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RCS Flow Measurement Using Elbow Tap Methodology at Watts Bar Unit 1

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

Reactor Coolant System (RCS) secondary calorimetric-based flow measurements at many pressurized water reactors (PWRs), including Watts Bar Unit 1, have been affected by increases in hot leg temperature streaming. The increases are related to changes in the reactor core radial power distribution, resulting from implementation of low leakage loading patterns (LLLPs). In some cases, measured flow appears to have decreased to, or below, the minimum flow required by the Technical Specifications, which require confirmation of RCS flow by measurement once per fuel cycle. Such occurrences require licensee actions to either account for the apparent flow reduction in the plant safety analyses or to confirm by other means that RCS flow has not decreased below the specified limit. In many cases, utilities have relied on the repeatability of RCS elbow tap flow meters to demonstrate that RCS flow has not decreased.

The current RCS calorimetric flow measurement method based on RCS temperature and secondary calorimetric power measurements has inherent limitations imposed by LLLPs. This report, prepared in response to a Tennessee Valley Authority (TVA) request, presents the justification of an alternate method to measure RCS flow, and the evaluation of RCS flow performance at Watts Bar Unit 1. The alternate method uses elbow tap flow measurements normalized to a baseline calorimetric flow to minimize the LLLP impact.

The following sections present information on:

- Hot leg temperature streaming phenomenon;
- Elbow tap flow measurement application and justification;
- Best estimate hydraulics analysis used to predict RCS flow;
- Evaluation of elbow tap and calorimetric flows at Watts Bar Unit 1;
- Elbow tap flow measurement licensing considerations;
- Measurement uncertainty using elbow taps; and
- Modifications to Watts Bar Technical Specifications.

2.0 SUMMARY

The procedure described in this report for verifying RCS total flow with normalized elbow tap flow measurements is similar to the Westinghouse procedure approved by the Nuclear Regulatory Commission (NRC) for application at Westinghouse 3-loop and 4-loop nuclear power plants. Applicability of the procedure is confirmed by comparing measured RCS elbow tap flow trends with best estimate flow trends based on analysis and application of RCS hydraulic test data.

The evaluation of plant operating data from Watts Bar Unit 1 has defined sufficiently accurate baseline parameters for both the elbow tap and calorimetric flow measurements. Flow changes measured by elbow taps obtained over several fuel cycles are consistent with the predicted flow changes due to changes in RCS hydraulics, as shown on Figure 6-1. Application of the flow measurement procedure using normalized elbow tap measurements will result in the recovery of the apparent decrease in flow attributed to changes in hot leg temperature streaming.

Modifications to the Watts Bar Technical Specifications will be required to allow use of the alternate RCS flow measurement procedure.

Section 7 describes the evaluation process required to prepare a licensing submittal.

Appendix B provides the supporting significant hazards evaluation and Technical Specification changes.

3.0 RCS HOT LEG TEMPERATURE STREAMING

3.1 PHENOMENON

The RCS hot leg temperature measurements are used in control and protection systems to ensure temperature is within design limits, and in a surveillance procedure to confirm RCS flow. The hot leg temperature measurement uncertainty can have a significant impact on PWR performance. A precise measurement of hot leg temperature is difficult due to the phenomenon defined as hot leg temperature streaming, i.e., large temperature gradients within the hot leg pipe resulting from incomplete mixing of the coolant leaving fuel assemblies at different temperatures. The magnitude of these hot leg temperature gradients where the temperatures are measured is a function of the core radial power distribution, mixing in the reactor vessel upper plenum, and mixing in the hot leg pipe.

Prior to application of LLLPs, the largest difference in fuel assembly exit temperatures at full power was typically no more than 30°F. The lowest temperatures were measured at the exit of fuel assemblies on the outer row of the core. Flow from a fuel assembly in the center of the core mixes with coolant from nearby fuel assemblies as it flows around control rod guide tubes and support columns. Flow from a fuel assembly on the outer row of the core has little opportunity to mix with hotter flows before reaching the nozzles, so a significant temperature gradient can exist at the nozzle.

Hot leg flow is highly turbulent, so additional mixing occurs in the hot leg pipe, and the maximum gradient where temperature is measured, 7 to 17 feet downstream from the reactor vessel nozzle, is less than at the nozzle. In 1968, gradients measured on the circumference of the pipe were as high as 7°F to 10°F, so turbulent mixing in the pipe did not eliminate the gradient introduced at the core exit. Figure 3-1 illustrates a postulated flow pattern in the reactor vessel upper plenum between the core exit and the hot leg nozzle. Figure 3-2 illustrates typical temperature gradients at the core exit and on the hot leg circumference at the point where the temperatures are measured.

3.2 HISTORY

Prior to 1968, there were no multiple temperature measurements on hot leg pipes, so temperature streaming gradients were undetected and resistance temperature detector (RTD) locations were based on other criteria. During a 3-loop plant startup in 1968, RTDs on opposite sides of the hot leg pipes measured different temperatures. Recalibrations confirmed that the measurements were valid, so it was concluded that the hot leg temperature differences resulted from incomplete mixing of flows leaving fuel assemblies at different temperatures. Thermocouples were strapped to the outside of two hot leg pipes to confirm this conclusion, and temperature gradients that increased as core power increased were detected. The temperature gradient reached 10°F in one loop and 7°F in the other loop. Since only one RTD measured hot leg temperature for the control and protection systems, the hot leg temperature measurement was not as accurate as intended.

A new hot leg temperature measurement system was installed at plants after 1968 to compensate for hot leg temperature streaming gradients. The new system, called the RTD Bypass System, employed scoops in the hot leg piping at three uniformly spaced locations on the pipe circumference. Holes on the upstream side of the scoop collected small sample flows that were combined and directed through an RTD manifold where the measured temperature of the mixed samples more closely represented the average hot leg temperature.

To eliminate personnel radiation exposure to the RTD Bypass System piping during plant shutdowns, many systems were replaced after 1988 with a system called the RTD Bypass Elimination System (RTDBE). This system has three thermowell RTDs in each hot leg, installed at uniformly spaced locations like the RTD bypass scoops, to retain the three measurement locations. In many cases the thermowell RTDs were installed inside the bypass scoops, so the average thermowell RTD measurement was the same as the temperature measured by the RTD Bypass System.

After 1968, additional hot leg streaming measurements were performed at 2-loop, 3-loop and 4-loop plants. The results of these measurements were used in several analyses to define hot leg temperature streaming uncertainties for protection setpoint calculations and safety analyses. Gradients measured in these tests varied from 7°F to 9°F. After 1988, the thermowell RTD systems provided hot leg streaming data from the three RTDs in each hot leg. The gradients measured prior to 1991 varied from 2°F to 9°F with most of the gradients measured at 5°F to 7°F.

3.3 HOT LEG STREAMING IMPACT ON RCS FLOW MEASUREMENTS

Before 1988, reports of hot leg temperature measurement problems were unusual, and no significant changes in streaming gradients were identified. In 1988, the first significant indication of a streaming change occurred at a 4-loop plant, followed by similar occurrences in 1989 and 1990 at three more 4-loop plants. In all four cases, the measured coolant temperature difference (ΔT) across the reactor vessel had increased from that measured in previous fuel cycles by as much as 3%. The increased ΔT indicated that RCS calorimetric flow had apparently decreased. It was noted that core exit temperature gradients had increased, with lower temperatures measured at the edge of the core, as shown on Figure 3-3. In all cases, RCS elbow tap flows indicated that the actual flow had not changed.

No additional analyses were performed in 1988 or 1989, since the calorimetric flow at those plants was still above the Technical Specification requirement. However, calorimetric flow measured at both units at a plant in 1990 was below the Technical Specification requirement. After additional data had been evaluated, the appropriate data from the elbow taps and core exit thermocouples confirmed that RCS flow was adequate. The NRC was advised of the apparent low flow and the elbow tap flow and core exit thermocouple data, and concurred with the utility's conclusion that RCS flow was adequate for safe operation at full power for the cycle.

Both 3-loop and 4-loop plants, including Watts Bar, subsequently reported apparent reductions in RCS calorimetric flow. The reductions occurred at plants measuring hot leg temperature with either an RTD bypass system or with the RTDBE system. In some cases, the apparent flow was just at the minimum Technical Specification requirement, raising a concern that measured flows could be lower in future cycles, requiring additional analyses or alternate flow measurements to justify that flow is adequate.

The alternate flow measurement procedure developed by Westinghouse, using elbow tap flow meters to verify flow, has been reviewed and approved by the NRC for a group of 3-loop plants and two 4-loop plants (South Texas Project and Seabrook). Elbow tap flow measurements are compared with elbow tap measurements obtained concurrently with early cycle calorimetric flow measurements, when the effects of core exit and hot leg temperature streaming gradients on the hot leg temperature measurement were minimal. If the comparison of elbow tap measurements shows that the flow has not changed, the flow is considered to be the same as determined by the initial calorimetric (baseline) flow.

3.4 CORRELATING CHANGES IN POWER DISTRIBUTION AND RCS FLOW

At the plants where apparent flow reductions were measured, it was noted that in all cases the core exit thermocouples measured much larger temperature gradients, approaching 60°F, as shown on Figure 3-3, due to much lower exit temperatures at the edge of the core. A review of core radial power distributions indicated that the power generated in outer row fuel assemblies was significantly lower than powers measured in earlier cycles, confirming the large core exit temperature gradients.

A comparison of radial power distributions and calorimetric flow measurements from several cycles at several 3-loop and 4-loop plants indicated that the apparent changes in flow correlate with the radial power distribution gradient at the edge of the core. Figure 3-4 plots apparent LLLP-induced calorimetric flow decreases measured at a group of 3-loop plants versus the difference between the average power generated in second row and outer row fuel assemblies. The apparent flow decreases appear to occur when the power differences exceed 47% of fuel assembly average power, a condition consistent with LLLP. The power/flow correlation is represented by the straight line shown on Figure 3-4. According to this data, the measured RCS flow appears to decrease by 3% as the difference between power in second row and outer row assemblies increases from 47% to 90% of assembly average power.

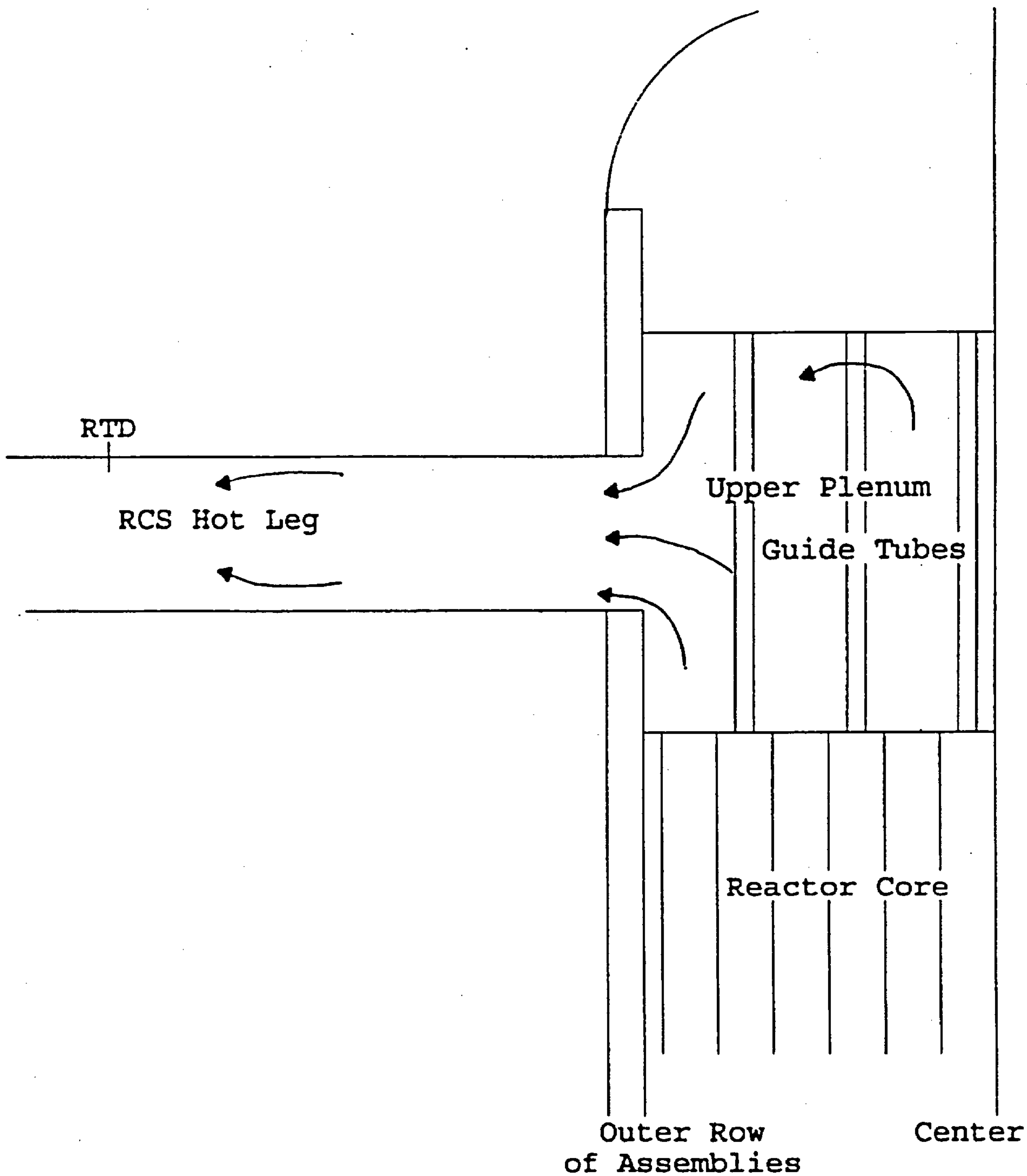


FIGURE 3-1 UPPER PLENUM AND RCS HOT LEG FLOW PATTERNS

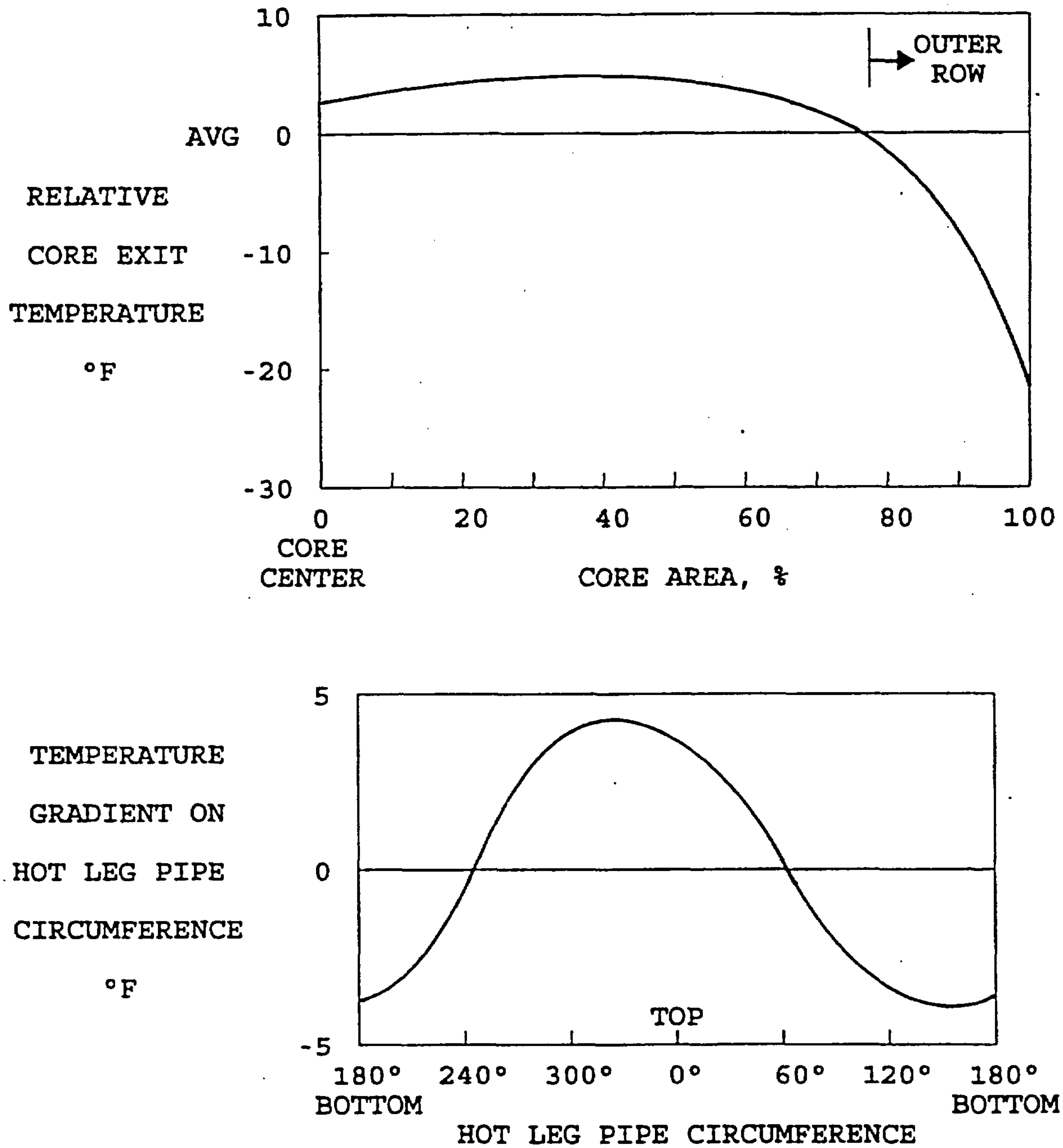
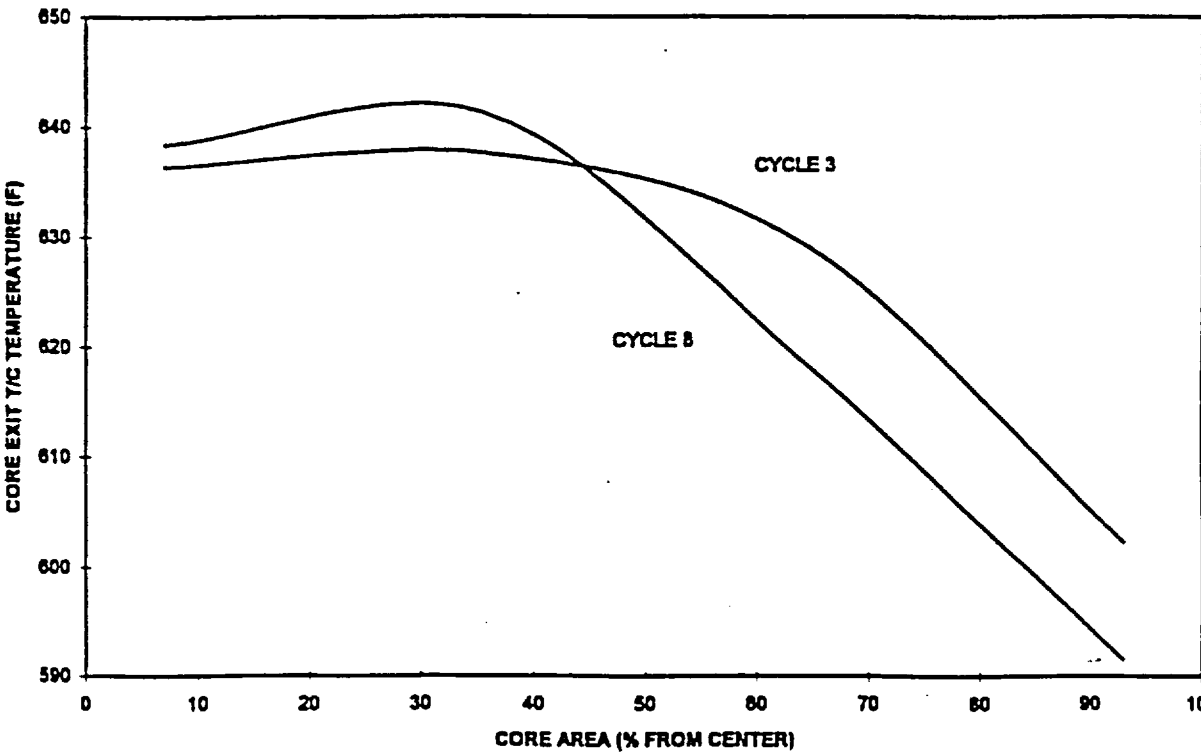


FIGURE 3-2 TYPICAL CORE EXIT TEMPERATURE GRADIENT AND RCS HOT LEG CIRCUMFERENTIAL TEMPERATURE GRADIENT



NOTE: CYCLE 3 (PRIOR TO IMPLEMENTATION OF LLLP)
CYCLE 8 (AFTER IMPLEMENTATION OF LLLPs)

FIGURE 3-3 TYPICAL CORE EXIT TEMPERATURE CHANGE

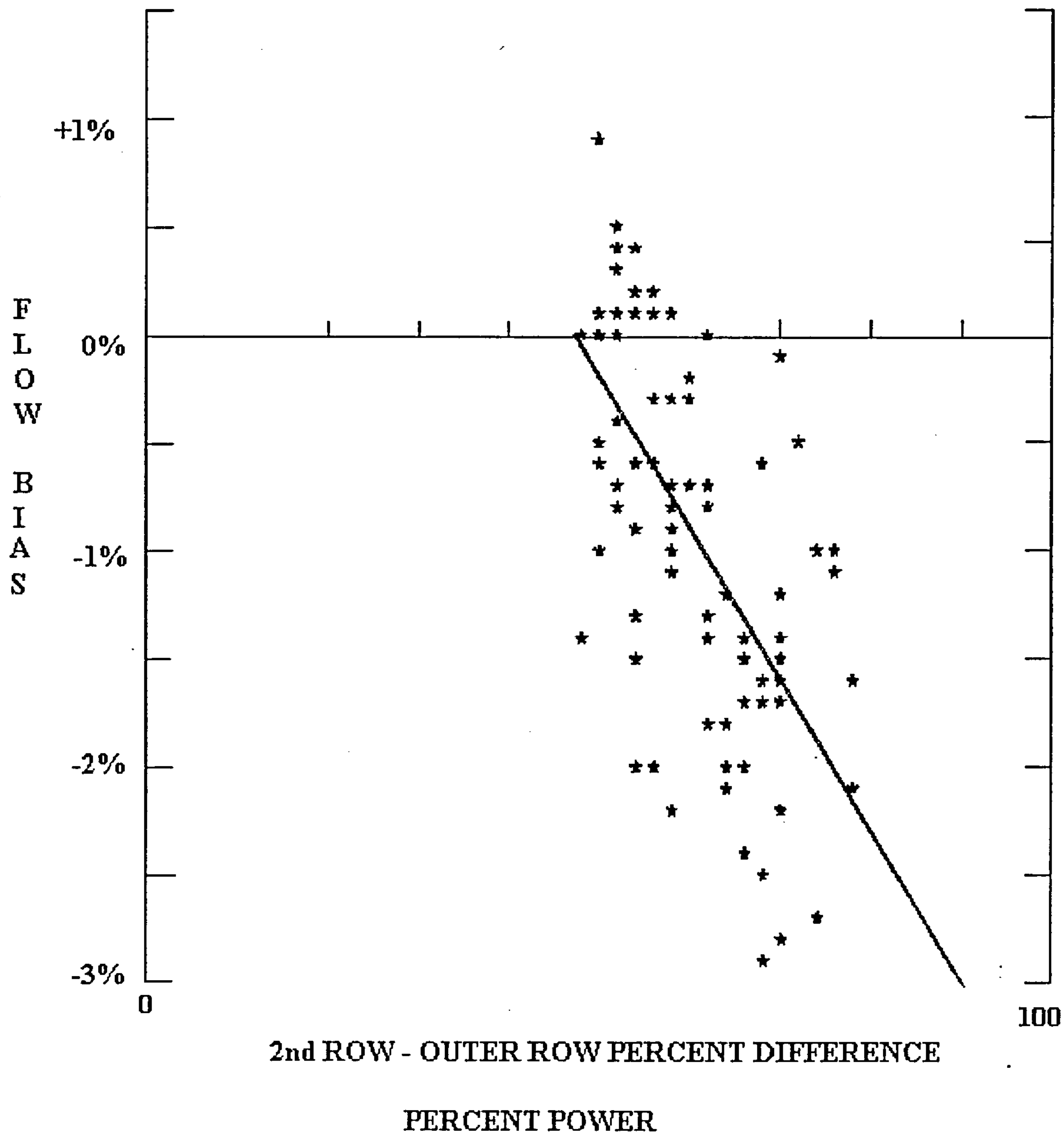


FIGURE 3-4 CALORIMETRIC FLOW MEASUREMENT BIAS VERSUS DIFFERENCE BETWEEN AVERAGE SECOND ROW AND OUTER ROW ASSEMBLY POWERS

4.0 ELBOW TAP FLOW MEASUREMENT APPLICATION

4.1 ELBOW TAP FLOW MEASUREMENTS

Elbow tap differential pressure (Δp) measurements are being used more frequently to confirm RCS flow changes from one fuel cycle to the next. Elbow tap flow meters are installed in all Westinghouse PWRs on the reactor coolant pump suction piping on each loop, as shown on Figure 4-1. The Δp taps are located on a plane 22.5° around the first 90° elbow. Each elbow has one high pressure and three low pressure taps connected to three redundant Δp transmitters. Elbow taps in this arrangement are used to define relative rather than absolute flows, due to the lack of upstream straight piping lengths. The Δp measurements are repeatable and thus provide accurate indications of flow changes during a cycle or from cycle to cycle.

Elbow tap flow meters (Reference 1) are a form of centrifugal meter, measuring momentum forces developed by the change in direction around the 90° elbow. The principal parameters defining the Δp for a specified flow are the elbow's radius of curvature and the flow channel diameter. Hydraulic tests described in Reference 1 demonstrated that elbow tap flow measurements have a high degree of repeatability and that the flow measurements are not affected by changes in the elbow surface roughness.

Phenomena that have affected other types of flow meters, or that might affect the elbow tap flow meters have been evaluated to determine if any of these phenomena would affect repeatability of the elbow taps. In addition, measurements at an operating plant equipped with a highly accurate RCS ultrasonic flow meter were compared with elbow tap flow measurements to demonstrate repeatability of the elbow taps. The results of these evaluations and comparisons are summarized below.

4.1.1 Venturi Fouling

Deposits (fouling) collecting on the surface and reducing the throat flow area affect venturi flow meters that measure feedwater flow. Fouling is caused by an electro-chemical ionization plating of copper and magnetite particles in the feedwater on the venturi surface, a process related to the velocity increase as flow approaches the smaller venturi flow area. There is no change in cross section to produce a velocity increase and ionization in an elbow, and surface roughness changes as experienced in venturi flow meters do not affect the elbow tap flow measurement.

4.1.2 Meter Dimensional Changes

The elbow tap flow meter is part of the RCS pressure boundary, so there would be only minimal dimensional changes associated with pipe stresses. Pressure and temperature would be essentially the same (full power conditions) whenever the flow is measured. Erosion of the elbow surface is unlikely since stainless steel is used, and velocities are low (42 fps) relative to erosion. The effects of dimensional change or erosion could only affect flow by changing elbow radius or pipe diameter, both very large relative to any possible dimensional change. Therefore, the elbow tap flow meter is considered to be a highly stable flow measurement element.

4.1.3 Upstream Velocity Distribution Effects

The velocity distribution entering the steam generator outlet nozzle is skewed by its off-center location relative to the tube sheet. The out-of-plane upstream 40° elbow on the steam generator outlet nozzle skews the velocity distribution entering the 90° elbow with Δp taps. These velocity distributions, including the distribution in the elbow tap flow meter, will remain constant, so the elbow tap flow meter Δp/flow relationship would not change.

Steam generator tube plugging is usually randomly distributed across the tube sheet, so the velocity distribution approaching the outlet nozzle would not change. The velocity distribution in the outlet plenum could change if extensive tube plugging were to occur in one area of the tube sheet. However, the outlet plenum velocity approaching the outlet nozzle is small compared to the pipe velocity (6 fps vs. 42 fps), and this large change in flow area would significantly reduce or flatten an upstream velocity gradient. Therefore, any tube plugging, even if asymmetrically distributed, would not affect the elbow tap flow measurement repeatability.

Also considered was the effect of replacing steam generators on elbow tap flow measurements. Replacement steam generators have the same outlet nozzle off-center location, diameter and taper. Since the same difference in plenum and nozzle velocity heads would result, steam generator replacement would have no impact on elbow tap flow coefficients. RCS flow would increase since steam generator flow resistance with no plugging would decrease, and the change in flow would be correctly measured.

4.1.4 Flow Measurement Comparisons

Leading Edge Flow Meters (LEFMs), ultrasonic devices installed in both reactor coolant loops at Prairie Island Unit 2, provide the data to confirm repeatability of the elbow tap flow meters. The comparisons covered 11 years of operation, during which a significant change in system hydraulics was made. One of the reactor coolant pump impellers was replaced, and the replacement impeller produced additional flow. The LEFM measurements after pump replacement were in agreement with the predicted change, and the elbow tap flow meters indicated similar changes, but slightly lower flows than measured by the LEFM.

The 11-year flow comparison showed that the average difference between elbow tap and LEFM flows was less than 0.3% flow. Another comparison performed before and after the impeller replacement showed that the LEFM and elbow tap measurements agreed to within an average of 0.2% on the ratio of flows when one and two pumps were operating, thus further confirming the relative flow accuracy of elbow tap flow meters. These comparisons are listed on Table 4-1.

Elbow tap flow measurements have also been compared with flows based on the hydraulics analysis described in Section 5. The comparisons showed that elbow tap and best estimate flow trends were in close agreement at many plants, including plants with changes in flow due to RCS hydraulics changes such as pump impeller replacement as described above, and steam generator tube plugging and replacement. The close agreement between elbow tap total flow and best estimate total flow occurs even where tube plugging and loop flows are significantly imbalanced. Elbow tap flows for five cycles at a plant with tube plugging increasing from 4% to over 19%, and with a loop-to-loop plugging spread of 7% were well within the repeatability allowance (0.4%) when compared with best estimate flows. RCS flows measured by elbow taps after replacing the steam generators at this plant were also in good agreement with the predicted flow, i.e., within 0.4%.

4.2 ELBOW TAP FLOW MEASUREMENT PROCEDURE

The elbow tap flow measurement procedure relies on repeatability of the elbow tap Δp measurements to accurately verify RCS flow. Comparison of elbow tap Δp measurements obtained at the same reactor power from one cycle to the next provides an accurate indication of the actual change in flow. When a current cycle tap Δp measurement is compared with a baseline cycle Δp measurement and normalized to a baseline calorimetric flow based on early cycle calorimetric flow measurements, elbow taps define an accurate flow for the current cycle.

The elbow tap flow measurement procedure is described below. Acronyms used in the procedure are defined on Table 4-2. The baseline parameters for the procedure and their development (baseline calorimetric flow and baseline elbow tap flow coefficient) are presented in Section 4.3.

4.2.1 Baseline Elbow Tap ΔP

Elbow tap Δps from the baseline calorimetric flow cycle define a baseline elbow tap flow coefficient, used in connection with the baseline calorimetric flow and a current cycle elbow tap flow coefficient to define the current cycle flow. Baseline elbow tap Δps are obtained when the reactor is operating between 90 and 100% power. The baseline elbow tap flow coefficient (B) is defined by Equation 1:

$$B = \Delta p_B * v_B \qquad \text{(Eq. 1)}$$

where B = baseline elbow tap total flow coefficient, (inches H_2O * ft^3/lb)

Δp_B = baseline average elbow tap Δp (inches H_2O)

v_B = baseline average cold leg specific volume (ft^3/lb)

The baseline elbow tap flow coefficient based on the average Δp from all elbow taps defines total flow, to be consistent with the total baseline calorimetric flow. Analyses of elbow tap Δp data at several plants have shown that the difference between total flow based on the average elbow tap Δp and total flow based on individual elbow tap transmitter Δps is negligible. The repeatability of the total flow measurement is improved when all elbow tap Δp measurements are used.

4.2.2 Flow Verification for Current Cycle

Elbow tap Δps from the beginning of the current cycle define the change in flow from the baseline cycle. The average of all elbow tap Δps measured when the reactor is operating between 90 and 100% power defines the current cycle elbow tap flow coefficient (K), applying Equation 2:

$$K = \Delta p_C * v_C \qquad \text{(Eq. 2)}$$

where K = current cycle elbow tap total flow coefficient, (inches H2O * ft^3/lb)

Δp_C = average current cycle elbow tap Δp (inches H_2O)

v_C = average current cycle cold leg specific volume (ft^3/lb)

The change in flow from the baseline cycle to the current cycle is defined by the elbow tap flow ratio (R), defined by Equation 3:

$$R = (K / B)^{1/2} \qquad \text{(Eq. 3)}$$

where R = ratio of current cycle flow to baseline flow

The current cycle flow is determined by multiplying the baseline calorimetric flow by the elbow tap flow ratio (R), per Equation 4:

$$CCF = R * BCF \qquad \text{(Eq. 4)}$$

where CCF = total current cycle flow, gpm

BCF = total baseline calorimetric flow, gpm

Baseline and current cycle elbow tap Δps are measured when the reactor is operating between 90 and 100% power to avoid the need to correct flow for the small decrease in flow (approximately 1%) as reactor power increased from zero to 100%. See section 5.2.5 for additional information.

4.2.3 Best Estimate Flow Confirmation

A current cycle flow defined by elbow taps is confirmed by comparing the elbow tap flow ratio (R) with an estimated flow ratio (R', defined by Equation 5), based on the best estimate flow analysis of known RCS hydraulics changes such as steam generator tube plugging and core Δp changes. Prior to beginning of the cycle, the current cycle estimated flow (CEF) is calculated for the new cycle, accounting for the known hydraulic changes.

$$R' = CEF / BEF \qquad \text{(Eq. 5)}$$

where CEF = current cycle estimated flow (RCS flow based on actual RCS hydraulics changes)

BEF = best estimate flow (initial (baseline) cycle RCS flow based on hydraulics analyses)

An acceptance criterion is applied to the comparison of R and R':

If $R \leq (1.004 * R')$, the elbow tap flow ratio R is used to calculate the current cycle RCS total flow using Equation 4.

If $R > (1.004 * R')$, the quantity $(1.004 * R')$ is used to define the current cycle RCS total flow, modifying Equation 4 to Equation 6 as indicated below.

$$CCF = 1.004 * R' * BCF \qquad \text{(Eq. 6)}$$

The multiplier (1.004) applied to R' is an allowance for the repeatability of the elbow tap flow measurement. The elbow tap flow measurement uncertainty presented in Appendix A includes elements (e.g., sensor and rack calibration allowances) that define a repeatability allowance for the flow measurement that is larger than 0.4%. A measured flow ratio R that is no greater than 0.4% above the estimated flow ratio R' will still define a conservative flow. Application of this acceptance criterion results in definition of a conservative current cycle flow, confirmed by both the elbow tap measurements and the best estimate hydraulics analysis.

4.3 BASELINE PARAMETERS FOR ELBOW TAP FLOW MEASUREMENTS

4.3.1 Baseline Calorimetric Flow

[

]+a,c

[

]$^{+a,c}$

[

]$^{+a,c}$

[

]$^{+a,c}$

[

]$^{+a,c}$

[

]$^{+a,c}$

4.3.2 Baseline Elbow Tap Δp

The baseline elbow tap flow coefficient (B), based on elbow tap Δps obtained in the baseline cycle, is defined by Equation 1. Section 6.3 describes the evaluation of elbow tap flow measurements that defined the baseline elbow tap flow coefficient for Watts Bar Unit 1. Based on the analysis, the procedure established the following coefficient:

Baseline Elbow Tap Flow Coefficient (B) [ ]$^{+a,c}$

Reference

1. "Fluid Meters, Their Theory and Application," 6th Edition, ASME, 1971.

TABLE 4-1
COMPARISONS OF LEADING EDGE FLOW METER AND ELBOW TAP FLOW MEASUREMENTS AT PRAIRIE ISLAND UNIT 2

RCS FLOW MEASUREMENT COMPARISONS AT FULL POWER gpm/loop				
LOOP	**A**	**A**	**B**	**B**
METER	**LEFM**	**ELBOW TAPS**	**LEFM**	**ELBOW TAPS**
DATE				
02/80	97,519	(Same)	97,950	(Same)
07/81	98,673	98,309	97,763	97,267
08/91	98,724	98,557	97,543	97,607

RATIO OF LOOP FLOW WITH 1 PUMP OPERATING TO LOOP FLOW WITH 2 PUMPS OPERATING				
LOOP	**A**	**A**	**B**	**B**
METER	**LEFM**	**ELBOW TAPS**	**LEFM**	**ELBOW TAPS**
DATE				
12/74	1.0819	1.0777	1.0852	1.0875
07/81	1.0794	1.0816	1.0820	1.0820

TABLE 4-2
ACRONYMS USED IN ELBOW TAP FLOW MEASUREMENT PROCEDURE

B	Baseline Flow Coefficient: defined by the elbow tap Δp and specific volume at average cold leg temperature measured at the beginning of the baseline cycle.
BCF	Baseline Calorimetric Flow: defined by calorimetric flows measured in early cycles with minimal impact from core radial power distribution.
BEF	Best Estimate Flow: estimated RCS flow for the baseline cycle, based on the best estimate hydraulics analysis.
CCF	Current Cycle Flow: correction to the Baseline Calorimetric Flow (BCF) to account for changes in flow, using the elbow tap flow ratio (R) or the estimated flow ratio (R'). CCF defines the RCS flow for the current cycle.
CEF	Cycle Estimated Flow: estimated RCS flow for the current cycle, based on actual RCS hydraulics changes.
K	Elbow Tap Flow Coefficient: current cycle flow coefficient defined by the elbow tap Δp and specific volume at average cold leg temperature measured at the beginning of the current cycle.
R	Measured Flow Ratio: elbow tap Δp ratio, defines the actual change in flow for the current cycle, used to define the Current Cycle Flow (CCF).
R'	Estimated Flow Ratio: defines the current cycle estimated change in flow relative to the baseline cycle Best Estimate Flow (BEF).
TSF	Technical Specification Flow: specified flow that must be confirmed by a flow measurement.

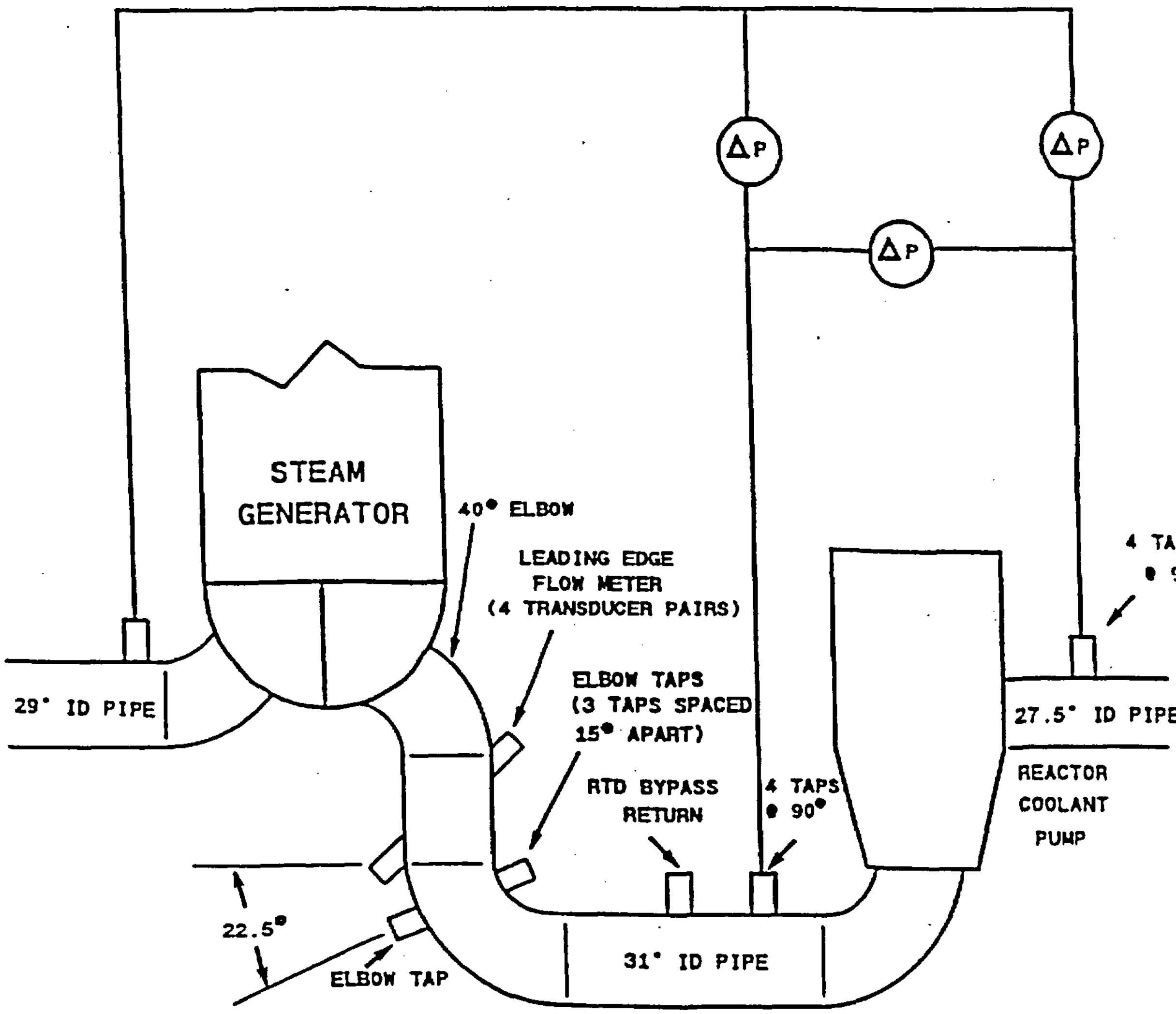


FIGURE 4-1 LEADING EDGE FLOW METER, ELBOW TAP FLOW METER AND COMPONENT ΔP TAP LOCATIONS AT PRAIRIE ISLAND UNIT 2

5.0 BEST ESTIMATE RCS FLOW ANALYSIS

5.1 BACKGROUND

The procedure for calculating best estimate RCS flow was developed in 1974 and has been used to estimate RCS flow at all Westinghouse-designed plants. The procedure uses component flow resistances based on calculations and special test measurements, and RCP performance estimates based on calculations and model test measurements with no margins applied, so the resulting flow calculations define a true best estimate of the actual flow.

Uncertainties in the best estimate hydraulics analysis, based on both plant and component test data, define a flow uncertainty of ±2% flow, indicating that actual flow is expected to be within 2% of the best estimate flow. Since the uncertainty of a component flow resistance contributes only a fraction of the best estimate flow uncertainty, the uncertainty of a change in flow due to a known hydraulics change to a component is much smaller than ±2%. The uncertainty of the flow change is estimated to be no more than 10% of the predicted change in flow due to the change in hydraulics.

The most significant input to the best estimate hydraulics analysis was the test data collected at Prairie Island Unit 2, where ultrasonic LEFMs were installed. The input from these tests was used to confirm or modify hydraulic performance analyses for the components and RCPs. These tests are described below.

5.2 PRAIRIE ISLAND HYDRAULICS TEST PROGRAM

The LEFM was installed in 1973 at Prairie Island Unit 2, on both loops as shown on Figure 4-1. Measurements were obtained during the hot functional and plant startup tests in 1974. In addition to the LEFM flows, component Δp taps shown on Figure 4-1 were provided to obtain concurrent measurements of reactor vessel and steam generator Δps and Reactor Coolant Pump (RCP) dynamic head. RCP input power and speed were also measured.

The program collected data during plant heatup from 200°F to normal operating temperatures with one and two RCPs operating. Full power flow measurements were obtained early in 1975. Subsequent flow and RCP input power data were obtained in 1979, 1980, 1981 and 1991.

The LEFM accuracy for the Prairie Island plant measurements was established by a calibration test at Alden Laboratories, and by analysis of dimensional tolerances, to be ±0.67% of measured flow. The Alden test modeled the piping configuration both upstream and downstream from the metered pipe section. Tests performed with the ultrasonic transducers installed at several locations on the pipe circumference defined the optimum location for the transducers in the pipe section relative to the angular orientations of the upstream and downstream elbows.

The Prairie Island component Δps were based on measurements at the three locations shown on Figure 4-1: hot leg, RCP suction and RCP discharge piping. The accuracy of the measurements was established by calibrations to be within ±1% of the measured Δp. Since the Δps were measured with common taps, the sum of the reactor and steam generator Δps equal the RCP Δp; these comparisons agreed to within 1%, further confirming the Δp measurement accuracy.

The first RCS flows measured in 1974-75 were 5% higher than predicted, due to the following effects, evaluated in additional analyses.

5.2.1 Reactor Coolant Pump Performance

RCP performance was higher than predicted from hydraulic model tests, producing an additional 2% flow, partly due to the impact of impeller thermal expansion not considered in the original predictions, and partly due to conservatism in the scale-up of the hydraulic model test measurements. With measurements of flow, head, input power and speed, hydraulic and electrical efficiency were verified. The LEFM was also capable of accurately measuring reverse flows, so the flow measurements also confirmed the flow resistance of the RCP impeller due to reverse flow.

5.2.2 Reactor Vessel Flow Resistance

The reactor vessel flow resistance was somewhat lower than predicted from reactor vessel model tests and fuel assembly Δp measurements. The reduced flow resistance was responsible for an RCS flow increase of almost 3%. Tests with one RCP in operation and reverse flow in the idle loop provided additional data that confirmed the division of flow resistances between reactor vessel internals and core (total flow) and reactor vessel nozzles (loop flow).

5.2.3 Steam Generator Flow Resistance

The steam generator flow resistance was measured to be the same as predicted from analysis, so changes in the analysis were not required. The large change in the predicted flow resistance resulting from the change in tubing Reynolds Number and friction factor during plant heatup was also confirmed by the flow resistance measurements.

5.2.4 Piping Flow Resistance

The RCS piping flow resistance, 6% of the total system resistance, was reduced by about 25% to be consistent with measured component flow resistances, accounting for reduced Δp due to close coupling of components and elbows in the piping. Part of an elbow Δp loss occurs as increased turbulence in the downstream piping, but the loss is reduced if a component or another elbow is located at or close to the elbow outlet.

5.2.5 Flow vs. Power

LEFM measurements at full power indicated that the Prairie Island Unit 2 RCS cold leg volumetric flow decreased by about 0.8% as the reactor was brought from zero to full power. This result confirmed the predicted effect of higher velocities in the core, hot leg, and steam generator tubes as temperatures at these locations increase above cold leg temperature. The RCS flow velocity in these regions increases by 5% to 12%, causing an increase in the total RCS flow resistance applied to the RCPs. The resulting decrease in flow as reactor power increases from zero to 100% is plant-specific, differing from 0.8% to 1.2%, depending on the plant-specific hot leg and cold leg temperatures, and flow resistances of the affected components.

5.3 ADDITIONAL PRAIRIE ISLAND TESTS

The flow measurements in later years contributed additional data on system hydraulics performance, used to revise and further validate the hydraulics analyses, as described below.

5.3.1 Impeller Smoothing

LEFM and RCP input power measurements were obtained at Prairie Island in 1979 and 1980 to reconfirm RCS flows and hydraulic performance. LEFM data indicated that RCS flows had decreased by 0.6% to 0.8%, and electrical data indicated that RCP input power had decreased by about 2%. After evaluating this data and other information, it was concluded that the flow decrease was due to impeller smoothing, where the impeller surface roughness decreases due to wear or deposit buildup between high points on the impeller surfaces. Smoothing occurs within one or two fuel cycles after initial startup. This flow decrease during early cycles has also been measured by elbow tap flow meters at several 3-loop and 4-loop plants.

5.3.2 RCP Impeller Replacement

The LEFMs were used at Prairie Island in 1981 to confirm RCS flows after replacement of an RCP impeller. The new impeller performance was predicted to be higher than the original impeller, and a loop flow increase was predicted. The LEFM confirmed this prediction.

5.3.3 Elbow Tap Flow Comparison

LEFM data in 1991 were compared with 1980 data to confirm that elbow taps measured the same flow changes over the same period. The comparison indicated that the elbow tap and LEFM loop flows were in good agreement, with an average difference of less than 0.3% over 11 years.

5.4 SYSTEM FLOW RESISTANCE ANALYSES

Flow resistances are calculated for each component, based on component hydraulic design data and hydraulics coefficients resulting from analysis of test data such as, but not limited to, the Prairie Island test program. Component flow resistances are combined to define total system flow resistance, and combined with the predicted RCP head-flow performance to define RCS flow. The background and bases for flow resistance calculations are described below.

5.4.1 Reactor Vessel

The reactor vessel flow resistance is defined in three parts:

a. The reactor core flow resistance is based on a full size fuel assembly hydraulic test, including Δps at RCS total flow through inlet and outlet core plates, as well as the core.

b. The vessel internals flow resistance is based on total flow through the downcomer, lower plenum, and upper plenum. The flow resistances are determined from hydraulic model test data for each type of reactor vessel, based on Δp measurements within the model.

c. The vessel nozzle flow resistances include Δps based on loop flow through the inlet and outlet nozzles.

In addition, the overall analysis accounts for small flows that bypass the reactor core through the upper head, hot leg nozzle gaps, baffle-barrel gaps, and control rod drive thimbles.

5.4.2 Steam Generator

The steam generator flow resistance is defined in five parts: inlet nozzle; tube inlet; tubes; tube outlet; and outlet nozzle. The Prairie Island test program (Section 5.2) confirmed the overall flow resistance. The analysis accounts for the plugged or sleeved tubes in each steam generator, so loop-specific flows can be calculated when different numbers of tubes are plugged or sleeved.

5.4.3 Reactor Coolant Piping

The RCS piping flow resistance combines the flow resistances for the hot leg, crossover leg, and cold leg piping. The flow resistance for each section is based on an analysis of the effect of upstream and downstream components on elbow hydraulic loss coefficients, using the results of industry hydraulics tests. The total flow resistance was consistent with the measurements from the Prairie Island test program (Section 5.2).

5.5 BEST ESTIMATE RCS FLOW CALCULATIONS

The best estimate flow analysis defines baseline best estimate flow (BEF) and current cycle estimated flow (CEF) for the elbow tap flow measurement procedure. The calculation combines component flow resistances and RCP performance predictions based on hydraulic model·tests, and defines RCS loop flows at the desired power or temperature with any combination of RCPs operating, with any fuel assembly design, and with different tube plugging in each steam generator. Estimated flows were in good agreement with calorimetric flow measurements from many plants before LLLPs were implemented. The calculated best estimate changes in flow from cycle to cycle have been in good agreement with changes measured by elbow taps.

6.0 WATTS BAR RCS FLOW PERFORMANCE EVALUATION

6.1 INTRODUCTION

RCS elbow tap flow and calorimetric flow measurements from Watts Bar Unit 1 were evaluated and compared with calculated best estimate flows to determine RCS flow performance. Elbow tap flow measurements define actual flow changes and are expected to compare well with changes predicted by the best estimate flow analysis. Calorimetric flow measurements establish a baseline flow and define flow changes caused by hot leg temperature streaming biases as well as hydraulics changes. Results of the Watts Bar flow measurement evaluation are described in the following paragraphs.

6.2 BEST ESTIMATE FLOW PREDICTIONS

Best estimate flow analyses defined flows for the five fuel cycles at Unit 1. The hydraulics changes that affected flows after Cycle 1, described below, are listed on Table 6-1.

a. Impeller Smoothing: As stated in Section 5.3.1, impeller smoothing is expected to cause a decrease of about 0.6% flow after initial plant startup. Since Watts Bar RCPs had operated for a considerable time prior to plant startup and prior to the Cycle 1 baseline Δp measurement, it was concluded that the flow decrease caused by impeller smoothing occurred prior to the Cycle 1 measurement. For this analysis, the flow decrease due to impeller smoothing was not applied.

b. Steam Generator Tube Plugging: Per Table 6-1, the estimated tube plugging impact on flow was negligible until Cycle 5. The estimated tube plugging impact on the Cycle 5 flow was –0.25% flow.

c. Fuel Design Changes: There have been no significant fuel design changes during plant operation. Therefore, no fuel design change flow impacts are listed on Table 6-1.

The Cycle 1 best estimate flow was defined to be [ ]$^{+a,c}$ Considering the hydraulic changes, the overall impact was estimated to be [ ]$^{+a,c}$ The flow trend defined on Table 6-1 is plotted on Figure 6-1, with Cycle 1 flow specified as the baseline cycle flow at 100% flow.

Based on the procedure defined in Section 4.2, the Cycle 5 estimated flow (CEF) was [ ]$^{+a,c}$ so the estimated flow ratio (R') for Cycle 5 and future cycles with no hydraulics changes is [ ]$^{+a,c}$

6.3 EVALUATION OF ELBOW TAP FLOWS

Elbow tap Δp measurements were obtained from all 12 Δp transmitters. The Δps expressed in inches of water at 100% flow and about 100% power are listed on Table 6-2. Also listed are the averages of the 12 Δps and the specific volume at the average cold leg temperature for each cycle. The Cycle 1 elbow tap Δps defined a baseline elbow tap flow coefficient (B) of [ ]$^{+a,c}$ Table 6-2 lists elbow tap loop and total flows for Cycles 2 to 5, normalized to the flow in Cycle 1, and Figure 6-1 plots the normalized flows in percent of baseline flow for comparison with best estimate and calorimetric flows.

The RTD Bypass System was removed prior to Cycle 1 and was replaced with thermowell RTDs. This modification has no effect on this analysis since it was performed prior to the Cycle 1 measurement.

6.4 EVALUATION OF CALORIMETRIC FLOWS

[

]+a,c

To avoid an LLLP impact, Requirement (d) disallows cycles with differences between 2nd row and outer row fuel assembly average powers that exceed 47%, unless the cycles are required to obtain the required number of flows. [

]+a,c

[

]+a,c

[

]+a,c

[

]+a,c

The total measured flow for each cycle, defined in percent of the Cycle 1 calorimetric flow on Table 6-3, is plotted on Figure 6-1 to compare with best estimate and elbow tap flow trends.

6.5 FLOW COMPARISONS

[

]+a,c

[

]+a,c

6.6 POWER/FLOW CORRELATION FOR WATTS BAR

[

]+a,c

TABLE 6-1
BEST ESTIMATE FLOW SUMMARY

+a,c

TABLE 6-2
ELBOW TAP ΔP SUMMARY

+a,c

Differential Pressures in Inches of Water

TABLE 6-3
CALORIMETRIC FLOW SUMMARY

+a,c

+a,c

FIGURE 6-1 FLOW COMPARISONS

+a,c

FIGURE 6-2 FLOW BIAS VERSUS POWER DIFFERENCE

7.0 ELBOW TAP FLOW MEASUREMENT LICENSING CONSIDERATIONS

7.1 Background

Plant Technical Specifications require that an RCS total flow measurement be performed after each refueling (an 18 month nominal, 22.5 months maximum surveillance interval) to verify that sufficient RCS flow is available to satisfy the safety analysis assumptions. This surveillance is normally performed at the beginning of each operating cycle. Technical Specifications also require that a qualitative RCS flow verification (i.e., channel check) be performed every 12 hours during Mode 1. These surveillances ensure RCS flow is maintained within the assumed safety analysis value, i.e., Minimum Measured Flow (MMF).

The refueling RCS flow surveillance is typically satisfied by a secondary power calorimetric-based RCS flow measurement and the 12 hour RCS flow surveillance is satisfied by control board RCS flow indicator or plant process computer readings using inputs from the RCS elbow tap Δp channels. These surveillances and the RCS Low Flow reactor trip are interrelated, since the calorimetric RCS flow measurement is used to correlate elbow tap Δp measurements to flow, and the flow at the Δp setpoint for the RCS Low Flow reactor trip (which is verified to be at or above the flow assumed in the safety analysis). The control board indication and process computer output is normalized to the calorimetric flow. The uncertainty associated with the refueling precision calorimetric is, therefore, included in the uncertainty calculations for the surveillance criterion and the RCS Low Flow trip.

The purpose of this evaluation is to support the use of elbow tap Δp measurements as an alternate method for performing the refueling RCS flow surveillance. Many plants in recent cycles have experienced apparent decreases in flow rates, which have been attributed to variations in hot leg streaming, as discussed in previous sections of this document. These effects directly impact the hot leg temperatures used in the precision calorimetric, resulting in the calculation of apparently low RCS flow rates. In using the elbow tap Δp method, the RCS elbow tap measurements are correlated (as described in Section 4.2) to a precision calorimetric measurement performed during Cycles 1 to 3 when hot leg streaming was unaffected by core low leakage loading patterns.

7.2 Supporting Calculations

In order to implement the elbow tap Δp method of measuring RCS flow, calculations must be performed to determine the uncertainty associated with the precision RCS flow calorimetric for the baseline cycle(s). These calculations must account for the plant instrumentation, test equipment, and procedures, which were in place at the time the calorimetric was performed.

In addition, uncertainty calculations must be performed for the indicated RCS flow (computer and/or control board indication) and the RCS low flow reactor trip. These calculations must reflect the correlation of the elbow taps to the baseline precision RCS flow calorimetrics noted above. Additional instrument uncertainties are required to reflect this correlation.

Appendix A contains uncertainty calculations that were performed using Watts Bar plant-specific inputs.

These uncertainty calculations have confirmed the acceptability of the Watts Bar plant specific safety analyses and associated protection and/or control system setpoints when periodic surveillance is performed via use of control board or plant process computer indication on a 22.5 month surveillance interval basis. The RCS total flow uncertainty due to the elbow tap Δp method has been determined when utilizing the control board or plant process computer indication. The calculated uncertainties are bounding by the uncertainties assumed in the Westinghouse Revised Thermal Design Procedure (RTDP) (currently 2.0% flow), which are used in deriving the Technical Specifications reactor core safety limits and the corresponding DNB limits. The low flow reactor trip setpoint uncertainty has increased somewhat but does not require a change to Technical Specifications trip setpoint (90.0% flow) or to the current Safety Analysis Limit (87.0% flow) due to the availability of margin in the uncertainty calculation. As a result of the increased uncertainties there is a change to the recommended Allowable Value as noted in Appendix B, Attachment 1 of this document.

7.3 Potential Document Impacts

The Watts Bar Technical Specifications are affected in three areas:

1) Specification 3.3.1, Table 3.3.1-1, Item 10, Reactor Coolant Flow-Low (Allowable Value magnitude changed to reflect the uncertainty calculation results).

2) Specification 3.4.1 (Surveillance Requirement 3.4.1.4 is modified to reflect the use of the elbow tap Δp method) and

3) The associated Bases for this specification (to include a description of the elbow tap Δp method of flow measurement and to note the indication sources).

Appendix B contains a markup of the Watts Bar Technical Specifications. This appendix also contains the 50.92 input for licensing documentation purposes.

In the case of the Watts Bar specific instrument uncertainty analyses shown in Appendix A, the RCS flow uncertainty associated with the elbow tap Δp method (when indication is by utilization of control board meters or the plant process computer) was less than or equal to the current Technical Specification value. RCS low flow reactor trip setpoint uncertainty calculations also verify that the current trip setpoint and Safety Analysis Limit remain valid.

APPENDIX A

INDICATED RCS FLOW

AND

REACTOR COOLANT FLOW - LOW REACTOR TRIP

INSTRUMENT UNCERTAINTIES

UNCERTAINTY CALCULATION ASSUMPTIONS

1. Elbow Tap Measurement is performed at approximately 90 - 100 % RTP at BOC, with the plant at 100% nominal flow.

2. Elbow Tap Measurement is typically performed with all twelve channels of analog output of the control board meters or digital output of the plant computer at BOC. To provide for one channel on each loop out of service for continuing surveillance, eight channels are assumed for the statistical uncertainty calculation.

3. Elbow Tap measurement is performed with Tavg and Pressurizer Pressure within the accuracy of their respective automatic control systems (±6.0 °F, ±70.0 psi).

TABLE A-1
BASELINE FLOW CALORIMETRIC
INSTRUMENTATION UNCERTAINTIES

(% Span)	T_{FW}	P_{FW}	ΔP_{FW}	P_{STM}	T_{HOT}	T_{COLD}	P_{PRZ}	
Sensor								+a,c
SCA =								
SM&TE =								
SRA =								
SPE =								
STE =								
SD =								
BIAS =								
Eagle-21 Racks								
RCA =								
RM&TE =								
RTE =								
RD =								
READ =								
Computer								
COMPDRIFT =								
COMPCAL =								
COMPM&TE =								
COMPTE =								
HPDAC =								
HPDACM&TE =								
CSA =								
# Inst Used								
	°F	psia	% ΔP	psia	°F	°F	psia	
INST SPAN	150	1300	106.5	1300	120^{+}	120^{+}	800	
INST UNC. (RANDOM) =								+a,c
INST UNC. (BIAS) =								
NOMINAL# =	432.9	1048.1	91.5	1014.9	612.3	559.7	2259.5	

+ T_{AVG} span
# Nominal parameter values are from the Cycle 1 measurement

TABLE A-2
FLOW CALORIMETRIC SENSITIVITIES

FEEDWATER FLOW		
FA		+a,c
TEMPERATURE	=	
MATERIAL	=	
DENSITY		
TEMPERATURE	=	
PRESSURE	=	
ΔP	=	
FEEDWATER ENTHALPY		
TEMPERATURE	=	
PRESSURE	=	
h_S	=	
h_F	=	
Δh(SG)	=	
STEAM ENTHALPY		+a,c
PRESSURE	=	
MOISTURE	=	
HOT LEG ENTHALPY		
TEMPERATURE	=	
PRESSURE	=	
h_H	=	
h_C	=	
Δh(Vessel)	=	
$Cp(T_H)$	=	
COLD LEG ENTHALPY		+a,c
TEMPERATURE	=	
PRESSURE	=	
$Cp(T_C)$	=	
COLD LEG SPECIFIC VOLUME		+a,c
TEMPERATURE	=	
PRESSURE	=	

* Sensitivity values are from the Cycle 1 measurement

TABLE A-3

CALORIMETRIC RCS FLOW MEASUREMENT UNCERTAINTIES

COMPONENT	INSTRUMENT ERROR	FLOW UNCERTAINTY#
FEEDWATER FLOW		
VENTURI		
THERMAL EXPANSION COEFFICIENT		
TEMPERATURE		
MATERIAL		
DENSITY (ρ)		
TEMPERATURE		
PRESSURE		
ΔP		
FEEDWATER ENTHALPY (h)		
TEMPERATURE		
PRESSURE		
STEAM ENTHALPY (h)		
PRESSURE		
MOISTURE		
NET PUMP HEAT ADDITION		
HOT LEG ENTHALPY (h)		
TEMPERATURE		
STREAMING, RANDOM		
STREAMING, SYSTEMATIC		
PRESSURE		
COLD LEG ENTHALPY (h)		
TEMPERATURE		
PRESSURE		
COLD LEG SPECIFIC VOLUME (υ)		
TEMPERATURE		
PRESSURE		

+a,c

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

Uncertainty values are from the Cycle 1 measurement

TABLE A-3 (Continued)
CALORIMETRIC RCS FLOW MEASUREMENT UNCERTAINTIES

+a,c

COMPONENT	FLOW UNCERTAINTY
	+a,c
BIAS VALUES	
PRESSURIZER PRESSURE	
h - HOT LEG	
h - COLD LEG	
υ - COLD LEG	
FLOW BIAS TOTAL VALUE	
4 LOOP UNCERTAINTY (With Appropriate BIAS)	

TABLE A-4

ELBOW TAP FLOW UNCERTAINTY (Control Board Indication)

INSTRUMENT UNCERTAINTIES

	% ΔP SPAN	% FLOW
		+a,c
Sensor		
PMA =		
PEA =		
SCA =		
SM&TE =		
SRA =		
SPE =		
STE =		
SD =		
BIAS =		
Eagle-21 Racks		
EAI and EAO Cards		
RCA =		
RM&TE =		
RTE =		
RD =		
Control Board Meter		
RCA =		
M&TE =		
RTE =		
RD =		
READABILITY =		
FLOW CALORIMETRIC BIAS =		
FLOW CALORIMETRIC =		

INSTRUMENT SPAN = 110.0

NUMBER TAPS PER LOOP = 2

4 LOOP RCS FLOW UNCERTAINTY = 1.9 % FLOW

TABLE A-4 (Continued)

ELBOW TAP FLOW UNCERTAINTY (Control Board Indication)

+a,c

TABLE A-5

ELBOW TAP FLOW UNCERTAINTY (Process Computer)

INSTRUMENT UNCERTAINTIES

	% ΔP SPAN	% FLOW
		+a,c
Sensor		
PMA =		
PEA =		
SCA =		
SM&TE =		
SRA =		
SPE =		
STE =		
SD =		
BIAS =		
Eagle-21 Racks		
EAI and EAO Cards		
RCA =		
RM&TE =		
RTE =		
RD =		
Plant Computer		
RCA =		
M&TE =		
RTE =		
RD =		
READABILITY =		
FLOW CALORIMETRIC BIAS =		
FLOW CALORIMETRIC =		

INSTRUMENT SPAN = 110.0

NUMBER TAPS PER LOOP = 2

4 LOOP RCS FLOW UNCERTAINTY = 1.7 % FLOW

TABLE A-5 (Continued)

ELBOW TAP FLOW UNCERTAINTY (Process Computer)

+a,c

TABLE A-6
LOW FLOW REACTOR TRIP

	% ΔP SPAN	% FLOW SPAN
		+a,c
PMA1 =		
PMA2 =		
PEA =		
SCA =		
M&TE =		
SPE =		
STE =		
SD =		
BIAS =		
RCA =		
M&TE =		
RTE =		
RD =		
BIAS =		

INSTRUMENT RANGE =	0 to 110.0 % FLOW
FLOW SPAN =	110.0 % FLOW
SAFETY ANALYSIS LIMIT =	87.0 % FLOW
NOMINAL TRIP SETPOINT =	90.0 % FLOW
TA =	2.7 % FLOW SPAN
	+a,c
CSA =	
MAR =	

+a,c

APPENDIX B

WATTS BAR 50.92 AND SUGGESTED MODIFICATIONS TO TECHNICAL SPECIFICATIONS

ATTACHMENT 1

SIGNIFICANT HAZARDS CONSIDERATION EVALUATION

1) NUCLEAR PLANT: WATTS BAR UNIT 1

2) SUBJECT: ELBOW TAP FLOW MEASUREMENT

3) TECHNICAL SPECIFICATIONS CHANGED:

See Section 2 below for summary of changes

4) A written evaluation of the significant hazards consideration, in accordance with the three factor test of 10CFR50.92, of a proposed license amendment to implement the subject change has been prepared and is attached. On the basis of the evaluation the checklist below has been completed.

Will operation of the plant in accordance with the proposed amendment:

4.1)	Yes	No X	Involve a significant increase in the probability or consequences of an accident previously evaluated?
4.2)	Yes	No X	Create the possibility of a new or different kind of accident from any accident previously evaluated?
4.3)	Yes	No X	Involve a significant reduction in a margin of safety?

5) REFERENCE DOCUMENTS:

1) WCAP-14738, Rev. 1, "Westinghouse Revised Thermal Design Procedure Instrument Uncertainty Methodology for Tennessee Valley Authority- Watts Bar Unit 1 - 1.4% Uprate to 3475 MW NSSS Power," 8/00.

2) WCAP-12096, Rev. 8, "Westinghouse Setpoint Methodology for Protection Systems Watts Bar Unit 1 Eagle 21 Version," 3/98.

3) WCAP-16067, Rev. 0, "RCS Flow Measurement Using Elbow Tap Methodology at Watts Bar Unit 1," 4/03.

10CFR50.92 EVALUATION

Pursuant to 10CFR50.92 each application for amendment to an operating license must be reviewed to determine if the proposed change involves a Significant Hazards Consideration. The amendment, as defined below, describing the Technical Specification (T/S) change associated with the change has been reviewed and deemed not to involve Significant Hazards Considerations. The basis for this determination follows.

1.0 Background

The refueling RCS flow surveillance (18 month nominal fuel cycle, 22.5 months maximum surveillance interval) is typically satisfied by a secondary power calorimetric-based RCS flow measurement. Many plants in recent cycles have experienced apparent decreases in flow rates, which have been attributed to variations in hot leg streaming. These effects directly impact the hot leg temperatures used in the precision calorimetric, resulting in the calculation of apparently low RCS flows. In using the elbow tap Δp method, the RCS loop elbow tap measurements are correlated to precision calorimetric measurements performed during Cycles 1 to 3 when hot leg streaming was unaffected by core Low Leakage Loading Patterns (LLLPs).

Similarly, Watts Bar in recent cycles has experienced apparent decreases in flow rates, which have been attributed to variations in hot leg streaming effects. These effects directly impact the hot leg temperatures used in the precision calorimetric, resulting in the calculation of low RCS flow rates. The apparent flow reduction has become more pronounced in fuel cycles that have implemented aggressive LLLPs. Evidence that the flow reduction was apparent, but not actual, was provided by elbow tap measurements. The results of this evaluation, including a detailed description of the hot leg streaming phenomenon, are documented in WCAP-16067 Rev.0, "RCS Flow Measurement Using Elbow Tap Methodology at Watts Bar Unit 1."

Watts Bar intends to begin using an alternate method of measuring flow using the elbow tap Δp measurements as described in the above noted WCAP. For this alternate method, the RCS elbow tap measurements are correlated to three precision calorimetric measurements performed during Cycles 1, 2, and 3 when hot leg streaming was unaffected by core LLLPs.

The purpose of this evaluation is to assess the impact of using the elbow tap Δp measurements as an alternate method for performing the refueling RCS flow surveillance on the licensing basis and demonstrate that it will not adversely affect the subsequent safe operation of the plant. This evaluation supports the conclusion that implementation of the elbow tap Δp measurement as an alternate method of determining RCS total flow rate does not represent a significant hazards consideration as defined in 10CFR50.92.

2.0 Proposed Change

The following Technical Specification and Bases changes are proposed as a result of use of the elbow tap Δp method to determine RCS total flow:

1. A change to Surveillance Requirement 3.4.1.4 on page 3.4-2 of the Technical Specifications to include the elbow tap method.

Basis: The Technical Specifications are changed to allow for the elbow tap Δp measurement as an alternate method of determining RCS total flow rate.

2. A change to the Technical Specification Bases section on page B 3.4-2 to add the following Insert A:

   Insert A: Use of the elbow tap Δp methodology to measure RCS flow rate results in a measurement uncertainty of *±1.7 % flow (process computer) or ±1.9 % flow (control board indication) based on the utilization of eight elbow taps correlated to the three baseline precision heat balance measurements of Cycles 1, 2, and 3. Correlation of the flow indication channels with this previously performed heat balance measurement is documented in Reference 3. Use of this method provides an alternative to performance of a precision RCS flow calorimetric.*

   Basis: This text has been added to the bases to describe the elbow tap Δp measurement as an alternate method of determining RCS total flow rate, and provide a reference to the topical report.

3. A change to the Technical Specification Bases section on page B 3.4-5 (SR 3.4.1.4) to add the following underlined information:

   "Measurement of RCS total flow rate by performance of a precision calorimetric heat balance ***or by using the elbow tap ΔP methodology described in Reference 3"***

   Basis: This text has been added to allow for the elbow tap Δp measurement as an alternate method of determining RCS total flow rate.

4. A change to the Technical Specification Bases section on page B 3.4-5 (References) to add Insert B for the Elbow Tap methodology WCAP reference as follows:

   Insert B:

   3. WCAP-16067, Rev. 0, "RCS Flow Measurement Using Elbow Tap Methodology at Watts Bar Unit 1," April 2003.

   Basis: This text has been added to provide a reference to the topical report.

5. A change to the Technical Specification Bases section on page B 3.3-24 to change from "% thermal design flow adjusted for uncertainties" to "% indicated loop" flow.

   Basis: Westinghouse recommends the use of the term "indicated loop flow," which is consistent with the wording found in the Technical Specifications for Seabrook (Amendment 77, page 2-5), Shearon Harris (Amendment 107, page 2-5), Comanche Peak 1 & 2 (Amendment 64, page 3.3-17) and Kewaunee (Amendment 162, page TS 2.3-3). The intent is to set the Nominal Trip Setpoint at greater than or equal to 90 % of the indicated flow for a given loop. This addresses the potential effect of flow asymmetry that may exist between loops. Westinghouse identified the potential effect of Reactor Coolant Loop Flow Asymmetry in Nuclear Safety Advisory Letter NSAL-00-008, 5/22/00.

6. A change to the Technical Specification Bases section on page B 3.3-25 to change from "% thermal design flow adjusted for uncertainties" to "% indicated loop" flow.

   Basis: Westinghouse recommends the use of the term "indicated loop flow," which is consistent with the wording found in the Technical Specifications for Seabrook (Amendment 77, page 2-5), Shearon Harris (Amendment 107, page 2-5), Comanche Peak 1 & 2 (Amendment 64, page 3.3-17) and Kewaunee (Amendment 162, page TS 2.3-3). The intent is to set the Nominal Trip Setpoint at greater than or equal to 90 % of the indicated flow for a given loop. This addresses the potential effect of flow asymmetry that may exist between loops. Westinghouse identified the potential effect of Reactor Coolant Loop Flow Asymmetry in Nuclear Safety Advisory Letter NSAL-00-008, 5/22/00.

7. A change to the Technical Specification Table 3.3.1-1 (page 3.3-17) "Reactor Trip System Instrumentation," to revise the RCS Flow – Low trip Allowable Value from 89.6% flow to 89.7% flow.

   Basis: The Allowable Value will be revised to reflect a change in calculated uncertainties.

8. A change to the Technical Specification Bases section on page B 3.3-4 to change the reference for the Reactor Coolant Flow-Low uncertainties for the elbow tap Δp method to the elbow tap methodology WCAP 16067, Rev. 0 which will be noted as reference 13.

   Basis: The explicit uncertainties for the Reactor Coolant Flow –Low for use with the elbow tap Δp method are defined in WCAP 16067, Rev. 0 which is a change from WCAP 12096, Rev. 7 which is identified as reference 6.

9. A change to the Technical Specification Bases section on page B 3.3-5 to add the reference for the Reactor Coolant Flow-Low uncertainties for the elbow tap Δp method to the elbow tap methodology WCAP 16067, Rev. 0 which will be noted as reference 13.

   Basis: The explicit uncertainties for the Reactor Coolant Flow –Low for use with the elbow tap Δp method are defined in WCAP 16067, Rev. 0 which is a change from WCAP 12096, Rev. 7 which is identified as reference 6.

10. A change to the Technical Specification Bases section on page B 3.3-63 to add a reference 13 for WCAP 16067, Rev. 0.

    Basis: A reference 13 will be added to support the change to page B 3.3-4. The reference will be WCAP 16067, Rev. 0 and will appears as:

    Insert C:

    13. WCAP-16067, Rev. 0, "RCS Flow Measurement Using Elbow Tap Methodology at Watts Bar Unit 1," April 2003.

The implementation of the elbow tap Δp measurement as an alternate method for measuring RCS flow represents a change to the Watts Bar Technical Specifications and is evaluated below.

3.0 Evaluation

Use of the elbow tap Δp method to determine RCS total flow requires that the Δp measurements for the present cycle be correlated to the precision calorimetric flow measurement which was performed during the baseline cycles (Cycles 1, 2, and 3). A calculation has been performed to determine the uncertainty in the RCS total flow using this method. This calculation includes the uncertainty associated with the cycle 1 measurement, which had slightly larger uncertainties than the average of the three RCS total flow baseline calorimetric measurements, as well as uncertainties associated with Δp transmitters and indication via control board meters or the plant process computer. The uncertainty calculation performed for this method of flow measurement is consistent with the methodology recommended by the NRC (NUREG/CR-3659, PNL-4973, 2/85). The only significant differences are the averaging of the three baseline RCS flow calorimetrics and the assumption of correlation to a previously performed RCS flow calorimetric. However, this has been accounted for by utilization of the larger cycle 1 calorimetric uncertainties and by the addition of instrument uncertainties previously considered to be zeroed out by the assumption of normalization to a calorimetric performed each cycle. Based on these calculations, the uncertainty on the RCS flow measurement using the elbow tap Δp method is 1.9% flow (control board indication) and 1.7% flow (process computer) which results in a minimum RCS total flow of 379,500 gpm. This is lower than the current technical specification requirement of 380,000, which must be measured via indication with the control board meters or the plant process computer at 90% – 100% RTP. Therefore the elbow tap Δp method is acceptable relative to the currently required MMF.

The calculations are documented in Tables A-1 through A-5. The specific calculations performed were: Precision RCS Flow Calorimetrics for the baseline cycles (Cycles 1, 2, and 3), Indicated RCS Flow (either control board meters or the plant process computer), and the Reactor Coolant Flow - Low reactor trip. The calculations for Indicated RCS Flow and Reactor Coolant Flow - Low reactor trip reflect correlation of the elbow taps to the baseline precision RCS Flow Calorimetric. As discussed above, additional instrument uncertainties were included for this correlation.

The uncertainty associated with the RCS Flow - Low trip increased slightly. It was determined that due to the availability of margin in the uncertainty calculation, no change was necessary to either the Trip Setpoint (90.0% flow) or to the current Safety Analysis Limit (87.0% flow) to accommodate this increase.

Since the flow uncertainty did not increase over the currently analyzed value, no additional evaluations of the reactor core safety limits must be performed. In addition, it was determined that the current Minimum Measured Flow (MMF) required by the plant technical specifications (380,000 gpm, based on 2.0% measurement uncertainty) bounds the required MMF used in the safety analyses and/or calculated for the elbow tap Δp method.

Based on these evaluations, the proposed change would not invalidate the conclusions presented in the FSAR.

1. Does the proposed modification involve a significant increase in the probability or consequences of an accident previously evaluated?

   An evaluation determined that the probability of an accident will not increase. Sufficient margin exists to account for all reasonable instrument uncertainties; therefore, no changes to installed equipment or hardware in the plant are required, thus the probability of an accident occurring remains unchanged.

The initial conditions for all accident scenarios modeled are the same and the conditions at the time of trip, as modeled in the various safety analyses are the same. Therefore, the consequences of an accident will be the same as those previously analyzed.

2. Does the proposed modification create the possibility of a new or different kind of accident from any accident previously evaluated?

   No new accident scenarios have been identified. Operation of the plant will be consistent with that previously modeled, i.e., the time of reactor trip in the various safety analyses is the same, thus plant response will be the same and will not introduce any different accident scenarios that have not been evaluated.

3. Does the proposed modification involve a significant reduction in a margin of safety?

   The proposed modification reflects changes due to the method used to verify RCS flow at the beginning of each cycle. However, no changes to the Safety Analysis assumptions were required; therefore, the margin of safety will remain the same.

4.0 Conclusion

Based on the preceding information, it has been determined that this proposed change to allow an alternate RCS total flow measurement based on elbow tap Δp measurements does not involve a Significant Hazards Consideration as defined in 10CFR50.92(c).

ATTACHMENT 2

WATTS BAR TECHNICAL SPECIFICATION MARKUPS

Table 3.3.1-1 (page 3 of 9)
Reactor Trip System Instrumentation

	FUNCTION	APPLICABLE MODES OR OTHER SPECIFIED CONDITIONS	REQUIRED CHANNELS	CONDITIONS	SURVEILLANCE REQUIREMENTS	ALLOWABLE VALUE	NOMINAL TRIP SETPOINT
9.	Pressurizer Water Level-High	1(f)	3	X	SR 3.3.1.1 SR 3.3.1.7 SR 3.3.1.10	≤ 92.7% span	92% span
10.	Reactor Coolant Flow-Low					≥ 89.7% flow	
	a. Single Loop	1(g)	3 per loop	N	SR 3.3.1.1 SR 3.3.1.7 SR 3.3.1.10 SR 3.3.1.15	≥ 89.6% flow	90% flow
	b. Two Loops	1(h)	3 per loop	X	SR 3.3.1.1 SR 3.3.1.7 SR 3.3.1.10 SR 3.3.1.15	≥ 89.6% flow ≥ 89.7% flow	90% flow
11.	Undervoltage RCPs	1(f)	1 per bus	M	SR 3.3.1.9 SR 3.3.1.10 SR 3.3.1.15	≥ 4734 V	4830 V
12.	Underfrequency RCPs	1(f)	1 per bus	M	SR 3.3.1.9 SR 3.3.1.10 SR 3.3.1.15	≥ 56.9 Hz	57.5 Hz

(continued)

(f) Above the P-7 (Low Power Reactor Trips Block) interlock.

(g) Above the P-8 (Power Range Neutron Flux) interlock.

(h) Above the P-7 (Low Power Reactor Trips Block) interlock and below the P-8 (Power Range Neutron Flux) interlock.

SURVEILLANCE REQUIREMENTS

	SURVEILLANCE	FREQUENCY
SR 3.4.1.1	Verify pressurizer pressure is ≥ 2214 psig.	12 hours
SR 3.4.1.2	Verify RCS average temperature is ≤ 593.2°F.	12 hours
SR 3.4.1.3	Verify RCS total flow rate is ≥ 380,000 gpm (process computer or control board indication).	12 hours
SR 3.4.1.4	--------------------NOTE-------------------- Required to be performed within 24 hours after ≥ 90% RTP. --	
	Verify by precision heat balance that RCS total flow rate is ≥ 380,000 gpm.	18 months

OR elbow TAP ΔP meThod

BASES

BACKGROUND

Signal Process Control and Protection System (continued)

input failure to the control system, which may then require the protection function actuation, and a single failure in the other channels providing the protection function actuation. Again, a single failure will neither cause nor prevent the protection function actuation. These requirements are described in IEEE-279-1971 (Ref. 4). The actual number of channels required for each unit parameter is specified in Reference 2.

Two logic trains are required to ensure no single random failure of a logic train will disable the RTS. The logic trains are designed such that testing required while the reactor is at power may be accomplished without causing trip.

Trip Setpoints and Allowable Values

The Trip Setpoints are the nominal values at which the bistables, setpoint comparators, or contact trip outputs are set. Any bistable or trip output is considered to be properly adjusted when the "as left" value is within the band for CHANNEL CALIBRATION accuracy.

The Trip Setpoints used in the bistables, setpoint comparators, or contact trip outputs are based on the analytical limits stated in Reference 6. The selection of these Trip Setpoints is such that adequate protection is provided when all sensor and processing time delays are taken into account. To allow for calibration tolerances, instrumentation uncertainties, instrument drift, and severe environment errors for those RTS channels that must function in harsh environments as defined by 10 CFR 50.49 (Ref. 5), the Trip Setpoints specified in Table 3.3.1-1 in the accompanying LCO are conservatively adjusted with respect to the analytical limits. A detailed description of the methodology used to calculate the Trip Setpoints, including their explicit uncertainties, is provided in the "Westinghouse Setpoint Methodology for Protection Systems, Watts Bar 1 and 2" (Ref. 6). The Source Range and Intermediate Range Neutron detector setpoints are based on the requirements and recommendations of ISA 67.04 (Reference 10) standard and recommended practice. The actual nominal

The uncertainties for Reactor Coolant Flow-Low Function using the elbow tap Δp flow measurement methodology are provided in (Ref. 13)

(continued)

BACKGROUND

Trip Setpoints and Allowable Values (continued)

Trip Setpoint entered into the bistable/comparator is more conservative than that specified by the Allowable Value to account for changes in random measurement errors detectable by a COT. One example of such a change in measurement error is drift during the surveillance interval. If the measured setpoint does not exceed the Allowable Value, the bistable is considered OPERABLE.

Setpoints in accordance with the Allowable Value ensure that SLs are not violated during AOOs (and that the consequences of DBAs will be acceptable, providing the unit is operated from within the LCOs at the onset of the AOO or DBA and the equipment functions as designed). Note that in the accompanying LCO 3.3.1, the Trip Setpoints of Table 3.3.1-1 are the LSSS.

Each channel of the process control equipment can be tested on line to verify that the signal or setpoint accuracy is within the specified allowance requirements of Reference 2. Once a designated channel is taken out of service for testing, a simulated signal is injected in place of the field instrument signal. The process equipment for the channel in test is then tested, verified, and calibrated. SRs for the channels are specified in the SRs section.

The Process Protection System is designed to permit any one channel to be tested and maintained at power in a bypassed mode. If a channel has been bypassed for any purpose, the bypass is continuously indicated in the control room.

References 6 and 13

The Trip Setpoints and Allowable Values listed in Table 3.3.1-1 are based on the methodology described in ~~Reference 6~~ and ISA 67.04 (Ref. 10), which incorporates all of the known uncertainties applicable for each channel. The magnitudes of these uncertainties are factored into the determination of each Trip Setpoint. All field sensors and signal processing equipment for these channels are assumed to operate within the allowances of these uncertainty magnitudes.

(continued)

APPLICABLE SAFETY ANALYSES, LCO, and APPLICABILITY

a. Reactor Coolant Flow-Low (Single Loop) (continued)

the core. In MODE 1 below the P-8 setpoint, a loss of flow in two or more loops is required to actuate a reactor trip (Function 10.b) because of the lower power level and the greater margin to the design limit DNBR.

The Reactor Coolant Flow-Low Trip Setpoint and Allowable Value are specified in % ~~thermal design~~ Indicated Loop flow ~~adjusted for uncertainties (95,000 gpm)~~, however, the Eagle-21™ values entered through the MMI are specified in an equivalent % differential pressure.

b. Reactor Coolant Flow-Low (Two Loops)

The Reactor Coolant Flow—Low (Two Loops) trip Function ensures that protection is provided against violating the DNBR limit due to low flow in two or more RCS loops while avoiding reactor trips due to normal variations in loop flow.

Above the P-7 setpoint and below the P-8 setpoint, a loss of flow in two or more loops will initiate a reactor trip. Each loop has three flow detectors to monitor flow. The flow signals are not used for any control system input.

The LCO requires three Reactor Coolant Flow—Low channels per loop to be OPERABLE.

In MODE 1 above the P-7 setpoint and below the P-8 setpoint, the Reactor Coolant Flow—Low (Two Loops) trip must be OPERABLE. Below the P-7 setpoint, all reactor trips on low flow are automatically blocked since no conceivable power distributions could occur that would cause a DNB concern at this low power level. Above the P-7 setpoint, the reactor trip on low flow in two or more RCS loops is automatically enabled. Above the P-8 setpoint, a loss of flow in any one loop will actuate a reactor trip because of the higher power level and the reduced margin to the design limit DNBR.

(continued)

APPLICABLE SAFETY ANALYSES, LCO, and APPLICABILITY

b. Reactor Coolant Flow-Low (Two Loops) (continued)

The Reactor Coolant Flow-Low Trip Setpoint and Allowable Value are specified in % ~~thermal design~~ flow ~~adjusted for uncertainties (95,000 gpm)~~. however, the Eagle-21™ values entered through the MMI are specified in an equivalent % differential pressure.

INDICATED LOOP

11. Undervoltage Reactor Coolant Pumps

The Undervoltage RCPs reactor trip Function ensures that protection is provided against violating the DNBR limit due to a loss of flow in two or more RCS loops. The voltage to each RCP is monitored. Above the P-7 setpoint, a loss of voltage detected on two or more RCP buses will initiate a reactor trip. This trip Function will generate a reactor trip before the Reactor Coolant Flow-Low (Two Loops) Trip Setpoint is reached. The loss of voltage in two loops must be sustained for a length of time equal to or greater than that set in the time delay. Time delays are incorporated into the Undervoltage RCPs channels to prevent reactor trips due to momentary electrical power transients.

The LCO requires one Undervoltage RCP channel per bus to be OPERABLE.

In MODE 1 above the P-7 setpoint, the Undervoltage RCP trip must be OPERABLE. Below the P-7 setpoint, all reactor trips on loss of flow are automatically blocked since no conceivable power distributions could occur that would cause a DNB concern at this low power level. Above the P-7 setpoint, the reactor trip on loss of flow in two or more RCS loops is automatically enabled.

12. Underfrequency Reactor Coolant Pumps

The Underfrequency RCPs reactor trip Function ensures that protection is provided against violating the DNBR limit due to a loss of flow in two or more RCS loops from a major network frequency disturbance. An underfrequency condition will slow down the pumps,

(continued)

BASES (continued)

REFERENCES

1. Watts Bar FSAR, Section 6.0, "Engineered Safety Features."

2. Watts Bar FSAR, Section 7.0, "Instrumentation and Controls."

3. Watts Bar FSAR, Section 15.0, "Accident Analysis."

4. Institute of Electrical and Electronic Engineers, IEEE-279-1971, "Criteria for Protection Systems for Nuclear Power Generating Stations," April 5, 1972.

5. 10 CFR Part 50.49, "Environmental Qualifications of Electric Equipment Important to Safety for Nuclear Power Plants."

6. WCAP-12096, Rev. 7, "Westinghouse Setpoint Methodology for Protection System, Watts Bar 1 and 2," March 1997.

7. WCAP-10271-P-A, Supplement 1, and Supplement 2, Rev. 1, "Evaluation of Surveillance Frequencies and Out of Service Times for the Reactor Protection Instrumentation System," May 1986 and June 1990.

8. Watts Bar Technical Requirements Manual, Section 3.3.1, "Reactor Trip System Response Times."

9. Evaluation of the applicability of WCAP-10271-P-A, Supplement 1, and Supplement 2, Revision 1, to Watts Bar.

10. ISA-DS-67.04, 1982, "Setpoint for Nuclear Safety Related Instrumentation Used in Nuclear Power Plants."

11. WCAP-13632-P-A Revision 2, "Elimination of Pressure Sensor Response Time Testing Requirements," January 1996

12. WCAP-14036-P-A, Revision 1, "Elimination of Periodic Protection Channel Response Time Tests," October 1998.

INSERT C

APPLICABLE SAFETY ANALYSES (continued)

result in meeting the DNBR criterion. This is the acceptance limit for the RCS DNB parameters. Changes to the unit that could impact these parameters must be assessed for their impact on the DNBR criteria. The transients analyzed for include loss of coolant flow events and dropped or stuck rod events. A key assumption for the analysis of these events is that the core power distribution is within the limits of LCO 3.1.7, "Control Bank Insertion Limits;" LCO 3.2.3, "AXIAL FLUX DIFFERENCE (AFD);" and LCO 3.2.4, "QUADRANT POWER TILT RATIO (QPTR)."

The pressurizer pressure limit of 2214 psig and the RCS average temperature limit of 593.2°F correspond to analytical limits of 2185 psig and 594.2°F used in the safety analyses, with allowance for measurement uncertainty.

The RCS DNB parameters satisfy Criterion 2 of the NRC Policy Statement.

LCO

This LCO specifies limits on the monitored process variables—pressurizer pressure, RCS average temperature, and RCS total flow rate—to ensure the core operates within the limits assumed in the safety analyses. Operating within these limits will result in meeting the DNBR criterion in the event of a DNB limited transient.

RCS total flow rate contains a measurement error of 1.6% (process computer) or 1.8% (control board indication) based on performing a precision heat balance and using the result to calibrate the RCS flow rate indicators. Potential fouling of the feedwater venturi, which might not be detected, could bias the result from the precision heat balance in a nonconservative manner. Therefore, a penalty of 0.1% for undetected fouling of the feedwater venturi raises the nominal flow measurement allowance to 1.7% (process computer) or 1.9% (control board indication).

Any fouling that might bias the flow rate measurement greater than 0.1% can be detected by monitoring and trending various plant performance parameters. If detected, either the effect of the fouling shall be quantified and compensated for in the RCS flow rate measurement or the venturi shall be cleaned to eliminate the fouling. The LCO numerical values for pressure, temperature, and flow rate are given for the measurement location and have been adjusted for instrument error.

INSERT A →

(continued)

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.4.1.4 *

OR by using the elbow tap Δp method described in Reference 3

Measurement of RCS total flow rate by performance of a precision calorimetric heat balance once every 18 months allows the installed RCS flow instrumentation to be calibrated and verifies the actual RCS flow rate is greater than or equal to the minimum required RCS flow rate.

The Frequency of 18 months reflects the importance of verifying flow after a refueling outage when the core has been altered, which may have caused an alteration of flow resistance.

This SR is modified by a Note that allows entry into MODE 1, without having performed the SR, and placement of the unit in the best condition for performing the SR. The Note states that the SR is not required to be performed until 24 hours after ≥ 90% RTP. This exception is appropriate since the heat balance requires the plant to be at a minimum of 90% RTP to obtain the stated RCS flow accuracies. The Surveillance shall be performed within 24 hours after reaching 90% RTP.

OR elbow tap Δp method

*Note: The accuracy of the instruments used for monitoring RCS pressure, temperature and flow rate is discussed in this Bases section under LCO (Ref. 2).

REFERENCES

1. Watts Bar FSAR, Section 15.0, "Accident Analysis," Section 15.2, "Normal Operation and Anticipated Transients," and Section 15.3.4, "Complete Loss Of Forced Reactor Coolant Flow."

2. Watts Bar Drawing 1-47W605-243, "Electrical Tech Spec Compliance Tables."

INSERT B

INSERT "A"

Use of the elbow tap Δp methodology to measure RCS flow rate results in a measurement uncertainty of ±1.7 % flow (process computer) or ±1.9 % flow (control board indication) based on the utilization of eight elbow taps correlated to the three baseline precision heat balance measurements of Cycles 1, 2, and 3. Correlation of the flow indication channels with this previously performed heat balance measurement is documented in Reference 3. Use of this elbow tap Δp method provides an alternative to performance of a precision RCS flow calorimetric.

INSERT "B"

3. WCAP-16067, Rev. 0, "RCS Flow Measurement Using Elbow Tap Methodology at Watts Bar Unit 1," April 2003.

INSERT "C"

13. WCAP-16067, Rev. 0, "RCS Flow Measurement Using Elbow Tap Methodology at Watts Bar Unit 1," April 2003.