no more than two or three so that the impact of uncertainties in hydraulics changes would be minimized.

The decision on which calorimetric flow measurements to use is based on a plant-specific evaluation of the calorimetric data, applying the criteria listed below to use or discard. In most cases, the evaluation of early cycle flow measurements has concluded that the baseline flow can be based on one cycle, usually the first cycle. This conclusion is reached when the single cycle flow measurement is consistent with other early cycle flows and the best estimate flow prediction. Criteria used in reaching this conclusion are as follows:

[

]$^{+a,c}$.

In only a few cases, such as at Farley, have more than one cycle of calorimetric data been used. At Unit 1, the second and third cycle data were not obtained at the beginning of the cycle and were not used in the evaluation. The baseline flow was the average of flows measured in Cycles 1, 4 and 5. At Unit 2, the Cycle 1 flow was well below the best estimate flow and the flows in subsequent cycles, and there was no change in hydraulics that would explain the increase in flow after Cycle 1. The baseline flow for both units was not significantly different from the hydraulically-corrected flow in any of the cycles used in the average.

<u>RAI No. 5</u>:

<u>NRC Question</u>:

Tables A-4 and A-5 respectively, provide the cold leg elbow tap flow uncertainty for the process computer and low flow reactor trip. Are the instrumentation uncertainty values sufficient to bound the uncertainties of the elbow tap measurement instrument, including the larger drift effects, caused by the absence of current normalization of elbow tap measurement against the precision heat balance measurement at the beginning of each cycle? Provide corrected uncertainty values, if necessary, and the basis for the uncertainty values.

Farley (WOG) Response:

[

]$^{+a,c}$. Therefore, it is concluded that no changes to the uncertainties or final resultants are necessary for Tables A-4 and A-5 of WCAP-14750.

FIGURE 1

+a,c

FIGURE 2

RCS HYDRAULIC NETWORK DIAGRAM

a,c