August 21, 2003

Mr. Gregory M. Rueger
Senior Vice President, Generation and
Chief Nuclear Officer
Pacific Gas and Electric Company
Diablo Canyon Power Plant
P.O. Box 3
Avila Beach, CA 93424

SUBJECT: DIABLO CANYON POWER PLANT, UNIT NO. 1 AND UNIT NO. 2 – ISSUANCE OF AMENDMENT – REVISION OF TECHNICAL SPECIFICATION (TS) TABLE 3.3.1-1, "REACTOR TRIP SYSTEM INSTRUMENTATION," AND REVISED REACTOR COOLANT SYSTEM FLOW MEASUREMENT (TAC NOS. MB6760 AND MB6761)

Dear Mr. Rueger:

The U. S. Nuclear Regulatory Commission (Commission) has issued the enclosed Amendment No. 161 to Facility Operating License No. DPR-80 and Amendment No. 162 to Facility Operating License No. DPR-82 for the Diablo Canyon Power Plant, Unit Nos. 1 and 2, respectively. The amendments consist of changes to the Technical Specifications (TS) in response to your application dated August 27, 2002, as supplemented by letters dated May 15, June 26, and August 1, 2003.

The amendments revise TS Table 3.3.1-1, "Reactor Trip System Instrumentation" to replace the term "minimum measured flow per loop" to "measured loop flow" in the allowable value and nominal trip setpoint for the reactor coolant flow-low reactor trip function, and delete footnote (l). In addition, the amendments allow an alternate method for the measurement of reactor coolant system (RCS) total volumetric flow rate through measurement of the elbow tap differential pressure on the RCS primary cold legs.

A copy of the related Safety Evaluation is enclosed. The Notice of Issuance will be included in the Commission's next regular biweekly *Federal Register* notice.

Sincerely,

/RA/

Girija S. Shukla, Project Manager, Section 2
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket Nos. 50-275 and 50-323

Enclosures:
1. Amendment No. 161 to DPR-80
2. Amendment No. 162 to DPR-82
3. Safety Evaluation

cc w/encls: See next page

A copy of the related Safety Evaluation is enclosed. The Notice of Issuance will be included in the Commission's next regular biweekly *Federal Register* notice.

Sincerely,
/RA/
Girija S. Shukla, Project Manager, Section 2
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket Nos. 50-275 and 50-323

Enclosures: 1. Amendment No. 161 to DPR-80
2. Amendment No. 162 to DPR-82
3. Safety Evaluation

cc w/encls: See next page

DISTRIBUTION:
PUBLIC
PDIV-2 Reading
RidsNrrDlpmLpdiv (HBerkow)
DDuvigneaud (PDIV-2)
RidsNrrPMGShukla
RidsNrrLAEPeyton
RidsOgcRp
RidsAcrsAcnwMailCenter
RidsRgn4MailCenter (AHowell)
GHill (4)
WBeckner (NRR/DRIP/RORP)
Glenn Kelly (NRR/DSSA/SPSB)

Package No.: ML032380205
Tech Spec Page No.: ML032380435 NRR-100
ADAMS Accession No.: ML032380158 *SE Memo NRR-058

OFFICE	PDIV-2/INT	PDIV-2/PM	PDIV-2/LA	SRXB*
NAME	GShukla for DDuvigneaud	GShukla	EPeyton	JUhle
DATE	8/8/03	8/8/03	8/8/03	7/14/03

OFFICE	OGC NLO w/changes	PDIV-2/SC
NAME	SCole	JNDonohew for SDembek
DATE	8/14/03	8/21/03

DOCUMENT NAME: G:\PDIV-2\DiabloCanyon\amd-mb6760,61.wpd
OFFICIAL RECORD COPY

Diablo Canyon Power Plant, Units 1 and 2

cc:

NRC Resident Inspector
Diablo Canyon Power Plant
c/o U.S. Nuclear Regulatory Commission
P.O. Box 369
Avila Beach, CA 93424

Mr. Pete Wagner
Sierra Club California
2650 Maple Avenue
Morro Bay, CA 93442

Ms. Nancy Culver
San Luis Obispo
Mothers for Peace
P.O. Box 164
Pismo Beach, CA 93448

Chairman
San Luis Obispo County Board of
Supervisors
Room 370
County Government Center
San Luis Obispo, CA 93408

Mr. Truman Burns
Mr. Robert Kinosian
California Public Utilities Commission
505 Van Ness, Room 4102
San Francisco, CA 94102

Diablo Canyon Independent Safety
Committee
ATTN: Robert R. Wellington, Esq.
Legal Counsel
857 Cass Street, Suite D
Monterey, CA 93940

Regional Administrator, Region IV
U.S. Nuclear Regulatory Commission
Harris Tower & Pavillion
611 Ryan Plaza Drive, Suite 400
Arlington, TX 76011-8064

Richard F. Locke, Esq.
Pacific Gas & Electric Company
P.O. Box 7442
San Francisco, CA 94120

Mr. David H. Oatley, Vice President
and General Manager
Diablo Canyon Power Plant
P.O. Box 56
Avila Beach, CA 93424

City Editor
The Tribune
3825 South Higuera Street
P.O. Box 112
San Luis Obispo, CA 93406-0112

Mr. Ed Bailey, Radiation Program Director
Radiologic Health Branch
State Department of Health Services
P.O. Box 942732 (MS 178)
Sacramento, CA 94234-7320

Mr. James D. Boyd, Commissioner
California Energy Commission
1516 Ninth Street (MS 31)
Sacramento, CA 95814

Mr. James R. Becker, Vice President
Diablo Canyon Operations
and Station Director
Diablo Canyon Power Plant
P.O. Box 3
Avila Beach, CA 93424

<u>PACIFIC GAS AND ELECTRIC COMPANY</u>

<u>DIABLO CANYON NUCLEAR POWER PLANT, UNIT NO. 1</u>

<u>DOCKET NO. 50-275</u>

<u>AMENDMENT TO FACILITY OPERATING LICENSE</u>

Amendment No. 161
License No. DPR-80

1. The Nuclear Regulatory Commission (the Commission) has found that:

   A. The application for amendment by Pacific Gas and Electric Company (the licensee) dated August 27, 2002, as supplemented by letters dated May 15, June 26, and August 1, 2003, complies with the standards and requirements of the Atomic Energy Act of 1954, as amended (the Act), and the Commission's regulations set forth in 10 CFR Chapter I;

   B. The facility will operate in conformity with the application, the provisions of the Act, and the rules and regulations of the Commission;

   C. There is reasonable assurance (i) that the activities authorized by this amendment can be conducted without endangering the health and safety of the public, and (ii) that such activities will be conducted in compliance with the Commission's regulations;

   D. The issuance of this amendment will not be inimical to the common defense and security or to the health and safety of the public; and

   E. The issuance of this amendment is in accordance with 10 CFR Part 51 of the Commission's regulations and all applicable requirements have been satisfied.

2. Accordingly, the license is amended by changes to the Technical Specifications as indicated in the attachment to this license amendment, and paragraph 2.C.(2) of Facility Operating License No. DPR-80 is hereby amended to read as follows:

(2) Technical Specifications

The Technical Specifications contained in Appendix A and the Environmental Protection Plan contained in Appendix B, as revised through Amendment No. 161, are hereby incorporated in the license. Pacific Gas and Electric Company shall operate the facility in accordance with the Technical Specifications and the Environmental Protection Plan, except where otherwise stated in specific license conditions.

3. This license amendment is effective as of its date of issuance and shall be implemented within 60 days from the date of issuance.

FOR THE NUCLEAR REGULATORY COMMISSION

/RA by JDonohew for/

Stephen Dembek, Chief, Section 2
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Attachment: Changes to the Technical Specifications

Date of Issuance: August 21, 2003

PACIFIC GAS AND ELECTRIC COMPANY

DIABLO CANYON NUCLEAR POWER PLANT, UNIT NO. 2

DOCKET NO. 50-323

AMENDMENT TO FACILITY OPERATING LICENSE

Amendment No. 162
License No. DPR-82

1. The Nuclear Regulatory Commission (the Commission) has found that:

   A. The application for amendment by Pacific Gas and Electric Company (the licensee) dated August 27, 2002, as supplemented by letters dated May 15, June 26, and August 1, 2003, complies with the standards and requirements of the Atomic Energy Act of 1954, as amended (the Act), and the Commission's regulations set forth in 10 CFR Chapter I;

   B. The facility will operate in conformity with the application, the provisions of the Act, and the rules and regulations of the Commission;

   C. There is reasonable assurance (i) that the activities authorized by this amendment can be conducted without endangering the health and safety of the public, and (ii) that such activities will be conducted in compliance with the Commission's regulations;

   D. The issuance of this amendment will not be inimical to the common defense and security or to the health and safety of the public; and

   E. The issuance of this amendment is in accordance with 10 CFR Part 51 of the Commission's regulations and all applicable requirements have been satisfied.

2. Accordingly, the license is amended by changes to the Technical Specifications as indicated in the attachment to this license amendment, and paragraph 2.C.(2) of Facility Operating License No. DPR-82 is hereby amended to read as follows:

(2) Technical Specifications

The Technical Specifications contained in Appendix A and the Environmental Protection Plan contained in Appendix B, as revised through Amendment No. 162, are hereby incorporated in the license. Pacific Gas and Electric Company shall operate the facility in accordance with the Technical Specifications and the Environmental Protection Plan, except where otherwise stated in specific license conditions.

3. This license amendment is effective as of its date of issuance and shall be implemented within 60 days from the date of issuance.

FOR THE NUCLEAR REGULATORY COMMISSION

/RA by JDonohew for/

Stephen Dembek, Chief, Section 2
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Attachment: Changes to the Technical Specifications

Date of Issuance: August 21, 2003

ATTACHMENT TO LICENSE AMENDMENT NO. 161

TO FACILITY OPERATING LICENSE NO. DPR-80

AND AMENDMENT NO. 162

TO FACILITY OPERATING LICENSE NO. DPR-82

DOCKET NOS. 50-275 AND 50-323

Replace the following page of the Appendix A Technical Specifications with the attached revised page. The revised page is identified by amendment number and contains marginal lines indicating the areas of change.

REMOVE	INSERT
3.3-14	3.3-14

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO AMENDMENT NO. 161 TO FACILITY OPERATING LICENSE NO. DPR-80

AND AMENDMENT NO. 162 TO FACILITY OPERATING LICENSE NO. DPR-82

PACIFIC GAS AND ELECTRIC COMPANY

DIABLO CANYON POWER PLANT, UNITS 1 AND 2

DOCKET NOS. 50-275 AND 50-323

1.0 INTRODUCTION

1.1 Summary of Amendment Request

In a letter dated August 27, 2002 (Reference 1), Pacific Gas and Electric Company (PG&E/the licensee) requested an amendment to the Technical Specifications (TS) for Diablo Canyon Power Plant Units 1 and 2 (DCPP). In response to the need for additional information, the licensee submitted letters dated May 15, June 26, and August 1, 2003 (References 2, 3, and 4, respectively) to clarify and supplement the Reference 1 request.

The request is to accomplish the following two changes:

(1) Revise the term "minimum measured flow per loop" to "measured loop flow" in the allowable value and nominal trip setpoint for the reactor coolant flow-low reactor trip function contained in TS 3.3.1, Table 3.3.1-1 "Reactor Trip System Instrumentation"; and

(2) Allow an alternate method for the measurement of reactor coolant system (RCS) total volumetric flow rate through measurement of the elbow tap differential pressures on the RCS cold legs.

In TS Table 3.3.1-1, the Reactor Coolant Flow-Low function allowable value and nominal trip setpoint are currently "$\geq$ 89.8%[l] of MMF/loop" and "90%[l] of MMF/loop" respectively where the footnote (l) states "Minimum measured flow (MMF) is 89,800 gpm per loop for Unit 1 and 90,625 gpm per loop for Unit 2."

The TS change would delete the footnote (l), and revise the Reactor Coolant Flow-Low function allowable value in TS Table 3.3.1-1 to "$\geq$ 89.8% of measured loop flow" and revise the Reactor Coolant Flow-Low function nominal trip setpoint to "90% of measured loop flow."

The May 15, June 26, and August 1, 2003, supplemental letters provided additional clarifying information, did not expand the scope of the application as originally noticed, and did not change the NRC staff's original proposed no significant hazards consideration determination published in the *Federal Register* on January 7, 2003 (68 FR 810).

1.2 Background Regarding Determination of RCS Flow Rate

In typical Westinghouse-designed nuclear steam supply systems, RCS flow rate was originally determined by first performing calorimetric measurements on the steam generator (SG) secondary side with the feedwater flow rates measured by venturi meters. The RCS flow rate was then calculated from the calorimetric measurements in conjunction with the enthalpy rise across the reactor vessel (RV) as determined from hot and cold leg temperature measurements.[1]

Precise hot leg temperature measurement is difficult due to a phenomenon defined as hot leg temperature streaming or "thermal streaming" – the large asymmetric temperature gradients within the hot leg pipe that result from incomplete mixing of the RCS water leaving the 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 RV upper plenum, and mixing in the hot leg pipe.

Prior to application of low leakage loading patterns (LLLPs), the largest difference in fuel assembly exit temperatures at full power was typically no more than 30°F, with the lowest temperatures measured at the exit of fuel assemblies on the outer row of the core. Water flowing from the exit of these assemblies has little opportunity to mix with hotter water flowing from more central core regions before reaching the RV exit nozzles. As a consequence, there can be a significant temperature gradient at the nozzles.

Hot leg flow is highly turbulent and mixing occurs as water flows down the hot leg. Hot leg temperature is typically measured about 7 to 17 feet downstream from the RV nozzles. In 1968, temperature variations of 7°F to 10°F were measured on the circumference of the hot legs, demonstrating that mixing was incomplete at the temperature measurement locations. Consequently, a new hot leg temperature measurement system, the resistance temperature device (RTD) manifold bypass system, was installed in 1994. This system employed scoops in the hot leg piping at three uniformly spaced locations on the pipe circumference. Water from the scoops was combined and directed through an RTD manifold where the measured temperature of the mixed samples was believed to more closely represent the average hot leg temperature. Return water flowed to the cross-over pipes between the SGs and the reactor coolant pumps (RCPs). A cold leg manifold was also used, taking water from downstream of the RCPs and returning it to the hot leg manifold return line.

The RTD manifold was found to cause significant personnel radiation exposure and it was removed from many plants after 1988. The subsequent hot leg temperatures were measured by three RTDs installed in uniformly spaced locations in each hot leg. In many cases, the new RTDs were installed inside the disconnected RTD manifold scoops. Gradients measured with the new RTDs prior to 1991 varied from 2°F to 9°F, with most varying from 5°F to 7°F.

---

[1]RCS flow rate is equal to the net heat generation rate between the locations of the hot and cold leg temperature determination points divided by the enthalpy difference corresponding to the measured temperatures and calculated pressures at those locations. Thus, if net heat generation rate and pressures are constant and temperature difference increases, enthalpy difference increases and calculated flow rate decreases.

Indications of a streaming change began to occur in 1988 with indicated hot to cold leg temperature difference (ΔT) increases of as much as 3 percent following refueling as low leakage cores were introduced. Core exit temperature gradients also increased, but in these early cases, the flow rates indicated by the elbow tap flow measurements did not change significantly. In 1990, flow rate determined by a calorimetric heat balance was lower than required by TSs, whereas flow rate indicated by the elbow taps showed an adequate RCS flow. Similar problems have occurred in several plants since then, and core exit temperature gradients approaching 60°F have been observed. These gradients have been confirmed to be due to the significantly lower power generation rates in the outer core fuel bundles.

Because of this inherent limitation of the calorimetric-based method, alternate measurement procedures were developed that use elbow tap flow meters to verify flow. These procedures have been reviewed and approved by the NRC for a group of three-loop plants and for several four-loop plants. These include McGuire Nuclear Station (Reference 5), Catawba Nuclear Station (References 6, 7, and 8), South Texas Project Electric Generating Station (Reference 9), Joseph M. Farley Nuclear Plant (Reference 10), and Seabrook Station (Reference 11). The staff also accepted the Westinghouse Owners Group Topical Report, WCAP-14750 (Reference 12), for generic application of elbow taps for RCS flow verification to Westinghouse 3-loop pressurized water reactors (PWRs). The methodology described in WCAP-14750 has subsequently been used for RCS flow verification in the Westinghouse 4-loop PWRs identified above, and is applicable to DCPP.

PG&E's amendment request is similar to many of the referenced requests that were approved by the NRC. However, other approved requests used somewhat different approaches and, recently, the staff became aware of some contradictory conclusions (Reference 13). As a consequence of this awareness, the staff elected to audit PG&E's request in greater detail than in the prior staff's reviews to both resolve the contradictory conclusions and to ensure that several previously unaudited details were correctly addressed.

2.0 REGULATORY EVALUATION

General Design Criterion (GDC) 10, "Reactor Design," in Appendix A to 10 CFR Part 50, requires that the reactor core and associated coolant, control, and protection systems be designed with appropriate margin to assure that specified acceptable fuel design limits (SAFDL) are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences (AOO). In 10 CFR 50.36, the Commission establishes its regulatory requirements related to the content of TSs.

The licensee proposes changing the wording of its TS 3.3.1 and proposes allowing an alternate method for measurement of RCS flow rate to meet its Surveillance Requirement (SR) 3.4.1. The staff evaluation of the proposed changes has been based on continued compliance with GDC 10, with 10 CFR 50.36 requirements, and with other applicable documents as identified in Section 3.4.5, below.

3.0 TECHNICAL EVALUATION

3.1 Introduction

The licensee's proposed changes include use of elbow tap differential pressure (ΔP) measurements to meet TS RCS flow rate requirements. Therefore, the staff's technical evaluation first discusses the licensee's application of elbow tap ΔP measurements to develop information that is applicable to the proposed TS changes.

3.2 Use of Elbow Taps for RCS Flow Measurement

3.2.1 Principle of Operation

The elbow taps are installed in a plane 22.5° around the 90° crossover elbow in each of the cold legs. Each elbow has three low-pressure taps spaced 15° apart on the inside pipe radius and one high-pressure tap on the outside pipe radius used as a common tap. The pressure taps are connected to ΔP transmitters to obtain ΔP data.

The principle of operation of an elbow tap flow meter is based on the centrifugal force of a fluid flowing through an elbow creating a ΔP between the outer and inner radii of the elbow. The relationship between the volumetric flow rate through an elbow and ΔP between the pressure taps at the outer and inner radii of the elbow can be expressed as flow rate equals $C\ \Delta P^{1/2}$. The elbow meter coefficient, C, is a function of elbow bend and cross-section radius, and is affected by the location of pressure taps, upstream and downstream piping, and other factors. The cold-leg elbow tap - flow element is not calibrated in advance in a laboratory, but the measurement is typically normalized against the RCS flow rate that is established from precision heat balance calorimetric flow measurements.[2]

3.2.2 Flow Measurement Repeatability

Available literature supports a conclusion that elbow tap flow meters are stable. For example an American Society of Mechanical Engineers (ASME) publication (Reference 14) states that hydraulic tests have demonstrated that elbow tap flow measurements have a high degree of repeatability, and are not affected by changes in the elbow surface roughness. Further, evaluation of various processes and phenomena for possible effects on the elbow tap flow measurements leads to the following conclusions:

- The conditions for fouling are not present in the cold-leg elbow since there is no change in cross section to produce a velocity increase and ionization.
- Surface erosion is unlikely because of the use of stainless steel in the pipe and the flow velocities are small relative to the conditions where erosion might be expected.
- The upstream velocity distribution, including the distribution in the elbow tap flow meter,

[2] As discussed in Section 1.2, above, thermal streaming can introduce an error into the precision heat balance calorimetric flow measurement. This error becomes greater for core designs that minimize fluence to the reactor vessel wall.

remains relatively constant so the elbow tap flow meter ΔP versus flow relationship does not change.

- The plenum velocity head approaching the SG outlet nozzle is small compared to the piping velocity head. Therefore, asymmetrically distributed SG tube plugging is not expected to affect elbow tap flow measurement repeatability.

- The elbow radius and pipe diameter are large in comparison to potential dimensional changes and dimensional changes are not expected to influence elbow tap calibration. Further, the elbow taps are used over a narrow range of temperature and pressure.

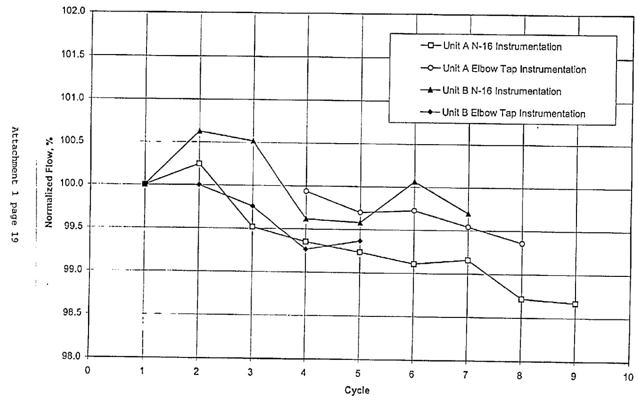
Significant experience is also available that supports a conclusion that elbow tap flow meters are stable during long-term operation. For example, Section 4.1.4 of WCAP-15113 (Reference 15) discusses an evaluation of comparisons between RCS flow measurement data using elbow taps and ultrasonic leading edge flow meters (LEFM) from the Hydraulic Test Program at Prairie Island Unit 2. The comparisons were stated to cover 11 years of operation during which an RCP impeller was replaced and included cases of both one and two RCPs operating. The data showed that the average flow rate difference between the elbow tap and the LEFM flow measurements was less than 0.3 percent. Another comparison performed before and after RCP replacement showed that the LEFM and elbow tap measurements agreed to within an average of 0.2 percent on the ratio of flows when one and two pumps were operating. WCAP-15113 and WCAP-14754-NP-A (Reference 16) provided the following data to substantiate these conclusions:

RCS FLOW MEASUREMENT COMPARISONS AT FULL POWER gpm/loop				
LOOP METER	A LEFM	A ELBOW	B LEFM	B ELBOW
DATE				
Feb 1980	97519	*	97950	*
Jul 1981	98673	98309	97763	97267
Aug 1991	98724	98557	97543	97607
RATIO OF FLOW WITH 1 PUMP OPERATING TO FLOW WITH 2 PUMPS OPERATING				
Dec 1974	1.0819	1.0777	1.0852	1.0875
Jul 1981	1.0794	1.0816	1.0820	1.0820
*Normalized to LEFM Flow				

The staff notes that, although the Prairie Island tests covered 11 years of operation, data were obtained sporadically and recalibrations may have been involved.

The staff obtained additional information during another review that is applicable to the topic of long-term elbow tap stability. Reference 7 discusses data obtained from three other plants equipped with N-16-based RCS loop flow rate instrumentation. In each case, usage was stated to be limited to the start of each cycle with the purpose of normalizing the main control board RCS flow rate indications. The reproduced Figure 5, to the right, provides normalized flow rate versus cycle data for two plants identified as Units A and B. The Unit A data for Cycles 4 through 8 show similar downward flow rate trends for the N-16 and elbow tap instrument data with a relatively consistent offset ranging from 0.4 percent to 0.7 percent. The Unit B data for Cycles 1 through 5 show somewhat more variation, with the N-16 and elbow tap data becoming closer together with increasing cycles. The N-16 fluctuations were attributed to the uncertainty band in the instrumentation, but substantiation for this conclusion was not provided other than to note the flow rate increases at Cycles 2 and 6 could not be attributed to real flow increases and therefore could be attributed to measurement process variation. Examination shows that the elbow tap indications appear to be more stable. Overall, there is no indication of a long-term change in the elbow tap indications in comparison to the N-16 indications and the limited data for Unit A generally substantiate that the elbow tap flow coefficients remain constant.

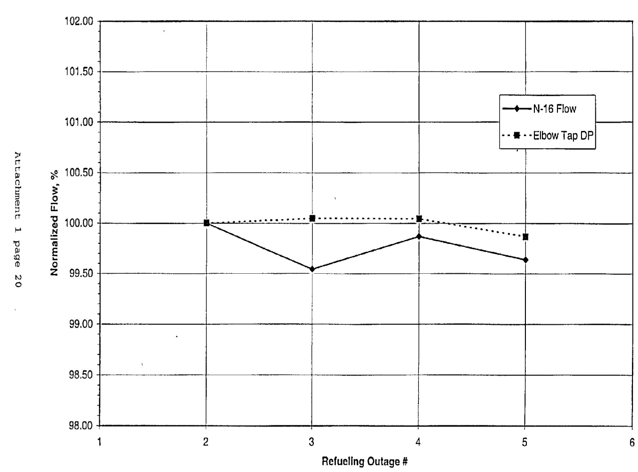
Figure 5



The reproduced Figure 6, to the right, provides a similar comparison of N-16 and elbow tap flow rates for a third plant. Again, the elbow tap data appear somewhat more stable than the N-16 indications, but overall there is little variation.

There is no evidence of a long-term change in the elbow tap indications in comparison to the N-16 indications and the data generally substantiate that the elbow tap flow coefficients remain constant with increasing time.

Figure 6



Based on the above evaluation, the staff finds that the elbow tap flow meter coefficients remain sufficiently constant that the relative changes of flow rate through the cold-leg elbows can be correlated with the relative changes in the elbow tap ΔPs.

3.2.3 Elbow Tap Flow Measurement Procedure

Section 4.2 of WCAP-15113 describes the procedure for determining the RCS flow from elbow tap ΔP measurements based on their repeatability. This elbow tap flow measurement procedure relies on the total baseline calorimetric flow rate, which is based on the calorimetric flow rate measurements from early fuel cycles before the deployment of the low leakage fuel loading pattern.[3] The procedure correlates the current cycle flow rate (CCF) with the elbow tap ΔP ratio of the current and the baseline cycles and the baseline calorimetric flow rate (BCF). The CCF is determined from the BCF multiplied by the elbow tap flow ratio (R) as described in the following steps:

- The baseline elbow tap flow coefficient B is defined as:

$$B = \Delta P_B \, V_B \qquad (1)$$

where: ΔP_B = baseline average elbow tap ΔP, the average ΔP from all elbow taps
V_B = baseline average cold leg specific volume

Using an average of all elbow tap ΔPs to obtain B does not directly address variations in flow rate from loop-to-loop that may develop over time nor does it directly address variations in loop flow caused by such factors as charging and pressurizer spray. However, if a physical change causes flow rate to change in one loop, an opposite change can be expected in the other loops that dampens the overall effect with respect to using an average. Further, as shown in Section 3.3.4 below, charging and pressurizer spray flow rates are small in comparison to the loop flow rates. There are also advantages with using an average, such as the repeatability of the total flow measurement is improved when all of the elbow tap ΔP measurements are used as an average. Finally, comparison of the averaging approach to considering individual ΔP measurements for several plants has been shown to introduce a negligible error. The staff approved this average ΔP approach in Reference 12.

- Elbow tap ΔPs are obtained at the beginning of the current cycle to define the change in flow rate from the baseline flow rate. The average of all elbow tap ΔPs measured at or near full power[4] defines the current cycle elbow tap flow coefficient, K, in accord with the following equation:

$$K = \Delta P \, V \qquad (2)$$

---

[3]Selection of the baseline flow rate is discussed in Section 3.2.5, below.

[4]The effect of power on RCS flow rate is discussed in Section 3.3.6, below.

where: ΔP = average ΔP from all elbow taps for the current cycle
V = average cold leg specific volume for current cycle

- The elbow tap flow ratio, R, is defined as:

$$R = (K/B)^{1/2} F_{RTDBE} \quad (3)$$

where: F_{RTDBE} = RTD bypass elimination flow correction factor
= 1.0 for Cycles 1-6 and 0.9985 starting with Cycle 7 for both units[5]

- The current cycle flow rate CCF is determined by multiplying R by the baseline flow rate:

$$CCF = R\ BCF \quad (4)$$

The staff finds this process includes an acceptable correction for the removal of the RTD bypass manifolds and it is consistent with the approved process described in Reference 12.

3.2.4 Best Estimate (BE) Flow Confirmation

In the safety evaluation for Reference 12, the staff stated that "the elbow tap flow measurement procedure includes a requirement that utilities are to perform a best estimate (BE) hydraulics analysis to confirm the future total RCS flow determined from the elbow tap measurement." The BE analysis is based on the flow resistances of the RCS components and the RCP performance characteristics. Therefore, changes in the RCS flow rate can be predicted based on such RCS changes as plugging and sleeving of SG tubes and fuel design changes. Reference 12 further stated that “the BE hydraulic analysis confirmation procedure specifies that utilities are to compare the elbow tap flow ratio (R) to an estimated future cycle flow ratio (R'). R is based on the elbow tap ΔP measurements as previously discussed. R' is the ratio of the estimated future cycle RCS flow to the estimated initial baseline cycle flow based on the flow analysis of known RCS hydraulics changes, such as SG tube plugging or fuel design changes. If the measured R is greater than (1.004 x R'), R will be limited to (1.004 x R'). The multiplier 1.004 applied to R' is a measure to provide an allowance of 0.4% for elbow tap measurement repeatability."

The licensee (Reference 15) stated that "prior to beginning of cycle RCS flow calorimetic (sic), the current cycle estimated flow (CEF) is calculated for the new cycle, accounting for the known hydraulic changes," by an estimated future cycle flow ratio R':

$$R' = CEF / BEF \quad (5)$$

where: CEF = current cycle estimated flow rate predicted from actual RCS hydraulic changes
BEF = best estimate flow rate predicted for the baseline cycle RCS flow rate

The licensee continued with "an acceptance criterion is applied to the comparison of R and R':

[5]Elimination of the RTD bypass manifolds is addressed in Section 3.3.7, below.

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 in place of R, to define the current cycle total flow rate CCF, and Equation 4 is modified 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."

Section 5.0 of Reference 15 describes a BE RCS flow analysis procedure developed by Westinghouse in 1974 to estimate RCS flow at all Westinghouse-designed plants. The analysis uses BE values of the RCS component flow resistances and pump performance. The flow resistances of the RCS loops (i.e., the RV, RCS piping, and SGs) are used in conjunction with the RCP head-flow performance to define individual loop and total RCS flow rates. The component hydraulic design data and hydraulic coefficients are determined from analyses of the test data. The flow resistance of the RV, consisting of the RV, RV internals, and RV nozzles, is determined from the ΔP measurements of a full size fuel assembly hydraulic test and hydraulic model test data for each type of RV. The RCS piping flow resistance combines the resistances of the hot-leg, crossover-leg, and cold-leg piping. The flow resistance is based on analyzing the effects of upstream and downstream components on elbow hydraulic loss coefficients, using the results of industry hydraulic tests. The flow resistance is defined in five parts: inlet nozzle; tube inlet; tubes; tube outlet; and outlet nozzle. Reference 15 indicates that numerous component flow resistance tests and analyses (including the overall flow resistance confirmed by the Prairie Island Unit 2 Hydraulics Test Program) have confirmed that this hydraulic analysis procedure has an uncertainty of 2 percent flow. This indicates that actual flow is expected to be within 2 percent of the calculated BE flow.

Figure 5-1 of Reference 12 provided an RCS hydraulic network diagram for Westinghouse three loop plants that is stated to be based on the procedure used to calculate BE RCS flow rate developed in 1974. The same procedure is referenced by the licensee in References 1 and 15. Figure 5-1 shows that the significant RV flow paths are addressed. Small flow paths that are associated with the hot and cold legs, such as the RTD bypass manifold, charging, letdown, RCP seal flow, and pressurizer connections, are not included. These have an essentially negligible effect on RCS pressure distribution, as is discussed in Sections 3.3.4 and 3.3.7 below. They have a potentially small effect on RCS flow rate and, in some cases, exceed some of the parameters that are quantified in the flow rate uncertainty analysis provided in Reference 15. As discussed in Sections 3.3.4 and 3.3.7 below, the licensee has addressed the effects omitted from Figure 5-1. The staff finds the licensee's approach to address these effects to be acceptable.

The licensee provided the following statement in Reference 1:

> The best estimate flow based on the hydraulic analysis is only used to confirm the elbow tap flow measurement while limiting the elbow tap flow measurement to a maximum value corresponding to the best estimate flow plus an allowance for the elbow tap flow repeatability uncertainty. The best estimate flow will not be used as a substitute for the TS SR for flow measurement.

This statement is consistent with the staff's finding in Reference 12 and is acceptable.

In Reference 15, the licensee stated that LEFM and RCP input power measurements were obtained at Prairie Island to reconfirm RCS flow rates and hydraulic performance. Data obtained after operation for some time indicated that RCS flow rates had decreased by 0.6 to 0.8 percent, and electrical data indicated that RCP input power had decreased by about 2 percent due to decrease in impeller surface roughness, an effect termed "impeller smoothing." The licensee further stated that smoothing occurs within one or two fuel cycles after initial startup, and that the effect has been measured by elbow tap flow meters at several plants.

In its BE flow predictions, the licensee assumed impeller smoothing would cause a flow decrease of 0.3 percent prior to Cycle 2 and would cause an additional 0.3 percent prior to Cycle 3. This differed from the Reference 12 Section 6.3 conclusion that impeller smoothing was complete prior to measuring flow rate during Cycle 2. In this respect, Reference 12 is consistent with the staff's observations that support that the greatest smoothing occurs early in plant operation, with the effect tapering off with increasing operation time. In Reference 2, the licensee stated that its assumption was more conservative than assuming all of the 0.6 percent flow decrease occurred due to smoothing early in plant operation. Consequently, the staff finds that the licensee's smoothing assumption is acceptable because the staff agrees with the licensee's statement that its assumption is conservative.

In Section 4.5 of Reference 1, the licensee discussed its calculation of the estimated flow ratio, R', and its comparison of BE to elbow tap flow data in Figures 6-1 and 6-2, for Units 1 and 2 respectively, of Section 6.5 of Reference 15. The licensee stated that flow rate comparisons show good agreement for the first three cycles in Figure 6-1, and for the first two and the fourth cycles in Figure 6-2. In explaining the Figure 6-1 behavior, the licensee stated that the "difference may be due to under-predicting the steam generator tube plugging flow decrease or over-predicting the fuel thimble plug removal flow increase" and it attributed some of the behavior to asymmetric SG tube plugging. Reference was also made to asymmetric SG tube plugging as a reason for differences in Figure 6-2.[6] On the basis of past reviews and other statements in the licensee's submittals, the staff believes that SG tube plugging effects can be accurately predicted. Consequently, the staff performed an audit calculation of the effect of SG tube plugging. The audit showed behavior similar to that described in Section 6.5.1 of Reference 15, an observation that caused the staff to question the licensee's ability to

[6]The staff believes asymmetric SG tube plugging would be better represented if the staff-approved loop ΔP averaging technique were not applied.

differentiate between the effects of SG tube plugging and core changes. In response to the staff's question the licensee made the following points:

1. "At other plants, additional evaluations have found a cause for the differences to be due to such changes as a calibration shift, which may reflect use of less accurate procedures that were in use prior to using elbow tap flow rate measurements to verify flow rates. In these cases, the baseline cycle and the most recent cycle elbow tap measurements have been in better agreement, as is the case for DCPP (Diablo Canyon Power Plant). The differences for the most recent cycles are considered to be acceptable to meet the elbow tap flow methodology requirements. Therefore, the use of elbow taps for future cycles is still considered to be appropriate."

2. "The comparison of elbow tap and best estimate flow trends is intended to confirm that the flow defined by the elbow taps is reasonable or conservative relative to the best estimate flow trend. This is reflected in the acceptance limit that assures that an elbow tap flow that exceeds the best estimate flow trend by more than the elbow tap repeatability allowance of +0.4 percent is not used."

3. "The total elbow tap flow is similar to, and conservative relative to the best estimate flow trend for Units 1 and 2."

The staff has observed the effect of improved calibration procedures in other reviews, such as in References 6 and 7. The staff also observes that the trend agreement in the licensee's Figures 6-1 and 6-2 is better in recent cycles. These observations, the acceptance limit based on the +0.4 percent repeatability, and the licensee's Item 3 conclusion above result in the staff's finding that the BE calculation and its usage are acceptable with respect to the staff's question regarding the licensee's ability to differentiate between the effects of SG tube plugging and core changes.

Core fouling has been observed to perturb RCS flow rate and changes associated with boric acid concentration may also have an effect on RCS flow rate. In Reference 2, the licensee acknowledged that these effects are not included in its calorimetric and elbow tap measurement procedures. The elbow tap data are compared to the hydraulic flow model at the beginning-of-cycle when minimal core crud buildup exists. Since the flow model was generated with no allowance for fouling, this is the opportune time for the comparison with respect to the model. Once calibrated, the elbow taps will reflect any RCS flow rate changes due to core fouling.

The boric acid concentration typically will be at a maximum at the beginning-of-cycle calibration. All analyses and the elbow tap calibrations are based on the assumption that the physical properties of pure water may be used for the RCS water. One physical property that appears in the equations of interest (see Section 3.3 below) is density. Density as a function of weight-percent of boric acid is as follows:

ppm boron	Wt % H_3BO_4	Density, g/cc		
		d_4^{20}	d_4^{15}	d_4^{66}
		Reference 17	Reference 18	Reference 19
0	0	0.9982*	0.9981*	0.9817
1000	0.57**	1.0005**	1.0017**	0.9830**
1748	1	1.0022	1.0045	0.9840
3495	2	1.0056	1.0103	0.9876
5243	3	1.0091	1.0165	0.9912
6991	4	1.0136	-	0.9844
*From steam tables **By interpolation				

If the boron concentration at the start-of-cycle is assumed to be 1000 ppm, then the percent change in density from pure water is 0.23, 0.36, and 0.13 percent for the References 17, 18, and 19 values, respectively. Equation 2 shows that the elbow tap coefficient is equal to specific volume times ΔP. Further, elbow tap flow rate is directly proportional to $(\Delta P)^{½}$. Hence, the flow rate indicated by the elbow taps is directly proportional to $\rho^{1/2}$, and the proportional change in flow rate indicated by the elbow taps due to a change in density, ρ, is equal to $(\rho_{new} / \rho_{old})^{½}$. If the above density changes are assumed applicable to RCS operating conditions and ΔP is assumed constant for comparison purposes, then, over an operating cycle the change in boric acid concentration will cause an indication of a decrease in flow rate due to the density effect of about 0.12, 0.18, and 0.07 percent, respectively, or about 100 gpm per loop.

The staff notes that the above is only an approximation of the effect because a calibration with a different boric acid concentration would likely affect the flow coefficient in Equation 2 since both specific volume and ΔP could be expected to change. The importance of the above comparison is a conclusion that the effect of boric acid concentration on RCS flow rate is small and in a conservative direction since the flow rate calibrations are performed with the highest boric acid concentration.

The staff finds the material summarized above, is either consistent with the process approved in Reference 12 or it provided additional confirmation of the adequacy of that process. Therefore, the licensee’s process is acceptable.

3.2.5 <u>Baseline Selection</u>

The licensee applied two corrections to define the average flow rate for baseline cycles (Reference 15):

- Flow rates obtained at about 90 percent power were reduced by 0.1 percent to account for the flow rate decrease associated with a power change from 90 percent to

100 percent. This is consistent with the staff's evaluation of the effect of power that is discussed in Section 3.3.6 below.

- Flow rates in Cycle 2 were increased by 0.3 percent to account for impeller smoothing. This selection was discussed in Section 3.2.4 above.

These corrections were stated to result in hydraulically consistent flow rates to be used to define the equivalent beginning of Cycle 1 baseline calorimetric flow rate.

Reference 15 states that the measured calorimetric flow rates must meet the following requirements to be used in the baseline:

- The flow rate must be determined at or above 90 percent power at the beginning of cycle to avoid added uncertainties due to reduced power or due to instrument drift.

- At least one of the determinations must have concurrent calorimetric flow rate and elbow tap ΔP measurements.

- SG tube plugging must be less than an average of 5 percent to minimize hydraulic uncertainty.

- To avoid bias, an LLLP cycle should not be used unless needed to obtain the required number of measurements for evaluation.

- Hydraulically corrected calorimetric flow rates that are not within a 1 percent band, or that differ from the baseline cycle best estimate flow by more than 2 percent, should not be used unless the cycle was impacted by LLLP.

The procedure for defining the baseline calorimetric flow rate is stated to be as follows:

(1) Select at least three flow calorimetric flow rates that have been hydraulically corrected to the baseline cycle from at least two cycles.

(2) Determine the baseline cycle flow rate (the average of two flow rates if two baseline cycle flow rates are used).

(3) Determine the average of the selected hydraulically corrected flow rates. When the flow rates include two flow rates from a cycle, both flow rates are to be considered in the average flow rate.

(4) Compare the baseline cycle flow rate from item (2) above, to the average flow rate obtained from item (3) above. The baseline calorimetric flow rate is the lower of these two flow rates.

In Reference 1, the licensee observed that all cycles after Cycle 1 in both units had average power differences between the second row and outer fuel assemblies that exceeded 50 percent. As a consequence, only the first cycle was likely to display characteristics with minimal thermal streaming. In both units, for Cycle 2, the licensee predicted that the low leakage loading pattern impact on calorimetric flow rate was about 0.5 percent and for Cycle 3, it was about one percent. Since two early cycle flow rates were measured in both Cycles 1 and 2, the licensee based the baseline calorimetric flow rate on two flows each from Cycles 1 and 2.

The licensee stated that the above-described process resulted in baseline calorimetric flow rates of 376,656 gpm and 379,089 gpm for Units 1 and 2, respectively.

Based on the above, the staff finds that the licensee has acceptably determined its baseline calorimetric flow rates.

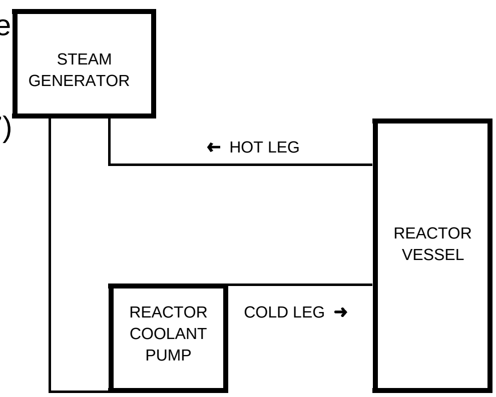
3.3 Evaluation of RCS Flow Measurement Calculation

3.3.1 Overall Heat Balance

The licensee's calorimetric RCS flow calculation methodology differed from the staff's understanding of the correct methodology that resulted from the review of a different plant (References 6, 7, and 13). Since the methodologies were in conflict, the staff conducted an investigation to resolve the conflict. The theoretical methodology is developed in Sections 3.3.1 and 3.3.2 below.

The RCS configuration illustrated in Figure 1 is used as a basis for flow rate analyses. An overall heat balance is taken over the control volume defined by the surface of the RCS to obtain Equation 7:

FIGURE 1. RCS LOOP CONFIGURATION



$$Q_{core} + Q_{RCP} - Q_{loss} = Q_{cal} \tag{7}$$

where: Q_{core} = nuclear heat generation rate in the core,
Q_{RCP} = rate of energy addition to RCS by RCPs,
Q_{loss} = net rate of RCS heat loss exclusive of SGs and RCPs,
Q_{cal} = rate of heat removal by SGs, and,

for now, no mass flow is assumed to pass through the RCS pressure boundary. This assumption is addressed in Section 3.3.4 below.

Since Q_{cal} is determined from the calorimetric, and Q_{loss} and Q_{RCP} can be estimated, this equation will provide Q_{core}.

3.3.2 Determination of Mass Flow Rate

With Q_{core} determined, one may assume that mass flow rate through the core could be determined by dividing Q_{core} by the enthalpy difference across the core if the enthalpy difference were known. However, these enthalpies are not known because (1) core inlet temperatures are not measured, (2) there is a wide variation in core outlet temperatures with position across the top of the core, and (3) pressure variation within the RCS is not measured. (Enthalpy can be determined when temperature and pressure are known.) Consequently, it is necessary to make the determination where temperatures are measured that are representative of the bulk flowing water. In practice, the hot and cold leg RTD temperatures, T_h and T_c respectively, are used. Pressure is determined by equating RCP head to the total pressure drop through the RCS for an assumed RCS flow rate and calculating the variation of pressure relative to a measured value in the pressurizer.[7]

Next, considering a general control volume and sum the forms of energy entering and leaving the volume through the control volume boundary, one would have the following for the conservation of energy:

heat + [mass flow rate]$_{in}${ internal energy + flow energy + kinetic energy + potential energy}$_{in}$ = work + [mass flow rate]$_{out}${ internal energy + flow energy + kinetic energy + potential energy}$_{out}$,

or:

$$Q + M_{in} \{ u + [144 P V + v^2 / (2 g) + Z] / f \}_{in} = W + M_{out} \{ u + [144 P V + v^2 / (2 g) + Z] / f \}_{out} \quad (8)$$

where: Q = heat addition rate, BTU/sec
M = weight flow rate, lbs/sec
u = internal energy per unit weight, BTU/lb
P = pressure, lbs/in^2 absolute
V = volume per unit weight, ft^3/lb
v = velocity, ft/sec
g = gravitation constant, 32.2 ft/sec^2
Z = elevation, ft
f = conversion factor = 778 ft-lbs/BTU
W = work performed by the fluid, BTU/sec

Since, by definition, enthalpy is:

$$h = u + 144 P V / f \text{ (BTU/lb)} \quad (9)$$

Equation 8 may be written as:

$$Q + M_{in} \{ h + [v^2 / (2 g) + Z] / f \}_{in} = W + M_{out} \{ h + [v^2 / (2 g) + Z] / f \}_{out} \quad (10)$$

Equation 10 may be applied to the RCS by selecting a control volume that encloses the RV and the pipes between the RV and the locations of T_h and T_c. There is no work done by the system within this control volume and W = 0. The hot and cold leg pipe elevations are identical and $Z_{in} = Z_{out}$. There is no accumulation of mass and $M_{in} = M_{out} = M$. Finally, since the heat addition is large and the differences in hot and cold leg velocity are small (because of the increase in hot leg diameter that accommodates the decrease in fluid density), one may assume that $v_{in} = v_{out}$. Substitution of these simplifications results in the following:

$$Q + M h_c = M h_h \quad (11)$$

---

[7]It may be necessary to iterate on head loss versus head developed by the RCP to obtain a converged solution. Further, although liquid enthalpy is a relatively weak function of pressure, it may be necessary to adjust the assumed RCS flow rate to agree with the calorimetrically-determined value and recalculate the pressure distribution to obtain a converged solution.

where: h_h = hot leg enthalpy, and
h_c = cold leg enthalpy.

But Q is Q_{core} minus that portion of Q_{loss} associated with the RV and the pipes between locations of T_h and T_c, $Q_{loss\Delta T}$. Thus:

$$M = (Q_{core} - Q_{loss\Delta T}) / (h_h - h_c) \tag{12}$$

3.3.3 Assessment of Equal Cold and Hot Leg Velocity Assumption

The licensee, in its analysis, assumed that $v_{in} = v_{out}$. The staff used the same assumption in deriving Equation 12. To confirm this assumption, the staff used the licensee's operational values of T_c = 540 °F and P_c = 2300 psia to obtain a density, ρ_c, of 47.5216 lb/ft^3 and h_c = 534.839 BTU/lb. A nominal flow rate of 94619 gpm is equal to (94619)(0.13368)/60 = 210.81 ft^3/sec or (210.81)(47.5216) = 10018.1 lbs/sec. With a 27.5 inch diameter cold leg, v_c = (210.81)/[π{(27.5/2/12)}^{2}] = 51.109 ft/sec. Neglecting $Q_{loss\Delta T}$, assuming an isenthalpic expansion through the RV, and assuming 3411 MW core power, $h_h - h_c$ = (3411/4)(10^6)(3.41275)/10018.1/3600 = 80.693 BTU/lb and h_h = 534.839 + 80.693 = 615.532 BTU/lb. Using the RV flow resistance provided by the licensee and an average ρ_c and ρ_h, the staff calculated a RV pressure drop of 49.41 psi which results in P_h = 2250.59 psia. With h_h and P_h determined, ρ_h = 43.0509 lbs/ft^3 via water property tables. With a hot leg diameter of 29 inches, v_h = (10018.1)/43.0509/[π{(29/2/12)}^{2}] = 50.732 ft/sec and $v_h - v_c$ = -0.377 ft/sec, a small value. The kinetic energy at the cold leg is (51.109)^2/2/32.174/778.26 = 0.0522 BTU/lb and at the hot leg it is (50.732)^2/2/32.174/778.26 = 0.0514 BTU/lb. The kinetic energy difference, 0.0514 - 0.0522 = -0.0008 BTU/lb, is negligible in comparison to the enthalpy change across the RV of 80.693 BTU/lb. Therefore, the staff finds that the licensee's $v_h = v_c$ assumption is acceptable.

3.3.4 Assessment of RCS Mass and Heat Transfer Assumptions

In the above comparisons, the staff assumed $Q_{loss\Delta T} = 0$ in Equation 12. A complete formulation must consider all mass and heat transfers across the control volume boundary. This includes consideration of charging flow (+), letdown flow (-), seal injection flow (+), RCP thermal barrier cooler heat removal (-), pressurizer spray flow (-), pressurizer surge line flow (+), component insulation heat loss (-), component support heat loss (-), and control rod drive mechanism heat loss (-). In Reference 4, the licensee stated that normal charging and the pressurizer spray line cross the boundary of the control volume, but letdown and the pressurizer surge line do not. Seal injection flow and RCP thermal barrier cooler heat removal are also outside of the control volume. The licensee's list of contributors to $Q_{loss\Delta T}$ is as follows:

Charging (minus seal injection) = 50 gpm @ 100 °F ≡ 1.66 MBTU/hr
RV heat loss rate = 0.23 MBTU/hr
Pressurizer spray = 0.41 MBTU/hr
Control rod drive heat loss rate = 1.98 MBTU/hr
Hot and cold leg pipe heat loss rate = 0.075 MBTU/hr

For simplicity, the licensee assumed the four RCS legs could be combined and the legs are identical. With this assumption, $Q_{loss\Delta T}$ = 1.089 MBTU/hr ≡ 0.293 MW. The licensee stated that an older value of 1.835 MBTU/hr was assumed for the RCS baseline flow rates, a conservative assumption equivalent to 25 gpm when substituted into Equation 12. (Using these same values, the staff's assumption of $Q_{loss\Delta T} = 0$ is equivalent to 60 gpm.)

Since underestimating the loss term in Equation 12 is non-conservative, the staff independently checked the above heat loss rate information by assuming the RCS heat loss rate is about 25 percent of the RCP heat, or about 1.25 MWt per loop (including 1/4 of the RV per loop). About half of this heat was assumed lost as the water flows from the location of T_c to the location of T_h. The difference between $Q_{loss\Delta T} = 0$ and $Q_{loss\Delta T} = 0.625$ MW results in a calculated T_h - T_c change of about 0.04 °F or about 275 gpm for four loops. The licensee stated this effect was less than 0.1 percent, or less than about 375 gpm. This is consistent with the staff's determination.

The licensee's assumption that charging is spread equally over four legs introduces a difference of about 70 gpm flow rate that is assumed spread over the four loops, with 50 gpm appearing between T_h and T_c that is accounted for in the calculation. The other 20 gpm does not directly influence the calculation. RCS flow passes through the elbow tap measurement location before a small letdown stream is removed. Assuming letdown and charging rates are identical, the same flow rate is reinjected into the RCPs and cold legs, so that RV flow is unaffected.

Pressurizer spray flows directly from the cold leg into the pressurizer bypassing the core. From a consideration of the above discussion, one may conclude that: (1) RV flow rate is calculated with consideration of the thermal influence of pressurizer spray; (2) the perturbation to the RCS flow rate and pressure distribution due to the pressurizer spray are not modeled in the RCS hydraulic network diagram; and (3) flow rate measured at the elbow tap on the loop attached to the pressurizer surge line is greater than calculated by the calorimetric determination due to the return of spray line water. However, from the licensee's pressurizer spray effect of 0.41 MBTU/hr, the staff estimates the pressurizer flow rate is less than approximately 15 gpm. The effect of pressurizer spray on overall RCS flow rate is small.

Overall, the staff finds the total of these flow rate perturbations may be neglected when compared to a total nominal flow rate of 378476 gpm.[8] The staff further finds that the licensee's assessment of mass and heat transfer through the RCS pressure boundary between T_c to T_h is acceptable.

3.3.5 Assessment of Treatment of Frictional Heating Effect Due to Flow in the RCS

The licensee stated that "as the coolant flows through the RCS, coolant pressure decreases and the compression energy is dissipated as friction, resulting in no change in coolant temperature, other than due to component heat losses." The staff evaluated this statement since friction is typically expected to cause a temperature increase as water flows through an

[8]This finding applies to the direct effect of the flow rate perturbations on RCS flow rate. It does not apply to the perturbation of RCS flow rate due to thermal energy transport caused by the items listed at the beginning of Section 3.3.4 above. The staff notes the licensee considered the thermal energy transport terms.

adiabatic (insulated) system. From the T_c to T_h locations, assuming no core heat, calculations using the model discussed above predict a temperature increase of 0.09°F for operation at typical Modes 4 and 5 conditions due to a combination of friction and kinetic energy change. However, at normal power operating conditions, there is no kinetic energy contribution between the T_c and T_h locations, and the water temperature is calculated to decrease by 0.08°F if there is no core heat, an unexpected result. This behavior is described by the Joule-Thompson coefficient, $\mu = (\partial T/\partial P)_h$, where cooling occurs if $\mu > 0$ and heating occurs if $\mu < 0$. Thus, the sign of the Joule-Thompson coefficient has reversed when changing from water near room temperature conditions to typical RCS operating conditions. The staff finds that the licensee's determination of RCS flow rate correctly incorporates this effect since the licensee uses enthalpy consistent with Equation 12.[9]

3.3.6 Assessment of Effect of Power on Calorimetric Analysis

Some calorimetric determinations are done at less than 100 percent core power. The reduced power will change water density and will influence the assumption that $v_h = v_c$. To assess the effect of power, Equation 4 may be rewritten with the assumptions of no change in M, Z, and W to obtain:

$$Q + M \{ h + v^2 / (2 g f) \}_{in} = M \{ h + v^2 / (2 g f) \}_{out} \tag{13}$$

or:

$$M = (Q_{core} - Q_{loss\Delta T}) / [h_h - h_c + (v_h^2 - v_c^2) / (2 g f)] \tag{14}$$

In Reference 20, Duke Power showed, by elbow tap flow meter results, that the variation of flow rate with power was linear and that flow rate varied by 1.0 percent in changing power from zero to 100 percent. In Reference 15, the licensee stated that LEFM measurements indicated that the Prairie Island Unit 2 RCS cold leg volumetric flow and RCP volumetric flow decreased by about 0.8 percent as the reactor was brought from zero to full power. It further stated that the variation of flow rate with power was plant-specific and differed from 0.8 percent to 1.2 percent. Thus, it is reasonable to assume a 0.2 percent change in flow rate due to a power change from 80 percent to 100 percent. The effect of core heat transfer and a 0.2 percent change in flow rate may have a small effect on differential pressure, but the effect will be negligible when applying Equation 14 because RCS water properties are a weak function of pressure. Therefore, the staff applied Equation 14 with the assumption that the RCS pressure distribution was constant with respect to power variation. The staff also assumed that $(T_h + T_c)/2$ was approximately constant, $Q_{loss\Delta T}$ = 0.625 MW per loop, and enthalpy change could be determined by assuming an isenthalpic expansion plus the change due to heat addition, $Q_{core} - Q_{loss\Delta T}$. The staff found that a 3 gpm/loop change is introduced into RCS flow rate by neglecting the velocity difference in Equation 14 when power is reduced from 100 percent to 80 percent. This error is negligible. The staff finds that assuming $v_h = v_c$ is acceptable for the changes in power level typically associated with calorimetric determinations.

---

[9]When operating at power, the kinetic energy changes between the RCP and SG entrances and exits cause small temperature changes. These changes have no influence on the calculation of RCS flow rate via Equation 12 because they are outside the control volume.

3.3.7 Assessment of Treatment of RTD Manifold Removal

The original calorimetric data for Diablo Canyon was obtained with RTD manifolds installed in the RCS. These were later removed and RTDs were installed directly in the hot and cold legs. RTD removal had the following approximate effects:

Effect with RTD Manifold Installed	Effect of RTD Removal
Hot leg manifold flow bypassed the elbow tap location so that elbow tap location flow rate was less than RCS flow rate	Elbow tap flow rate became equal to RCS flow rate and elbow tap calibration for RCS flow rate was changed
Cold leg manifold flow passed from the RCP exit to the RCP inlet so that RCP flow rate was greater than RCS flow rate	RCP flow rate became equal to RCS flow rate and removal of the bypass flow increased RCP effectiveness
RTD hot leg manifold flow bypassed SGs so that flow resistance “seen” by the RCP was decreased	SG and RCS flow rates became equal and effective resistance of the RCS was increased

The licensee stated in Reference 2 that since calculations showed that the elbow taps would measure about 0.15 percent more flow after removal of the RTD manifolds, elbow tap flow rates were adjusted to avoid measuring a non-conservative flow rate. The licensee also stated that its calculations showed that the net RV flow rate without manifolds increased by only 15 gpm per RCP and, therefore, no adjustments in RCS flow rate were necessary. The staff elected to audit these assumptions since a 0.15 percent change would result in approximately a 560 gpm total RCS flow rate change and the staff was unsure that the RCS flow rate change was only 15 gpm/loop.

To calculate the effect of RTD manifolds, the licensee assumed the pressure difference across the manifold connections would be unchanged by the flow perturbation due to the manifolds and calculated the manifold flow resistances using RCS pressure drops obtained without manifold flow. The manifold resistances were then combined with the RV and SG resistances according to the formula:

$$R_{total} = \{ 1 / [(1 / R_1)^{½} + 1 / (1 / R_2)^{½}] \}^2 \quad (15)$$

where: R_{total} = Combined flow resistance
R_1 = RV or SG resistance
R_2 = corresponding cold leg or hot leg manifold resistance

The licensee then substituted the combined flow resistances for the initial calculation resistances and recomputed the RCP flow rate, reducing flow rates at other locations consistent with introduction of the manifold flow rates. This approach is consistent with the licensee’s assumption that elimination of the RTD manifolds has a negligible effect on the RCS pressure distribution and, hence, upon RCS flow rate. However, the pressure distribution is affected by changes in flow rates and this would result in a small perturbation in the flow resistance values. The staff elected to avoid the constant resistance assumption in the independent staff audit.

The staff used the licensee's RCS flow resistance values from Reference 3 and performed an independent calculation that included the perturbation of RCS flow due to manifold flow. Since the licensee did not provide RCP characteristics information, the staff used an available curve fit to a flow versus head curve and adjusted the curve to be consistent with the licensee's predicted flow rate of 94619 gpm/loop with manifolds removed. The effect of the manifolds was included by inputting manifold flow rates and iterating all flow rates and pressure drops against the RCP curve until convergence was obtained. (Manifold flow resistances did not need to be calculated by the staff's method.) The staff repeated its calculations when the licensee provided Reference 3 that contained the measured bypass flow rates. The following table summarizes the licensee's and the NRC's results for Unit 1:

Item with Design Manifold Flow Rates (Hot Leg = 150 gpm, Cold Leg = 100 gpm)	Flow Rate with Manifolds Installed, gpm/loop		Change in Flow Rate due to Manifold Removal, gpm/loop	
	Licensee	NRC	Licensee	NRC
RV	94604	94591	+15	+28
RCP	94704	94691	-85	-72
Elbow Tap	94454	94441	+165	+178

Item with Measured Manifold Flow Rates (Hot Leg = 134 gpm, Cold Leg = 128 gpm)	Flow Rate with Manifolds Installed, gpm/loop		Change in Flow Rate due to Manifold Removal, gpm/loop	
	Licensee	NRC	Licensee	NRC
RV	94592	94572	+27	+47
RCP	94720	94700	-101	-81
Elbow Tap	94458	94438	+161	+181

The licensee assumed a 0.15 percent change (141 gpm) in elbow tap flow rate indication due to manifold removal. The above tables show manifold removal caused indicated flow rate to increase more than the 0.15 percent. However, the licensee did not allow for a change in RV flow rate when removing the manifolds. The tables show that combining the elbow tap and RV changes with the 0.15 percent change results in a net conservative bias that is of negligible magnitude. The staff finds that the licensee's conclusion that "the calorimetric flow measurements are therefore not affected by differences in RCP flows or RTD bypass flows" is correct when the 0.15 percent allowance is included.

3.4 Assessment of Proposed Technical Specifications Change

3.4.1 Definitions

Terms used in the licensee's TSs and TS Bases have the following meanings:

- Indicated RCS total flow - Total flow rate indicated by the RCS cold leg elbow taps. This is continuously compared to the reactor coolant flow-low nominal trip setpoint

- Measured RCS total flow and measurement of RCS total flow rate - The 24 month measurement of the RCS total flow rate using cold leg elbow tap methodology or by performance of a precision flow rate calorimetric to normalize the elbow tap indications and to verify that the actual RCS flow rate is greater than or equal to the minimum required RCS flow rate. See also Measured loop flow.

- Minimum required RCS flow rate - The minimum required RCS flow rate mentioned in the SR 3.4.1.4 Bases refers to the RCS total flow rate limits in Table 3.4.1-1 for Unit 1 and Table 3.4.1-2 for Unit 2.

- Measured loop flow - The RCS loop flow rate measured every 24 months by the cold leg elbow taps or by a precision calorimetric in accord with SR 3.4.1.4[10]. See also measured RCS total flow and measurement of RCS total flow rate. Measured loop flow is a constant from the time it is measured until a new measurement is made 24 months later.

- Reactor coolant flow-low nominal trip setpoint - With implementation of the requested change to Table 3.3.1-1, Function 10, the setpoint will be set to 90 percent of measured loop flow.

- Reactor coolant flow-low reactor trip allowable value - This is based on a percentage of the loop flow measured every 24 months by SR 3.4.1.4.

3.4.2 Discussion of Affected TSs

TS 3.3.1 contains the requirements for reactor trip system instrumentation. The reactor trip system initiates a shutdown based on the values of selected parameters to protect against violating SAFDL and RCS pressure boundary limits during AOO. The reactor trip system functions are identified in TS Table 3.3.1-1. TS Table 3.3.1-1, Function 10, "Reactor Coolant Flow-Low reactor trip," ensures that protection is provided against violating the departure from nucleate boiling ratio (DNBR) limit due to low flow rate. The RCS flow-low trip provides primary

---

[10]In order to preclude the interpretation that the measured loop flow is a variable, the licensee has committed to add the following sentences to the Bases of TS 3.3.1, Table 3.3.1-1, Function 10: "The allowable value and nominal trip setpoint are based on a percentage of the loop flow measured every 24 months by SR 3.4.1.4. The RCS cold leg elbow taps indicated flow is continuously compared to the Reactor Coolant Flow-Low nominal trip setpoint." (Reference 3)

protection against a partial loss of flow accident (one or two RCPs coasting down) and a locked rotor accident, and provides secondary protection for a complete loss of flow event (four RCPs coasting down).

The purpose of the surveillance requirements, of SR 3.4.1.3 – every 12 hours, and SR 3.4.1.4 – every 24 months, is to verify that the RCS total flow rate is greater than the initial flow rate assumed in the accident analyses where a lower flow rate results in more severe results. SR 3.4.1.3 is presently met by a process based upon flow rates indicated by the elbow tap flow meters. SR 3.4.1.4 is currently met by performing a flow measurement using a method based on RCS primary temperature and an RCS secondary power calorimetric – the precision flow calorimetric. The calorimetric then allows the installed RCS flow instrumentation to be normalized and it verifies that the actual RCS flow rate is greater than or equal to the minimum required flow rate.

The proposed change would allow the use of the elbow tap ΔP for the measurement of total RCS flow rate to meet SR 3.4.1.4. The elbow tap ΔP correlation to flow rate would be normalized to Cycle 1 and 2 calorimetrics to reduce the effect of hot leg streaming in future low-leakage fuel cycles. The licensee stated in Reference 1 that this would avoid a likely unnecessary derating of the units prior to reaching the 15 percent SG plugging limit.

The reactor coolant flow-low function allowable value and nominal trip setpoint in TS Table 3.3.1-1 are currently "≥89.8%(1) of MMF/loop" and "90%(1) of MMF/loop," respectively, where Footnote (1) states "Minimum measured flow (MMF) is 89,800 gpm per loop for Unit 1 and 90,625 gpm per loop for Unit 2." The change would revise the Reactor Coolant Flow-Low function allowable value in TS Table 3.3.1-1 to "≥89.8% of measured loop flow" and revise the reactor coolant flow-low function nominal trip setpoint to "90% of measured loop flow." This change is proposed to eliminate an interpretation that a specific RCS loop flow requirement must be met, and that adjustment is required to the low flow reactor trip setpoint for individual loops that are determined not to meet the loop MMF value. The licensee pointed out that there is no safety analysis basis or requirement for resetting the reactor coolant flow-low reactor trip setpoint in a loop where flow rate is less than the total RCS MMF divided by four - the safety limits and analyses are based upon total RCS flow rate. The licensee further explained that if the total loop flow rate meets the required values and there is a loop asymmetry that results in some loops that are below the loop MMF, the remaining loops will exceed the loop MMF. Consequently, the licensee maintains that there is no need to address individual loop flow rates to meet the TS-required values. The licensee also stated in Reference 1 that the change is consistent with the NUREG-1431, Revision 2 specification of the allowable value of reactor coolant flow-low of "≥[89.2]%" and the reactor coolant flow-low nominal trip setpoint of "[90]%" (Reference 21).

3.4.3 Assessment of RCS Flow Measurement Uncertainties and Proposed TSs

The implementation of the elbow tap ΔP method of measuring RCS flow requires the determination of uncertainties associated with the precision RCS flow calorimetric for the baseline cycles for each of the units. Appendix A of WCAP-15113, Revision 1 (Reference 15) contains the uncertainty calculation to support the elbow tap ΔP method of measuring RCS flow rate. The licensee has stated that this uncertainty calculation is consistent with that described in WCAP-11594, Revision 2 (Reference 22) and WCAP-11082, Revision 5 (Reference 23), which were reviewed and accepted by the NRC in a letter dated February 17, 1998 (Reference 24).

The licensee stated that the uncertainty calculation in Reference 15 is consistent with the methodology described in NUREG/CR-3659 (Reference 25) with two exceptions - (1) the use of multiple calorimetric flow rate measurements, and (2) the presumption that the elbow taps are normalized to the single cycle specific calorimetric measurement each cycle. For difference (1), in Reference 2, the licensee stated that the elbow tap process defines a baseline calorimetric flow for correlation with elbow tap measurements in future cycles. At Diablo Canyon, two measurements were taken for Cycle 1 and two measurements were taken for Cycle 2 on each unit. The baseline calorimetric flow was then based either on the average of the four calorimetric flows or on the calorimetric flow measured in Cycle 1, whichever was smaller (i.e., more conservative). The unit with the more limiting average of the measurement uncertainty was determined and that unit's measurement uncertainties were conservatively used to envelope the precision calorimetric flow measurement average uncertainty for both units. The licensee further stated that the difference between the value it used and the largest uncertainty number from the four measurements is covered by the repeatability allowance (0.4 percent), and therefore it is not necessary to use the results with the largest uncertainty. The staff finds the licensee's approach to be acceptable.

The second difference is the presumption that the elbow taps are normalized to the single cycle specific flow calorimetric measurement each cycle. Reference 15 identifies a process by which the baseline measurements are used to establish a correlation between elbow tap differential pressure and the previously performed calorimetric flow rate determination. This process requires the appropriate inclusion of additional uncertainties associated with the elbow tap differential pressure measurements each cycle. Based on this, the staff finds that the licensee has properly justified the differences from Reference 25 and the licensee's uncertainty treatment meets the intent of the methodology.

Reference 15 provides the results of the uncertainty calculation. However, Appendix A lists some unjustified assumptions. The licensee clarified this oversight in Reference 2 by stating that (1) these items are under plant control, (2) the licensee has verified that all assumptions are met for the baseline calorimetric calculations, and (3) the licensee will include a requirement to control the uncertainty calculation assumptions in the future to ensure they are within the assumed limits when the RCS flow is measured using the elbow tap methodology. The staff finds the licensee's clarification acceptable.

The licensee also clarified whether the uncertainty numbers used in Appendix A have properly accounted for different surveillance intervals by stating that the plant procedure requires the licensee to have the instrument within its tolerance band after each surveillance test and therefore it does not have to normalize the uncertainty for different surveillance intervals. The staff finds the licensee's response acceptable.

Table A-4 of Reference 15 shows an overall RCS flow rate uncertainty of 2.3 percent for the control room indicator. This bounds the uncertainties for the process computer uncertainties, but is slightly less than the current NRC licensed value of 2.4 percent used in both the NRC-approved Westinghouse Improved Thermal Design Procedure (ITDP) and the non-ITDP departure from nucleate boiling (DNB) analyses, which were used to derive the TS 2.1 reactor core safety limits and corresponding TS 3.4.1 DNB limits. Therefore, the staff finds that the uncertainty for use of the elbow tap flow measurement method is bounded by that assumed in the current safety analyses and no changes to the RCS flow rate value contained in the safety analyses are required. Also, Table A-5 of Reference 15 shows the calculated channel statistical allowance for the reactor trip function is lower than the total allowance flow span of 4.2 percent assumed for the low flow reactor trip function. Therefore, the staff finds that no change is required to the TS Table 3.3.1-1 reactor coolant flow - low nominal trip setpoint value of 90 percent flow or the current safety analyses value of 85 percent due to availability of margin in the uncertainty calculation.

3.4.4 Assessment of Proposed RCS Flow Rate Measurement Methodology

As discussed in Section 3 above, the staff has evaluated the proposed use of the cold-leg elbow tap ΔP measurement methodology described in Reference 15 for RCS flow rate measurement. The staff has found that each audited issue was acceptably addressed by the licensee. Consequently, the staff finds that the proposed use of the cold-leg elbow tap ΔP measurement methodology is an acceptable alternative to a precision calorimetric determination.

3.4.5 Assessment of Proposed TS Changes

As discussed in Section 3.4.2 above, the licensee has proposed to replace the MMF/loop to measured loop flow for allowable value and nominal trip setpoint for Function 10, TS Table 3.3.1-1, reactor coolant flow - low, and has proposed to delete the footnote (l) which defines the minimum measured flow. This trip function provides the primary protection against the partial loss of flow accident and backup protection for the complete loss of flow accidents. The licensee has stated that there is no safety analysis basis or requirement to have a loop minimum measured flow. The licensee has analyzed the partial loss of flow (PLOF) and complete loss of flow (CLOF) accident and has determined that the elimination of the reference to the loop MMF in the reactor coolant flow - low function allowable value and nominal trip setpoint in TS Table 3.3.1-1 has no adverse effect on the design basis accidents, which credit the reactor coolant flow-low function nominal trip setpoint. Also, the elimination of the reference to the loop MMF is consistent with Reference 21. The licensee has used References 22 and 23, which were submitted to the NRC in support of its submittal for extended fuel cycles to 24 months, and which were reviewed and approved by Reference 24. Based on the revised uncertainty evaluation, the licensee has determined the allowable values to be ≥89.8 percent of RCS loop flow and a nominal trip setpoint of 90 percent of RCS loop flow, measured every 24 months by the cold leg elbow taps or by a precision calorimetric. These values are consistent with the current TSs. Also, the nominal reactor trip setpoint of 90 percent flow is 5 percent higher than the current safety analysis limit. Hence, it provides sufficient margin to allow for the increased instrument uncertainties due to normalization of the elbow tap, as shown in Table A-5 of Reference 15, where the allowance for the low flow trip setpoint is shown to be larger than the statistical channel allowance. The staff, therefore, finds the proposed TS change acceptable that would delete the footnote (l), and revise the Reactor Coolant Flow-Low function allowable value in TS Table 3.3.1-1 to "≥ 89.8% of measured loop flow" and revise the Reactor Coolant Flow-Low function nominal trip setpoint to "90% of measured loop flow."

3.5 Commitments

In order to preclude the interpretation that the measured loop flow is a variable, the licensee has committed to add the following sentences to the Bases of Table 3.3.1-1 Function 10: "The allowable value and nominal trip setpoint are based on a percentage of the loop flow measured every 24 months by SR 3.4.1.4. The RCS cold leg elbow taps indicated flow is continuously compared to the Reactor Coolant Flow-Low nominal trip setpoint." Because this is a clarification of the Bases, the licensee's commitment is sufficient.

Appendix A of Reference 15 listed some unjustified assumptions as part of the uncertainty calculation. As discussed in Section 3.4.3 above, in Reference 2 the licensee committed to include a requirement to control the uncertainty calculation assumptions in the future to ensure they are within the assumed limits when the RCS flow is measured using the elbow tap methodology.

3.6 Conclusions

The staff has reviewed PG&E's amendment request described in References 1, 2, 3, and 4 to accomplish the following two changes:

(1) Revise the term "minimum measured flow per loop" to "measured loop flow" in the allowable value and nominal trip setpoint for the reactor coolant flow-low reactor trip function contained in TS 3.3.1, Table 3.3.1-1 "Reactor Trip System Instrumentation," and

(2) Allow an alternate method for the measurement of RCS total volumetric flow rate through measurement of the elbow tap differential pressures on the RCS cold legs.

During the initial conduct of its review, the staff discovered an inconsistency in past staff reviews of the calibration of elbow tap flow measurement instrumentation. Consequently, the staff elected to perform a detailed audit of the licensee's request with the purpose of both correcting the past inconsistency and reasonably ensuring that the technical aspects of the request were evaluated in depth. This review resulted in several topics being addressed in greater depth than conducted in previous reviews.

The findings may be grouped into two categories: (A) generic findings that are applicable to the PG&E amendment request and that may be directly referenced in future applications without further justification; and (B) findings applicable to the review of the PG&E amendment request.

The Category A findings are as follows:

A. In Section 3.2.2, above, the staff found that elbow tap flow meter coefficients may be treated as constant and the relative changes of flow rate through the cold-leg elbows can be correlated with the relative changes in the elbow tap ΔPs at Diablo Canyon and similar plants. No further justification of this finding is necessary for plants with configurations and analyses identical to those assessed herein,

B. In Section 3.2.3, above, the staff found that RCP impeller smoothing will result in an RCS flow rate decrease of about 0.6 to 0.8 percent during initial operation. This effect is greatest early in operation and the effect on RCS flow rate essentially ceases by the end of the second cycle. The staff further found that PG&E had justified the assumptions it used to describe the smoothing effect as a function of time.

No further justification of this finding is necessary in plants equipped with RCP impellers that are essentially identical to the impellers considered herein. Licensees should, however, justify the assumptions used to describe the smoothing effect as a function of time. A determination that such assumptions are conservative will constitute acceptable justification.

C. PG&E provided information that established that the RCS hot and cold leg flow velocities are essentially identical when operating at power and established that the following equation is applicable for calculation of RCS flow rate.

$$M = (Q_{core} - Q_{loss\Delta T}) / (h_h - h_c) \qquad (12)$$

where: Q_{core} = core heat generation rate
$Q_{loss\Delta T}$ = net heat loss rate associated with the RV and the pipes between the locations of T_h and T_c (includes the heat transport contributions due to such items as charging flow, letdown flow, seal injection flow, RCP thermal barrier cooler heat removal, pressurizer spray flow, pressurizer surge line flow, component insulation heat loss, component support heat loss, and control rod drive mechanism heat loss when the effect is the introduction of or removal of heat between the locations of T_h and T_c)
h_h = hot leg enthalpy, and
h_c = cold leg enthalpy.

In Section 3.3, above, the staff reviewed the theory and assumptions used to derive this equation and found the equation to be acceptable for calculation of RCS flow rate at Diablo Canyon. The staff further finds that the equation is acceptable for calculation of RCS flow rate in other plants that have hot and cold leg diameters that result in essentially equal hot and cold leg velocities when operating at power.

D. In plants where an RTD manifold was installed, the effect of the RTD manifold should be included for those cycles where the manifold is installed or when the manifold has been removed but reference is made to cycles when the manifold was installed. The staff reviewed PG&E's treatment of bypass manifold review in Section 3.2.3, above, and found it to: (a) provide an acceptable correction for the removal of the RTD bypass manifolds; and (b) to be consistent with the approved process described in Reference 12.

The Category B findings that are applicable to the review of the PG&E amendment request are as follows:

E. As summarized in Section 3.2.4, above, the staff audited the PG&E procedure for determining the RCS flow rate from elbow tap ΔP measurements described in WCAP-15113. It found that:

   A. Small flow paths that are associated with the hot and cold legs, such as the RTD bypass manifold, charging, letdown, RCP seal flow, and pressurizer connections, are not included, but have an essentially negligible effect on RCS pressure distribution (Sections 3.3.4 and 3.3.7, above). Further, the staff found the PG&E approach to address these effects to be acceptable.

   B. PG&E uses an average of elbow tap ΔPs approach that the staff approved in Reference 12. This is acceptable.

   C. PG&E's usage of the best estimate flow based on the hydraulic analysis was stated to only be used to confirm the elbow tap flow measurement while limiting the elbow tap flow measurement to a maximum value corresponding to the best estimate flow plus an allowance for the elbow tap flow repeatability uncertainty. The best estimate flow is not to be used as a substitute for the TS SR for flow measurement. This usage is consistent with the staff's finding in Reference 12 and is acceptable.

F. As reported in Section 3.2.5, above, the staff found that PG&E used acceptable processes to determine its baseline calorimetric flow rates. (The baseline calorimetric flow rate for Unit 1 was stated to be 376,656 gpm and, for Unit 2, it was stated to be 379,089 gpm.)

G. As reported in Sections 3.4.2, 3.4.3, and 3.4.5, above, the staff audited the proposed TSs, the flow measurement uncertainties, and the effect on the affected TSs. The staff found the PG&E approach and changes to be consistent with previous approved approaches or that differences were acceptably addressed. The staff, therefore, finds the proposed TS change acceptable.

In conclusion, based on the above, the staff finds that PG&E's amendment request is consistent with previously approved, applicable references. The reactor core and associated coolant, control, and protection systems will continue to have an appropriate margin to assure that SAFDL are not exceeded during any condition of normal operation, including the effects of AOO. Consequently, the proposed changes are consistent with continued compliance with GDC 10. Further, the request is consistent with continued compliance with 10 CFR 50.36(c)(2)(ii). Consequently, the staff concludes that the proposed changes are acceptable.

4.0 STATE CONSULTATION

In accordance with the Commission's regulations, the California State official was notified of the proposed issuance of the amendments. The State official had no comments.

5.0 ENVIRONMENTAL CONSIDERATION

These amendments change a requirement with respect to the installation or use of a facility component located within the restricted area as defined in 10 CFR Part 20, or changes an inspection or a surveillance requirement. The NRC staff has determined that the amendments involve no significant increase in the amounts, and no significant change in the types, of any effluents that may be released offsite, and that there is no significant increase in individual or cumulative occupational radiation exposure. The Commission has previously issued a proposed finding that the amendments involve no significant hazards consideration and there has been no public comment on such finding (68 FR 810). Accordingly, the amendments meet the eligibility criteria for categorical exclusion set forth in 10 CFR 51.22(c)(9). Pursuant to 10 CFR 51.22(b) no environmental impact statement or environmental assessment need be prepared in connection with the issuance of the amendments.

6.0 CONCLUSION

The Commission has concluded, based on the considerations discussed above, that: (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) such activities will be conducted in compliance with the Commission's regulations, and (3) the issuance of the amendments will not be inimical to the common defense and security or to the health and safety of the public.

7.0 REFERENCES

1. Rueger, Gregory M., "License Amendment Request 02-05, 'Revision to Technical Specification Table 3.3.1-1, 'Reactor Trip System Instrumentation,' and Revised Reactor Coolant System Flow Measurement,'" Letter to NRC from Pacific Gas and Electric Company, DCL-02-097, August 27, 2002.

2. Oatley, David H., "Response to NRC Request for Additional Information Regarding License Amendment Request 02-05, 'Revision to Technical Specification Table 3.3.1-1, 'Reactor Trip System Instrumentation,' and Revised Reactor Coolant System Flow Measurement,'" Letter to NRC from Pacific Gas and Electric Company, DCL-03-056, May 15, 2003.

3. Oatley, David H., "Response to NRC Request for Additional Information Regarding License Amendment Request 02-05, 'Revision to Technical Specification Table 3.3.1-1, 'Reactor Trip System Instrumentation,' and Revised Reactor Coolant System Flow Measurement,'" Letter to NRC from Pacific Gas and Electric Company, DCL-03-079, June 26, 2003.

4. Becker, James R., "Information to Support Review of PG&E License Amendment Request on Revised RCS Flow Method," Letter to NRC from Pacific Gas and Electric Company, DCL-03-092, August 1, 2003.

5. Letter from V. Nerses (USNRC) to T. C. McMeekin (Duke Power Company), "Issuance of Amendments - McGuire Nuclear Station, Units 1 and 2, Reactor Coolant System (RCS) Flow Rate Measurement (TAC Nos. M88659 and M88660)," January 12, 1995.

6. Patel, Chandu P., "Catawba Nuclear Station, Unit 2 Re: Issuance of Amendment (TAC No. MB1498)," NRC Letter to Duke Energy Corporation, October 2, 2001.

7. Martin, Robert E., "Catawba Nuclear Station, Unit 2 Re: Issuance of Amendment, Cold Leg Elbow Tap Flow Coefficients (TAC No. MB6529)," NRC Letter to Duke Energy Corporation, March 19, 2003.

8. Letter from R. E. Martin (USNRC) to D. L. Rehn (Duke Power Company), "Issuance of Amendments - Catawba Nuclear Station, Units 1 and 2, Reactor Coolant System (RCS) Flowrate Measurement (TAC Nos. M88480 and M88658)," February 17, 1995.

9. Letter, Thomas W. Alexion (USNRC) to William T. Cottle (STP Nuclear Operating Company), "South Texas Project, Units 1 and 2 - Issuance of Amendments, Re: Reactor Coolant System Flow Monitoring (TAC Nos. M99245 and M99246)," April 19, 1999.

10. Letter, L. Mark Padovan (USNRC) to D. N. Morey (Southern Nuclear Operating Company), "Joseph M. Farley Nuclear Plant, Units 1 and 2 - RE: Approval to Use WCAP-14750 at Farley (TAC Nos. M97325 and M97326)," June 30, 1999.

11. "Seabrook Station, Unit No. 1 - Issuance of Amendment RE: Reactor Coolant System Flow Measurement (TAC No. MA9301)," NRC Letter for License Amendment No. 77 to Facility Operating License No. NPF-86, October 26, 2000.

12. WCAP-14750-A, Revision 1, WCAP-14750-P-A, Revision 1 (proprietary), "RCS Flow Verification Using Elbow Taps at Westinghouse 3-Loop PWRs," September 1999.

13. Martin, Robert E., "Catawba Nuclear Station, Unit 2, RE: Cold Leg Elbow Tap Flow Coefficients," NRC Letter to G. R. Peterson, Duke Energy Corporation, July 1, 2003.

14. "Fluid Meters, Their Theory and Application," 6th Edition, Howard S. Bean, ASME, New York, 1971.

15. "RCS Flow Measurement Using Elbow Tap Methodology at Diablo Canyon Units 1 and 2," WCAP-15113, Revision 1, Westinghouse Electric Company LLC, April 2002.

16. "RCS Flow Verification Using Elbow Taps at Westinghouse 3-Loop PWRs," WCAP-14754-NP-A, October 14, 1999.

17. Nemeth, Bela A., "Chemical Tables," John Wiley & Sons, 1975.

18. Washburn, Edward W., "International Critical Tables of Numerical Data, Physics, Chemistry and Technology," Vol. III, McGraw Hill, 1928.

19. Caso, C. L., "Long Term Core Cooling-Boron Considerations," Westinghouse Electric Corporation Letter to T. M. Novak (NRC), CLC-NS-309, April 1, 1975.

20. Peterson, Gary R., "Duke Energy Corporation, Catawba Nuclear Station, Unit 2, Docket Number 50-414, Response to Request for Additional Information for Unit 2 Reactor Coolant System Cold Leg Elbow Tap Flow Coefficients," Duke Letter to NRC, February 26, 2003.

21. "Standard Technical Specifications, Westinghouse Plants," NUREG-1431, Vol. 2, Rev. 2, June, 2001.

22. "W Improved Thermal Design Procedures Instrument Uncertainty Methodology, Diablo Canyon Units 1 & 2, 24 Month Fuel Cycle Evaluation," WCAP-11594, Revision 2, January 31, 1997.

23. "W Setpoint Methodology for Protecting System, Diablo Canyon Units 1 & 2, 24 Month Fuel Cycle Evaluation," WCAP-11082, Revision 5, January 31, 1997.

24. Bloom, Steven D., "Issuance of Amendments for Diablo Canyon Nuclear Power Plant, Unit No. 1 (TAC No. M97472) and Unit 2 (TAC No. M97473)," NRC Letter to Gregory M. Rueger, Pacific Gas and Electric Company, February 17, 1998.

25. "A Mathematical Model for Assessing the Uncertainties of Instrumentation Measurements for Power and Flow of PWR Reactors," NUREG/CR-3659, February 28, 1985.

Principal Contributors: Warren Lyon
Hukam Garg

Date: August 21, 2003