March 19, 2003

Mr. G. R. Peterson
Site Vice President
Catawba Nuclear Station
Duke Energy Corporation
4800 Concord Road
York, South Carolina 29745-9635

SUBJECT: CATAWBA NUCLEAR STATION, UNIT 2 RE: ISSUANCE OF AMENDMENT COLD LEG ELBOW TAP FLOW COEFFICIENTS (TAC NO. MB6529)

Dear Mr. Peterson:

The Nuclear Regulatory Commission (NRC) has issued the enclosed Amendment No. 199 to Facility Operating License NPF-52 for the Catawba Nuclear Station, Unit 2. The amendment authorizes the licensee to continue to use, for operational cycle 13 beginning in March 2003, and subsequent cycles of operation, the reactor coolant system cold leg elbow tap flow coefficients that were approved by the NRC on an interim basis for cycle 12 in Amendment No. 186. The amendment involves changes to your Updated Final Safety Analysis Report and are in response to your application dated October 10, 2002, as supplemented by letters dated February 7 and February 26, 2003.

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

Sincerely,

/RA/

Robert E. Martin, Senior Project Manager, Section 1
Project Directorate II
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket No. 50-414

Enclosures:
1. Amendment No. 199 to NPF-52
2. Safety Evaluation

cc w/encls: See next page

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DUKE ENERGY CORPORATION

NORTH CAROLINA MUNICIPAL POWER AGENCY NO. 1

PIEDMONT MUNICIPAL POWER AGENCY

DOCKET NO. 50-414

CATAWBA NUCLEAR STATION, UNIT 2

AMENDMENT TO FACILITY OPERATING LICENSE

Amendment No. 199
License No. NPF-52

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

   A. The application for amendment to the Catawba Nuclear Station, Unit 2 (the facility) Facility Operating License No. NPF-52 filed by the Duke Energy Corporation, acting for itself, North Carolina Municipal Power Agency No. 1 and Piedmont Municipal Power Agency (licensees), dated October 10, 2002, as supplemented by letters dated February 7 and February 26, 2003, complies with the standards and requirements of the Atomic Energy Act of 1954, as amended (the Act), and the Commission's rules and regulations as 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 set forth in 10 CFR Chapter I;

   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, changes to the Updated Final Safety Analysis Report (UFSAR) are authorized to reflect the continued usage, for Cycle 13 and subsequent cycles of operation, of the reactor coolant system cold leg elbow tap flow coefficients that were approved on an interim basis for Cycle 12 in Amendment No. 186, issued on October 2, 2001. These coefficients are listed on page 2 of attachment 1 to the licensee's application dated October 10, 2002. The licensee shall submit the revised description authorized by this amendment with the next update of the UFSAR.

3. This license amendment is effective as of its date of issuance and shall be implemented within 30 days of issuance.

FOR THE NUCLEAR REGULATORY COMMISSION

/RA/

John A. Nakoski, Chief, Section 1
Project Directorate II
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Date of Issuance: March 19, 2003

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO AMENDMENT NO. 199 TO FACILITY OPERATING LICENSE NPF-52

DUKE ENERGY CORPORATION, ET AL.

CATAWBA NUCLEAR STATION, UNIT 2

DOCKET NO. 50-414

1.0 INTRODUCTION

By letter dated October 10, 2002 (Reference 2), as supplemented February 7 and February 26, 2003 (References 3 and 4, respectively), Duke Energy Corporation, et al. (the licensee), submitted a proposal for amendment of the Facility Operating License for the Catawba Nuclear Station, Unit 2. The amendment would authorize the licensee to continue to use, for operational Cycle 13, beginning in March 2003, and subsequent cycles of operation, the reactor coolant system (RCS) cold leg elbow tap flow coefficients that were approved by the Nuclear Regulatory Commission (NRC) on an interim basis for cycle 12 in Amendment No. 186, issued on October 2, 2001. Cycle 12 was completed in February 2003, and Cycle 13 will begin in March 2003, following a refueling outage. The licensee proposed these coefficients, as listed below, for continued usage "based on technical justification that the revised flow coefficients are an appropriate and sufficiently conservative method for confirming that the RCS flow assumed in the core design and safety analyses is maintained."

Tap	Loop A	Loop B	Loop C	Loop D
I	0.30680	0.30313	0.31712	0.29936
II	0.29606	0.28601	0.29659	0.29929
III	0.30382	0.30689	0.30389	0.30137

The licensee's request is consistent with the issuance of Amendment No. 186 on October 2, 2001, (Reference 1) to the Catawba, Unit 2 operating license, that approved the use of these elbow tap coefficients for Cycle 12 and stipulated that any future changes to the elbow tap coefficients would require prior review and approval by the NRC staff. This amendment does not change the Technical Specifications (TSs). The licensee has provided a commitment in its letter dated February 26, 2003, that these elbow tap coefficients will be included in the Updated Final Safety Analysis Report (UFSAR). The NRC staff authorizes the licensee, by issuance of this amendment, to make the associated changes to the UFSAR and requires the licensee to submit the revised description authorized by this amendment with the next update of the UFSAR. The supplemental information in the letters dated February 7 and February 26, 2003, does not expand the scope of the application as originally noticed nor does it change the staff's initial no significant hazards consideration determination.

2.0 REGULATORY EVALUATION

General Design Criterion 10, "Reactor Design," in Appendix A to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, requires that the reactor core and certain associated systems be designed with appropriate margin to assure that specified acceptable fuel design limits (SAFDLs) are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences (AOOs). The SAFDLs for AOOs are that neither departure from nucleate boiling (DNB) nor melting at the fuel centerline occurs. The results of the safety analyses calculations are used to assure that the SAFDLs are met.

The RCS flow rate is one of the inputs for calculation of the departure from nucleate boiling ratio (DNBR). The inputs to the transient and accident analyses include the initial condition of RCS thermal design flow rate. The minimum RCS flow rate requirement in the TSs is consistent with the assumed RCS thermal design flow.[1]

On February 17, 1995, Amendment Nos. 128 and 122 (Reference 5) were issued for the Facility Operating Licenses for Catawba Nuclear Station, Units 1 and 2, respectively. The amendments revised the TS to allow a change in the method for measuring RCS flowrate from the calorimetric heat balance method to a method based on a calibration of the RCS cold leg elbow differential pressure taps. A portion of the licensee's justification for this change, as presented in the licensee's letter dated January 10, 1994, is as follows:

> The calculated Reactor Coolant System flowrates as determined by the current Technical Specification surveillance method have changed significantly over the past several fuel cycles at the McGuire and Catawba Nuclear Stations. These changes are not substantiated by the changes that have occurred in the system hydraulics, and are not confirmed by other indications of loop flow. These changes have on occasion resulted in closely approaching the Technical Specification minimum measured flow limit, with a minimum flow margin of as low as 0.1% having occurred at McGuire Unit 2. This situation has resulted in Technical Specification changes to reduce the minimum measured flow and has impacted the thermal margin and operating space in the reload designs. The current surveillance method calculates RCS flow based on steam generator thermal output from a calorimetric measurement, divided by the enthalpy difference across the reactor vessel as indicated by the hot and cold leg RTDs [resistance temperature detectors]. Uncertainty in the hot leg temperature as indicated by the RTD has been identified as the main contributor to calculated decreases in RCS flow. Changes in core reload designs have resulted in core exit temperature distributions that, when combined with incomplete flow mixing and asymmetric flow patterns in the upper plenum [of the reactor vessel], produce varying hot leg temperature indications. The net effect of these phenomena has resulted in what has been referred to as hot leg streaming. The three hot leg RTDs are oriented approximately at 120 degree angles on the cross section of the hot leg pipe. The RTDs can indicate different temperatures in each loop, between loops, and can also change during the fuel cycle as the core power distribution changes. Due to the observed error in this method of flow surveillance and the consequences related to core thermal margin and operating space, an alternate method of performing the flow surveillance using the cold leg elbow tap indication of flow is proposed. The elbow taps are used for the Reactor Protection System

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[1] As discussed further in the reference 5 safety evaluation section 3.1

monitoring of loop flow and are a true measurement of flow. The elbow taps were originally used for the Technical Specification flow surveillance at McGuire and other Westinghouse plants, but a change to the calorimetric based flow method was adopted with the intent of benefitting from supposed better accuracy. The unanticipated impact of hot leg streaming has eliminated the benefit of the calorimetric method. In the proposed method, the existing historical calorimetric data is used to establish a calibration of the elbow taps and then the future flow surveillance is performed by using the elbow tap flow indications.

The NRC staff's safety evaluation for the 1995 amendment (reference 5) noted that the flow coefficients obtained from the above method were proposed to be frozen for future operating cycles and that the selection of the frozen coefficients was influenced by the number of cycles that provided the data for the coefficients. These flow coefficients were based on data from the first few plant cycles where thermal streaming was less significant as well as on data from later plant cycles that had additional conservatism due to hot leg streaming. The significance of these choices for the reference 5 amendment is explored in the following discussion.

By letters dated March 9, July 25, September 10 and September 13, 2001, the licensee requested further changes to the cold leg elbow tap flow coefficients. The NRC staff issued Amendment No. 186 to the operating license for Catawba, Unit 2, in response to this request on October 2, 2001 (Reference 1). The safety evaluation for the 2001 amendment notes that the coefficients proposed by the licensee and approved in the 1995 amendment, were based on 11 sets of calorimetric data taken over a period of almost 7 years. The licensee's application claimed that including all of these calorimetrics resulted in a severe flow penalty because of the increasing bias with increasing time due to hot leg streaming.[2] The licensee proposed to calculate a revised set of coefficients using three of the calorimetrics that were performed early in the plant's life, since these three calorimetrics would contain less of the bias attributed to hot leg streaming. The NRC staff approved this request on October 2, 2001, but limited this approval to the Catawba, Unit 2 operating Cycle 12 because of concerns with the calorimetric determination process and with potential variation in long-term elbow tap characteristics.

The licensee's letter dated October 10, 2002, as supplemented on February 7 and February 26, 2003, requested approval to continue the use of the calorimetrics approved in Amendment No. 186 for future operating cycles at Catawba, Unit 2. The evaluation provided below addresses this request.

3.0 TECHNICAL EVALUATION

3.1 Current Status

RCS flow rate at Catawba, Unit 2 is calculated from cold leg elbow tap differential pressure measurements by an equation that contains an empirically-determined flow coefficient. The current TSs specify a minimum RCS flow rate of 390,000 gallons per minute (gpm). The flow rate determined by the elbow taps using the Cycle 12 elbow tap coefficients at the startup of Cycle 12 was 394,400 gpm and was projected to be 393,700 gpm at the end of Cycle 12. The projected flow rate at the startup of Cycle 13 was 393,800 gpm with a minimum flow rate during

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[2] Further discussion and definition of the hot leg streaming phenomena may be found in references 5 and 6 and in Attachment 1 of reference 2.

the cycle of 393,100 gpm. This provides a margin for Cycle 13 to the TS limit of 3100 gpm that is less than one percent of the TS value.

The initial determination of RCS flow rate at Catawba was based on an initial secondary-side calorimetric to determine thermal power, and this was converted to an RCS flow rate using hot and cold leg temperatures. Three elbow tap flow meter indications in each RCS loop were then “calibrated” by calculating flow coefficients from the calorimetrically-determined flow rates. Historically, as calorimetric determinations were performed in later cycles, the information was used to revise the elbow tap coefficients. However, this led to a continuing decrease in the RCS flow rates indicated by the elbow taps that was attributed to calibration errors caused by thermal streaming, as discussed in Section 2, above.

In Reference 1, the staff evaluated the impact of thermal streaming and assessed the premise that elbow tap flow coefficients should be constant over the life of the plant. On the basis of this assessment, it approved elbow tap coefficients for use during Cycle 12 that were based on early calorimetric determinations. However, in discussing this approval, the staff stated:

> We discovered several errors in the licensee’s submittals and we found several aspects where we disagree with the licensee’s conclusions. Although these errors and disagreements affect some of the quantitative aspects of the licensee’s request, they do not lead to a conclusion that the licensee’s request is unjustified. On the contrary, we find the licensee’s request is reasonable and we find it acceptable for the upcoming reload Cycle 12.

and:

> The analytic model represents an important aspect of long-term confirmation of elbow tap response since, when correctly configured and applied, it can lead to identification of unrecognized problems or inaccuracies. Our audit of the licensee’s analytic model identified weaknesses and errors. We expect the licensee to revise its analytic model to correct these weaknesses and errors when applying the proposed elbow tap coefficients to determination of RCS flow rate in reload Cycle 13 and later cycles.

As identified in Reference 3, a key aspect of the staff’s previous review was that the licensee should substantiate that elbow tap coefficients would remain constant for the life of the plant. The staff identified two methods that could contribute to such substantiation:

(1) Comparisons of the effect of physical plant changes on RCS flow rate as determined by analysis and by elbow taps, and

(2) Assessment of long-term elbow tap behavior by other means.

In Reference 1, the staff identified several issues where additional understanding was necessary. Further issues were identified during the current review. These issues and associated topics were consolidated into the following topics:

(1) Appropriateness of the RCS flow rate analytical model for trending and for evaluation of long term elbow tap coefficient behavior

(2) Evaluation of elbow tap flow coefficient determination

(3) Other means of assessing stability of elbow tap flow coefficients

These topics are addressed in the remainder of Section 3, below.

3.2 The RCS Flow Rate Analytical Model

3.2.1 Description of the Analytical model

The licensee provided a copy of the RCS flow rate analytical model in Reference 3 and updated the model in Reference 4. Observed characteristics of the model are summarized in the following table:

Characteristic	Description	Comments
Flow modeling	Nodes & 4 loops connected to reactor vessel. Pressure drop (ΔP) was ratioed from reference design via square of flow rate.	Consistent with typical modeling assumptions. Nodalization judged adequate. Incorrect reference values used in core loadings starting for February 1993. See table in Section 3.2.2.2.
	Constant temperatures were assumed for all calculations.	Not a concern. See Section 3.2.2.1
	A density variation was allowed in the steam generator (SG) model but not in remainder of RCS. Other properties were constant.	
	No provision was provided for effect of core power on core flow resistance.	Not a concern when all analyses are for 100% power.
Reactor vessel	Model assumed a one dimensional flow path through downcomer, up through core into upper plenum.	Multi-dimensional flow was not modeled. Licensee determined the bounding case to increase ΔP by 0.03 psi. Staff substituted the increase into the spreadsheet and calculated about a 70 gpm decrease in total flow rate. Use of a one dimensional flow path is acceptable.
	Leakage paths between downcomer and upper plenum and via core bypass were taken as fixed fractions of total flow	Flow rate is a function of core pressure drop and hence of the type of fuel used. Licensee-assumed flow fractions were modified in Reference 4. Changes did not affect staff findings. See Section 3.2.2.2

Characteristic	Description	Comments
RTD bypass manifolds	Included for cases where they were connected. Assumed connected at midpoints of hot legs and pump discharge cold legs.	Effect of this hardware was not included in licensee's earlier analyses. Apparent errors discovered during staff's review. Changes did not affect staff findings. See Section 3.2.2.4.
Buoyancy effect due to differential temperature	A constant negative of 1.3 ft of water was assumed.	Staff calculations confirmed the value to be reasonable. The value is not expected to vary significantly since the analytical model is used for full power
Reactor Coolant Pump (RCP)	Flow rate was calculated from ΔP (expressed as head loss) using the fitted curve for constant water properties.	Staff did not identify a need to audit the fidelity of the curve.
	Wear-in early in life	Determined not to be a concern. See Section 3.3.4
Makeup / letdown	Not included	Typically ~100 gpm or less. Judged to be negligible.
In-cycle variables	Effects, such as fouling and boric acid deposit buildup and the effect of boric acid concentration on water properties, were not included.	Licensee judges this to be variable from outage to outage. Reference 2 estimated 700 gpm for Cycles 12 and 13. Staff determined this not to be a concern. See Section 3.2.2.3.
Methodology	The ΔP was calculated for each loop with assumed loop flow rates and for reactor vessel with total of loop flow rates. The ΔP was input into RCP curve to calculate new loop flow rates. New loop flow rates were input into new assumption and the process was repeated until it converged.	The staff found that convergence was stable when the new estimate was the average of old estimate and the new calculated flow rate. But, see Section 3.2.2.4 for apparent error in calculations that include RTD bypass manifolds.

3.2.2 Analytical Model and Sensitivity Evaluations

3.2.2.1 RCS Temperature

As identified in Section 3.2.1, above, the analytical model does not include the effect of variation in temperature on RCS coolant physical properties. To assess the potential impact of this assumption, the staff considered the licensee's November 1995, RCS temperature reduction of 3.3 °F by substituting an approximation for the density change into the Reference 3 version of the analytical model. The temperature decrease was predicted to increase flow rate by about 300 gpm. The corresponding viscosity increase would decrease the flow rate change, but the staff did not pursue this aspect. The staff concluded that a small temperature change does not appear to cause a pronounced change in RCS flow rate.

A variation in RCS flow rate will also affect temperature. For example, a 4000 gpm increase in flow rate will decrease the RCS temperature differential by about 0.6 °F = [65 °F]{1 - [400,000- 4000]/400,000}, and would cause a negligible effect on physical properties. Conversely, a measurement error of about 0.6 °F will cause a calorimetric flow rate error of about 4000 gpm, a significant effect and an indication of the sensitivity of calorimetric flow rate to thermal streaming. Finally, the licensee uses the analytical model for full power analyses and large temperature changes are not expected.

Since the assumption of constant physical properties has negligible influence on results for the temperature changes expected for full power operation, and the licensee only uses the analytical model to predict full power operation behavior with respect to the comparisons discussed herein, the staff finds it is acceptable to exclude temperature variation from the analytical model.

3.2.2.2 Core and Core Bypass Modeling

As identified in Section 3.2.1, above, the analytical model uses reference flow rates to calculate the effect of changes in flow rate on pressure drop and the original model assumed core bypass was a constant fraction of total flow. The licensee (Reference 4) identified errors in these calculations as summarized in the following table:

Fuel	Original Reference Value	Correct Reference Value	Original Core Bypass Flow	Correct Core Bypass Flow
Westinghouse OFA	21.6 psi @ 406800 gpm	Original is correct.	5.7%	6.24%
Framatome Advanced Nuclear Products Mark-BW Fuel	20.75 psi @ 406800 gpm	20.75 psi @ 403600 gpm	5.7%	6.17%
Westinghouse Robust Fuel Assembly (RFA)	25.1 psi @ 406800 gpm	25.1 psi @ 390000 gpm	5.7%	7.02%

The licensee stated that the combined effect of these errors resulted in an 829 gpm reduction in predicted RCS flow rate for the 2003 core loading.[3] It also provided a corrected comparison of

[3]DNBR requirements correlate directly to flow rate through the core. Core flow rate is less than the total flow rates at the reactor vessel nozzles by the amounts of the bypass flows of 6.24 percent, 6.17 percent, and 7.02 percent for the three fuel loadings

predicted flow rates with elbow tap flow rates that accounted for the changes identified in the above table.

Reference 4 also described a VIPRE-01 analysis performed to show the effect of increasing the radial peaking factor from 1.2 to 1.8 in eight fuel assemblies to obtain a fuel assembly exit void fraction of 2 percent in those fuel assemblies. Core pressure drop was reported to have increased by 0.03 percent, a negligible amount.[4] (Exit voids are not generated during normal operation.)

The licensee originally assumed core bypass paths were not a function of core loading. It subsequently incorporated an allowance for variability into the model to include the effect. This resulted in a more accurate prediction of RCS flow rate. As part of the assessment, the licensee also showed that multidimensional representation of core flow was not necessary for this application.

3.2.2.3 Variations During a Fuel Cycle

The licensee stated that the boric acid effect is straight-forward, but only contributes to a 200 gpm flow rate change during a fuel cycle, with the flow rate decreasing during the cycle. Another contributor to in-cycle flow variation, as identified in Reference 2, is the flow rate decrease due to apparent buildup of crud on the fuel assemblies. As noted in the table in Section 3.2.1 above, the total in-cycle variability due to these effects is about 700 gpm. The staff judged these effects to be sufficiently small that they would not change any review conclusions. Further, they are not included in the analytical model since there is no attempt to include variations within a cycle. The staff finds the licensee's approach to neglecting variations during a fuel cycle to be acceptable. However, the staff notes that this effect is a potential contributor to uncertainty when comparing analytical model predictions to operational data, and the uncertainty can be reduced by correcting for the approximate effect of the time during a cycle when operational data are obtained.

3.2.2.4 RTD Manifold Removal

The version of the licensee's analytical program in effect during the staff's Reference 1 review did not model the RTD manifold. The analytical program provided in the Reference 3 model included the RTD manifold. The effects of this change are addressed as follows:

In References 3 and 4, the licensee identified the effect of RTD bypass flow as 111 gpm/loop bypassing part of the hot legs, the SGs, and the elbow tap flow meter connections; and 172 gpm/loop flowing from the RCP discharge back to the RCP suction which also bypassed the flow meter connections. These flow paths are shown in the following sketch where the values are percentages of total flow rate at the reactor vessel nozzles and the elbow tap flow meter location is identified by the ★:

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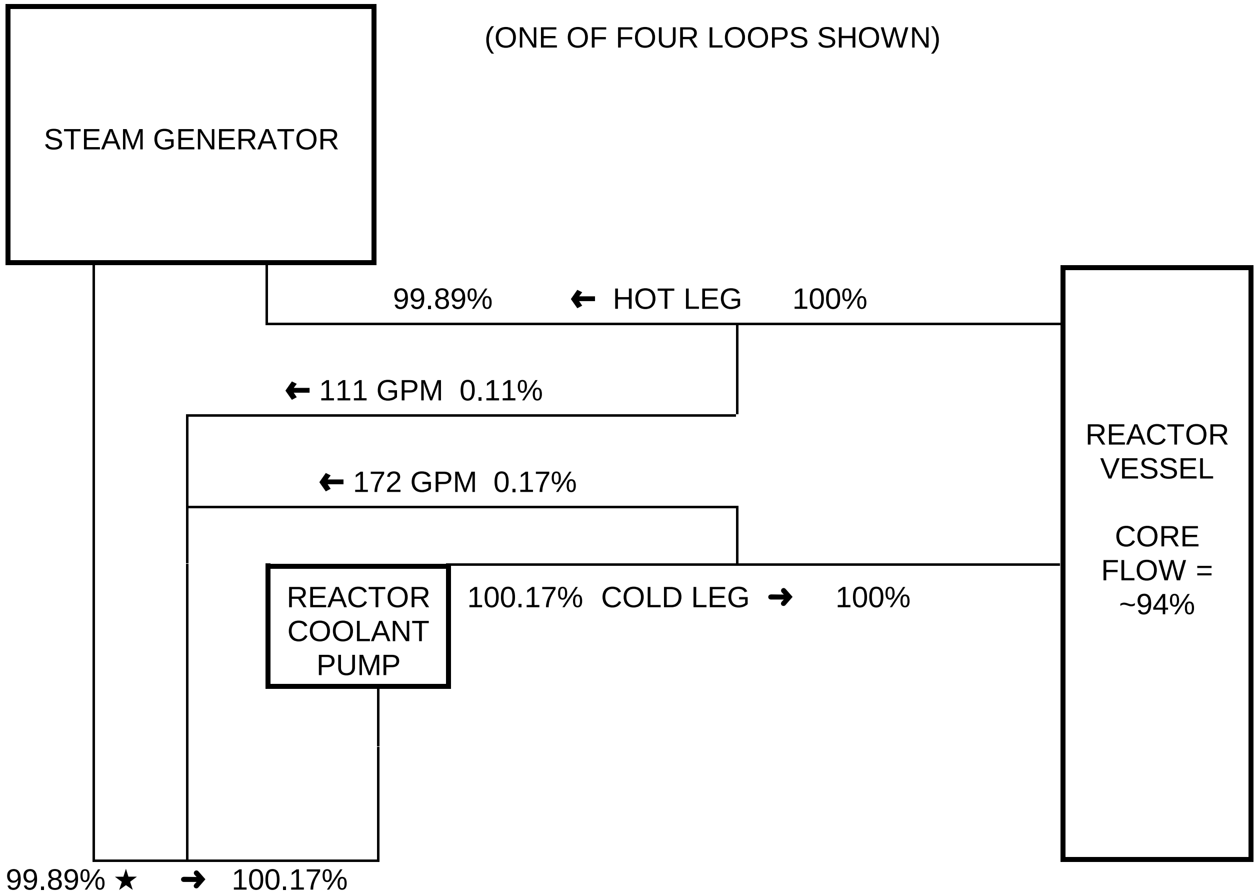
[4]The staff has reviewed and approved use of VIPRE-01 for core analyses as noted in Technical Specification 5.6.5.



The flow rate at the reactor vessel nozzles is generally the flow rate the licensee uses in discussing analytical model predictions. Thus, in a converged analytical model calculation, the following flow rates should occur for cases where the RTD manifolds are installed:

Reactor vessel flow rate	100%
Steam generator flow rate	99.89%
Flow rate indicated by elbow taps	99.89%
Flow rate through RCPs	100.17%

In the calculations, the licensee's analytical model first assumes loop flow rates at the reactor vessel nozzles and then calculates ΔPs throughout the RCS. The calculated ΔPs are then entered into an RCP head versus flow rate correlation to predict RCP flow rates. The RCP flow rates are subsequently used to modify the previously assumed loop flow rates and the modified flow rates are used to calculate new ΔPs. The process is repeated until convergence is obtained. Although the licensee correctly modeled these flow rates in its ΔP calculations, it incorrectly assumed numerical convergence on the assumption that total RCP flow rates calculated by the correlation were equal to the reactor vessel flow rate. The correct calculation would decrease RCP flow rates by 172 gpm/loop when obtaining new loop flow rates. These new loop flow rates would then be used as the basis for recalculation of the ΔPs at the RCPs, and the process repeated until converged.

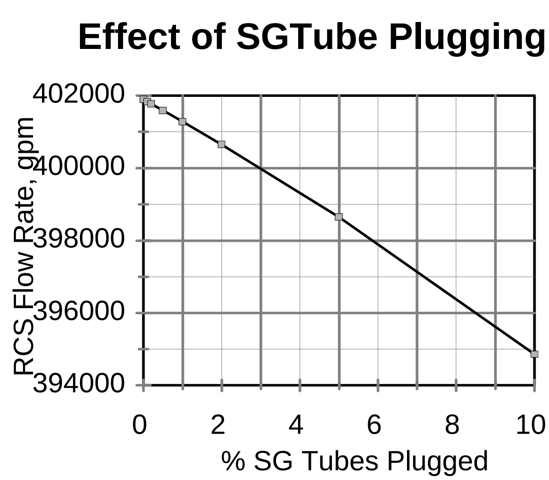
The staff used the licensee's analytical model with the staff's correction of the RCP flow rate to achieve convergence with the following results for the August 1986 case:

Item	Licensee RCP Flow Rate, gpm	Licensee Loop Flow Rate, gpm	Staff RCP Flow Rate, gpm	Staff Loop Flow Rate, gpm
Loop A	100465	100465	100550	100378
Loop B	100440	100440	100526	100353
Loop C	100465	100465	100550	100378
Loop D	100448	100448	100534	100362
Total	401818	401818	402160	401472

As shown in the table above, the staff calculated a total RCS flow rate of 401,472 gpm that is 346 gpm smaller than the licensee's calculated flow rate of 401,818 gpm. For the July 1986 case, the staff calculated a flow rate that is 345 gpm smaller than the licensee's flow rate. Differences in flow rate between four loops shown above are considered to be due to steam generator tube plugging. Since these differences are small, they may be neglected.

Differences in values due to removal of RTD manifolds are small in comparison to the conservatism the licensee introduced into its elbow tap flow coefficient determination. Consequently, the staff has neglected these perturbations in reaching its conclusions. Similarly, the staff finds that the corrections to the analytical model identified in Reference 4 also will not affect its conclusions.

In summary, RTD manifolds introduce differences between flow rates in various components of the RCS that do not exist for operation after the manifolds were removed. In its evaluation of manifold modeling, the staff found that the correct flow rates were used throughout the loops and reactor vessel, but the staff questioned whether the analytical program was being converged correctly due to the RCP flow rate assumption being the same as flow rate at the reactor vessel. This question was not fully resolved during the review, but the staff found the potential error to be a factor of ten smaller than the overall conservatism in the model. Consequently, it is not of concern with respect to a review finding.



3.2.2.5 Steam Generator Tube Plugging

The information provided in Reference 3 includes steam generator tube plugging changes as one of the inputs for the analytical model and predicted a small effect from this on RCS flow rate. The total number of tubes plugged from July 1986 to October 2001 was 215 tubes.

During this time, the largest number of tubes plugged in a cycle was 43 in February 1993. To assess the independent effect of SG tube plugging, the staff used the Reference 3 analytical model to generate the result shown in the adjacent figure for an assumed February 1988 core configuration. Currently, about 1 percent of the tubes are plugged. Therefore, the slight asymmetries in tube plugging to date are expected to have little impact on overall RCS flow rate. The staff concludes that there are no concerns with SG tube induced errors in the early calorimetrics.

3.2.2.6 Fuel Configurations

The staff incorporated the corrections discussed elsewhere in this Safety Evaluation into the Reference 3 analytical model and calculated the following RCS flow rates with changes in the core configuration with the additional assumption that no SG tubes were plugged:

Fuel Configuration	RCS Flow Rate, gpm
Feb 88: Westinghouse OFA Fuel	402228
Nov 95: Mark-BW Fuel	402214
Mar 03: 90 percent RFA Fuel, 10 percent Mark-BW Fuel	398046
All RFA Fuel	397644

Note there is almost no predicted difference between the original Optimized Fuel Assembly (OFA) fuel and the Mark-BW fuel, whereas the Robust Fuel Assembly (RFA) fuel exhibits a significant influence on RCS flow rate. This is discussed further in Section 3.3.7, below.

3.2.2.7 Staff Assessment of the Analytical Model

In Reference 2, the licensee stated that it relies upon the analytical model for the intended purpose of predicting and trending significant changes in RCS flow rate. The licensee stated that situations in which the analytical model results do not agree with the plant data trends do occur, and that these situations are evaluated and explanations are sought, including any related to the accuracy of the input data. The licensee has also used the analytical model to assess other effects, such as the influence of the RTD bypass manifold.

In its Reference 1 review, the staff relied on the analytical model to provide insights into some of the calorimetric and elbow tap data behavior. During the review reported herein, the staff elected to review the analytical model to further assess its behavior in view of the licensee's request for long-term approval of the elbow tap flow coefficients. This review resulted in discovery of incorrect modeling assumptions and quantified the effect of other assumptions. However, based on the discussions in Section 3.2 above, in addition to the staff's previous review as summarized in Reference 1, the staff concludes that the analytical model, as identified herein, is sufficient for the purpose of predicting and trending significant changes in RCS flow rate.

3.3 Evaluation of Elbow Tap Flow Coefficient Determination

In Reference 1, the staff provided an extensive discussion of the determination of elbow tap flow coefficients through the use of calorimetric test data, and it identified issues where additional understanding and information was necessary before it could approve use of constant flow coefficients for the long term. In Section 3.2, above, the staff addressed issues pertaining to the analytical model. The remaining issues are addressed in the remainder of Section 3.3, below.

3.3.1 Thermal Streaming Early in Life

3.3.1.1 Hot leg effects

In Reference 2, the licensee stated:

> The stability of the elbow tap Δp data in Cycle 1, along with the trend of a conservative effect of hot leg streaming on RCS flow in later cycles beginning with Cycle 2, strongly supports the absence of any non-conservative hot leg streaming effect in the Catawba Unit 2 data used as a basis for the revised flow coefficients. The relatively small change in the nature of the core power distribution from Cycle 1 to Cycle 2 also supports the conclusion that the hot leg streaming effect was conservative or neutral in Cycle 1. The inclusion of the Cycle 2 calorimetric, which introduces a 1500 gpm hot leg streaming penalty (when averaged with the two data points from Cycle 1), is a sufficiently conservative approach for selection of the revised flow coefficients.

In partial support of the above, Reference 2, Attachment 1, page 12, provided the following peaking factor and calorimetric RCS flow rate information:

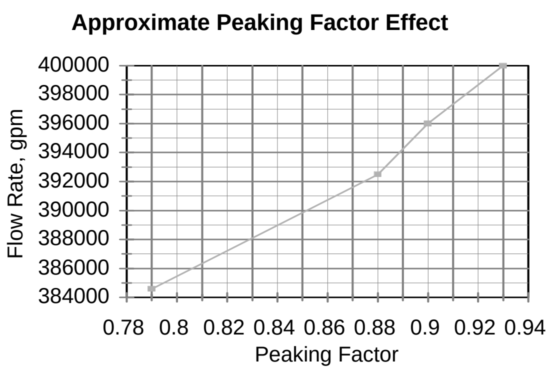
Cycle	Peripheral Region Average Radial Peaking Factor	Approximate Calorimetric RCS Flow Rate, gpm
1	0.92	401000
2	0.90	396000
3	0.88	392500
12	0.79	380000

The staff adjusted this information to remove certain other effects so that the effect of peaking factor alone on RCS flow rate could be more clearly observed and presents this information in the graph below. First, with respect to Cycle 12 data, the staff notes that about 4600 gpm of the 21,000 gpm difference in Cycle 1 and Cycle 12 flow rates is due to the higher hydraulic resistance of the fuel assemblies used in Cycle 12. Accordingly, the Cycle 12 flow rate at a peaking factor of 0.79 is adjusted to 384,600 gpm.

The first cycle calorimetric was affected, as discussed in Section 3.3.4, below, by RCP impeller smoothing that may result in a flow rate reduction of no greater than 1000 gpm. Accordingly, the Cycle 1 flowrate was adjusted from 401,000. gpm to 400,000 gpm in the graph below.

The first cycle was also affected by the presence of the RTD manifolds. The staff evaluated the licensee's information by assuming that the thermal streaming error with RTD manifolds installed in Cycle 1 would be reduced in comparison to later cycles when temperature is determined by RTDs in the hot legs. The staff compensated for this by assuming a peaking factor increase of 0.01 to 0.93 for Cycle 1 instead of the tabulated value of 0.92. Therefore, the graph of flow rate as a function of peaking factor presented below differs from the tabulated data above by the adjustment to Cycle 12 flow rate and the adjustments to Cycle 1 peaking factor and flow rate.

The graph shows that there is a steady upward trend in flow rate as the peaking factor approaches a value of 1.0. A value of 1.0 would represent a flat reactor core power profile for which no thermal streaming would be expected. Similar behavior will be obtained for any reasonable assumption regarding the effective reduction in peaking factor due to the better thermal sampling with RTD manifolds installed. This illustrates that there is no significant evidence of a non-conservative perturbation associated with thermal streaming during early plant operation.



The same conclusion can be reached by assuming the early flow rate perturbations have diminished after the first three data points in the licensee's Figure 2 of Reference 2, and by extrapolating the fourth and later points back to initiation of plant operation.

On the basis of this evaluation and the licensee's arguments, the staff concludes that there is no significant evidence of a non-conservative perturbation associated with thermal streaming being introduced during early plant operation and that this issue is resolved.

3.3.1.2 Cold Leg Effects

Reference 2 stated that using a cold leg RTD that indicates lower temperature will result in predicting a lower RCS flow rate when performing a calorimetric. At Catawba, Unit 2, in Loops A, B, and C, the spare RTDs indicate lower temperatures than the normal RTDs. In Loop D, the spare RTD indicates higher temperatures than the normal RTD by 0.28 °F. On average, the spare RTDs are 0.31 °F lower than the normal RTDs. Selecting the spare RTDs, as compared to selecting the normal RTDs, introduces a change of about (400,000)[1-(65.31)/(65)] = -1900 gpm into the calorimetric. Although this is not proof that cold leg streaming is not a factor, selecting the spare RTDs, coupled with mixing at the RCP outlet that results in relatively small variations in cold leg temperature with measurement position, leads the staff to conclude that the licensee has acceptably addressed cold leg streaming concerns.

3.3.1.3 Staff Conclusions in Regard to Thermal Streaming

As discussed above, the licensee provided information to support the absence of any non-conservative hot leg streaming effect in the Catawba, Unit 2 data used as a basis for the revised flow coefficients. The licensee also acceptably addressed cold leg streaming concerns.

Consequently, the staff concludes that there is no remaining concern with introducing a non-conservative perturbation associated with thermal streaming during early plant operation.

3.3.2 Reactor Coolant Pump (RCP) Thermal Energy Error

An error in accounting for RCP heating was identified during the Reference 1 review. The licensee calculated that this error would cause actual flow rate to be about 1045 gpm higher than indicated by the calorimetrics. The licensee elected not to correct this error as it contributes to the conservatism in determining flow coefficients. The staff finds this acceptable.

3.3.3 Effect of Power Level

In Reference 4, the licensee provided a plot of percent of TS flow versus percent power for the initial power escalation for Cycle 12 based upon elbow tap indications. The behavior of flow versus power was linear, with 102.2 percent flow at 0 percent power and 101.2 percent flow at 100 percent power. This represents a decrease of about 4000 gpm over this power range. Thus, indicated flow rate is at a minimum when the unit is at its highest power and will result in the maximum challenge to meeting DNBR requirements. Accordingly, the staff is satisfied that the indicated RCS flow rate will adequately cover operational flow rate needs.

3.3.4 RCP Impeller Smoothing

RCP impeller smoothing results in an approximately one percent reduction in flow rate during the first few cycles of operation, with the dominant effect occurring during initial RCP operation. However, the actual wear-in rate is not well known. The calorimetric data tabulated in Reference 1 show a significant decrease in flow rate with increasing time until September 1986, with the decrease limited to about 600 gpm from September to November 1986. The Reference 2 elbow tap data illustrate a similar early decrease in flow rate, with an earlier decrease in the rate of flow reduction. The staff agrees with the licensee that there are several potential contributors to this behavior, but it does not agree that the data support that pump wear-in would be expected to have occurred during that initial period of operation prior to the calorimetric measurements. On the basis of the industry experience in this area and the above data, the staff has concluded that the RCP smoothing effect is bounded by a change of 1000 gpm over the time span applicable to the licensee’s selection of the September 1986, November 1986, and March 1988 calorimetrics for determination of elbow tap coefficients.

As discussed in Section 3.3.2, above, the licensee elected not to correct for the RCP thermal energy error of about 1045 gpm. This clearly compensates for any staff concerns regarding the effect of impeller smoothing. Consequently, the staff concludes that RCP impeller smoothing is not a concern with respect to elbow tap coefficient determination.

3.3.5 Steam Generator Tube Plugging

The analytical program predicts that SG tube plugging will cause a flow rate decrease of about 50 gpm from July 1986 to August 1986 and a further decrease of about 25 gpm from November 1986 to March 1988. Clearly, SG tube plugging does not have a significant influence on RCS flow rate over the time of interest for determination of elbow tap coefficients. Further, the effects are included in both the calorimetrics and the elbow tap flow rate indications.

Consequently, the staff finds that the effects of steam generator tube plugging are not of concern.

3.3.6 RTD Manifold Removal and Effect of Hot Leg Streaming During Calorimetrics

The information provided in Sections 3.2.2.4 and 3.3.1, above, leads the staff to conclude that the effects of RTD manifold removal and streaming are not of concern with respect to the calorimetric determinations used as a basis for elbow tap flow coefficient determinations.

3.3.7 Calibration Observations

Examination of elbow tap flow rate data indicated a decrease in October 1991 and February 1993 followed by an increase in flow rate that was not predicted by the analytical program. In Reference 4, the licensee reported that a calibration oversight caused an incorrect indicated flow rate reduction of 0.74 percent for the 1993 calibration. It further stated that the recalculated 1993 data were consistent with expected flow rate results for 10 of 12 transmitters, but that Loop C, Channel 1 and Loop B, Channel 3 exhibited large and unexplained increases of 8.4 percent and 3.6 percent, respectively, whereas the average change for the 12 transmitters was 1.5 percent. Excluding these two transmitters resulted in an average change of 0.6 percent. Further, when the transmitters were replaced in 1994, the new transmitter scaling values essentially returned to the 1991 values.

The licensee also reported that it examined other potential influences on RCS flow rate during this time period, such as human factors issues associated with technician changes, and none were found to be significant contributors to the flow rate decreases observed in 1991 and 1993.

The licensee completed addressing these anomalies by stating that, since 1993 additional processes have been implemented for transmitter scaling that include changing transmitter scaling through the station modification process and evaluating and documenting scaling changes through a formal scaling calculation. The staff concludes that the licensee’s response provides an acceptable explanation and disposition for this issue.

3.4 Other Means of Assessing Stability of Elbow Tap Flow Coefficients

3.4.1 Leading Edge Flow Meter Comparisons

The staff discussed leading edge flow meter (LEFM) information in Reference 1 that had been obtained sporadically over a period of 11 years of operation at another plant. The licensee was also pursuing additional data that could be used to confirm long-term elbow tap behavior. This was discussed as follows in Reference 1:

> The licensee has previously provided qualitative discussions covering long-term behavior. Reference [6] states that “The 11 year flow comparison (at Prairie Island) showed that the average difference between elbow taps and LEFMs was less than 0.3% flow,” and we obtained similar differences in [our] comparison. On this basis, and with consideration of the above information, we conclude that the elbow coefficients can be assumed constant for the operating cycle scheduled to begin in October, 2001.

This information also applies to the licensee's amendment request of Reference 2 since there is nothing that limits its consideration to only one operating cycle. In Reference 2, the licensee reported that it had been unsuccessful in obtaining additional LEFM data.

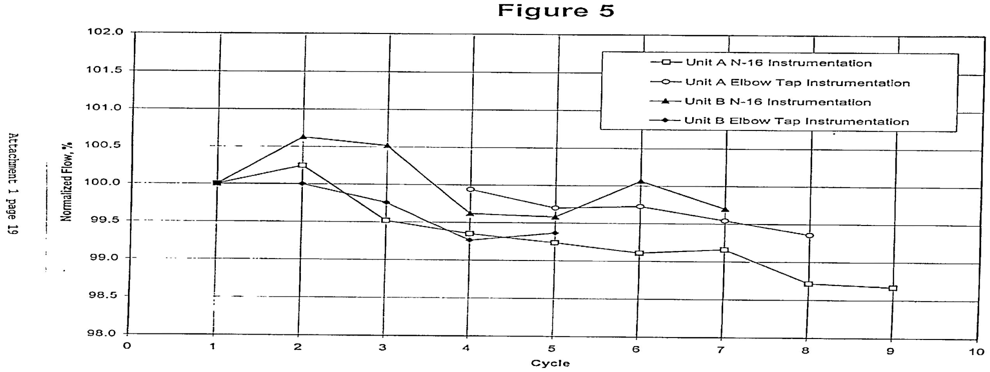
Although limited in scope, the LEFM information provided by the licensee provides support for a conclusion that elbow tap flow coefficients remain constant in long-term operation.

3.4.2 <u>Nitrogen 16 (N-16) Flow Meter Comparisons</u>

In Reference 2, the licensee discussed 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.

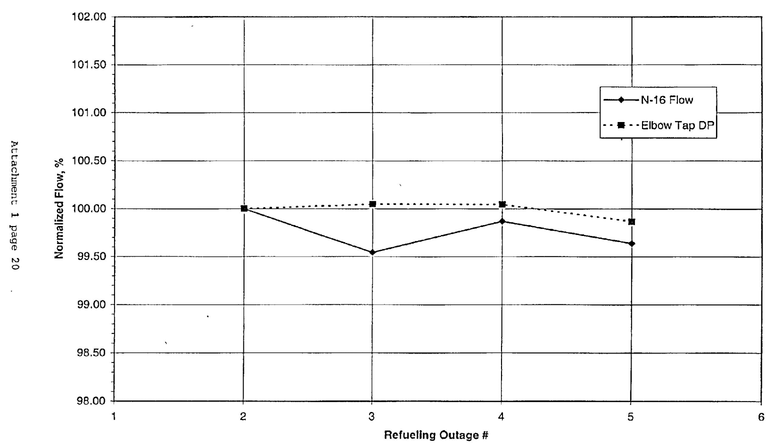
The licensee's Figure 5 from Reference 2, reproduced below, provides data for two plants identified as Units A and B. The Unit A data for Cycles 4 through 8 shows similar downward flow rate trends for the N-16 and elbow tap instrument data with a relatively consistent offset ranging from 0.4 percent to 0.7 percent. The Unit B data for Cycles 1 through 5 shows somewhat more variation, with the N-16 and elbow tap data coming closer together with additional cycles. The licensee attributed the N-16 fluctuations to the uncertainty band in the instrumentation, but did not provide substantiation for this conclusion 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 substantiates that the elbow tap flow coefficients remain constant.

Figure 5



The data in the licensee's Figure 6, reproduced below, provides a 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.

Figure 6



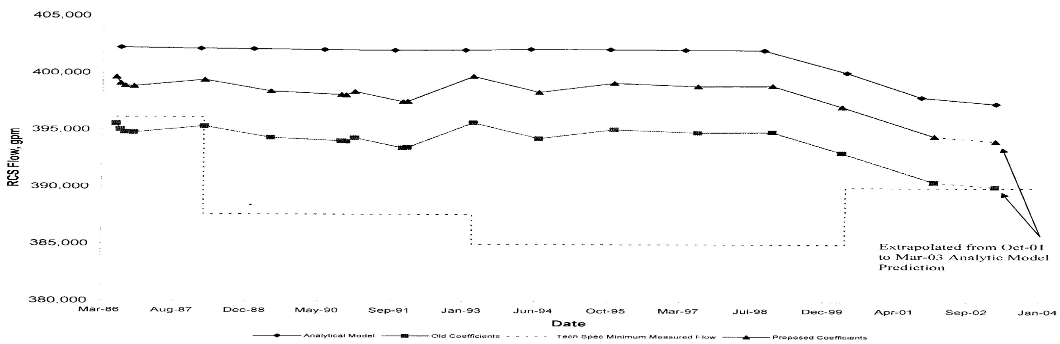
Overall, there is no evidence of a long-term change in the elbow tap indications in comparison to the N-16 indications and the data generally substantiate that the elbow tap flow coefficients remain constant with increasing time.

3.4.3 <u>Staff Assessment of Observed and Calculated Behavior Using Most Recent Information</u>

Reference 4 provided the following Figure 1 that the staff finds to be particularly informative:

The analytical model predicts almost no change in RCS flow rate until loading of RFA fuel in 1998, consistent with the staff's discussion in Section 3.2.2.6, above. The elbow tap flow rates show a general decrease in flow rate until loading of Mark-BW fuel in 1991 with a flow rate recovery to roughly the original value with a full core of Mark-BW fuel in 1995. After 1995, there is excellent agreement between the analytical model and the elbow tap flow rates, with a constant offset that the staff believes reflects the conservatism the licensee introduced through the calorimetric determinations of the elbow tap flow coefficient. It is interesting to note that the licensee changed to Rosemount transmitters in 1994 (discussed in Reference 4) and changed its transmitter scaling to be consistent throughout the data processing process. Further, 1993 is the time at which the licensee identified scaling problems. Consequently, the staff places a high reliance on the post-1995 elbow tap behavior. The staff further notes that an elbow tap coefficient change would be manifested by a change in the difference between the elbow tap and analytical model flow rates. No such change is evident in the August 1987 and post-1994 data. Consequently, the staff concludes that the licensee's Figure 1 shows there is no long-term change in the elbow tap flow coefficients.

Figure 1
Analytic Model vs. Elbow Tap Flow Comparison, RCS Total Flow



3.5 <u>Summary of Technical Evaluation</u>

The RCS flow rate at Catawba, Unit 2 is calculated from cold leg elbow tap differential pressure measurements by equations that contain empirically-determined flow coefficients. On October 2, 2001 (Reference 1), the staff approved an amendment to the Catawba, Unit 2 operating license that specified the elbow tap flow coefficients that would be in effect for the duration of Cycle 12. In that assessment, the staff concluded that further substantiation was necessary for the licensee to use the Cycle 12 elbow tap coefficients for further operational cycles.

In its request to extend use of the Cycle 12 elbow tap coefficients (References 2 through 4), the licensee has provided the necessary additional substantiation, as evaluated by the staff in this Safety Evaluation. Consequently, the staff concludes that the licensee has justified its request to use the Cycle 12 elbow tap flow coefficients for Cycle 13 and subsequent operational cycles.

4.0 <u>STATE CONSULTATION</u>

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

5.0 <u>ENVIRONMENTAL CONSIDERATION</u>

The amendments change requirements with respect to installation or use of a facility component located within the restricted area as defined in 10 CFR Part 20. 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 (67 FR 70765). 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. Letter from C. P. Patel, to Duke Energy Corporation, "Catawba Nuclear Station, Unit 2 Re: Issuance of Amendment (TAC No. MB1498)," October 2, 2001.

2. Letter from G. R. Peterson, "Duke Energy Corporation, Catawba Nuclear Station, Unit 2, Docket Number 50-414, Proposed License Amendment for Unit 2 Reactor Coolant System Cold Leg Elbow Tap Flow Coefficients," October 10, 2002.

3. Letter from G. R. Peterson, "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," February 7, 2003.

4. Letter from G. R. Peterson, "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," February 26, 2003.

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

6. Letter from G. R. Peterson, "Duke Energy Corporation, Response to Request for Additional Information for Revision of Unit 2 Reactor Coolant System Cold Leg Elbow Tap Flow Coefficients," July 25, 2001.

7. Letter from M. S. Tuckman, Duke Power Company to NRC, TS Revision to Change Method of Measuring Reactor Coolant System Flow Rate, January 10, 1994.

8. Letters from Duke Power Company to NRC Requesting Revision of Catawba Unit 2 Reactor Coolant System Cold Leg Elbow Tap Flow Coefficients, dated March 9, July 25, September 10, and September 13, 2001, supporting issuance of Reference 1.

9. Report from Westinghouse Electric Company, LLC, WCAP-14754-NP-A, Revision 1, "RCS Flow Verification Using Elbow Taps at Westinghouse 3-Loop PWRs," September 1999.

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