UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

April 13, 1994

Docket Nos. 50-413, 50-414
50-369, and 50-370

LICENSEE: Duke Power Company

FACILITY: Catawba Nuclear Station, Units 1 and 2
McGuire Nuclear Station, Units 1 and 2

SUBJECT: SUMMARY OF FEBRUARY 10, 1994, MEETING WITH DUKE POWER COMPANY ON RCS FLOW MEASUREMENT METHODOLOGY

On February 10, 1994, members of the NRC staff met with representatives of the Duke Power Company (DPC) in Rockville, Maryland. The purpose of the meeting was to discuss the licensee's application dated January 10, 1994, that proposed to change the method for determining reactor coolant system (RCS) flow rate for both the Catawba and McGuire Nuclear Stations. A list of attendees is included as Enclosure 1.

The past method has been based on use of a calorimetric heat balance (CHB) on the plant secondary side, divided by the primary side differential enthalpy. On entry of Catawba Unit 1 into Cycle 8 operation in early January 1994, the CHB method provided an indicated RCS flow rate that allowed operation only up to 97% power. The licensee's slide number 20 in Enclosure 2 illustrates the history of the Catawba Unit 1 RCS flow rate determined by the CHB method. In response, the licensee proposed a change in the method for measuring RCS flow rate to one based on a one-time normalization of the RCS cold leg elbow tap signals to constants derived from averaged valid calorimetrics from previous cycles. Slide 31 presents a comparison of the flow indicated by the CHB method to that indicated by the elbow taps.

The licensee's presentation summarized the RCS flow measurement problem, provided an overview of the proposed alternate method, discussed the error associated with the elbow tap flow measurement, and discussed responses to particular topics identified by the NRC staff prior to the meeting. The licensee's slides are provided as Enclosure 2.

Slide number 35 of Enclosure 2 indicates that the methodology for the RPS trip flow measurement is identical to that submitted during the initial licensing of each station and references letters from DPC to NRC dated October 8, 1981, and July 30, 1984, for McGuire and Catawba, respectively. Although not specifically stated by the licensee, the Catawba reference is understood to be the letter from Mr. Hal B. Tucker, DPC, to Mr. Harold R. Denton, NRC, dated July 30, 1984, and its enclosure, "Westinghouse Setpoint Methodology for Protection Systems, Catawba Station," June 1984, by R. L. Jansen and C. R. Tuley. A copy of this reference was not available to the staff until well after the meeting. Slide number 35 references a letter from DPC to NRC

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dated November 23, 1982, for McGuire and references Catawba FSAR question 492.7 as providing the uncertainty methodology for the Technical Specificatio surveillance flow measurement. The McGuire reference was the subject of Amendments 22 and 3 to the McGuire licenses, issued on June 28, 1983. A copy of the response to FSAR question 492.7 was provided by the licensee on February 8, 1994, and is included as Enclosure 3.

Enclosure 4 includes topics for discussion identified by the staff prior to the meeting and Enclosure 5 includes the licensee's responses to them. Enclosure 5 included an RCS Flow Uncertainty Analysis in its Attachment 2 that was indicated to be proprietary information by DPC. Duke Power has been requested to submit a letter and affadavit attesting to its proprietary nature. Accordingly, it is not included with this summary.

Enclosure 6 includes further topics for conversation identified by the staff prior to the meeting. These topics were discussed during the meeting as needed.

/s/
Robert E. Martin, Senior Project Manager
Project Directorate II-3
Division of Reactor Projects - I/II
Office of Nuclear Reactor Regulation

Enclosures:
1. List of Attendees
2-6. Handouts

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See next page

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DATE	4/13/94	4/13/94	4/13/94

OFFICIAL RECORD COPY DOCUMENT NAME: G:\CATAWBA\SUMMARY2.MTG dated November 23, 1982, for McGuire and references Catawba FSAR question 492.7 as providing the uncertainty methodology for the Technical Specification surveillance flow measurement. The McGuire reference was the subject of Amendments 22 and 3 to the McGuire licenses, issued on June 28, 1983. A copy of the response to FSAR question 492.7 was provided by the licensee on February 8, 1994, and is included as Enclosure 3.

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2-6. Handouts

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ENCLOSURE 1

FEBRUARY 10, 1994

RCS FLOW RATE METHODOLOGY MEETING

ATTENDEES

Name	Organization
Bob Martin	NRC/PDII-3
Gregg Swindlehurst	DPC
Scott Gewehr	DPC
Jacky Lee	DPC
Michael Carroll	DPC
Ken Canady	DPC
Mark Caruso	NRC/SRXB
Tai Huang	NRR/SRXB
Harry Balukjian	NRR/SRXB
Bintoro Aji	NRC/Assignee-SRXB

ENCLOSURE 2

NRC / DUKE POWER MEETING
FEBRUARY 10, 1994

TECH SPEC REVISION TO CHANGE THE METHOD OF REACTOR COOLANT SYSTEM FLOW MEASUREMENT

PRESENTATION

I. SUMMARY OF THE RCS FLOW MEASUREMENT PROBLEM AT McGUIRE AND CATAWBA

II. OVERVIEW OF THE PROPOSED METHOD OF USING THE ELBOW TAP FLOW INSTRUMENTATION FOR THE TECH SPEC FLOW SURVEILLANCE

III. DISCUSSION OF THE ERROR ASSOCIATED WITH THE ELBOW TAP FLOW MEASUREMENT

IV. DISCUSSION OF THE PROPOSED TECH SPEC REVISIONS REQUIRED TO IMPLEMENT THE USE OF THE ELBOW TAP INSTRUMENTATION

V. RESPONSES TO THE NRC QUESTIONS RECEIVED

VI. ADDITIONAL DISCUSSION AND SUMMARY

I. SUMMARY OF THE RCS FLOW MEASUREMENT PROBLEM AT McGUIRE AND CATAWBA

- THE RCS FLOW TECH SPEC SURVEILLANCE AT McGUIRE WAS ORIGINALLY PERFORMED BY USING THE COLD LEG ELBOW TAP INDICATION OF FLOW. THIS INDICATION IS USED BY THE RPS TO TRIP THE REACTOR DURING FLOW REDUCTION EVENTS.

- THE FLOW SURVEILLANCE METHOD WAS CHANGED TO A CALORIMETRIC BASED METHOD IN ORDER TO OBTAIN BETTER ACCURACY. THIS METHOD WAS ALSO IN THE ORIGINAL CATAWBA TECH SPECS.

- OVER THE YEARS, THE CALORIMETRIC BASED METHOD OF FLOW SURVEILLANCE HAS RESULTED IN A DECREASING INDICATED FLOW TREND THAT IS NOT CONSISTENT WITH THE CHANGES IN THE SYSTEM HYDRAULICS OR OTHER INDICATIONS OF FLOW.

- CONSEQUENTLY, THE TECH SPEC FLOW REQUIREMENT HAS BEEN LOWERED TO ACCOMODATE THE INDICATED FLOW REDUCTION

- THE CONTINUATION OF THIS TREND HAS RESULTED IN AN UNACCEPTABLE PENALTY AND AN INABILITY TO PREDICT A PARAMETER THAT IS ESSENTIAL FOR OPERATION AND SAFETY.

THE CALORIMETRIC FLOW MEASUREMENT METHOD

- A SECONDARY HEAT BALANCE CALCULATION IS USED TO ESTABLISH THE THERMAL POWER LEVEL
- THE TEMPERATURE RISE ACROSS THE REACTOR VESSEL AS INDICATED BY THE RTDs IN THE HOT AND COLD LEGS IS MEASURED (LOOP ΔT)
- THE PRIMARY COOLANT FLOW RATE IS DETERMINED BY DIVIDING THE THERMAL POWER BY THE ENTHALPY RISE ACROSS THE REACTOR VESSEL
- A SET OF ELBOW TAP COEFFICIENTS ARE DETERMINED EACH CYCLE TO NORMALIZE THE ELBOW TAP ΔP BASED FLOW TO THE CALORIMETRIC FLOW.
- SMALL CHANGES IN LOOP ΔT TRANSLATE INTO LARGE CHANGES IN RCS FLOW
- INCREASES IN LOOP ΔT HAVE OCCURRED TO DIFFERING EXTENTS IN THE FOUR McGUIRE AND CATAWBA UNITS

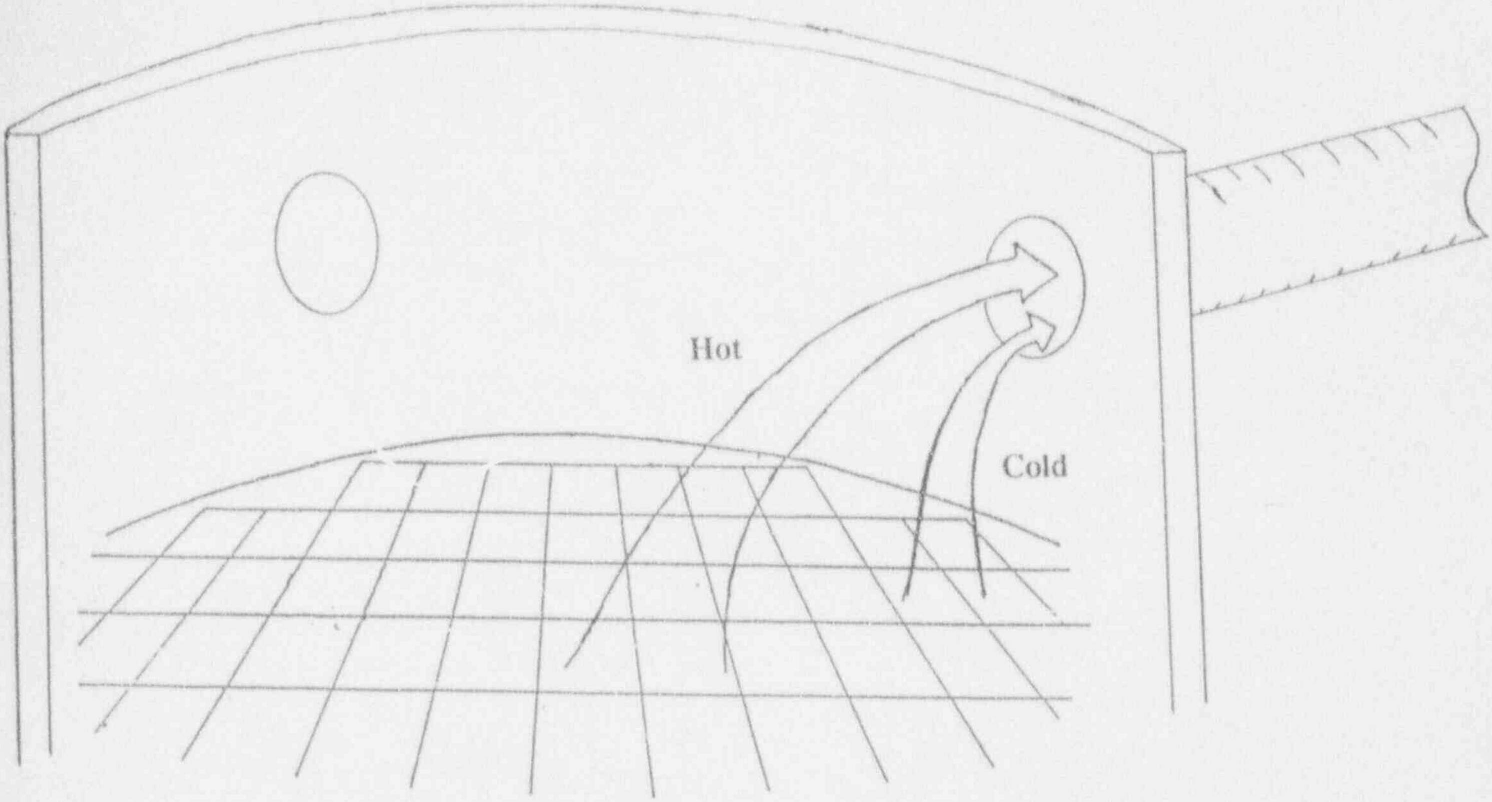
CAUSES FOR CHANGES IN INDICATED RCS FLOW

- REAL FLOW CHANGES
  - STEAM GENERATOR TUBE PLUGGING
  - FUEL DESIGN CHANGES
  - CORE BAFFLE UPFLOW MODIFICATION
  - REACTOR COOLANT PUMP PERFORMANCE
  - TYPICALLY EXPECTED AND PREDICTABLE

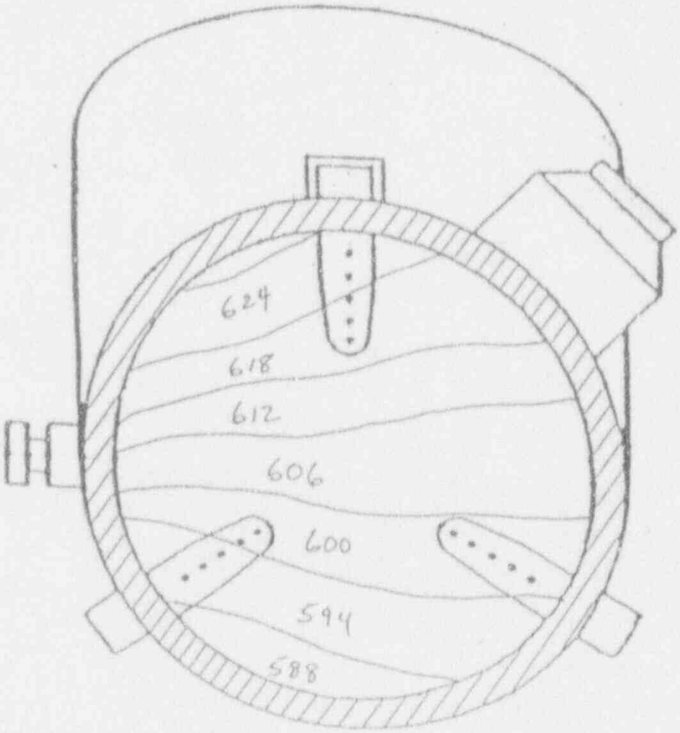
- INDICATED FLOW CHANGES
  - REAL FLOW CHANGES
  - INSTRUMENTATION PROBLEMS

- HOT LEG STREAMING
  - OBSERVED IN MANY WESTINGHOUSE PLANTS
  - CAUSED BY INCOMPLETE MIXING IN REACTOR VESSEL UPPER INTERNALS
  - OBSERVED TO DIFFERING EXTENTS IN THE FOUR McGUIRE AND CATAWBA UNITS
  - STEP CHANGES POSSIBLE DURING REFUELING
  - GRADUAL CHANGES DURING THE FUEL CYCLE
  - HAS BEEN INCREASING IN RECENT FUEL CYCLES
  - UNPREDICTABLE

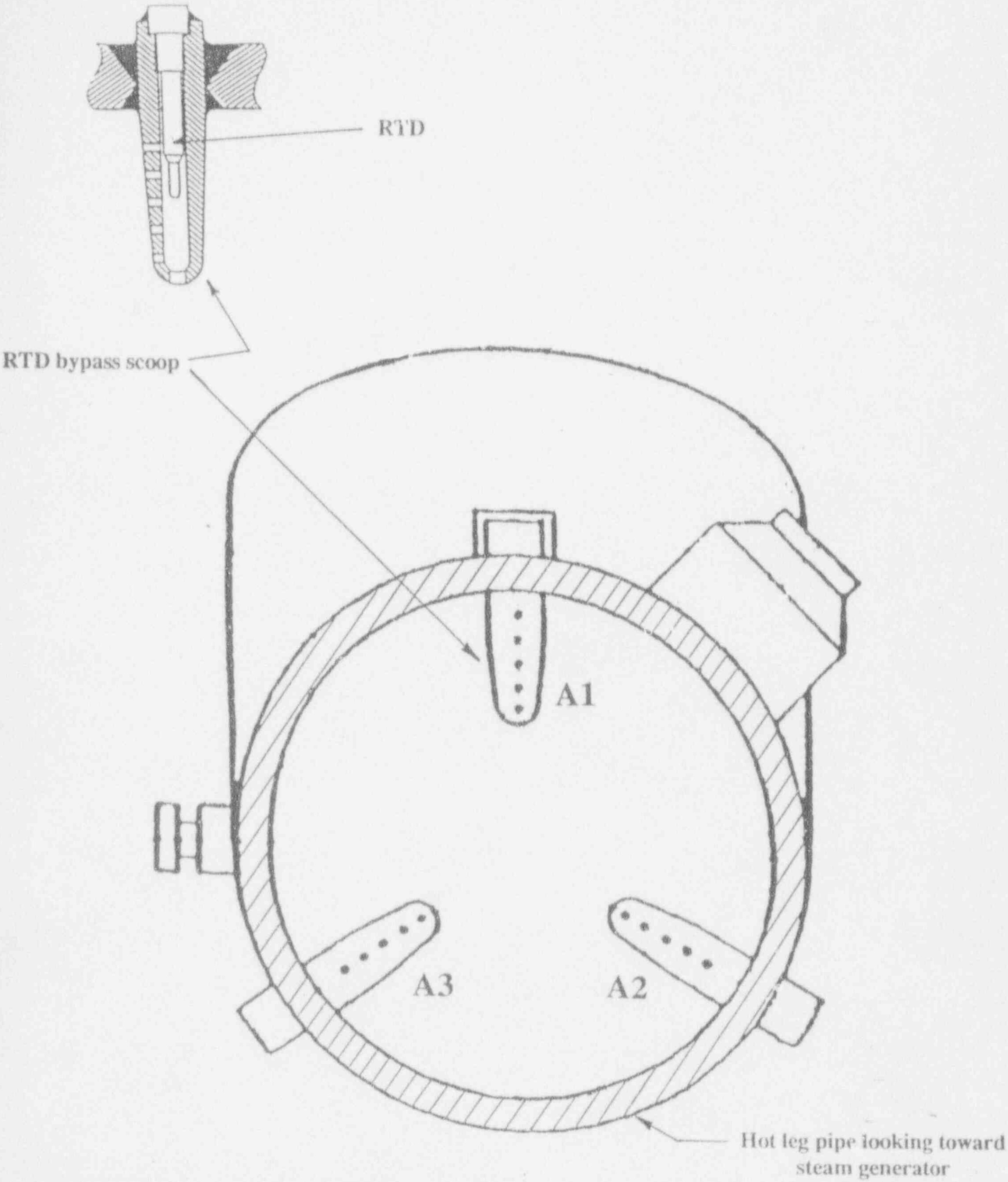
Hot Leg Streaming Phenomenon



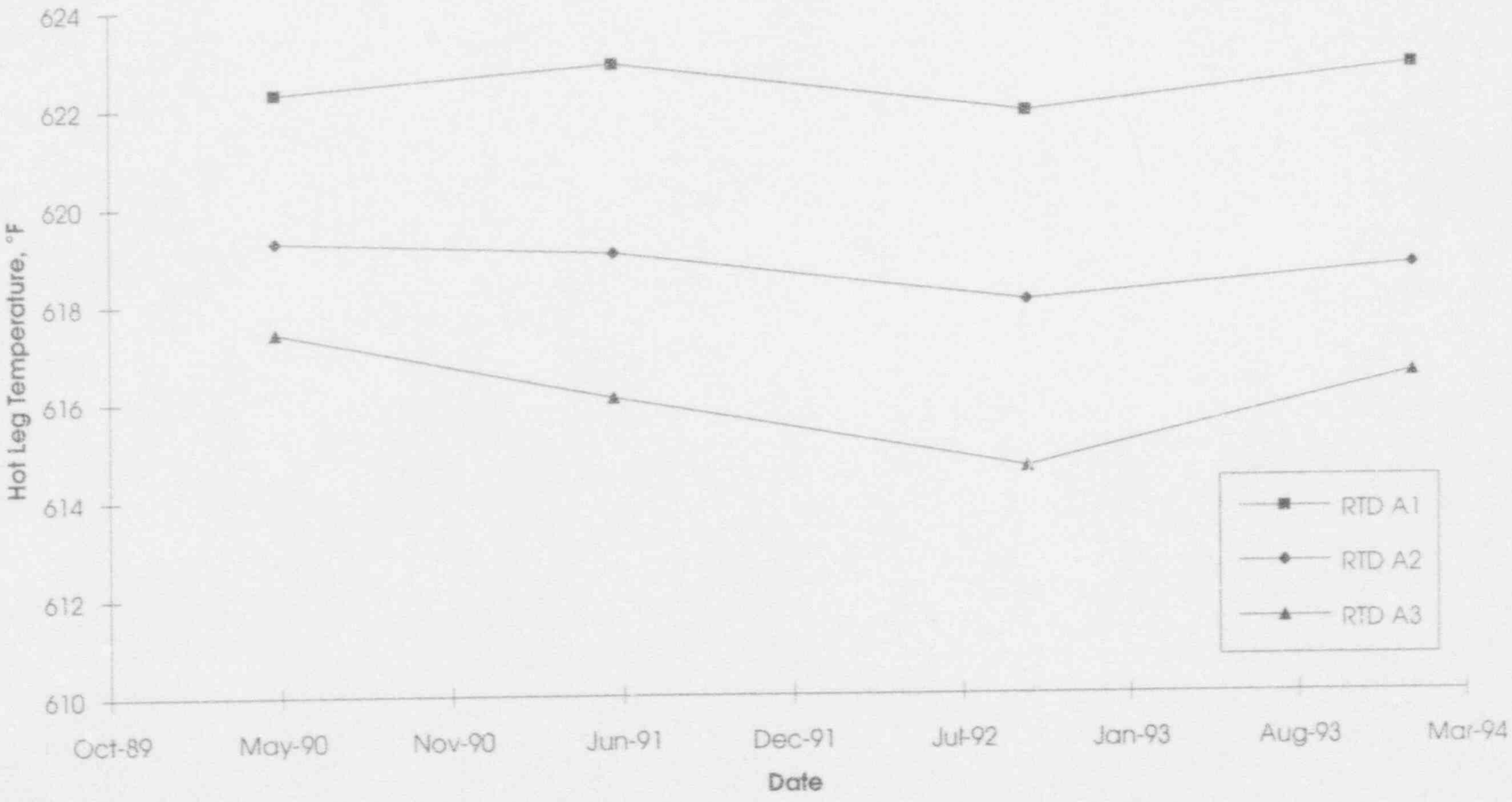
Example Hot Leg Temperature Gradient



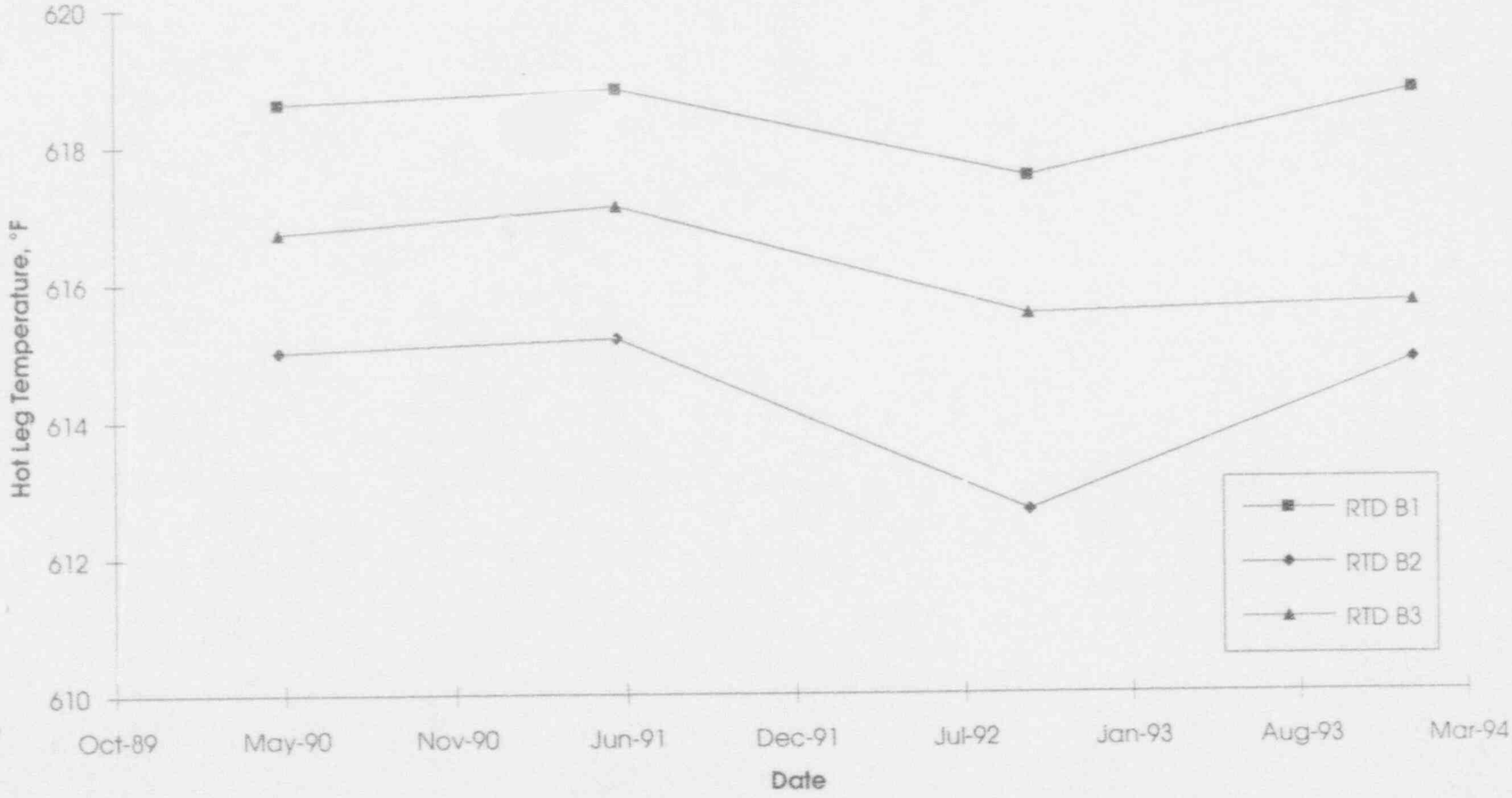
Hot Leg Pipe and RTD Orientation



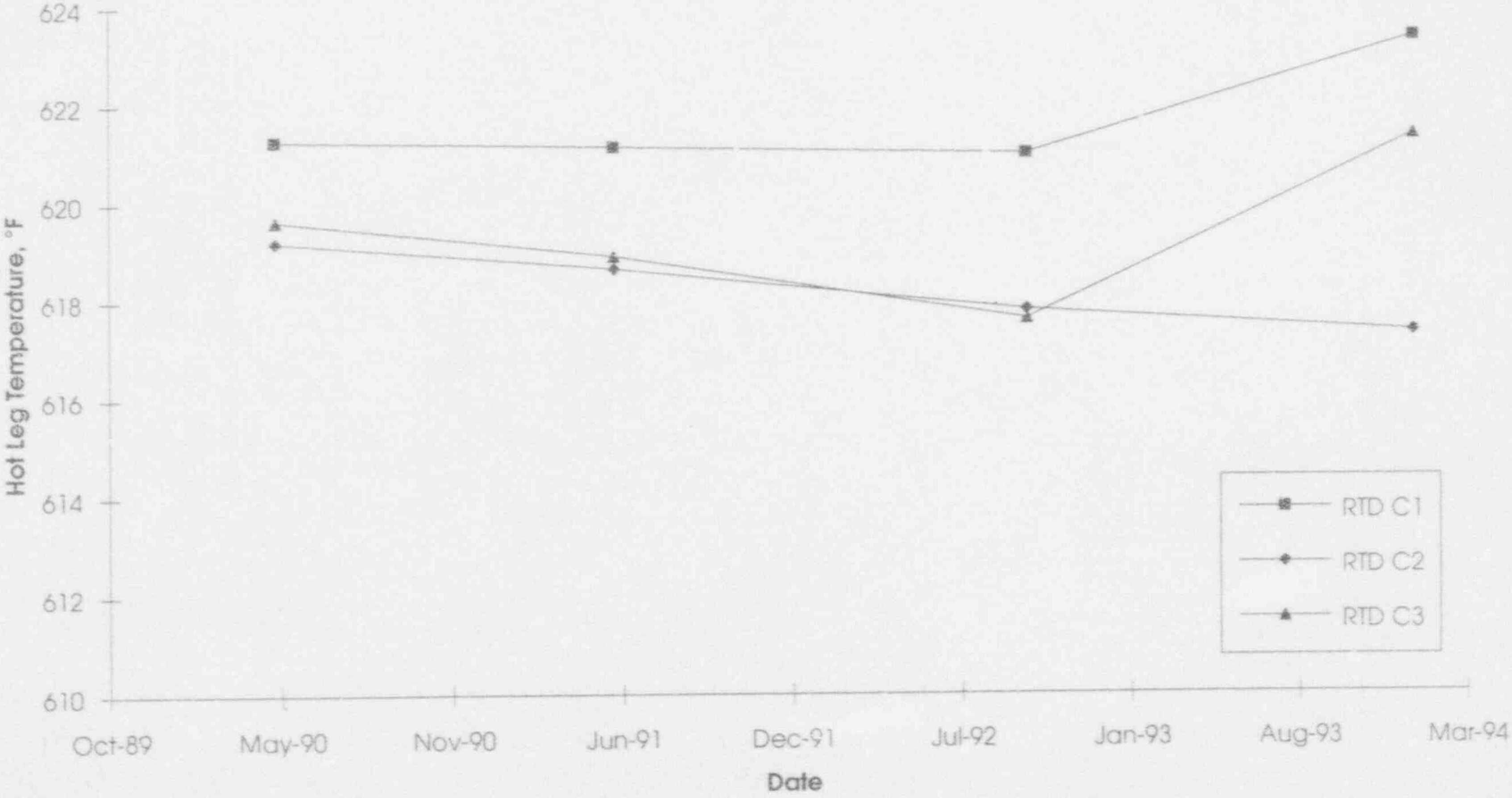
Catawba Unit 1Hot Leg Temperatures Measured During RCS Flow Calorimetric, Loop A



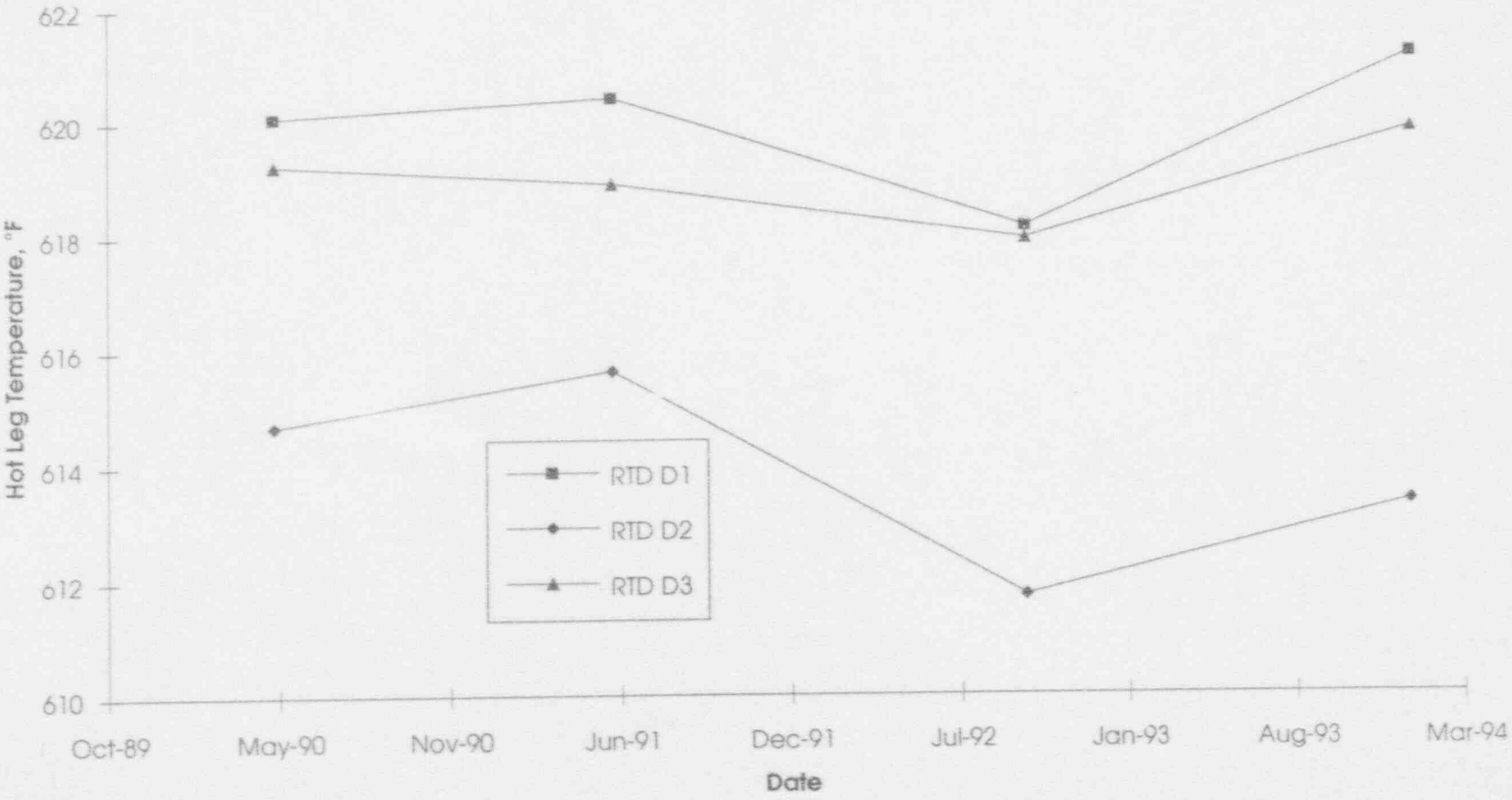
Catawba Unit 1Hot Leg Temperatures Measured During RCS Flow Calorimetric, Loop B



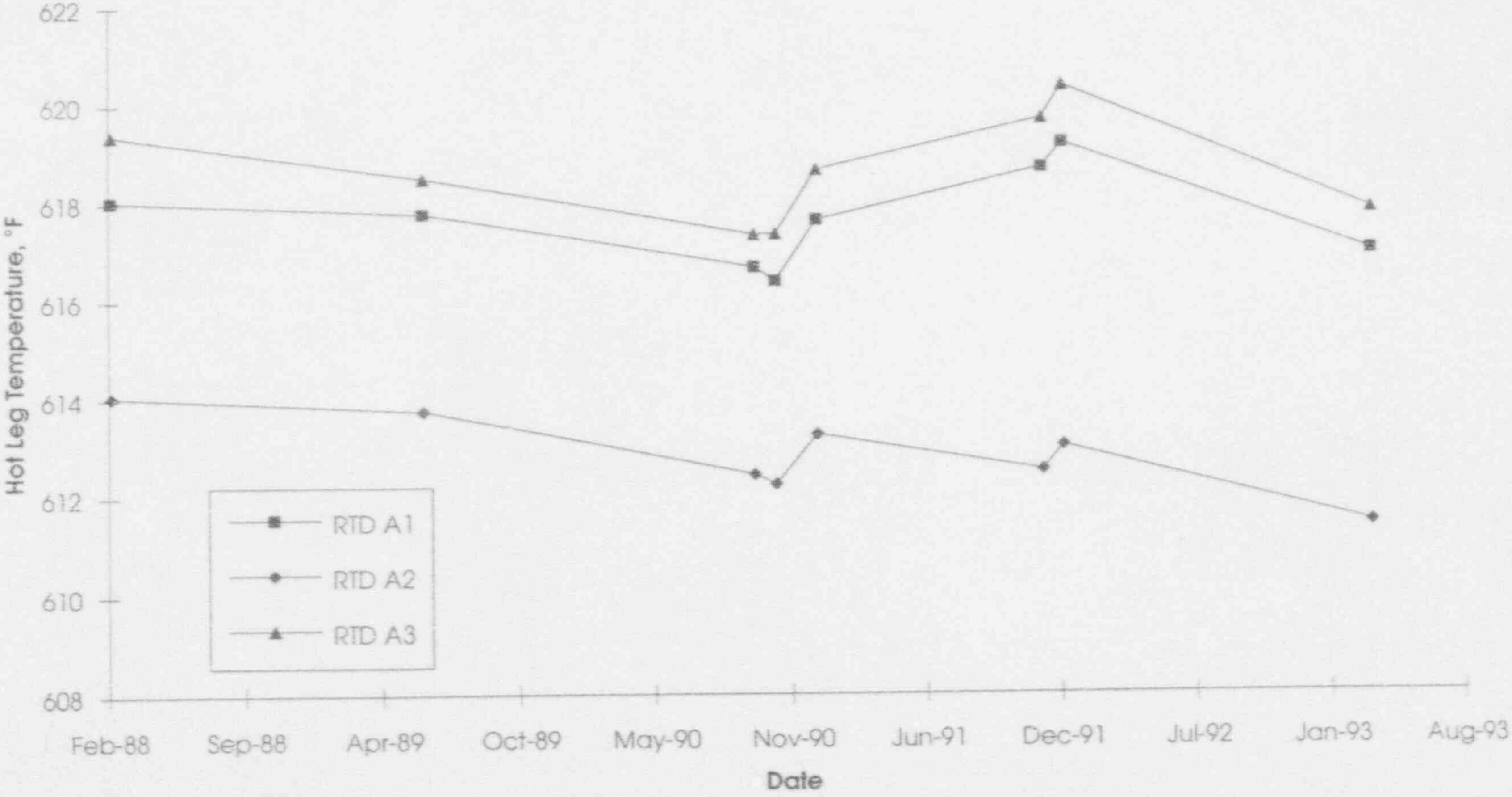
Catawba Unit 1Hot Leg Temperatures Measured During RCS Flow Calorimetric, Loop C



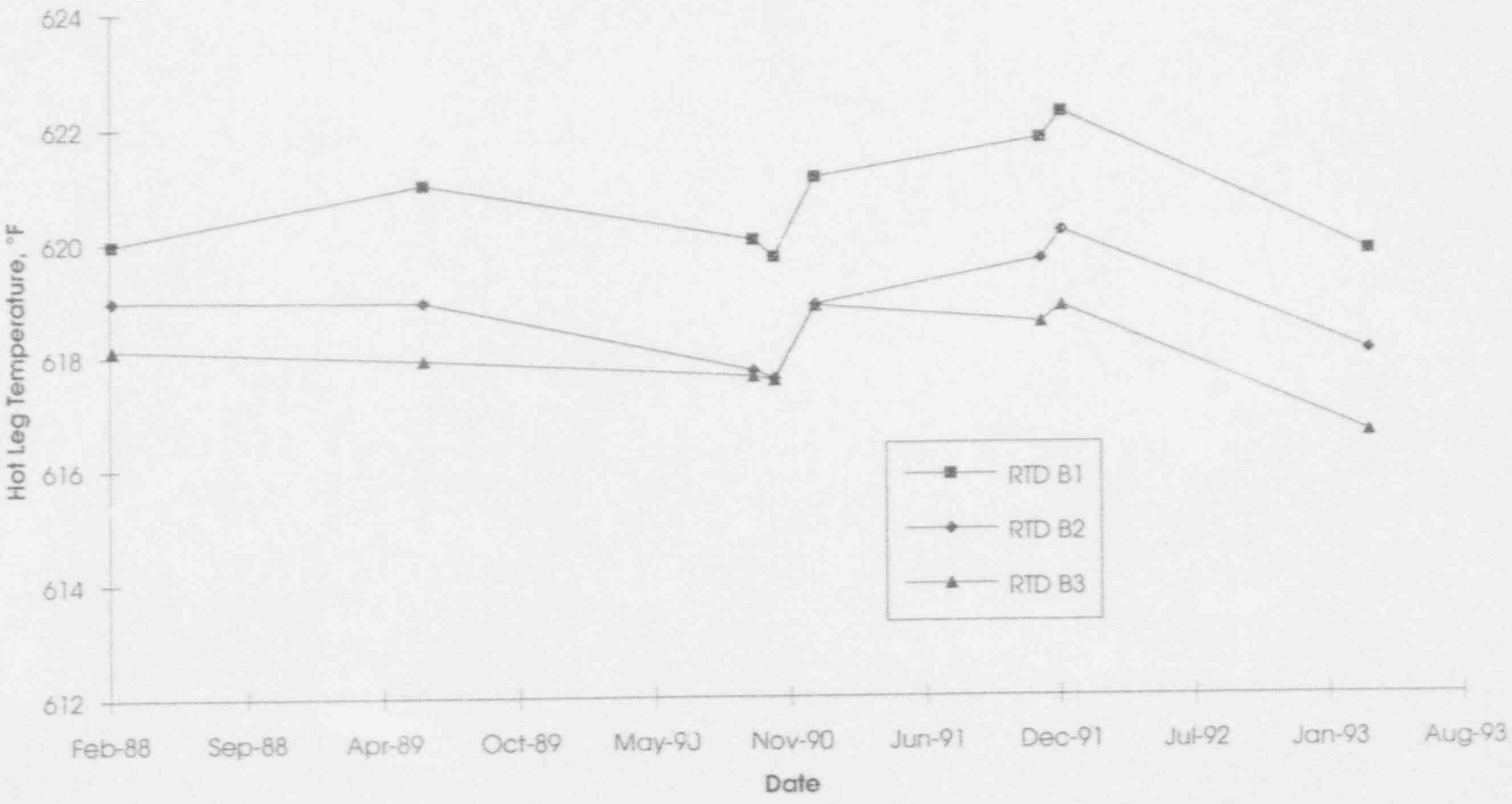
Catawba Unit 1Hot Leg Temperatures Measured During RCS Flow Calorimetric, Loop D

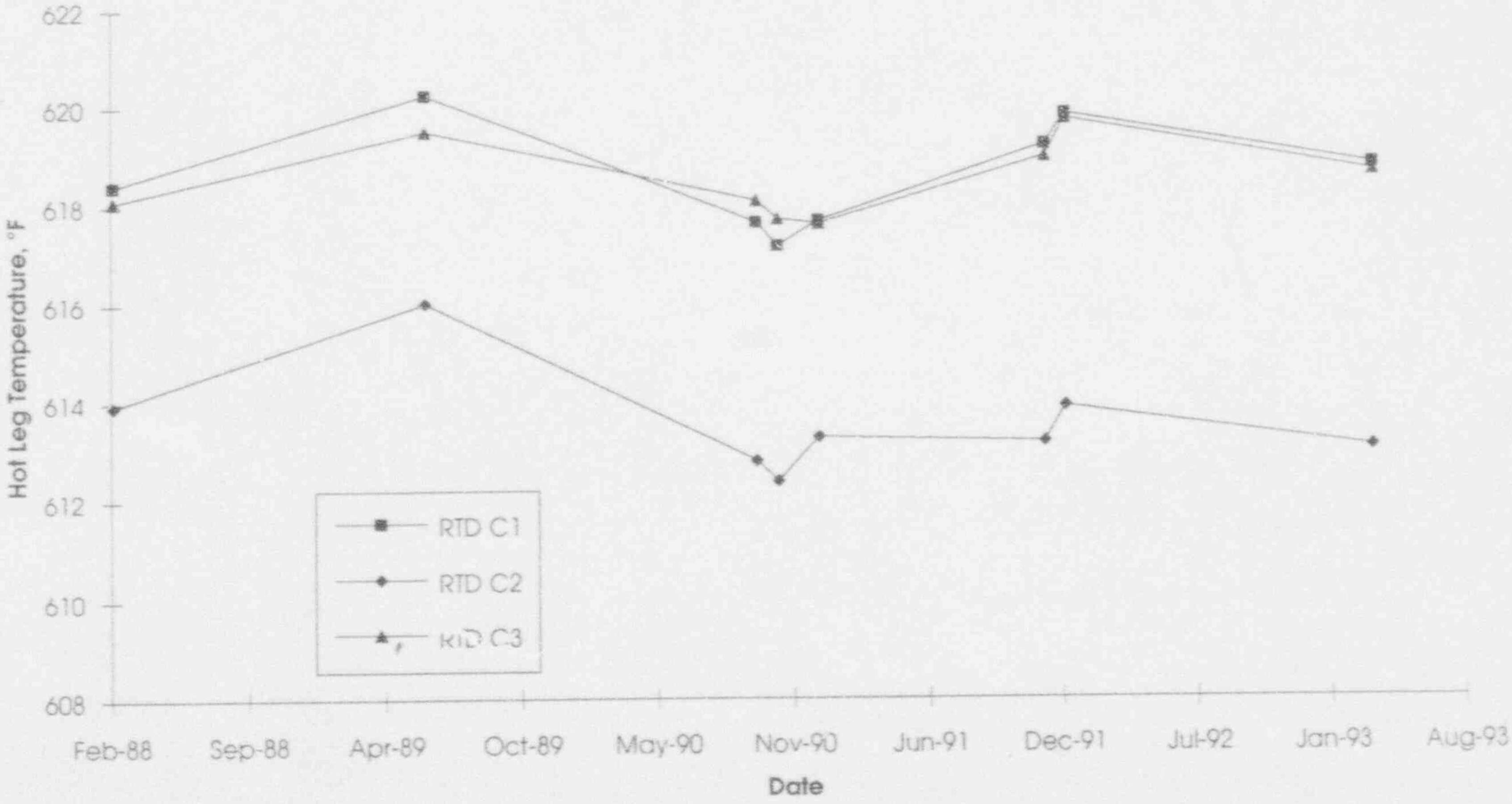


Catawba Unit 2 Hot Leg Temperatures Measured During RCS Flow Calorimetric, Loop A

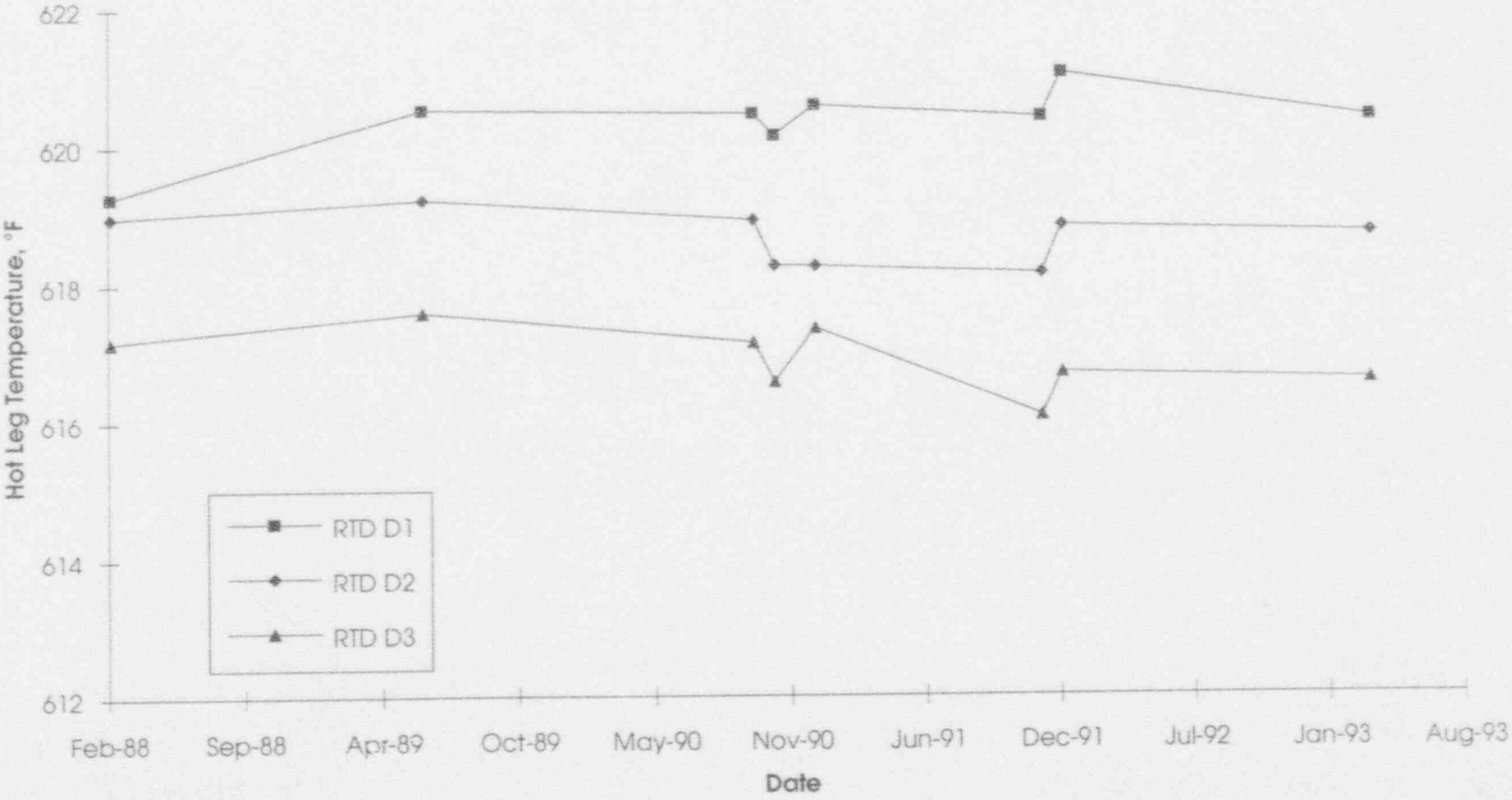


Catawba Unit 2 Hot Leg Temperatures Measured During RCS Flow Calorimetric, Loop B

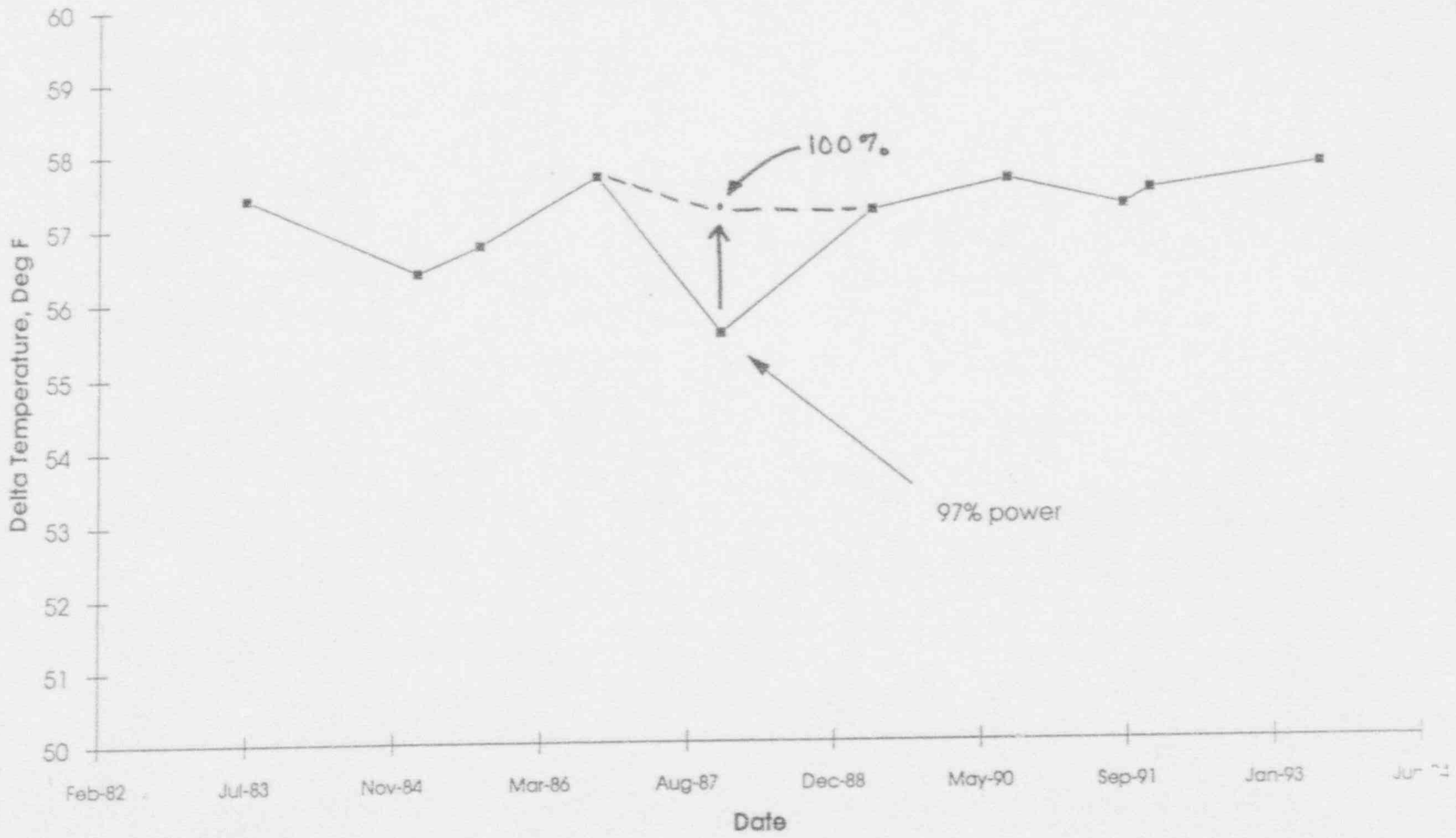



Catawba Unit 2 Hot Leg Temperatures Measured During RCS Flow Calorimetric, Loop C

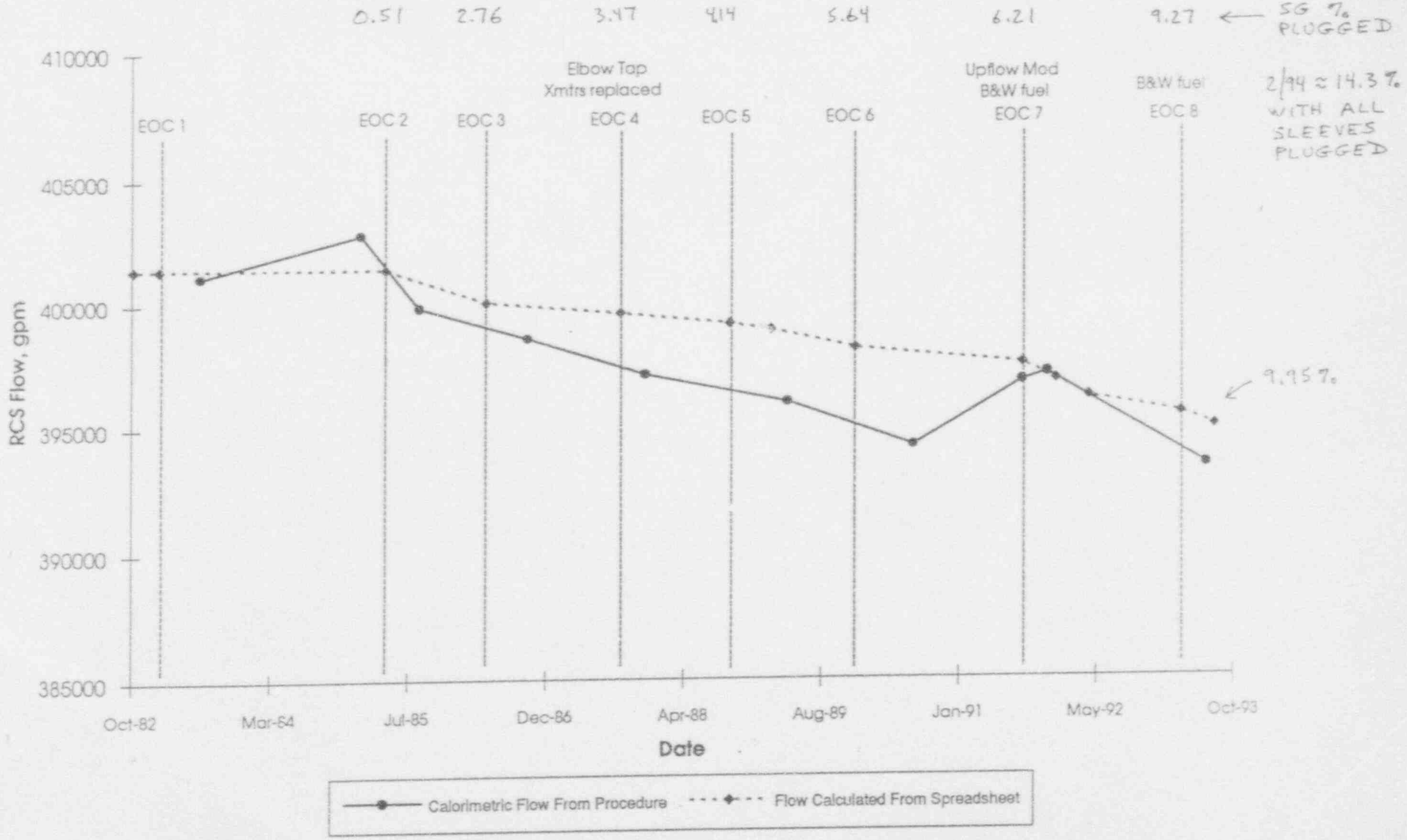
Catawba Unit 2 Hot Leg Temperatures Measured During RCS Flow Calorimetric, Loop D

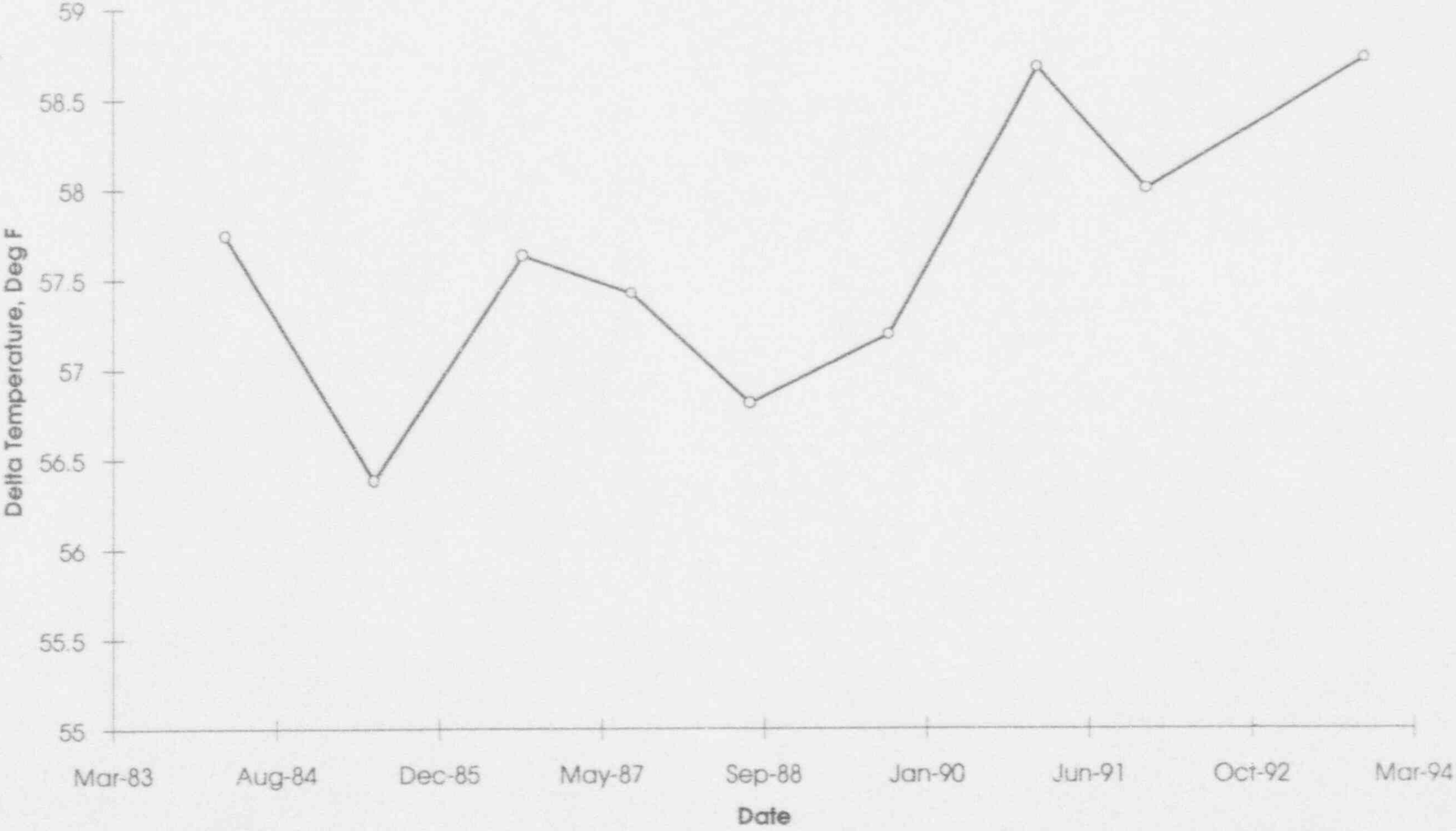


McGuire Unit 1 Measured Delta Temperature

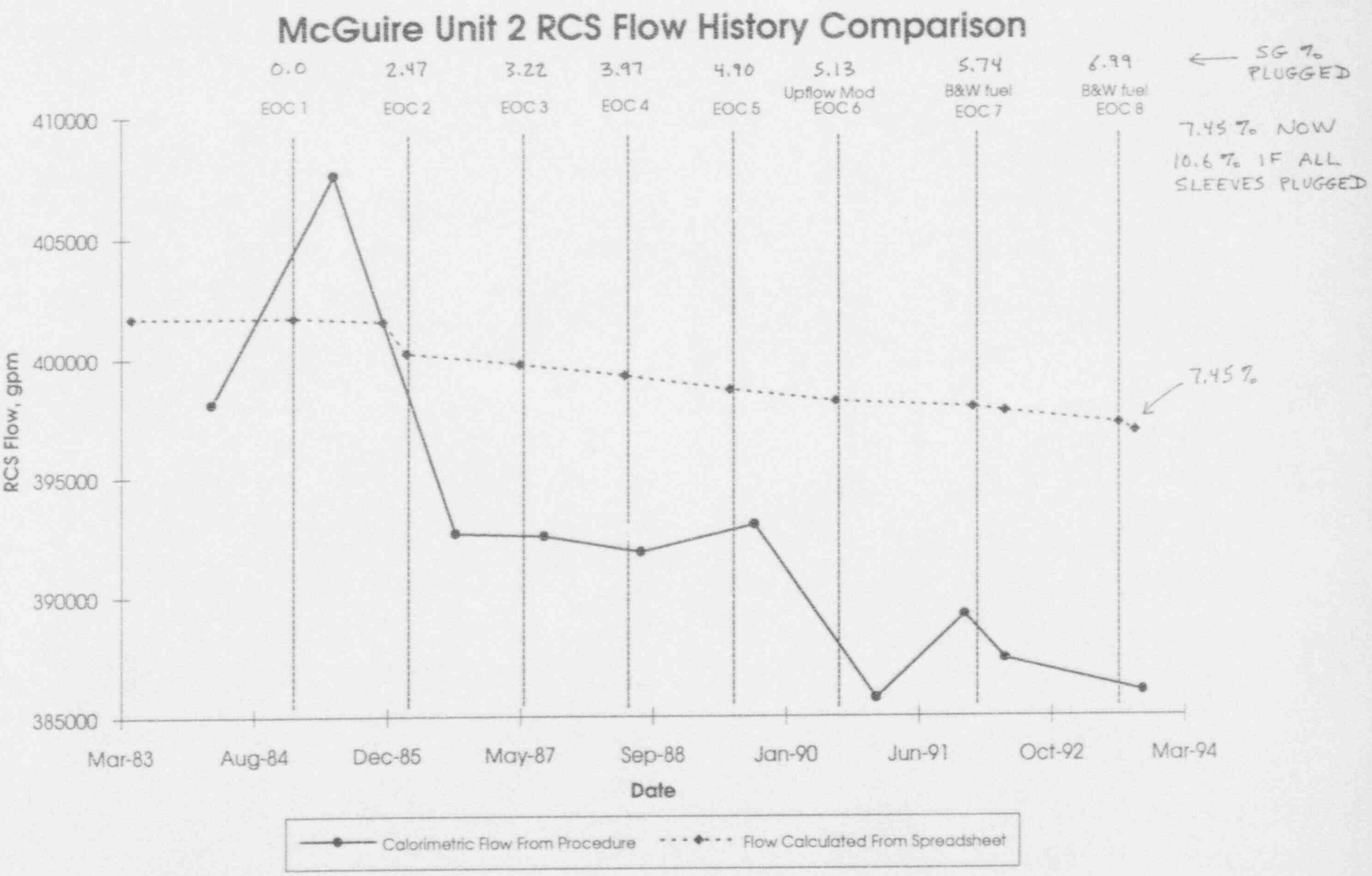


McGuire Unit 1 RCS Flow History Comparison





McGuire Unit 2 Measured Delta Temperature



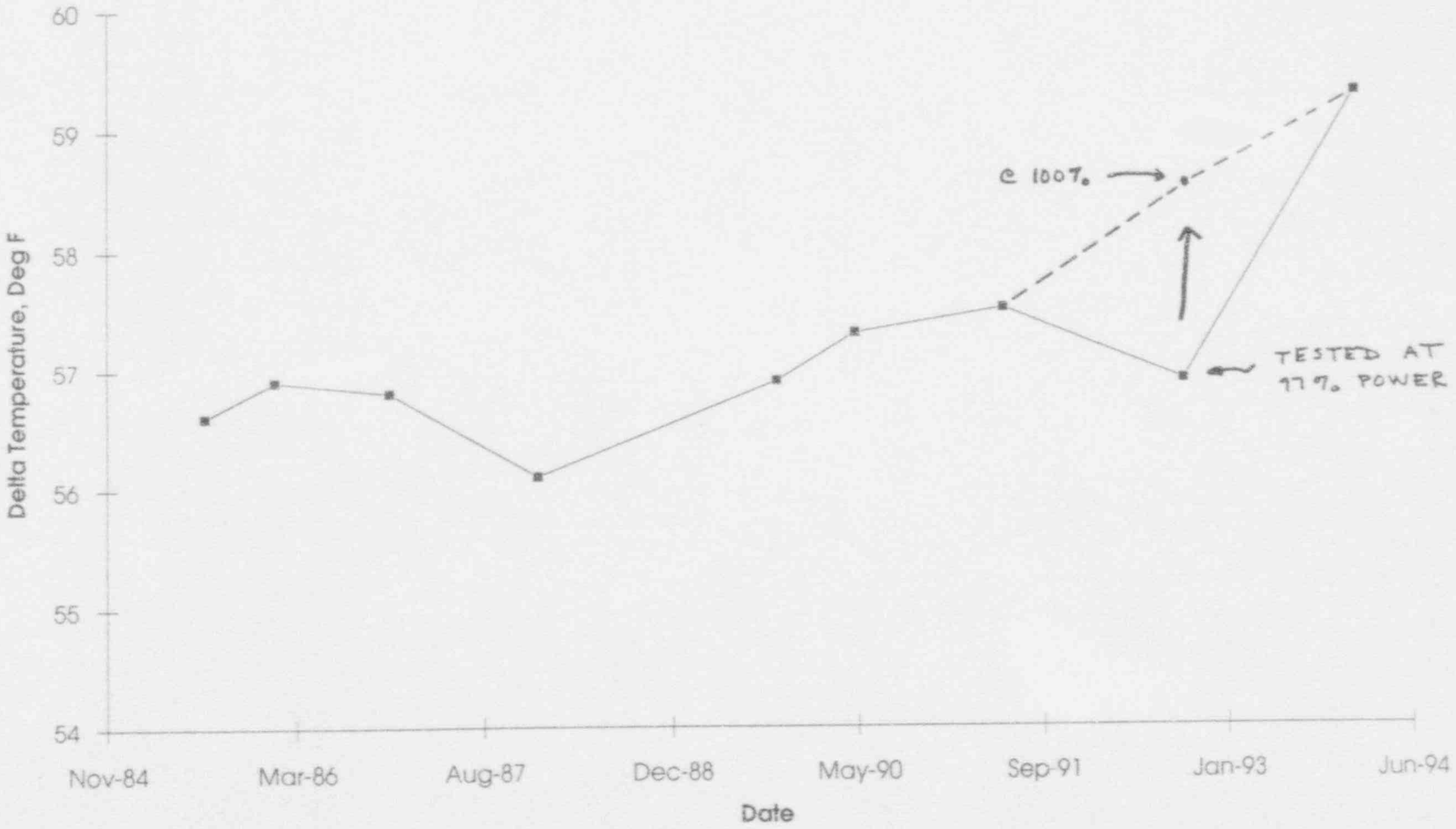
McGuire Unit 2 RCS Flow History Comparison

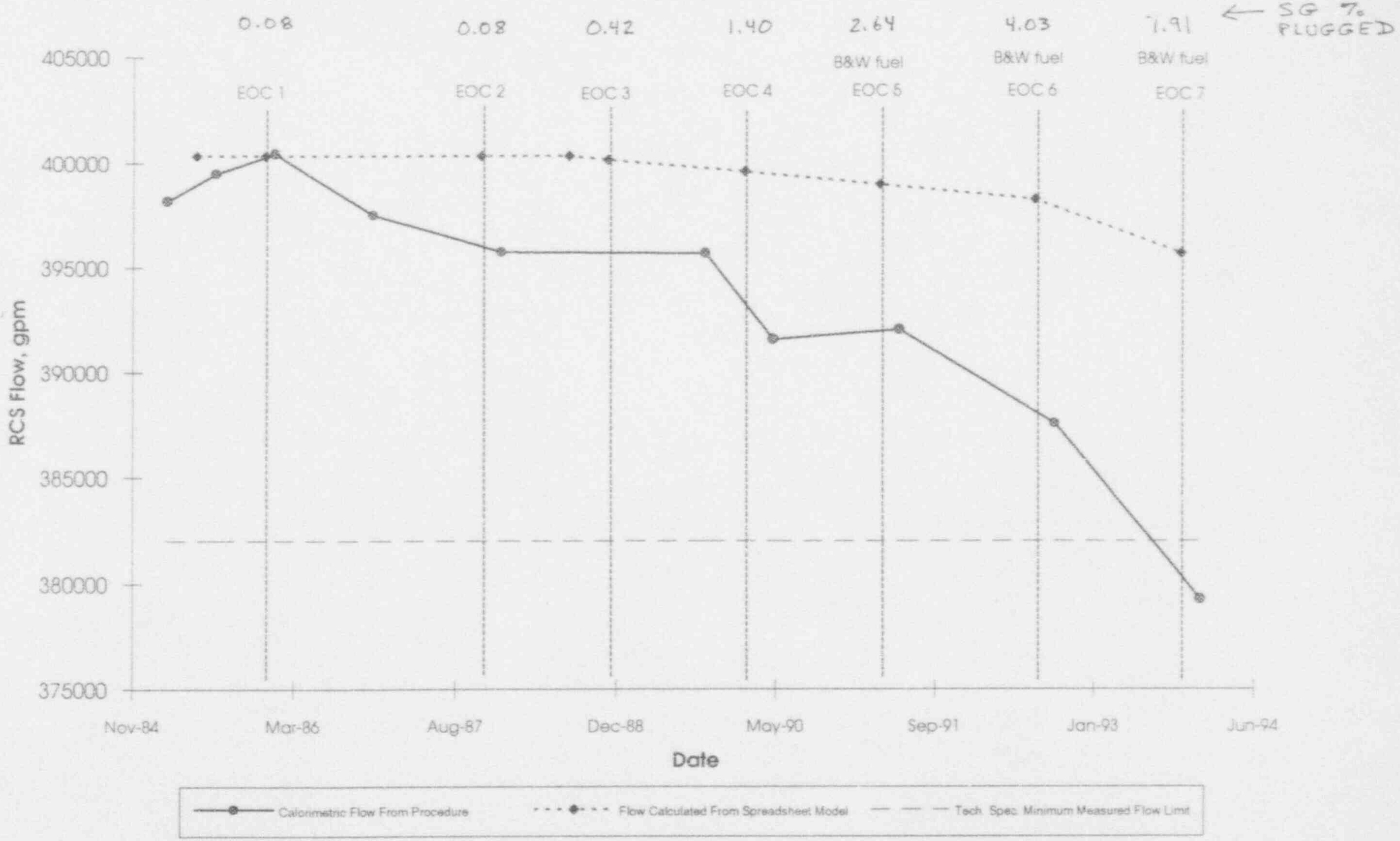
← SG % PLUGGED

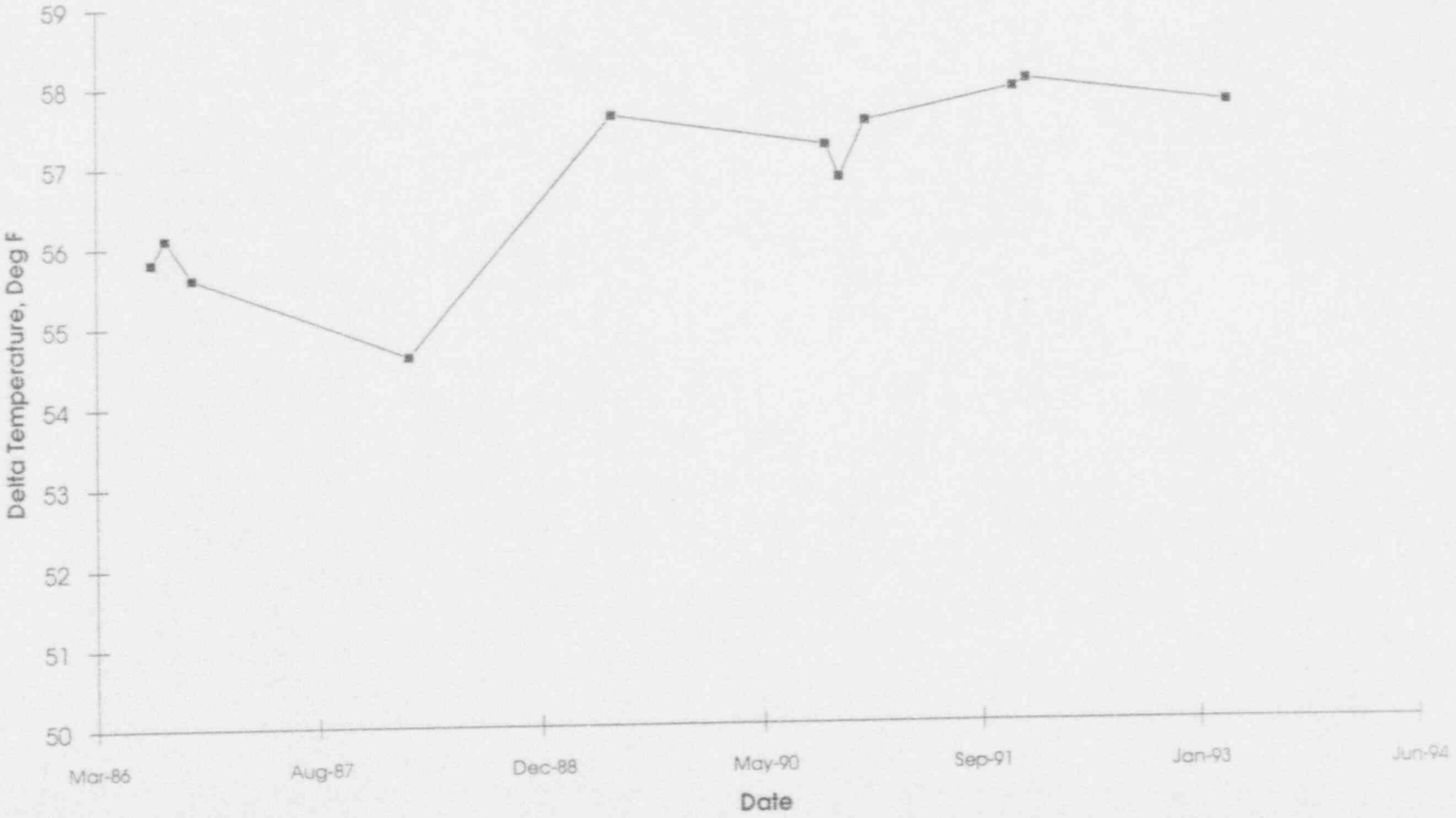
7.45 % NOW

10.6 % IF ALL SLEEVES PLUGGED

Catawba Unit 1 Measured Delta Temperature

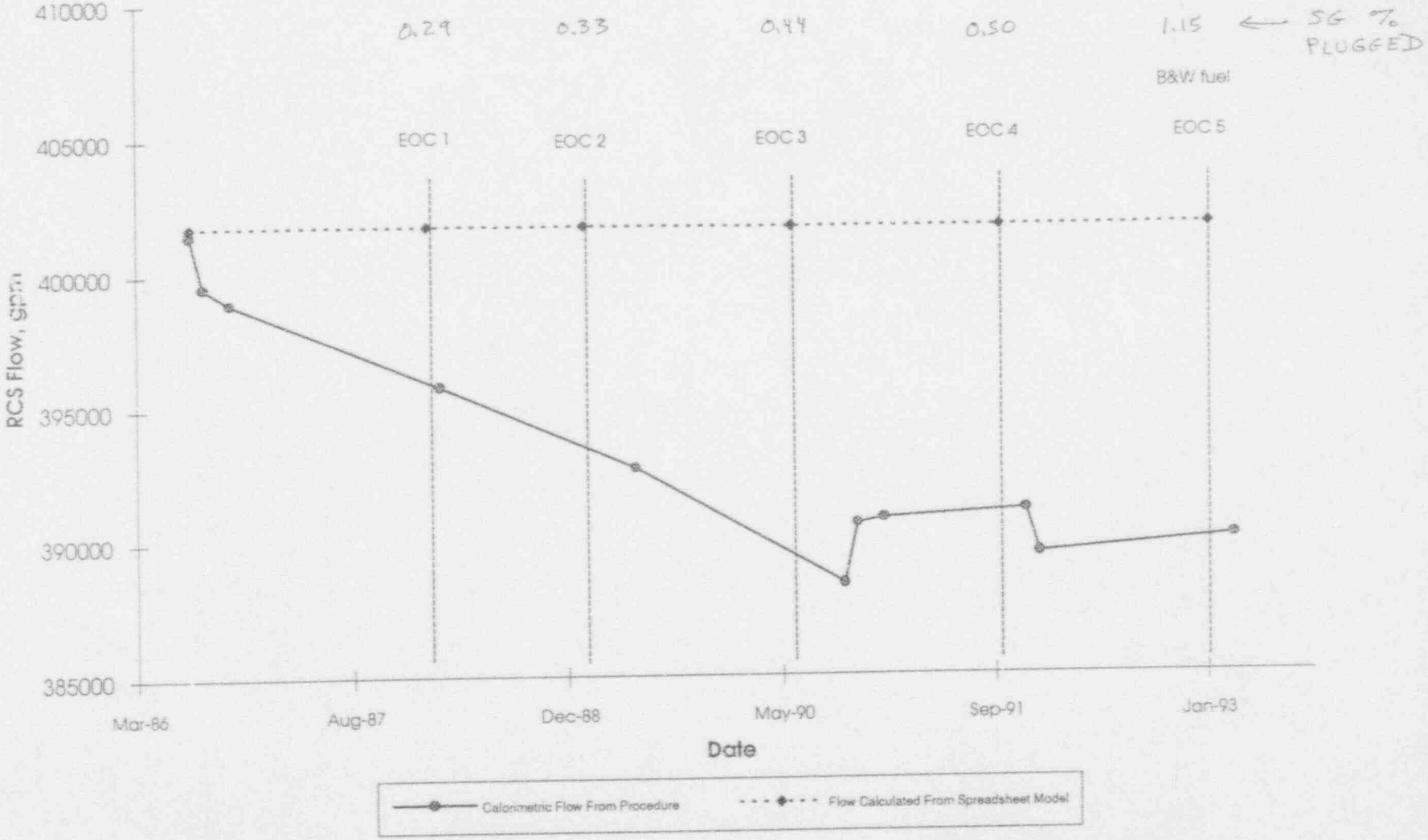



Catawba Unit 1 RCS Flow History Comparison



Catawba Unit 2 Measured Delta Temperature

Catawba Unit 2 RCS Flow History Comparison



II. OVERVIEW OF THE PROPOSED METHOD OF USING THE ELBOW TAP FLOW INSTRUMENTATION FOR THE TECH SPEC FLOW SURVEILLANCE

- EACH COLD LEG HAS THREE ELBOW TAPS AND ASSOCIATED INSTRUMENTATION THAT ARE USED IN THE RPS TO TRIP THE REACTOR ON LOW FLOW

- THE TREND OF THE ELBOW TAP DATA IS CONSISTENT WITH THE EXPECTED CHANGES IN RCS FLOW THAT OCCUR DUE TO SG TUBE PLUGGING AND FUEL DESIGN CHANGES.

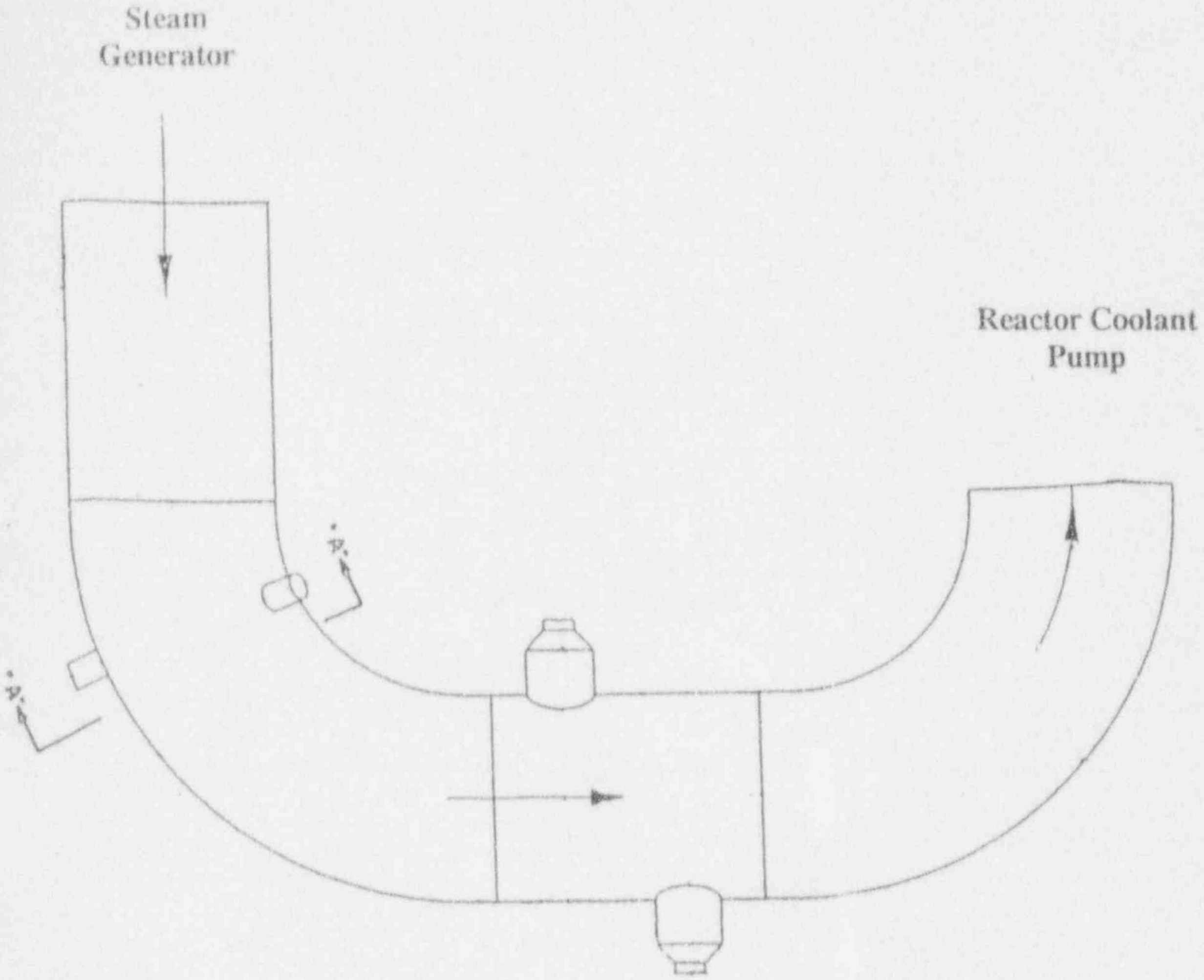
- A HYDRAULIC MODEL OF THE RCS HAS BEEN DEVELOPED WHICH SERVES AS AN ANALYTICAL CONFIRMATION OF THE RCS FLOW CHANGE AS INDICATED BY THE ELBOW TAP DATA

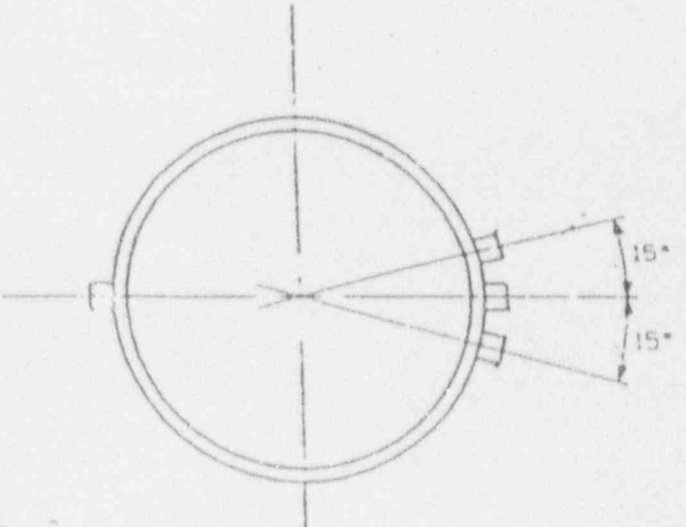
- THE ELBOW TAPS REQUIRE CALIBRATION TO SOME BASELINE FLOW VALUE. HOWEVER, THE ELBOW TAP COEFFICIENT IS A PHYSICAL PARAMETER WHICH DOES NOT CHANGE.

- A ONE-TIME CALIBRATION OF THE ELBOW TAPS WILL BE PERFORMED BASED ON AN AVERAGE OF ALL OF THE VALID CALIBRATION DATA THAT IS AVAILABLE.

- THIS SET OF ELBOW TAP COEFFICIENTS WILL BE USED FOR THE FLOW SURVEILLANCE AS LONG AS THE FLOW MEASUREMENT PROCESS REMAINS UNCHANGED.

Cold Leg Crossover Pipe and Elbow Tap Orientation





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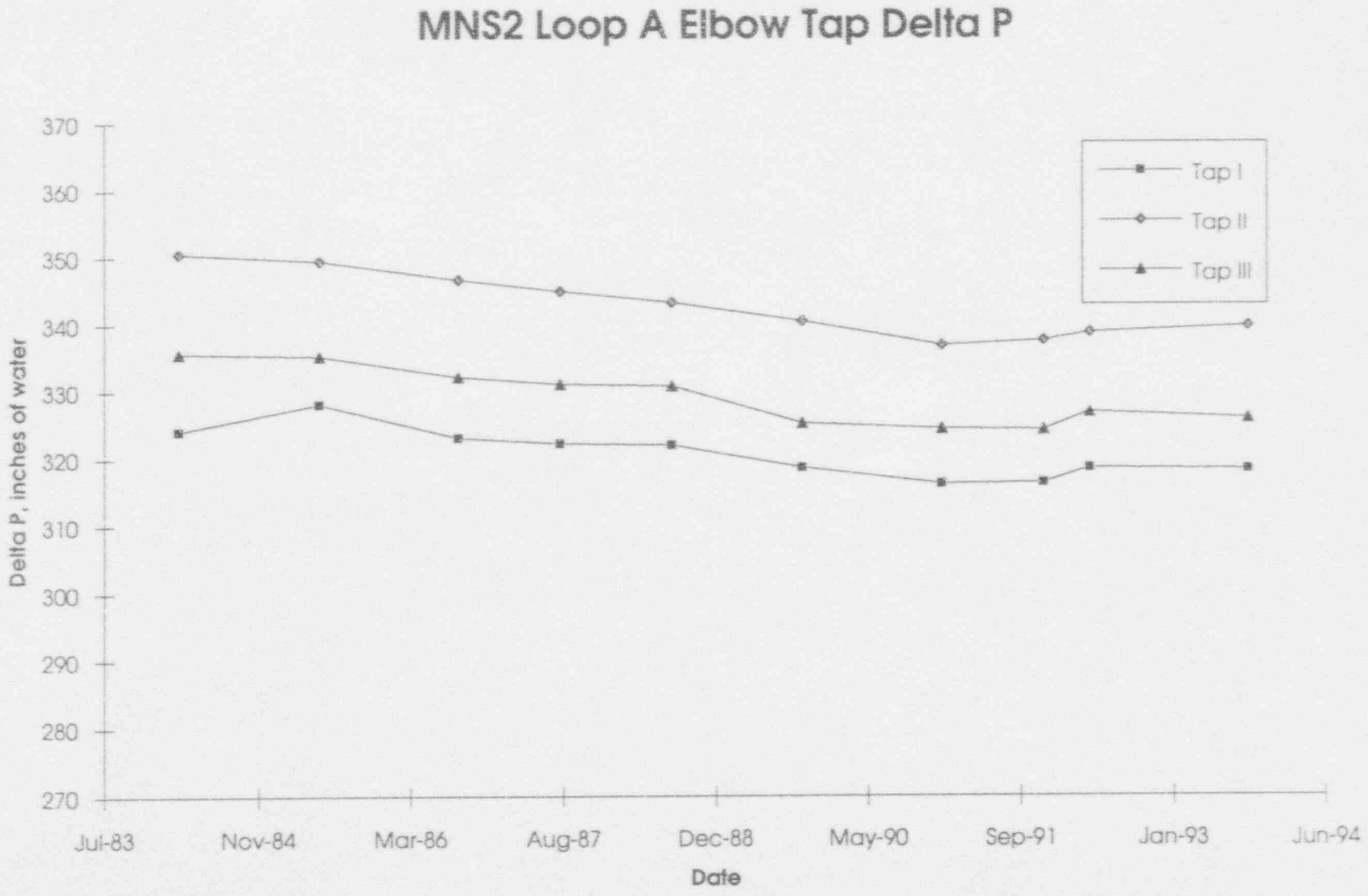
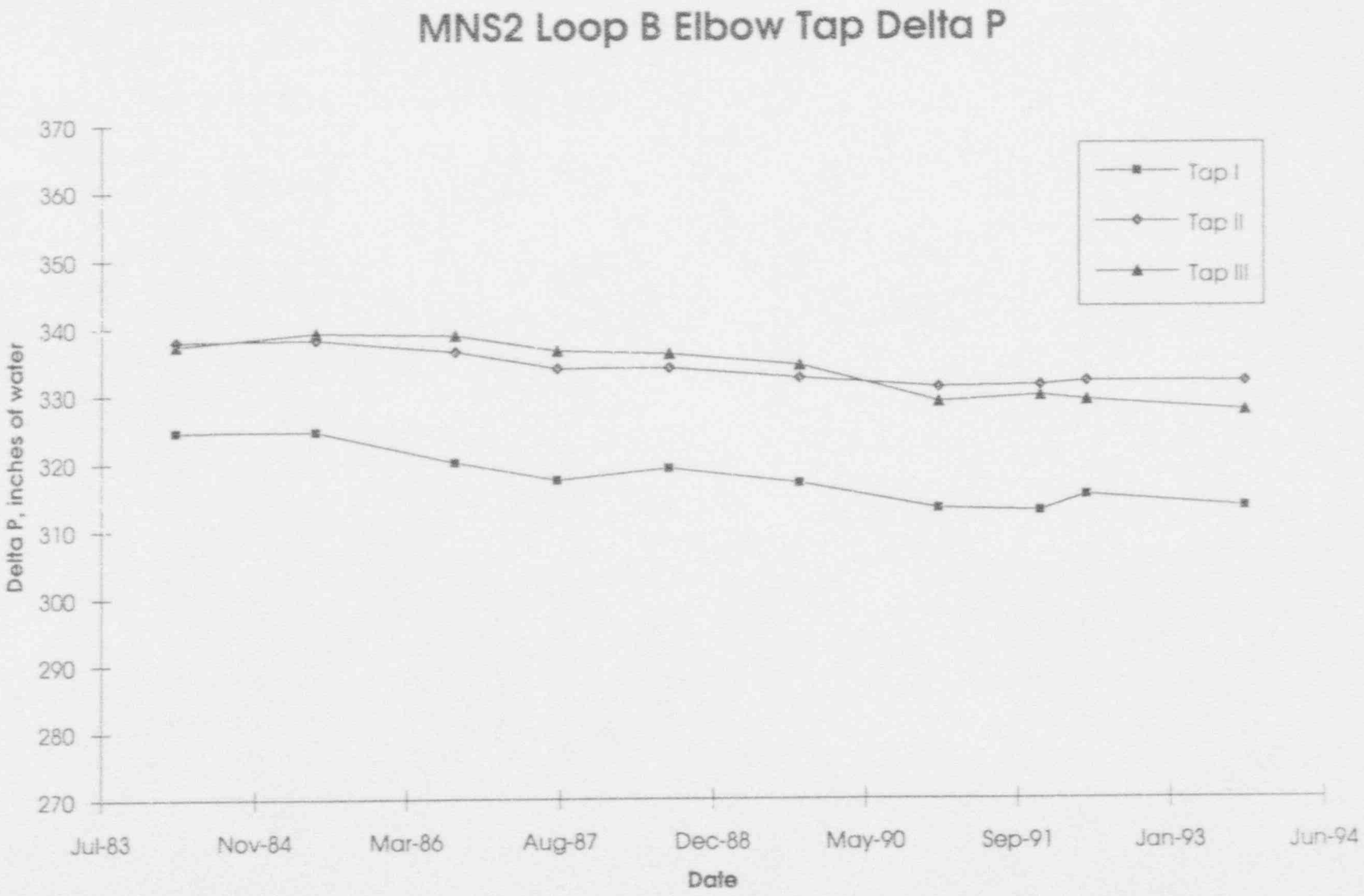
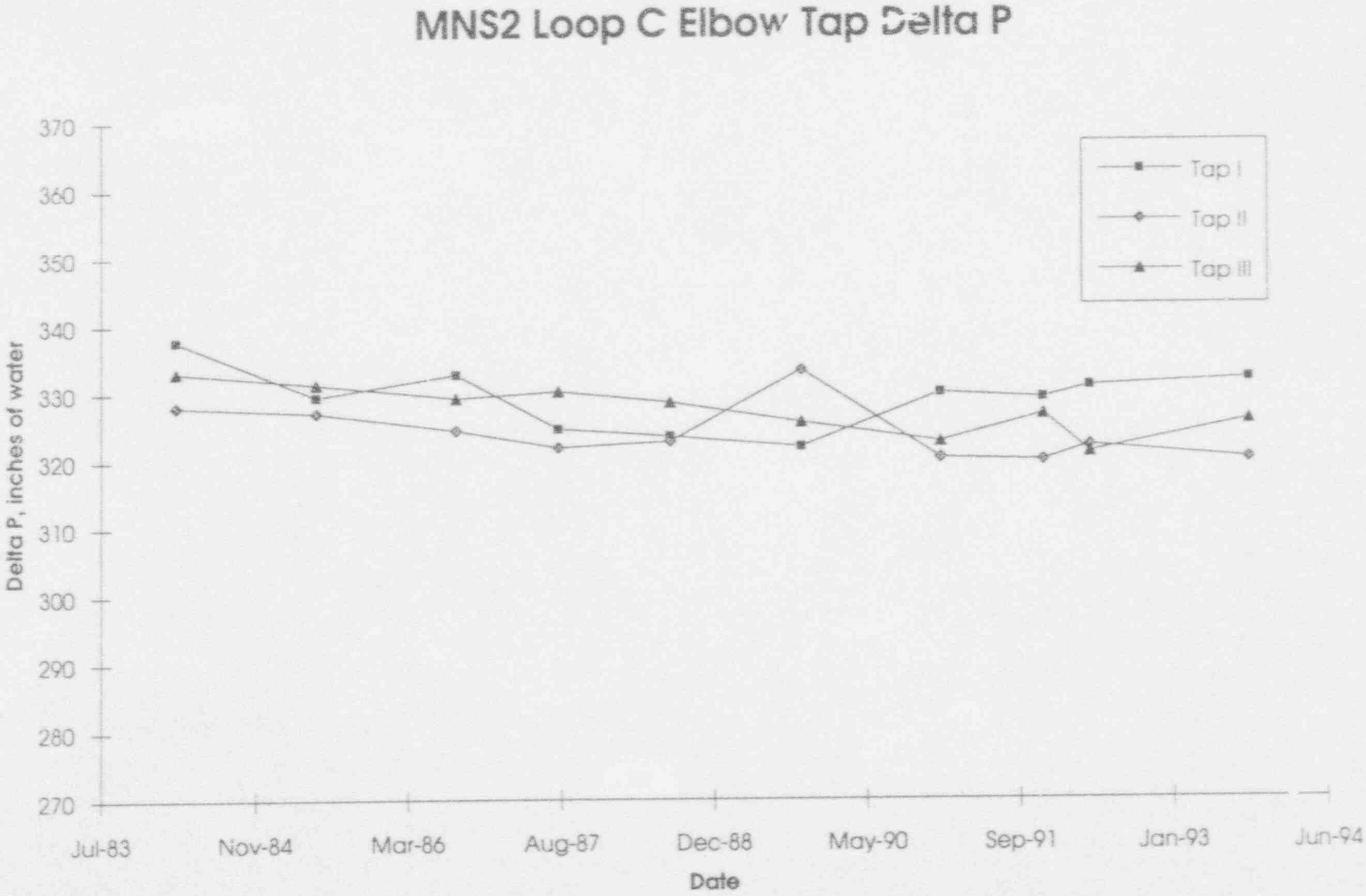
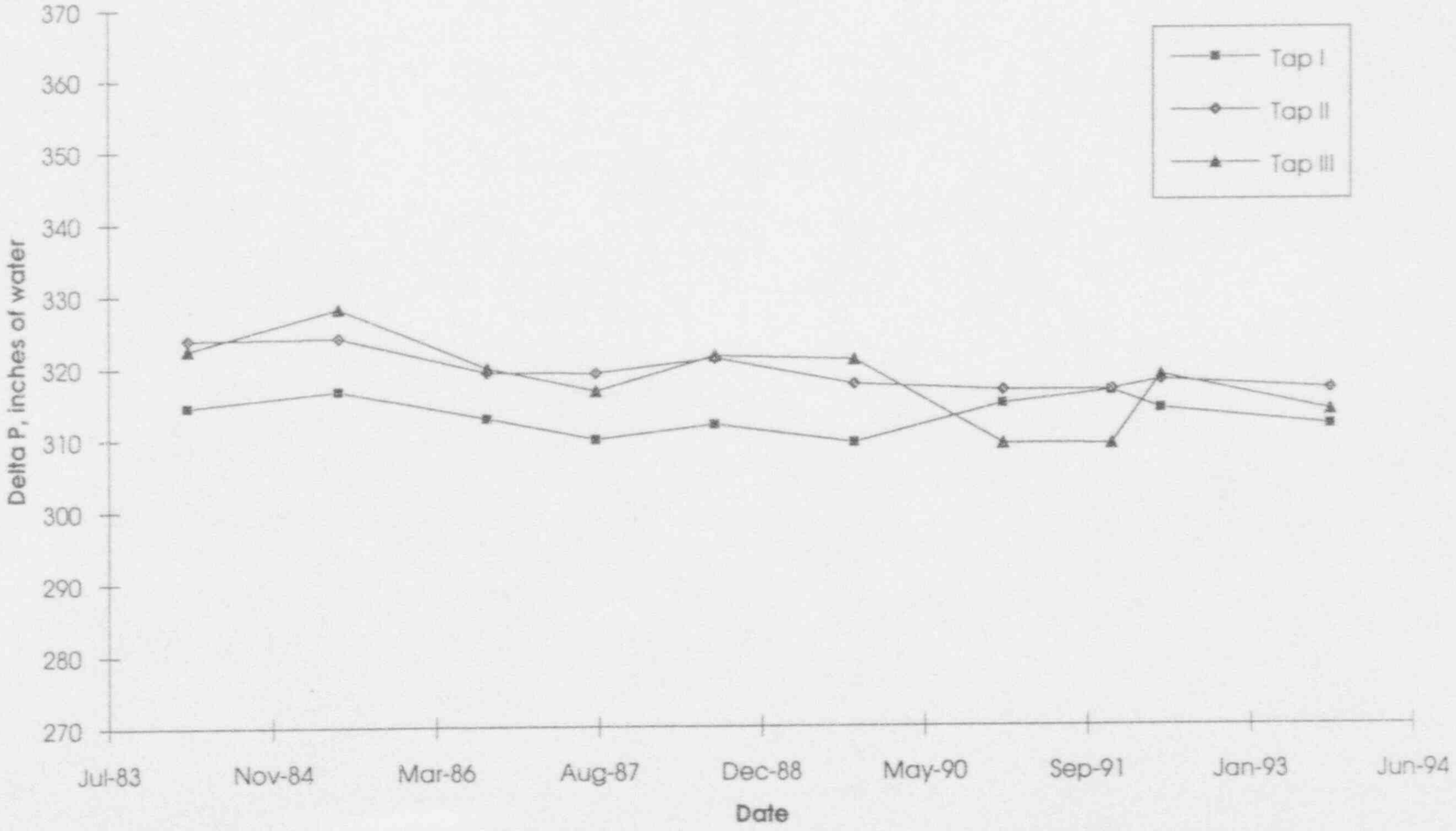

MNS2 Loop A Elbow Tap Delta P
Delta P, inches of water
370
360
350
340
330
320
310
300
290
280
270
Jul-83
Nov-84
Mar-86
Aug-87
Dec-88
May-90
Sep-91
Jan-93
Jun-94
Date
Tap I
Tap II
Tap III

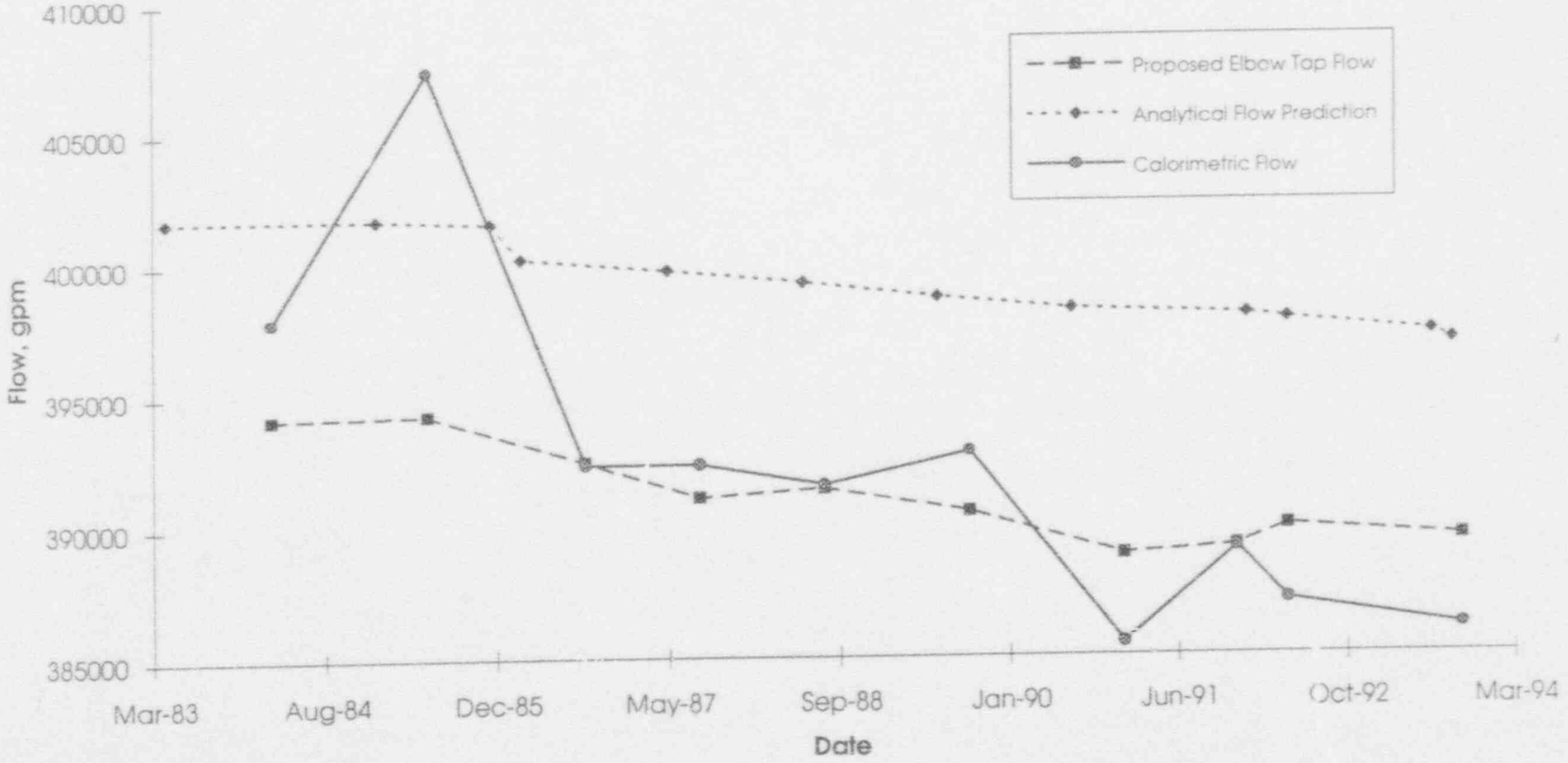

MNS2 Loop B Elbow Tap Delta P
Delta P, inches of water
370
360
350
340
330
320
310
300
290
280
270
Jul-83
Nov-84
Mar-86
Aug-87
Dec-88
May-90
Sep-91
Jan-93
Jun-94
Date
Tap I
Tap II
Tap III


MNS2 Loop C Elbow Tap Delta P

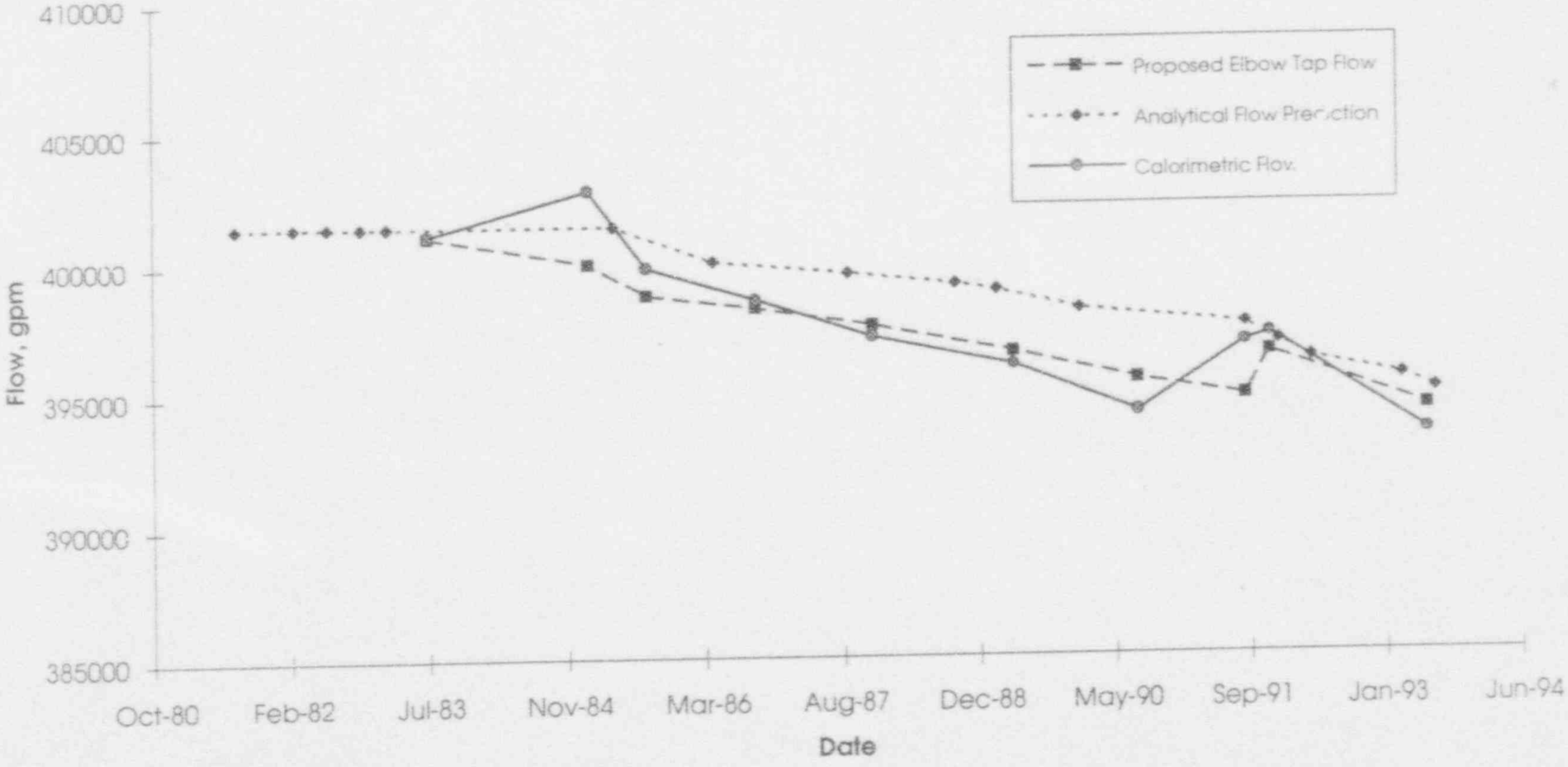
MNS2 Loop D Elbow Tap Delta P



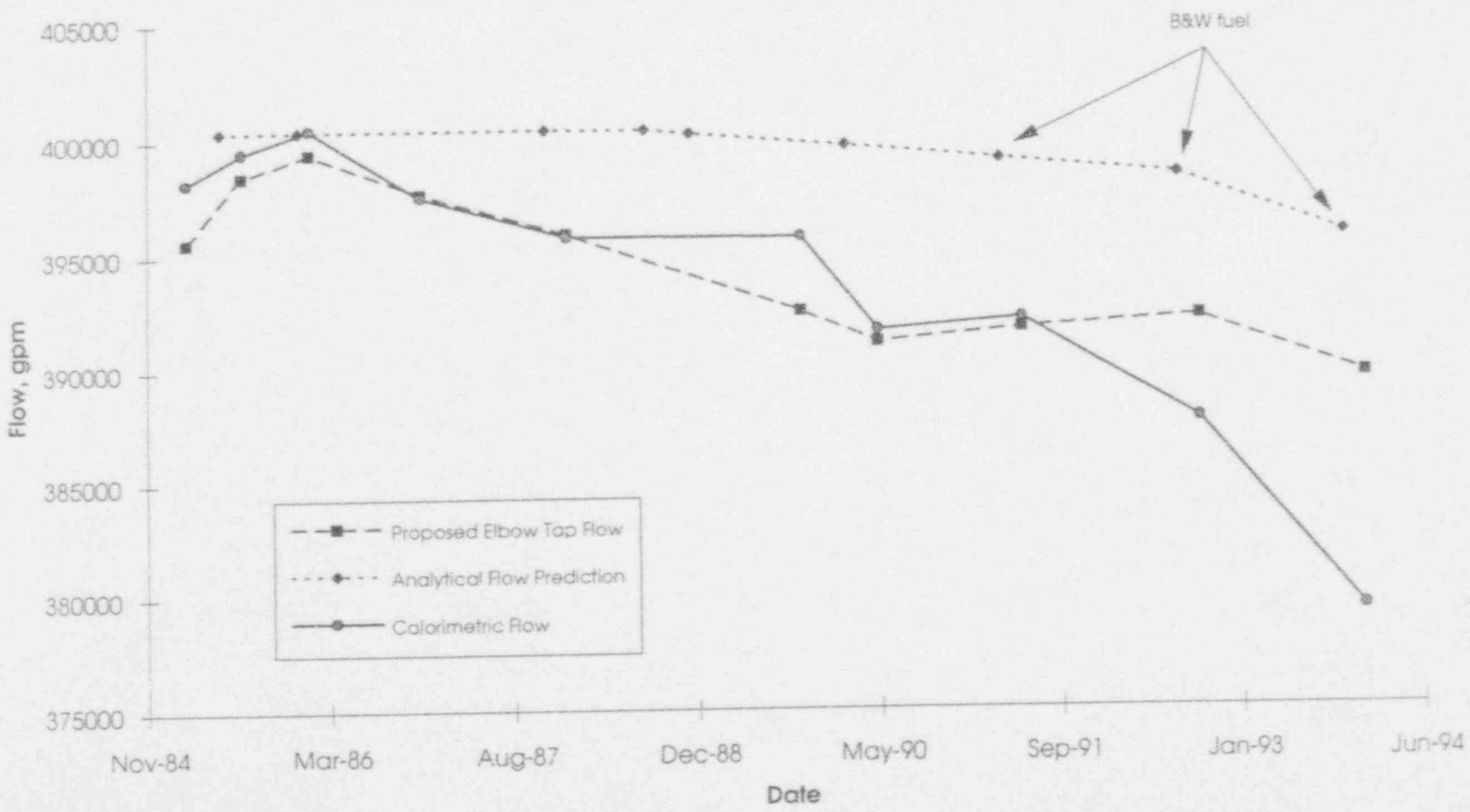
MNS-2 Flow Comparison Between Analytical Flow Prediction, Proposed Elbow Tap Method And Calorimetric Flow



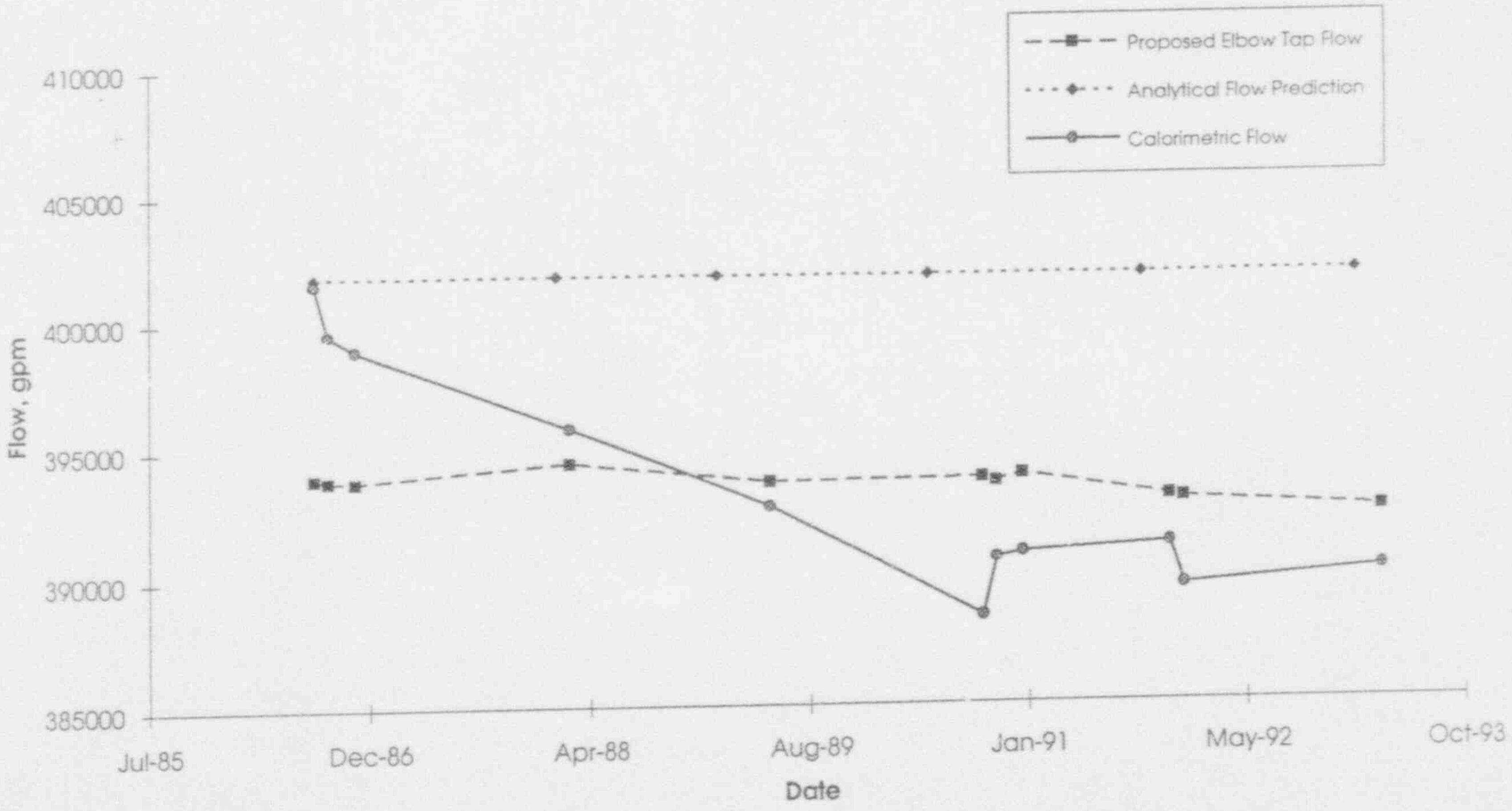
MNS-1 Flow Comparison Between Analytical Flow Prediction, Proposed Elbow Tap Method And Calorimetric Flow



CNS-1 Flow Comparison Between Analytical Flow Prediction, Proposed Elbow Tap Method And Calorimetric Flow



CNS-2 Flow Comparison Between Analytical Flow Prediction, Proposed Elbow Tap Method And Calorimetric Flow



OBSERVATIONS AND RESULTS

- THE ELBOW TAP DATA TREND WELL WITH THE ANALYTICAL MODEL, THUS CONFIRMING THAT THE CALORIMETRIC BASED FLOW IS ERRONEOUS, AND CONSERVATIVELY LOWER THAN REALITY.

- THE UNPREDICTABILITY OF THE FLOW CHANGES RESULTING FROM THE CALORIMETRIC METHOD CAN BE AVOIDED WITH THE ELBOW TAP METHOD.

- THE METHOD OF AVERAGING PAST CALORIMETRIC DATA IN ORDER TO ESTABLISH A BASELINE FOR THE ELBOW TAP COEFFICIENTS IS CONSERVATIVE.

- ALTHOUGH THE TREND FOR THE CURRENT METHOD HAS BEEN TO UNDERPREDICT FLOW, THE POSSIBILITY OF OVERPREDICTING FLOW WILL BE ELIMINATED.

- THE ANALYTICAL MODEL WILL ENABLE PREDICTING RCS FLOW CHANGES AND WILL AVOID UNNECESSARY LICENSING AND OPERATIONAL PROBLEMS.

CURRENT McGUIRE/CATAWBA RCS FLOW SITUATION

UNIT	TECH SPEC FLOW	CURRENT FLOW METHOD	PROPOSED FLOW METHOD
MNS-1	385,000 *	393,330	394,271
MNS-2	385,000 *	386,027	389,422
CNS-1	382,000	379,285	389,533
CNS-2	385,000	390,040	392,389

* - REDUCTION TO 382,000 IN PROGRESS

III. DISCUSSION OF THE ERROR ASSOCIATED WITH RCS FLOW MEASUREMENT

- TWO SPECIFIC UNCERTAINTIES ARE CALCULATED FOR THE PROPOSED TECHNICAL SPECIFICATION CHANGE:
  - LOW REACTOR COOLANT FLOW REACTOR TRIP
  - TS 4.5.2.1 AND 4.5.2.3 FLOW MEASUREMENT

- THE UNCERTAINTY METHODOLOGY FOR THE TRIP FLOW MEASUREMENT IS IDENTICAL TO THAT SUBMITTED DURING THE INITIAL LICENSING OF EACH STATION (LETTERS FROM DUKE TO NRC DATED 10-8-81 AND 7-30-84)

- THE UNCERTAINTY METHODOLOGY FOR THE SURVEILLANCE FLOW MEASUREMENT IS IDENTICAL TO THAT SUBMITTED DURING THE INITIAL LICENSING OF EACH STATION (LETTER FROM DUKE TO NRC DATED 11-23-82 AND CATAWBA FSAR QUESTION 492.7)

- THE TWO METHODOLOGIES ARE VERY SIMILAR, AND EACH DIVIDES THE MEASUREMENT HARDWARE STRING INTO SENSOR (MEASURING DEVICE) AND RACK (EVERYTHING ELSE)

- FOR BOTH THE SENSOR AND RACK PORTIONS, UNCERTAINTIES DUE TO CALIBRATION, DRIFT, AND TEMPERATURE EFFECTS ARE CONSIDERED

- FOR THE RACK THE UNCERTAINTY IN SETTING A BISTABLE SETPOINT IS ALSO CONSIDERED

- FOR THE SENSOR, UNCERTAINTIES FOR TRANSMITTER PRESSURE EFFECTS, PRIMARY ELEMENT (IN THIS CASE THE ELBOW TAP) ACCURACY, AND PROCESS MEASUREMENT ACCURACY ARE CONSIDERED

SUMMARY OF TRIP
FLOW MEASUREMENT UNCERTAINTY CALCULATION

- FOR THE FOLLOWING PARAMETERS, THE VALUES ARE IDENTICAL TO THOSE USED IN THE LATEST CALCULATIONS SUBMITTED TO THE NRC (SUBMITTAL JUSTIFYING REMOVAL OF THE RTD BYPASS MANIFOLDS):
  - RACK CALIBRATION ACCURACY (RCA)
  - RACK DRIFT (RD)
  - RACK TEMPERATURE EFFECT (RTE)
  - DENSITY EFFECTS ON ΔP CELL (PMA_1)
  - NOISE (PEA)
  - SENSOR DRIFT (SD)
  - DIFFERENTIAL PRESSURE TRANSMITTER BIAS

  THESE PARAMETER VALUES WERE REVIEWED TO ENSURE THAT THE VALUES FROM THE RTD BYPASS MANIFOLD SUBMITTALS REMAINED CONSERVATIVE

- FOR THE FOLLOWING PARAMETERS:
  - SENSOR CALIBRATION ACCURACY (SCA)
  - SENSOR TEMPERATURE EFFECT (STE)
  - SENSOR PRESSURE EFFECT (SPE)

  THE CURRENT CALCULATION ASSUMES ZERO VALUES BECAUSE CALIBRATION TO THE CALORIMETRIC IS CREDITED. FOR THE PROPOSED UNCERTAINTY CALCULATION, CONSERVATIVE VALUES WERE TAKEN FROM THE TRANSMITTER VENDOR'S DOCUMENTATION.

- FOR THE CALORIMETRIC FLOW MEASUREMENT UNCERTAINTY (PMA_2), VALUES LARGER THAN THOSE IN THE RTD BYPASS MANIFOLD REMOVAL SUBMITTALS WERE USED.

- FOR THE RACK COMPARATOR SETTING ACCURACY (RCSA), VALUES LARGER THAN THOSE IN THE RTD BYPASS MANIFOLD REMOVAL SUBMITTALS WERE USED TO ACCOUNT FOR ACTUAL CALIBRATION PROCEDURE TOLERANCES. THIS LARGER VALUE BOUNDS THE UNCERTAINTY INTRODUCED BY ACTUAL SITE CALIBRATION METHODS.

SUMMARY OF SURVEILLANCE FLOW MEASUREMENT UNCERTAINTY CALCULATION

- FOR THE FOLLOWING RACK PARAMETERS, THE VALUES ARE IDENTICAL TO THOSE USING IN THE LATEST CALCULATIONS SUBMITTED TO THE NRC (SUBMITTAL JUSTIFYING REMOVAL OF THE RTD BYPASS MANIFOLDS):
  - RACK CALIBRATION ACCURACY (RCA)
  - RACK DRIFT (RD)
  - RACK TEMPERATURE EFFECT (RTE)
  - COMPUTER ISOLATOR DRIFT (ID)
  - ALLOWANCE FOR NOISY SIGNAL (RDOT)
  - ANALOG-TO-DIGITAL CONVERSION ACCURACY (A/D)
  - DENSITY EFFECTS ON ΔP CELL (PMA_1)
  - NOISE (PEA)
  - SENSOR DRIFT (SD)
  - DIFFERENTIAL PRESSURE TRANSMITTER BIAS

  THESE PARAMETER VALUES WERE REVIEWED TO ENSURE THAT THE VALUES FROM THE RTD BYPASS MANIFOLD SUBMITTALS REMAINED CONSERVATIVE

- FOR THE FOLLOWING PARAMETERS:
  SENSOR CALIBRATION ACCURACY (SCA)
  SENSOR TEMPERATURE EFFECT (STE)
  SENSOR PRESSURE EFFECT (SPE)
  THE CURRENT CALCULATION ASSUMES ZERO VALUES BECAUSE CALIBRATION TO THE CALORIMETRIC IS CREDITED. FOR THE PROPOSED UNCERTAINTY CALCULATION, CONSERVATIVE VALUES WERE TAKEN FROM THE TRANSMITTER VENDOR'S DOCUMENTATION.

- FOR THE CALORIMETRIC FLOW MEASUREMENT UNCERTAINTY (PMA_2), VALUES LARGER THAN THOSE IN THE RTD BYPASS MANIFOLD REMOVAL SUBMITTALS WERE USED.

SUMMARY OF UNCERTAINTY CALCULATIONS

- THE METHODOLOGY USED IS IDENTICAL TO THAT APPROVED DURING ORIGINAL LICENSING
- MOST OF THE VALUES USED ARE IDENTICAL TO THOSE APPROVED IN THE 1987 RTD BYPASS MANIFOLD REMOVAL SUBMITTAL
- ALL VALUES HAVE BEEN REVIEWED TO ENSURE CONSERVATISM

IV. PROPOSED TS REVISIONS

TABLE 2.2-1

REACTOR TRIP SYSTEM INSTRUMENTATION TRIP SETPOINTS

FUNCTIONAL UNIT	TRIP SETPOINT	ALLOWABLE VALUE
1. Manual Reactor Trip	N.A.	N.A.
2. Power Range, Neutron Flux		
a. High Setpoint	≤109% of RTP*	≤110.9% of RTP*
b. Low Setpoint	≤25% of RTP*	≤27.1% of RTP*
3. Power Range, Neutron Flux, High Positive Rate	≤5% of RTP* with a time constant ≥ 2 seconds	≤6.3% of RTP* with a time constant ≥ 2 seconds
4. Intermediate Range, Neutron Flux	≤25% of RTP*	≤31% of RTP*
5. Source Range, Neutron Flux	≤10^5 cps	≤1.4 x 10^5 cps
6. Overtemperature ΔT	See Note 1	See Note 2
7. Overpower ΔT	See Note 3	See Note 4
8. Pressurizer Pressure-Low	≥1945 psig	≥1938 psig***
9. Pressurizer Pressure-High	≤2385 psig	≤2399 psig
10. Pressurizer Water Level-High	≤92% of instrument span	≤93.8% of instrument span
11. Reactor Coolant Flow-Low	91 ≥~~90%~~ of loop minimum measured flow**	89.7% ~~≥88.9%~~ of loop minimum measured flow**

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*RTP = RATED THERMAL POWER

**Loop minimum measured flow = 95,500 gpm

***Time constants utilized in the lead-lag controller for Pressurizer Pressure-Low are 2 seconds for lead and 1 second for lag. Channel calibration shall ensure that these time constants are adjusted to these values.

3/4.2.5 DNB PARAMETERS

LIMITING CONDITION FOR OPERATION

2. Within 24 hours of initially being within the region of prohibited operation specified on Figure 3.2-1, verify that the combination of THERMAL POWER and Reactor Coolant System total flow rate are restored to within the regions of restricted or permissible operation, or reduce THERMAL POWER to less than 5% of RATED THERMAL POWER within the next 2 hours.

SURVEILLANCE REQUIREMENTS

4.2.5.1 Each of the parameters of Table 3.2-1 shall be verified to be within their limits at least once per 12 hours.

4.2.5.2 The Reactor Coolant System total flow rate indicators shall be subjected to a CHANNEL CALIBRATION at least once per 18 months. The measurement instrumentation shall be calibrated within 7 days prior to the performance of the ~~calorimetric~~ flow measurement.

4.2.5.3 The Reactor Coolant System total flow rate shall be determined by ~~precision heat balance~~ measurement at least once per 18 months.

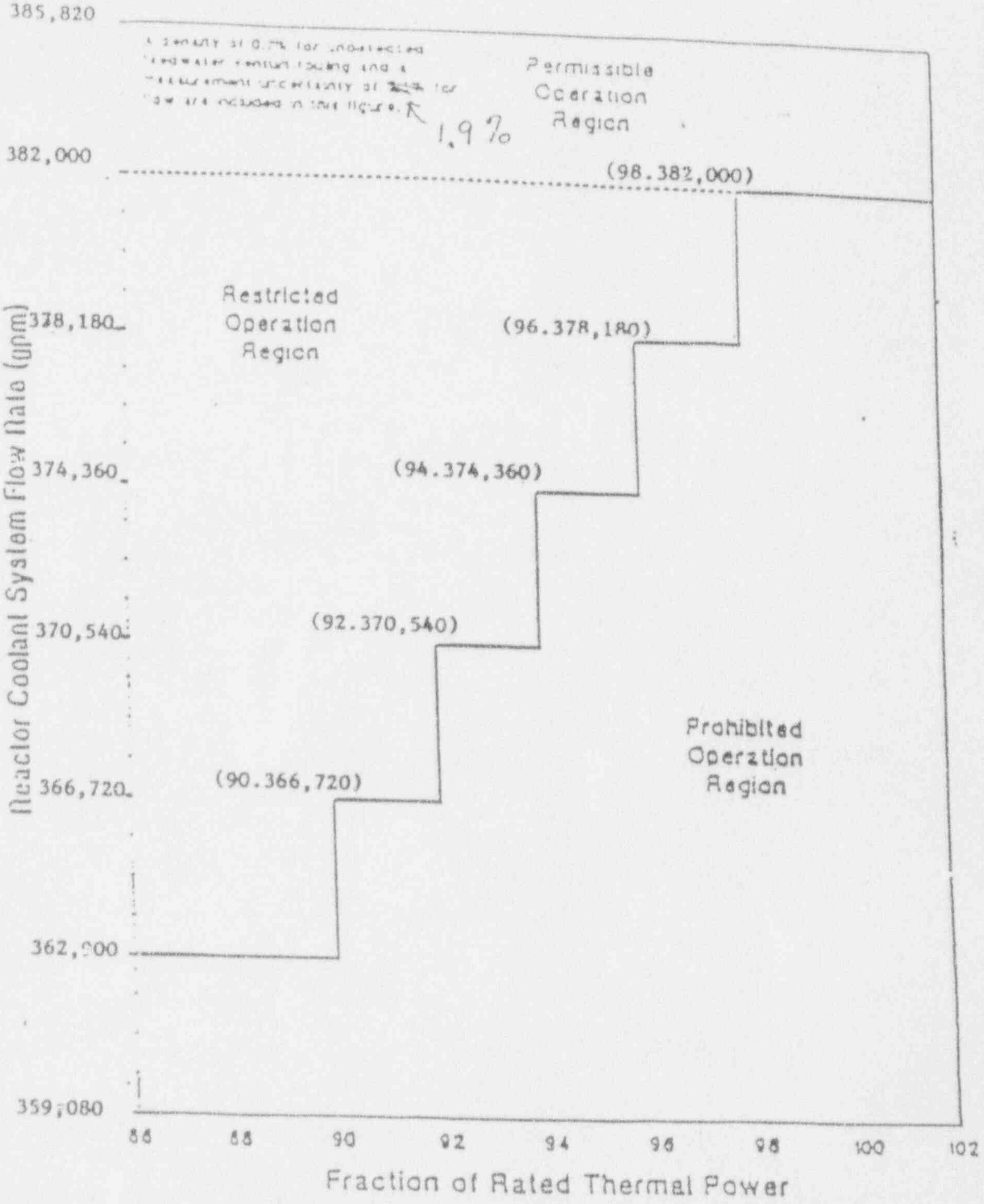


Figure 3.2-1 Reactor Coolant System Total Flow Rate Versus Rated Thermal Power - Four Loops in Operation

CNS

$$\text{limit } F^N_{\Delta H} = 1.55 \, [1 + 0.3 \, (1-P)]$$

where P is the fraction of rated full power.

The maximum calculated value of the operating nuclear enthalpy rise factor as a function of power level, including uncertainty allowance, does not exceed the design limit at any power level.

The .3 multiplier has previously been approved for the Reference Code Report for the 17x17 Optimized Fuel Assembly (WCAP 9500). In addition, justification for the coefficient change to 0.3 was previously provided to the NRC in NS-TMA-2323 from T. Anderson to J. Miller dated October 24, 1980 in which the justification is discussed in Response #2.

492.7
(4.4.6) Operating experience on two pressurized water reactors, not of Westinghouse design, indicate that a significant reduction in the core flow rate can occur over a relatively short period of time as a result of crud deposition on the fuel rods. In establishing the Technical Specifications for the Catawba units, we will require provisions to assure that the minimum flow rates are consistent with the safety analyses. Therefore, provide a description of the flow measurement capability for the Catawba units as well as a description of the procedures to detect flow degradation.

Response:

There has been no case reported to Westinghouse of significant flow reduction in a relatively short period of time due to buildup of crud on the fuel rods at any Westinghouse plant. Additionally there has been no report to Westinghouse of a significant flow reduction in a relatively short period of time for any reason (excluding steam generator tube plugging) of any Westinghouse plant. Therefore Westinghouse is of the opinion that this portion of the question is not applicable.

Flow measurement technique and frequencies are addressed in Technical Specification 3/4.2.3 and in the following discussion of flow measurement techniques which require a monthly calorimetric flow measurement.

Specification 3.2.3, RCS Flow Rate and R, in the Standard Technical Specifications requires that total reactor flow (total flow through the vessel from all loops) be above some minimum value and if above that minimum value allows a trade off between rod bow penalty and reactor flow. The minimum flow value is thermal design flow corrected for flow measurement uncertainties. Historically the uncertainty has been specified as 3.5%. Flow measurement uncertainties much less than this can be achieved however by using modern statistical error combination techniques and a calorimetric flow measurement method. The accuracy claimed for this technique depends primarily on the measurement procedure employed and on how well the instrument errors are understood and controlled by plant personnel. The calorimetric flow calculation, the measurements required and the measurement uncertainty analysis are described in the following paragraphs and tables.

Reactor coolant loop flow is determined from the steam generator thermal output, corrected for the loop's share of the net pump heat input, and the enthalpy rise (Δh) of the coolant. Total reactor flow is the sum of the individual loop flows. Table Q492.7-1 lists the calorimetric equations and defines the terms.

To establish the overall flow measurement uncertainty, the accuracy and relationship to flow of each process instrument used for the calorimetric measurements (see Table Q492.7-2) must be determined. In most cases there are several components (transducer, converter, isolator, OAC input, readout device, etc.) which contribute to the overall uncertainty of the measurement. Table Q492.7-3 provides a list of typical components involved in the calorimetric loop flow measurement, a corresponding conservative instrument error allowance and the effect of the instrument error allowance on the calculated power or flow value. The overall loop flow measurement uncertainty is the statistical combination of the individual uncertainties and appears at the bottom of Table Q492.7-3. Total reactor flow measurement uncertainty is the statistical combination of the individual loop flow uncertainties and also appears at the bottom of Table Q492.7-3.

In summary, individual loop flow is determined by performance of a calorimetric and these values summed to arrived at total reactor flow. The measurement uncertainty is determined by statistically combining individual component and loop uncertainties. A calorimetric flow measurement must be performed to take credit for this particular measurement uncertainty.

Table Q492.7-1

REACTOR COOLANT LOOP FLOW CALCULATION

$$W_L = \frac{[Q_{SG} - Q_p + (\frac{Q_L}{N})]V_c \quad 0.1247}{[h_H - h_c]}$$

where: W_l = Loop flow (gpm)

Q_{SG} = Steam generator thermal output (Btu/hr.)

Q_L = Primary system net heat losses (Btu/hr.)

N = Number of loops

Q_p = Reactor coolant pump heat adder (Btu/hr.)

h_H = Hot leg enthalpy (Btu/lb.)

h_{CY} = Cold leg enthalpy (Btu/lb.)

V_c = Cold leg specific volume (cu. ft./lb.)

$$Q_{SG} = (h_s \quad h_f)\ W_F$$

where: h_s = Steam enthalpy (Btu/lb.)

h_F = Feedwater enthalpy (Btu/lb.)

W_F = Feedwater flow (lb./hr.)

$$W_F = K\ F_a \sqrt{P_F \Delta P}$$

where: K = Feedwater venturi flow coefficient

F_a = Feedwater vneturi correction for thermal expansion

P_F = Feedwater density (lbl/cu. ft.)

ΔP = Feedwater venturi pressure drop (inches H_2O)

Table Q492.7-2

MEASUREMENTS REQUIRED

Parameter	Instrument	Function
1. Feedwater venturi pressure differential	Rosemount ΔP guage and compatible readout	feedwater flow
2. Feedwater temperature	Continuous lead thermocouple	feedwater enthalpy and density venturi thermal expansion
3. Steam pressure	Transducer and process computer readout	steam enthalpy
4. Reactor coolant T_{hot}	Narrow range RTD and data acquisition system or DVM readout	RCS hot leg enthalpy
5. Reactor coolant T_{cold}	Narrow range RTD and data acquisition system or DVM readout	RCS cold leg enthalpy RCS specific volume
6. Reactor coolant pressure	Transducer and process computer readout	RCS enthalpy and specific volume

Other information required for the calculation is as follows:

7. Feedwater venturi coefficient from vendor calibration.

8. Primary system heat losses and pump heat input obtained from calculations.

Table Q492.7-3 (Page 1)

CALORIMETRIC FLOW MEASUREMENT UNCERTAINTIES

Component	Instrument Error	Uncertainty % Power or % Flow
Secondary Power		
Feedwater Flow		
Venturi K	± 0.25% K	± 0.25%
Thermal Expansion coefficient		
Temperature	± 2.0°F	
Material	± 5.0%	± 0.06%
Density		
Temperature	± 2.0°F	± 0.09%
Pressure	± 60 psi	
DP Cell Calibration	± 0.25% of RDG	± 0.13%
DP Cell Precision Error	± 0.50%	± 0.25%
Tempering Aux. Feedwater Flow Error	± 5.0% x 0.011%/%	±0.06%
Blowdown Flow Error	± 10% x 0.017%/%	±0.17%
Feedwater Enthalpy		
Temperature	± 2.0°F	± 0.28%
Pressure	± 60 psi	
Steam Enthalpy		
Pressure	± 40 psi	± 0.15%
Moisture Carryover	± 0.25%	± 0.22%
Total Secondary Thermal Power Uncertainty	$\sqrt{\Sigma(e)^2}$	± 0.58%
Primary Enthalpy		
T_H RTD	± 1.2°F	± 2.27%
T_H Data Acquisition System or equivalent DMM	± 0.5°F	± 0.95%
T_H Readout	± 0.1°F	± 0.19%
T_H Temperature Streaming	± 1.2°F	± 2.27%
T_H Pressure Effect	± 30 psi	± 0.24%
T_C RTD	± 1.2°F	± 1.87%
T_C Data Acquisition System or equivalent DMM	± 0.5°F	± 0.79%
T_C Precision Error	± 0.1°F	± 0.16%
T_C Pressure Effect	± 30 psi	± 0.06%
Net Pump Heat Addition	± 20%	± 0.085%
Total Loop Flow Uncertainty	$\sqrt{\Sigma(e)^2}$	± 3.98%
Total Reactor Flow Uncertainty 4-loop		± 1.99%

Table Q492.7-3 (Page 2)

ASSUMPTIONS

The values on page 1 are based on some specific assumptions about the instruments and readouts.

1. Feedwater flow is obtained from several readings of Rosemount differential pressure gauges installed on the feewater venturi.
2. Credit was taken for the 3 tap scoop RTD bypass loop in reducing uncertainties due to streaming.

ENCLOSURE 4

2/3/94

COMMENTS ON PROPOSED TS CHANGE FOR CATAWBA AND MCGUIRE UNITS 1&2 FOR RCS FLOW-RATE MEASUREMENT - (TS 4.2.5.3)

1.0 References

1. Letter from M. S. Tuckman, Duke Power Company (DPC), to USNRC, dated January 10, 1994.

2. Amendment Nos. 34/25, Technical Specification Change for Figure 3.2-3, RCS Flow vs R for Catawba Units 1 and 2", dated November 24, 1987.

3. Amendment Nos. 40/33, Replacement of RTD Bypass Manifold System with In Line RTDs, February 18, 1987.

4. Amendment Nos. 113/107, Technical Specification Changes for Duke Power Company Catawba and McGuire Nuclear Stations, Units 1 and 2 to Reduce Required Minimum Measured Reactor Coolant System Flow, dated December 17, 1993.

5. Amendment Nos. 107/101, Technical Specification Changes for Catawba Nuclear Station for Unit 2, Cycle 6, dated March 23, 1993.

   Note: The McGuire plant has similar references to those for the Catawba plants listed above. They are not listed as they seem to be identical to the Catawba plant changes which usually occurred first.

6. <u>Fluid Meters, Their Theory and Application</u>, Report of ASME Research Committee on Fluid Meters, Fifth Edition, 1959.

7. <u>Fundamentals of Temperature, Pressure, and Flow Measurements</u>, Robert P. Benedict, John Wiley and Sons, Inc.

2.0 Background

As stated in reference 1, the Duke Power Company (DPC), proposed TS changes related to the method of measuring the reactor coolant system (RCS) flow rate (TS 4.2.5.3) during the 18-month surveillance. DPC states that the current method, calorimetric heat balance, has a large uncertainty due to hot leg temperature streaming. It is proposed to replace this method with a method using the elbow taps.

As a background to the RCS flow rate situation the following references pertaining to the Catawba plant are listed:

Reference 2 presented information regarding trade-off between RCS flow and power to allow continued operation when less than the TS flow value would be indicated by the plant. This would allow operation with flow reduced by up to 5% from TDF at reduced power levels (a corresponding maximum limit on power of 90% RTP). The power to flow relationship used is a 2.0% power reduction for each 1.0% RCS flow below TDF.

Reference 3 was related to the RTD bypass system removal and the flow measurement uncertainty was analyzed as 1.8% although the existing value of 2.2% was kept. Both values include a 0.1% penalty for feed water venturi fouling,

Reference 4 was based on re-analyses to support a reduced minimum measured RCS flow rate which was needed because of increased steam generator tube plugging.

Reference 5 concerned the use of B&W Mark-BW fuel.

References 6 and 7 refer to flow meters.

It is understood that the new proposed method for RCS flow measurement differs from previous calculations because the normalization of the cold leg elbow taps is to a previously performed RCS flow calorimetric measurement which requires the inclusion of additional uncertainties in the determination of the indicated RCS flow uncertainty. This new method using a previously normalized elbow tap reading replaces the method where a current RCS flow calorimetric heat balance normalization is used.

3.0 Questions

A. Questions Relating to the Use of Elbow Taps for Flow Measurement:

Much basic research has been performed for flow nozzles and orifices such that nozzle discharge coefficients can be approximated by methods in part on boundary layer theory and in part on the experimental characteristics of ASME flow nozzles (References 6 and 7). For large venturi tubes, such as used on the secondary side feedwater piping for the precision heat balance, the venturi discharge coefficient is determined by calibration in a laboratory as recommended by the ASME (Reference 6).

For pipe elbow tap meters the flow rate is determined from pipe taps on the pipe elbows. The holes from the pipe taps can be connected to two separate gages or connected to a differential gage to determine the pressure drop. However, "the relation between this difference of pressure and the rate of flow has to be determined experimentally" (Reference 6). Normally this calibration is carried out over a range of flows so that the calibration curves cover the range of flows that the flow meter will be used for.

DPC has stated (Ref. 1) that "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."

1. To get a better understanding on the use of past data, information is needed on the history of the elbow tap delta-P readings from the past reloads for the Catawba and McGuire plants. This should include the flow rates obtained from past calorimetric heat balances, the flow measurement uncertainty (FMU) used, and the corresponding elbow tap delta-P values. The dates of each calorimetric heat balance should be provided and any special additional historical information such as what the steam generator tube plugging situation was (percent tubes plugged affect on resistance),

the type of fuel (affect of fuel resistance changes), amount of hot leg streaming, and knowledge of RCS pump flow degradation. It is realized that the elbow tap readings are normalized and assigned a zero reference value, but a delta-P reading must have been initially recorded.

2. It is not clear how DPC plans to use the previous calorimetric data. Is DPC going to use a particular calorimetric from a past cycle? The flow calorimetric for a given cycle provides a single point calibration and therefore for any other flow rate the elbow tap pressure drop value would have to be interpreted by extrapolating the curve by a theoretical relationship of pressure drop to flow rate. If the curve is extrapolated how is this uncertainty accounted for? In this approach, would DPC pick a particular previous a calorimetric heat balance in which the hot leg streaming was not extreme as the reference? If this approach is used, provide information on the reference precision heat balance that DPC plans to use.

   If not using a particular calorimetric from a past cycle, is DPC planning to use the previous data to develop a curve over a small range of elbow tap pressure drop readings versus flow? It would appear that this method would not necessarily provide test data from a consistent RCS "test rig" as there have been changes in the RCS flow loop with time. These changes include; flow changes from resistance changes (steam generator tube plugging (Ref. 4), various fuels with different geometries and resistances (Ref. 5)), effects of various degrees of hot leg streaming, and flow changes from continuous pump wear. Also, since the RCS pump is a constant speed pump, it is not possible to get data over a wide range of flow rates. It would appear that the best data for which the a elbow tap meter calibration could be based on would be from data which closely resembles the current configuration. Please provide more background information and provide the analysis for the flow measurement uncertainty if this approach is being used.

3. If DPC is going to develop a curve using historic data taken over a range of flows, does the range of the data (as requested in the question 1 above) cover the anticipated range over which the plant will operate under? If not, how does DPC interpret the pressure drop value for values for which there is no corresponding flow value from a previous calorimetric heat balance? Is an expanded curve derived from theoretical relationships?

B. <u>Questions from Attachment 1a of Reference 1</u>:

1. DPC states in the TS for Catawba, Figure 3.2-1, "Reactor Coolant System Total Flow Rate Versus Rated Thermal Power - Four Loops in Operation," that "A penalty of 0.1% for undetected feedwater venturi fouling and a measurement uncertainty of 1.9% are included in this figure." Is this flow measurement uncertainty of 1.9% (2.0% with the fouling penalty) what DPC plans to assign to the elbow tap meter reading? Please submit the flow measurement uncertainty (FMU) analysis that supports the FMU value. An FMU is required when there are changes made that effect the method of

measuring RCS flow (Ref. 3).

2. DPC has changed some of the values in the TS for Catawba, Table 2.2-1, "Reactor Trip System Instrumentation Trip Setpoints." For Functional Unit 11, Reactor Coolant Flow-Low, the new value for the "Trip Setpoint" is equal to or greater than 91% of loop minimum measured flow and the new value for the "Allowable Value" is equal to or greater than 89.7% of loop minimum measured flow. Please provide the analysis for arriving at these values.

C. Questions from Attachment II of Reference 1:

1. In the sections entitled "Background" and "Justification and Safety Analysis," DPC states that the elbow taps were originally used for the Technical Specification (TS) flow surveillance at McGuire and other Westinghouse plants, but a change to the calorimetric based flow method was adopted with the intent of benefiting from supposed better accuracy. In regards to this please provide additional information as follows:

   (a) How were the elbow taps originally used to measure flow for TS surveillance without the current method of calibration using the precision heat balance? You have mentioned that the elbow tap coefficient, or K value, is needed for determining the flow rate from the elbow-tap delta-P indications. The K value is usually obtained from a test calibration. How was this K value obtained? The K value usually varies with flow rate. What uncertainty was associated with the K value?

   (b) When this original elbow tap method was used what was the value of the flow measurement uncertainty used to convert the measured value of flow to the actual value of flow?

2. In DPC's section on "Elbow Tap Flow Measurement Repeatability" DPC has several sub-headings for which we have questions as follows:

   (a) In the sub-section on "Venturi Fouling" DPC states that there is no large change in cross section to produce velocity increase to affect the elbow flow measurement. For orifices and nozzles, Reference 6 indicates that as the area ratio increases from small values the percent of maximum differential pressure differential decreases from large values (approaching 100%) to small values (approaching 0%). This indicates that for orifices and nozzles with relatively large area ratios the pressure drop is small and therefore the reading is less accurate (changes in flow do not register a large value to read and therefore cannot be read as accurately).

   For the elbow tap method of measurement the delta-P for the specified flow depends on the parameters of the radius of curvature of the elbow and the diameter of the flow channel through the elbow. It would appear that relatively large pipes area would reduce the sensitivity to small changes in flow. A relatively large pipe radius would also appear to have low sensitivity to small flow changes. A large flow area and large pipe radius could affect the ability to sense the small changes in flow (less than 1%) for which there is a concern. Please comment on the sensitivity of the elbow tap meter measurement for the Catawba plant in regards to its ability to sense small changes in flow rate accurately.

DPC mentions that fouling is not a concern since there is not a large velocity increase as in a venturi when the flow approaches the throat. What is the effect of possible fouling at the elbow tap juncture of the relatively small tubing for the pressure taps from which the pressure is sensed?

(b) In the section on "Upstream Velocity Distribution Effects" DPC discusses the skewed inlet flow from the upstream 40° elbow on the steam generator (SG) outlet nozzle, and the skewed flow to the SG outlet nozzle due to its off-center location relative to the tube sheet. However, DPC stated that these geometric effects remain constant through a fuel cycle, so the elbow meter delta-P would not change.

DPC also stated that the velocity distribution in the SG from plugged tubes would not have a significant effect on the velocity distribution through the elbow tap even if the tube plugging was asymmetrically distributed as there is a SG plenum where the velocity is small (6 fps) compared to the downstream cold leg pipe velocity.

Even though the velocity distribution effects from plugging in the SG may not effect the elbow taps readings, another concern is the effect of resistance changes in the RCS from SG tube plugging over time as stated in Section 2.

(c) In the section on "Flow Measurement Comparisons" DPC discusses the flow measurement comparisons conducted at Prairie Island Unit 2 which has the Leading Edge Flow Meter (LEFM) installed. DPC states that this test confirmed the repeatability of elbow tap meters. However, obtaining an accurate flow reading is not only be due to repeatability but also on a accurate calibration of the elbow tap meter over a range of flow rates.

For the elbow tap meter to be used as a primary flow rate device in the manner DPC is proposing, it has to have an independent calibration over a range of flows and has to evaluated to obtain its flow measurement uncertainty. Has this been accomplished?

A previous TS change (Ref. 2) was issued to provide relief in the event that a condition of reduced RCS flow was found. This was an amendment to allow for a small reduction in power in case the RCS flow went below the TS 100% power value. For some plants, when the RCS system flow rate falls below the TS 100% power value the power has to be reduced to at least 50%. However, for Catawba this has been changed previously to allow for a 2% reduction in power for each 1% reduction in RCS flow rate below the limit to a maximum of 5% RCS flow rate reduction.

Since the hot leg streaming effect results in a overly conservative RCS flow, DPC indicates it will have difficulty in meeting the TS requirements since margin to the TS minimun measured flow rate is small. Does DPC have conservatism in the flow measurement margins for which credit can taken? Is there a way to improve the instrumentation to get a more accurate hot leg temperature? Or can a method that measures the primary side flow rate without the input of hot leg streaming be used? The Comanche Peak plant uses such a method by means of a N-16 transit time flow meter on the primary side. It is important for the RCS flow rate to have high accuracy as RCS flow is a parameter in the calculation for DNBR. The DNBR is based on the accuracy of the RCS flow rate being such that the required 95/95 probability/confidence level is met. Please comment on the above.

Question Related to the RCS Flow Rate Measurement Proposed for Catawba & McQuire

1. The calorimetric heat balance instead of cold leg elbow taps for the RCS flow rate measurement has been used for both Catawba and McQuire since 1982. Based on the extensive use of the calorimetric heat balance, a great uncertainty was experienced. Now, the old method of cold leg elbow taps is proposed mainly to meet the Technical Specification & Surveillance requirements. Please provide the following information:

   a. Describe both methodologies including governing equations.

   b. Explain the applications of both methodologies in terms of the RCS flow measurement and the calibration procedures.

   c. Provide a complete comparison between both methods based on the measuring data obtained from Prairie Island, McQuire, Catawba or other applicable plants.

   d. Identify advantages and disadvantages between both methods in terms of the accuracy and repeatability of the measurements.

Duke Power Responses To NRC Questions Relating To The Use of Elbow Taps For Flow Measurement

Information within brackets is Duke Power Proprietary

PROPRIETARY
DUKE POWER CO.

A. Questions Relating to the Use of Elbow Taps for Flow Measurement:

Much basic research has been performed for flow nozzles and orifices such that nozzle discharge coefficients can be approximated by methods in part on boundary layer theory and in part on the experimental characteristics of ASME flow nozzles (References 6 and 7). For large venturi tubes, such as used on the secondary side feedwater piping for the precision heat balance, the venturi discharge coefficient is determined by calibration in a laboratory as recommended by the ASME (Reference 6).

For pipe elbow tap meters the flow rate is determined from pipe taps on the pipe elbows. The holes from the pipe taps can be connected to two separate gages or connected to a differential gage to determine the pressure drop. However, "the relation between this difference of pressure and the rate of flow has to be determined experimentally" (Reference 6). Normally this calibration is carried out over a range of flows so that the calibration curves cover the range of flows that the flow meter will be used for.

DPC has stated (Ref. 1) that "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."

1. To get a better understanding on the use of past data, information is needed on the history of the elbow tap delta-P readings from the past reloads for the Catawba and McGuire plants. This should include the flow rates obtained from past calorimetric heat balances, the flow measurement uncertainty (FMU) used, and the corresponding elbow tap delta-P values. The dates of each calorimetric heat balance should be provided and any special additional historical information such as what the steam generator tube plugging situation was (percent tubes plugged affect on resistance), the type of fuel (affect of fuel resistance changes), amount of hot leg, streaming, and knowledge of RCS pump flow degradation. It is realized that the elbow tap readings are normalized and assigned a zero reference value, but a delta-P reading must have been initially recorded.

Response to question A1:

The requested information is provided in Attachment 1. Flow rates obtained from past calorimetrics and flow measurement uncertainties used for each are provided in Tables 1-4. These tables give the flow in gallons per minute as determined by the precision flow calorimetric for the periodic RCS flow surveillance performed each cycle. Elbow tap ΔP data as determined for each RCS flow calorimetric, in inches of water column, is provided in Tables 5-8. Steam generator tube plugging information is provided in Tables 9-12. The tube plugging data is in percent of steam generator tubes plugged. In addition other significant changes to RCS flow resistance accounted for in the flow prediction model are given in the far right column of these tables. Hot leg average and cold leg temperature data gathered during the calorimetric is provided in Tables 13 - 16.

2. **It is not clear how DPC plans to use the previous calorimetric data. Is DPC going to use a particular calorimetric from a past cycle? The flow calorimetric for a given cycle provides a single point calibration and therefore for any other flow rate the elbow tap pressure drop value would have to be interpreted by extrapolating the curve by a theoretical relationship of pressure drop to flow rate. If the curve is extrapolated how is this uncertainty accounted for? In this approach, would DPC pick a particular previous calorimetric heat balance in which the hot leg streaming was not extreme as the reference? If this approach is used, provide information on the reference precision heat balance that DPC plans to use.**

   If not using a particular calorimetric from a past cycle, is DPC planning to use the previous data to develop a curve over a small range of elbow tap pressure drop readings versus flow? It would appear that this method would not necessarily provide test data from a consistent RCS "test rig" as there have been changes in the RCS flow loop with time. These changes include; flow changes from resistance changes (steam generator tube plugging (Ref. 4), various fuels with different geometries and resistances (Ref. 5)), effects of various degrees of hot leg streaming, and flow changes from continuous pump wear. Also, since the RCS pump is a constant speed pump, it is not possible to get data over a wide range of flow rates. It would appear that the best data for which the a elbow tap meter calibration could be based on would be from data which closely resembles the current configuration. Please provide more background information and provide the analysis for the flow measurement uncertainty if this approach is being used.

Response to question A2:

A single particular calorimetric from a past cycle is not used to produce the elbow tap coefficients. The valid calorimetric data from previous measurements is used to determine an averaged set of elbow tap coefficients which will reasonably and conservatively represent the actual coefficient values for each elbow. Reactor coolant flows are then calculated from these average elbow tap coefficients and elbow tap ΔPs. This removes the effect of temperature changes on the RCS flow. Some data was not realistic or accurate and was excluded from the method of determining the elbow tap coefficients.

3. **If DPC is going to develop a curve using historic data taken over a range of flows, does the range of the data (as requested in the question 1 above) cover the anticipated range over which the plant will operate under? If not, how does DPC interpret the pressure drop value for values for which there is no corresponding flow value from a previous calorimetric heat balance? Is an expanded curve derived from theoretical relationships?**

Response to question A3:

An RCS flow prediction model has been developed which determines flows based on the reactor coolant pump head curves in the region of anticipated plant operation and calculated system head loss curves. The reactor coolant flow may be calculated by first determining the system head loss curve for a reactor coolant loop with a given configuration. Once the system head loss curve has been established it is compared to the reactor coolant pump performance curve to determine the intersection of the two curves. The intersection of the two head curves will define the system operating point, the point where the loop head loss matches the head produced by the reactor coolant pump. By establishing the system head losses for each loop and accounting for changes in these system losses due to plant changes over time, i.e., steam generator tube plugging, modifications and different fuel designs, a reasonably accurate RCS flow may be calculated for each plant configuration. The system head losses are based on the head losses calculated and used in the FSAR Chapter 15 accident analysis models. This analytical model provides an independent prediction of RCS flow for anticipated changes in the RCS head losses. For anticipated loop changes such as steam generator tube plugging, fuel assembly pressure drop changes and internal modifications the flow prediction model can be used to predict a relative flow change. This flow change is then used as a comparison with the actual flow change in the plant as indicated by the elbow tap ΔPs. The flows calculated by the calorimetric have been in the range of 407,363 gpm to 379,285 gpm. The analytical model has predicted flows which are well within these extremes for the same period. Therefore, it is believed that the analytical model will adequately predict flow over the range of flows expected during normal plant operation. The primary function of the elbow taps in the existing Technical Specifications is to provide a flow indication for the Reactor Protection System such that a reactor trip will occur at 90% loop flow. As such, the elbow tap flow meters were designed to provide an accurate flow indication over the range from 100% to 90 % flow.

B. Questions from Attachment Ia of Reference 1:

1. DPC states in the TS for Catawba, Figure 3.2-1, "Reactor Coolant System Total Flow Rate Versus Rated Thermal Power - Four Loops in Operation," that "A penalty of 0.1% for undetected feedwater venturi fouling and a measurement uncertainty of 1.9% are included in this figure." [illegible] is flow measurement uncertainty of 1.9% (2.0% with the fouling penalty) what DPC plans to assign to the elbow tap meter reading? Please submit the flow measurement uncertainty (FMU) analysis that supports the FMU value. An FMU is required when there are changes made that effect the method of measuring RCS flow (Ref. 3).

Response to question B1:

See Attachment 2, "RCS Flow Uncertainty," for the RCS flow measurement uncertainty analysis.

2. **DPC has changed some of the values in the TS for Catawba, Table 2.2-1, "Reactor Trip System Instrumentation Trip Setpoints." For Functional Unit 11, Reactor Coolant Flow-Low, the new value for the "Trip Setpoint" is equal to or greater than 91% of loop minimum measured flow and the new value for the "Allowable Value" is equal to or greater than 89.7% of loop minimum measured flow. Please provide the analysis for arriving at these values.**

Response to question B2:

> See Attachment 2, "RCS Flow Uncertainty," for the RCS flow measurement uncertainty analysis.

C. **Questions from Attachment II of Reference 1:**

1. **In the sections entitled "Background" and "Justification and Safety Analysis," DPC states that the elbow taps were originally used for the Technical Specification (TS) flow surveillance at McGuire and other Westinghouse plants, but a change to the calorimetric based flow method was adopted with the intent of benefiting from supposed better accuracy. In regards to this please provide additional information as follows:**

   (a) **How were the elbow taps originally used to measure flow for TS surveillance without the current method of calibration using the precision heat balance? You have mentioned that the elbow tap coefficient, or K value, is needed for determining the flow rate from the elbow tap delta-P indications. The K value is usually obtained from a test calibration. How was this K value obtained? The K value usually varies with flow rate. What uncertainty was associated with the K value?**

   Response to question C1a:

   At McGuire Units 1&2 the original intended method of flow surveillance was the elbow tap ΔPs indications after normalization to a heat balance. The elbow taps would initially be calibrated using a heat balance calculation to determine the initial flow and elbow tap K values. The elbow tap K values calculated as a result of this heat balance are used to normalize the plant computer readout of flow in the control room. The elbow tap flow indications from the plant computer would then be utilized to perform the periodic flow surveillances. The elbow tap K values are coefficients which account for manufacturing tolerances and physical pipe dimensions and as such do not change with flow. The uncertainty in the K values were not explictly determined but, were assumed to be a component of the elbow tap flow indication uncertainty of 3.5% flow.

(b) When this original elbow tap method was used what was the value of the flow measurement uncertainty used to convert the measured value of flow to the actual value of flow?

Response to question C1b:

The original RCS flow measurement uncertainty value was 3.5% flow. During preoperational testing, the flow measurement uncertainty when using the elbow tap ΔPs for flow surveillances was based on a somewhat arbitrary calculation performed by Westinghouse in 1978. It was estimated at the time, that the heat balance uncertainty would be less than 2.0% flow and that the repeatability of the cold leg elbow taps would be less than 1.5% flow. These two values were arithmetically summed to arrive at a value of 3.5% flow. It was believed at that time this would be conservative and yet provide a minimum measured flow Technical Specification that the plant would have little trouble satisfying. However, the RCS flows measured, during startup testing using a precision heat balance calculation, were found to be below the Technical Specification minimum measured flow limit. This prompted an effort to minimize the RCS flow measurement uncertainty in order to gain flow margin such that the plant would not be limited in power during commercial operation. A Technical Specification change was then submitted (Nov. 82) which specified the method of RCS flow surveillance to be a precision heat balance. This allowed increased flow margin due to the decreased uncertainty (1.7% flow + 0.1% flow for undetected feedwater venturi fouling) associated with this method of flow surveillance.

2. **In DPC's section on "Elbow Tap Flow Measurement Repeatability" DPC has several sub-headings for which we have questions as follows:**

   (a) In the sub-section on "Venturi Fouling" DPC states that there is no large change in cross section to produce velocity increase to affect the elbow flow measurement. For orifices and nozzles, Reference 6 indicates that as the area ratio increases from small values the percent of maximum differential pressure differential decreases from large values (approaching 100%) to small values (approaching 0%). This indicates that for orifices and nozzles with relatively large area ratios the pressure drop is small and therefore the reading is less accurate (changes in flow do not register a large value to read and therefore cannot be read as accurately).

   For the elbow tap method of measurement the delta-P for the specified flow depends on the parameters of the radius of curvature of the elbow and the diameter of the flow channel through the elbow. It would appear that relatively large pipes area would reduce the sensitivity to small changes in flow. A relatively large pipe radius would also appear to have low sensitivity to small flow changes. A large flow area and large pipe radius could affect the ability to

sense the small changes in flow (less than 1%) for which there is a concern. Please comment on the sensitivity of the elbow tap meter measurement for the Catawba plant in regards to its ability to sense small changes in flow rate accurately.

DPC mentions that fouling is not a concern since there is not a large velocity increase as in a venturi when the flow approaches the throat. What is the effect of possible fouling at the elbow tap juncture of the relatively small tubing for the pressure taps from which the pressure is sensed?

Response to question C2a:

Elbow meters of any dimensions are generally not a good choice for low flow situations. However, the flow in the reactor coolant loops is large and generates sufficient ΔP to sense small changes in flow. The elbow tap ΔPs have already shown themselves to be sensitive to small changes in flow. The elbow tap ΔP flow indication is currently being used to provide the reactor trip on low RCS loop flow.

The elbow taps will not be subject to fouling in the manner usually seen with venturis. No flow is being passed through the elbow taps to cause fouling as is seen in feedwater venturis. The taps merely provide a static means of transmitting the pressure indication from the reactor coolant to the ΔP transmitter. Therefore, as long as the tap opening is not obstructed completely, the elbow tap should not be effected by fouling. An obstructed elbow tap will be detectable by an abnormal ΔP reading.

(b) **In the section on "Upstream Velocity Distribution Effects" DPC discusses the skewed inlet flow from the upstream 40° elbow on the steam generator (SG) outlet nozzle, and the skewed flow to the SG outlet nozzle due to its off-center location relative to the tube sheet. However, DPC stated that these geometric effects remain constant through a fuel cycle, so the elbow meter delta-P would not change.**

DPC also stated that the velocity distribution in the SG from plugged tubes would not have a significant effect on the velocity distribution through the elbow tap even if the tube plugging was asymmetrically distributed as there is a SG plenum where the velocity is small (6 fps) compared to the downstream cold leg pipe velocity.

Even though the velocity distribution effects from plugging in the SG may not effect the elbow taps readings, another concern is the effect of resistance changes in the RCS from SG tube plugging over time as stated in Section 2.

Response to question C2b:

The effect of SG tube plugging will cause the elbow tap ΔP readings to change. The SG tube plugging results in decreased flow and the elbow tap ΔPs decrease along with the flow decrease. Any change in real flow will be indicated by the elbow tap ΔP.

(c) **In the section on "Flow Measurement Comparisons" DPC discusses the flow measurement comparisons conducted at Prairie Island Unit 2 which has the Leading Edge Flow Meter (LEFM) installed. DPC states that this test confirmed the repeatability of elbow tap meters. However, obtaining an accurate flow reading is not only due to repeatability but also on a accurate calibration of the elbow tap meter over a range of flow rates.**

For the elbow tap meter to be used as a primary flow rate device in the manner DPC is proposing, it has to have an independent calibration over a range of flows and has to evaluated to obtain its flow measurement uncertainty. Has this been accomplished?

A previous TS change (Ref. 2) was issued to provide relief in the event that a condition of reduced RCS flow was found. This was an amendment to allow for a small reduction in power in case the RCS flow went below the TS 100% power value. For some plants, when the RCS system flow rate falls below the TS 100% power value the power has to be reduced to at least 50%. However, for Catawba this has been changed previously to allow for a 2% reduction in power for each 1% reduction in RCS flow rate below the limit to a maximum of 5% RCS flow rate reduction.

Since the hot leg streaming effect results in a overly conservative RCS flow, DPC indicates it will have difficulty in meeting the TS requirements since margin to the TS minimum measured flow rate is small. Does DPC have conservatism in the flow measurement margins for which credit can taken? Is there a way to improve the instrumentation to get a more accurate hot leg temperature? Or can a method that measures the primary side flow rate without the input of hot leg streaming be used? The Comanche Peak plant uses such a method by means of a N-16 transit time flow meter on the primary side. It is important for the RCS flow rate to have high accuracy as RCS flow is a parameter in the calculation for DNBR. The DNBR is based on the accuracy of the RCS flow rate being such that the required 95/95 probability/confidence level is met. Please comment on the above

Response to question C2c:

Yes, the elbow meter has been independently calibrated by establishing a set of elbow tap flow coefficients from historical data. In addition, an evaluation was conducted to determine the flow measurement uncertainty. See the answer to question A2 above.

Our experience with hot leg streaming has largely resulted in a conservative calculation of flow. However, hot leg streaming effects could result in a non-conservative calculation of flow. This makes the heat balance flow determination method undesirable when actual flow approaches the Technical Specification RCS minimum measured flow limit.

RCS flow margin was gained by reanalysis, but the margin gain has since been exceeded on some of the MNS & CNS units due to hot leg streaming penalties Even with a reduction in the Tech. Spec.flow limit from 385,000 gpm to 382,000 gpm during the last refueling, the Catawba Unit 1 flow measurement, using a heat balance, resulted in a flow less than the new minimum measured flow limit.

Few other methods of measuring hot leg temperature accurately are available without major plant modifications and the results may not be any better than the current method. Other methods for measuring flow have been evaluated as possible solutions to the problem of RCS flow measurement. However, these solutions usually require extensive plant modifications and investments in equipment.

An accurate measurement of flow is certainly important with regards to DNBR. This Technical Specification change is intended to provide a more reliable and predictable measurement of flow which will ensure an adequate margin of safety.

D. Question Related to the RCS Flow Rate Measurement Proposed for Catawba & McGuire:

1. **The calorimetric heat balance instead of cold leg elbow taps for the RCS flow rate measurement has been used for both Catawba and McGuire since 1982. Based on the extensive use of the calorimetric heat balance, a great uncertainty was experienced. Now, the old method of cold leg elbow taps is proposed mainly to meet the Technical Specification & Surveillance requirements. Please provide the following information:**

   (a) **Describe both methodologies including governing equations.**

   (b) **Explain the applications of both methodologies in terms of the RCS flow measurement and the calibration procedures.**

   (c) **Provide a complete comparison between both methods based on the measuring data obtained from Prairie Island, McGuire, Catawba or other applicable plants.**

   (d) **Identify advantages and disadvantages between both methods in terms of the accuracy and repeatability of the measurements.**

Response to question D1a:

The calorimetric method determines flow by performing a secondary side heat balance calculation to establish the thermal power level and measuring the temperature rise across the reactor vessel as indicated by the RTDs in the hot and cold legs. The primary coolant flow rate is determined by dividing the thermal power by the enthalpy rise across the vessel. The governing equation for flow using this method is:

$$\dot{m} = \frac{Q}{\Delta h}$$

where $\dot{m}$ is the RCS flow, Q is the secondary side power and Δh is the enthalpy rise across the reactor vessel.

The proposed method will use the elbow tap ΔPs and the cold leg density to calculate flow. Since flow is proportional to the square root of the ΔP as measured by the elbow taps, the following governing equation is used to calculate RCS flow:

$$\dot{m} = K\sqrt{\Delta P \rho}$$

where $\dot{m}$ is the RCS flow, ΔP is the elbow tap ΔP, ρ is the cold leg density and K is the elbow tap coefficent.

Response to question D1b:

The heat balance is used for flow surveillance and to calculate new elbow tap coefficients which are used to normalize the elbow tap based flow to the calorimetric flow each cycle. The elbow tap flow indication is used for the low flow reactor trip and for frequent surveillance.

The elbow tap ΔP method of measuring flow will be used to perform the flow surveillance after the elbow taps have been calibrated using the coefficients developed from plant data. The elbow tap flow indication will continue to be used for the low flow reactor trip and for frequent surveillance.

Response to question D1c:

The comparison between the calorimetric and the proposed method of flow measurement is shown in Figures 1 - 4 of Attachment 3. Data from Prairie Island and other plants was not used to develop this method.

Response to question D1d:

Advantages and disadvantages of the calorimetric method of flow measurement include:

1. Subject to the effects of hot leg streaming and other potential temperature measurement effects.
2. Not repeatable.
3. Accurate absolute measurement method if temperatures are accurate.
4. Can be non-conservative and unsafe.
5. Flow is calculated, not measured.
6. Affected by the core power distribution.

Advantages and disadvantages of the proposed method of flow measurement include:

1. Accurate and repeatable once calibrated.
2. Not affected by hot leg streaming phenomena.
3. Not affected by the core power distribution
4. Elbow tap ΔPs are a direct measurement of flow.

ATTACHMENT 1

Historical Plant Data

McGuire and Catawba RCS Flow Rates Obtained From Calorimetrics

Table 1

Date	MNS-1 Calorimetric Flow,gpm	Flow Uncertainty % Flow
Jun-83	Preoperation	3.5
Jul-83	401010	1.8
Feb-85	402722	1.8
Sep-85	399816	1.8
Oct-86	398524	1.8
Dec-87	397080	1.8
May-89	395699	1.8
Aug-90	393567	1.8
Sep-91	396539	1.8
Dec-91	396537	1.8
Jul-93	393330	1.8

Table 2

Date	MNS-2 Calorimetric Flow,gpm	Flow Uncertainty % Flow
Mar-84	397837	1.8
Jun-85	407363	1.8
Sep-86	392317	1.8
Aug-87	392313	1.8
Aug-88	391523	1.8
Oct-89	392757	1.8
Jan-91	385453	1.8
Dec-91	389044	1.8
May-92	387054	1.8
Oct-93	386027	1.8

Table 3

Date	CNS-1 Calorimetric Flow, gpm	Flow Uncertainty % Flow
Mar-85	398663	2.2
Aug-85	399194	2.2
Feb-86	400937	2.2
Dec-86	397770	2.2
Dec-86	398057	2.2
Jan-88	396519	2.2
Oct-89	396334	2.2
May-90	392313	2.2
Jun-91	392702	2.2
Oct-92	388007	2.2
Jan-94	379285	2.2

Table 4

Date	CNS-2 Calorimetric Flow, gpm	Flow Uncertainty % Flow
Jul-86	406947	2.2
Aug-86	402475	2.2
Sep-86	400477	2.2
Nov-86	399917	2.2
Mar-88	396202	2.2
Jun-89	392927	2.2
Oct-90	388268	2.2
Nov-90	390583	2.2
Jan-91	390826	2.2
Dec-91	391127	2.2
Jan-92	389611	2.2
Apr-93	390040	2.2

Table 5, McGuire Unit 1 Elbow Tap Delta P Data, INWC

Date	Jul-83	Feb-85	Sep-85	Oct-86	Dec-87	May-89	Aug-90	Sep-91	Dec-91	Jul-93
Loop A, Tap I	*287.1*	*283.7*	*286.2*	*281.4*	292.5	289.8	288.1	287.8	292.9	289.3
Loop A, Tap II	*299.6*	*290.2*	*297.4*	*295.8*	304.2	305.0	310.0	308.0	309.7	306.9
Loop A, Tap III	*294.6*	*297.0*	*295.2*	*291.9*	300.9	300.9	299.4	298.3	300.7	297.3
Loop B, Tap I	*385.3*	*383.9*	*361.9*	*367.0*	382.6	378.4	374.6	374.1	375.9	372.4
Loop B, Tap II	*378.2*	*376.3*	*366.4*	*372.3*	382.0	378.1	376.4	374.8	377.0	374.7
Loop B, Tap III	*371.3*	*370.3*	*370.9*	*366.8*	372.5	371.0	368.2	367.5	369.8	365.0
Loop C, Tap I	*363.2*	*362.4*	*363.0*	*360.3*	363.9	364.1	356.6	356.1	358.0	355.0
Loop C, Tap II	*296.0*	*293.7*	*292.8*	*290.7*	303.3	302.4	297.7	296.8	301.6	298.0
Loop C, Tap III	*293.1*	*306.3*	*306.3*	*310.6*	332.3	330.3	326.7	326.6	327.9	327.1
Loop D, Tap I	*309.7*	*309.3*	*307.7*	*309.8*	314.7	313.4	312.4	311.9	313.5	310.5
Loop D, Tap II	*350.9*	*335.8*	*334.2*	*330.6*	343.8	338.9	342.3	339.0	342.4	339.9
Loop D, Tap III	*323.6*	*322.0*	*321.3*	*317.0*	327.9	326.2	324.1	321.9	325.6	317.1

Note: Calorimetrics for Jul-83 through Oct-86 shown in italics not included in calculation of averaged elbow tap coefficients. All transmitters replaced causing step change in delta-Ps.

Table 6, McGuire Unit 2 Elbow Tap Delta P Data, INWC

Date	Mar-84	Jun-85	Sep-86	Aug-87	Aug-88	Oct-89	Jan-91	Dec-91	May-92	Oct-93
Loop A, Tap I	324.0	*328.0*	323.1	322.2	322.0	318.6	316.1	316.3	318.4	318.2
Loop A, Tap II	350.5	*349.4*	346.6	344.9	343.2	340.4	336.8	337.5	338.6	339.5
Loop A, Tap III	335.6	*335.2*	332.1	331.0	330.7	325.2	324.3	324.1	326.7	325.8
Loop B, Tap I	324.5	*324.6*	320.1	317.4	319.1	316.9	313.1	312.7	315.1	313.3
Loop B, Tap II	338.0	*338.2*	336.4	333.8	333.9	332.4	331.0	331.2	331.8	331.7
Loop B, Tap III	337.4	*339.2*	338.8	336.5	336.1	334.3	328.8	329.7	329.0	327.4
Loop C, Tap I	337.7	*329.4*	332.6	324.5	323.5	321.9	329.8	329.0	330.7	331.7
Loop C, Tap II	328.0	*327.0*	324.4	321.8	322.7	333.2	320.2	319.8	322.0	320.0
Loop C, Tap III	333.0	*331.2*	329.2	330.0	328.4	325.5	322.6	326.5	321.0	325.6
Loop D, Tap I	314.6	*316.7*	312.8	309.9	311.9	309.3	314.7	316.4	313.9	311.6
Loop D, Tap II	323.9	*324.1*	319.2	319.1	321.2	317.5	316.5	316.5	317.9	316.6
Loop D, Tap III	322.4	*328.1*	319.8	316.6	321.4	320.9	309.1	309.0	318.6	313.6

Note: Calorimetric for Jun-85 shown in italics not included in calculation of averaged elbow tap coefficients. This calorimetric performed at less than 100% power.

Table 7, Catawba Unit 1 Elbow Tap Delta P Data, INWC

Date	Mar-85	Aug-85	Feb-86	Dec-86	Jan-88	Oct-89	May-90	Jun-91	Oct-92	Jan-94
Loop A, Tap I	*332.2*	333.4	333.3	344.3	336.3	330	329.3	329.3	328.2	326.4
Loop A, Tap II	*346.2*	347.2	347.7	347.8	347	339.1	337.4	337.4	336.8	336.2
Loop A, Tap III	*343.1*	343.8	346.1	339.6	342.6	336.8	331.9	331.9	335	329.3
Loop B, Tap I	*307.6*	303.0	324.2	309.3	309	305.1	307	307	307.8	307.8
Loop B, Tap II	*304.7*	309.1	308.6	303	303.4	297.7	289.7	289.7	298.6	299.7
Loop B, Tap III	*307.8*	315.0	312.6	308.9	308.1	305.5	302.6	302.6	305.6	306
Loop C, Tap I	*353.8*	356.3	355.8	355.8	354.9	349.2	347.5	347.5	346.6	338.1
Loop C, Tap II	*346.7*	389.5	398.2	371.6	352	347.1	346.6	346.6	340.4	335.2
Loop C, Tap III	*351.7*	354.2	356.5	349.3	350.9	342.3	340.4	340.4	341.4	331.9
Loop D, Tap I	*317.1*	318.5	326.4	313	312.7	306	305.2	305.2	308.2	299.8
Loop D, Tap II	*321.6*	324.5	329.3	322.1	321.6	317.6	314.6	314.6	318.8	311.7
Loop D, Tap III	*300.7*	303.6	304.2	299.1	300.6	294.2	292.4	292.4	295.2	289.9

Note: Calorimetric for Mar-85 shown in Italics not included in calculation of averaged elbow tap coefficients. This calorimetric performed at less than 100% power.

Table 8, Catawba Unit 2 Elbow Tap Delta P Data, INWC

Date	Jul-86	Aug-86	Sep-86	Nov-86	Mar-88	Jun-89	Oct-90	Nov-90	Jan-91	Dec-91	Jan-92	Apr-93
Loop A, Tap I	*308.0*	305.8	305.6	306.1	303.1	302.9	302.9	302.6	302.7	300.8	301.3	300.8
Loop A, Tap II	*330.3*	327.6	327.3	325.6	329.6	329.2	329.3	329.1	329.4	328.4	328.2	326.6
Loop A, Tap III	*312.9*	310.7	310.6	310.9	311.3	311	310.4	310	310.2	308.6	308.5	309.3
Loop B, Tap I	*322.2*	319.5	319.4	319.2	318.2	317.2	317.4	316.9	317.1	315.9	315.4	314.7
Loop B, Tap II	*361.5*	358.4	358.3	357.7	358.8	356.5	356.5	356.2	356.3	354.2	354	352.7
Loop B, Tap III	*315.1*	312.0	311.9	311.5	310.2	314.3	314.3	314	314.3	313	312.7	308.7
Loop C, Tap I	*302.3*	299.7	299.7	299.2	301.4	299.2	300.7	300.5	300.9	300.2	300.1	301.8
Loop C, Tap II	*343.0*	340.1	340.1	340.4	348.8	343.1	343	342.8	344.4	343.1	342.8	342
Loop C, Tap III	*329.4*	326.5	326.5	326.9	325.9	324.1	324.5	324.3	325	323.3	323.1	324.8
Loop D, Tap I	*334.5*	331.5	331.5	331.9	333.6	331.2	331	330.9	331.4	329.5	329.4	327.4
Loop D, Tap II	*335.2*	332.3	332.2	332.5	332.8	330.9	330.8	330.6	331.2	330.2	330.1	329
Loop D, Tap III	*330.8*	327.8	327.2	327.5	329	327.1	326.7	326.6	327.1	325.52	325.3	324

Note: Calorimetric for Jul-86 sho italics not included in calculation of averaged elbow tap coefficients. lorimetric performed at less than 100% power.

Table 9

McGuire Unit 1 SG Tube Plugging Percentages

OUTAGE	TYPE	EOC	EQUIV CUM PLUG A%	EQUIV CUM PLUG B%	EQUIV CUM PLUG C%	EQUIV CUM PLUG D%	EQUIV CUM PLUG %TUBES	Comments
Aug-81	S/U		0.428	0.449	0.428	0.428	0.433	
Mar-82	S/U		0.471	0.449	0.428	0.428	0.444	
Jul-82	S/U		0.492	0.449	0.428	0.428	0.449	
Nov-82	S/U		0.599	0.449	0.449	0.428	0.481	
Feb-83	RFO	1	0.642	0.449	0.449	0.428	0.492	
May-85	RFO	2	0.642	0.492	0.471	0.449	0.513	
May-86	RFO	3	2.696	2.546	2.567	3.231	2.760	
Sep-87	RFO	4	3.252	3.659	2.931	4.044	3.471	Elbow tap Xmtrs Replaced
Oct-88	RFO	5	3.851	4.236	3.594	4.878	4.140	RTD Bypass Removed
Mar-89	LKR		4.172	4.750	3.937	5.285	4.536	
Jan-90	CLSP	6	4.516	6.005	5.991	6.062	5.643	
Sep-91	RFO	7	5.281	6.585	6.384	6.610	6.215	B&W Fuel, Upflow Mod
Jan-92	LKR		6.133	7.651	7.560	7.270	7.153	
May-92	MCO		7.841	8.079	8.330	8.253	8.126	
Apr-93	RFO	8	8.587	9.382	9.269	9.833	9.268	B&W Fuel
Aug-93	LKR		9.534	9.874	9.739	10.668	9.954	

Table 10

McGuire Unit 2 SG Tube Plugging Percentages

OUTAGE	TYPE	EOC	EQUIV CUM PLUG A%	EQUIV CUM PLUG B%	EQUIV CUM PLUG C%	EQUIV CUM PLUG D%	EQUIV CUM PLUG %TUBES	
May-83	S/U		0.021	0.000	0.000	0.000	0.005	
Jan-85	S/U		0.021	0.000	0.000	0.000	0.005	
Dec-85	RFO	1	0.021	0.000	0.000	1.070	0.273	
Mar-86	RFO	2	2.460	2.439	2.482	2.503	2.471	
May-87	RFO	3	3.209	3.338	3.124	3.231	3.225	
Jun-88	RFO	4	4.086	4.086	4.236	3.487	3.974	RTD Bypass Removed
Jul-89	RFO	5	5.327	4.792	4.942	4.536	4.899	
Aug-90	RFO	6	5.512	5.079	5.229	4.710	5.132	Upflow mod
Jan-92	RFO	7	5.874	6.023	5.616	5.450	5.741	B&W Fuel
May-92	MCO		6.128	6.279	5.872	5.705	5.996	
Jul-93	RFO	8	7.305	7.306	6.621	6.754	6.996	B&W Fuel
Oct-93	LKR		7.663	8.141	6.941	7.075	7.455	

Table 11

Catawba Unit 1 SG Tube Plugging Percentages

OUTAGE	TYPE	EOC	EQUIV CUM PLUG A%	EQUIV CUM PLUG B%	EQUIV CUM PLUG C%	EQUIV CUM PLUG D%	EQUIV CUM PLUG %TUBES	Comments
Jun-85	S/U	0	0.064	0.150	0.043	0.064	0.080	
Jan-86	RFO	1	0.064	0.150	0.043	0.064	0.080	
Nov-87	RFO	2	0.064	0.150	0.043	0.064	0.080	
Aug-88	LKR		0.064	0.150	0.043	0.107	0.091	
Dec-88	RFO	3	0.492	0.385	0.300	0.513	0.423	
Feb-90	RFO	4	2.204	0.471	1.284	1.626	1.396	
Apr-91	RFO	5	2.598	0.941	4.151	2.884	2.643	B&W Fuel
Aug-92	RFO	6	4.438	1.562	6.025	4.104	4.032	B&W Fuel
Nov-93	RFO	7	6.95	3.47	11.17	10.06	7.91	B&W Fuel

Table 12

Catawba Unit 2 SG Tube Plugging Percentages

OUTAGE	TYPE	EOC	EQUIV CUM PLUG A%	EQUIV CUM PLUG B%	EQUIV CUM PLUG C%	EQUIV CUM PLUG D%	EQUIV CUM PLUG %TUBES	Comments
Aug-86	S/U		0.175	0.175	0.175	0.175	0.175	
Aug-86	S/U		0.197	0.328	0.197	0.284	0.252	
Feb-88	RFO	1	0.284	0.350	0.197	0.328	0.290	
Feb-89	RFO	2	0.328	0.460	0.219	0.328	0.334	
Jun-90	RFO	3	0.525	0.481	0.263	0.481	0.438	
Oct-91	RFO	4	0.678	0.481	0.350	0.503	0.503	
Feb-93	RFO	5	0.985	0.613	0.635	0.722	0.739	B&W Fuel

Table 13
MNS-1 Hot and Cold Leg Temperatures

	Jul-83	Feb-85	Sep-85	Oct-86	Dec-87	May-89	Aug-90	Sep-91	Dec-91	Jul-93
Hot Leg A Temp	615.5	615.5	616.4	615.7	614.9	617.1	616.8	616.7	615.2	615.6
Cold Leg A Temp	557.8	559.2	558.5	557.4	559.2	558.8	558.3	558.1	557.6	557.1
Hot Leg B Temp	616.4	616.1	616.1	615.9	614.8	616.1	616.6	616.4	615.7	615.6
Cold Leg B Temp	559.5	559.9	559.3	558.1	559.7	559.9	559.6	559.7	558.7	558.2
Hot Leg C Temp	616.2	615.8	616.6	615.7	616.7	616.8	616.8	615.6	616.4	615.8
Cold Leg C Temp	558.8	559.7	559.8	558.5	560.1	559.4	559.1	558.6	558.7	557.9
Hot Leg D Temp	616.1	615.8	616.2	616.3	614.7	616.5	616.7	616.4	616	615.5
Cold Leg D Temp	559	559.3	560.1	558.7	560	559.3	559.3	559.1	558.3	558.1

Table 14
MNS-2 Hot and Cold Leg Temperatures

	Mar-84	Jun-85	Sep-86	Aug-87	Aug-88	Oct-89	Jan-91	Dec-91	Oct-93
Hot Leg A Temp	616.4	615.8	617	616.8	615.4	616.5	618.2	617.7	617.2
Cold Leg A Temp	559.3	559.2	559.3	559	559.2	559.6	559.2	560	558.7
Hot Leg B Temp	615.6	613.7	615.1	615.4	614.6	615.3	616.2	617	616.8
Cold Leg B Temp	558.4	558.4	558.4	558.8	558.5	559.1	558.3	559.1	558.5
Hot Leg C Temp	617.5	615.6	617.8	618	617.1	617.1	618	618.1	618.7
Cold Leg C Temp	558.3	558.4	558.2	559.[illegible]	558.3	559.2	558.4	559.1	558.4
Hot Leg D Temp	615.6	615.4	615.9	615.7	614.2	616.3	616.5	615.8	616.1
Cold Leg D Temp	558.3	558.5	558.6	559	558.2	558.9	558.4	558.5	558.5

Table 15
CNS-1 Hot and Cold Leg Temperatures

	Mar-85	Feb-86	Dec-86	Jan-88	Oct-89	May-90	Jun-91	Oct-92	Jan-94
Hot Leg A Temp	598.8	618.3	618.8	618	619.3	619.3	619.3	618.2	619.3
Cold Leg A Temp	560	561	561.7	561.7	561.6	561.3	561.3	560.3	559.2
Hot Leg B Temp	597	616.5	615.9	615.6	616.7	615	617.1	615.3	616.4
Cold Leg B Temp	556.7	559.8	559.6	560.2	560.4	560	560.2	557.6	557.6
Hot Leg C Temp	599	618	618.3	618.9	618.5	619.1	619.6	618.8	620.7
Cold Leg C Temp	559.7	560.8	561.1	562	561	561.8	562	560.2	559.6
Hot Leg D Temp	599.8	616.1	617.1	617.1	617	614.6	618.3	615.9	618.1
Cold Leg D Temp	559.4	560.3	560.6	561.2	561	560.3	560.7	559.2	559.4

Table 16
CNS-2 Hot and Cold Leg Temperatures

	Jul-86	Aug-86	Sep-86	Nov-86	Mar-88	Jun-89	Oct-90	Nov-90	Jan-91	Dec-91	Jan-92	Apr-93
Hot Leg A Temp	599.5	616.9	616.9	616.4	615.6	616.7	615.5	615.3	616.5	617	617.5	615.7
Cold Leg A Temp	557.2	561.6	561.3	561.4	560.7	559.5	559	559	559.5	559.1	559.6	558.8
Hot Leg B Temp	600.86	618.7	618.9	618.5	617.4	619.3	618.4	618.3	619.6	620	620.4	618.3
Cold Leg B Temp	558.1	562.9	562.7	562.3	561.2	561.1	560.2	560.3	560.7	560.8	561.2	559.7
Hot Leg C Temp	600.2	617.8	617.9	617.3	615.1	618.6	616.2	615.7	616.2	617.1	617.8	617.1
Cold Leg C Temp	557	561.8	561.6	561.2	561.5	560.8	559.8	559.9	559.9	560.1	560.5	[illegible]
Hot Leg D Temp	600.9	618.8	618.9	618.4	616.8	619.1	618.8	618.3	618.7	618.2	618.8	618.8
Cold Leg D Temp	558.2	563	562.7	562.8	562.8	561.8	560.9	561	560.9	560.8	561.2	560.7

ATTACHMENT 3

Flow Method Comparison

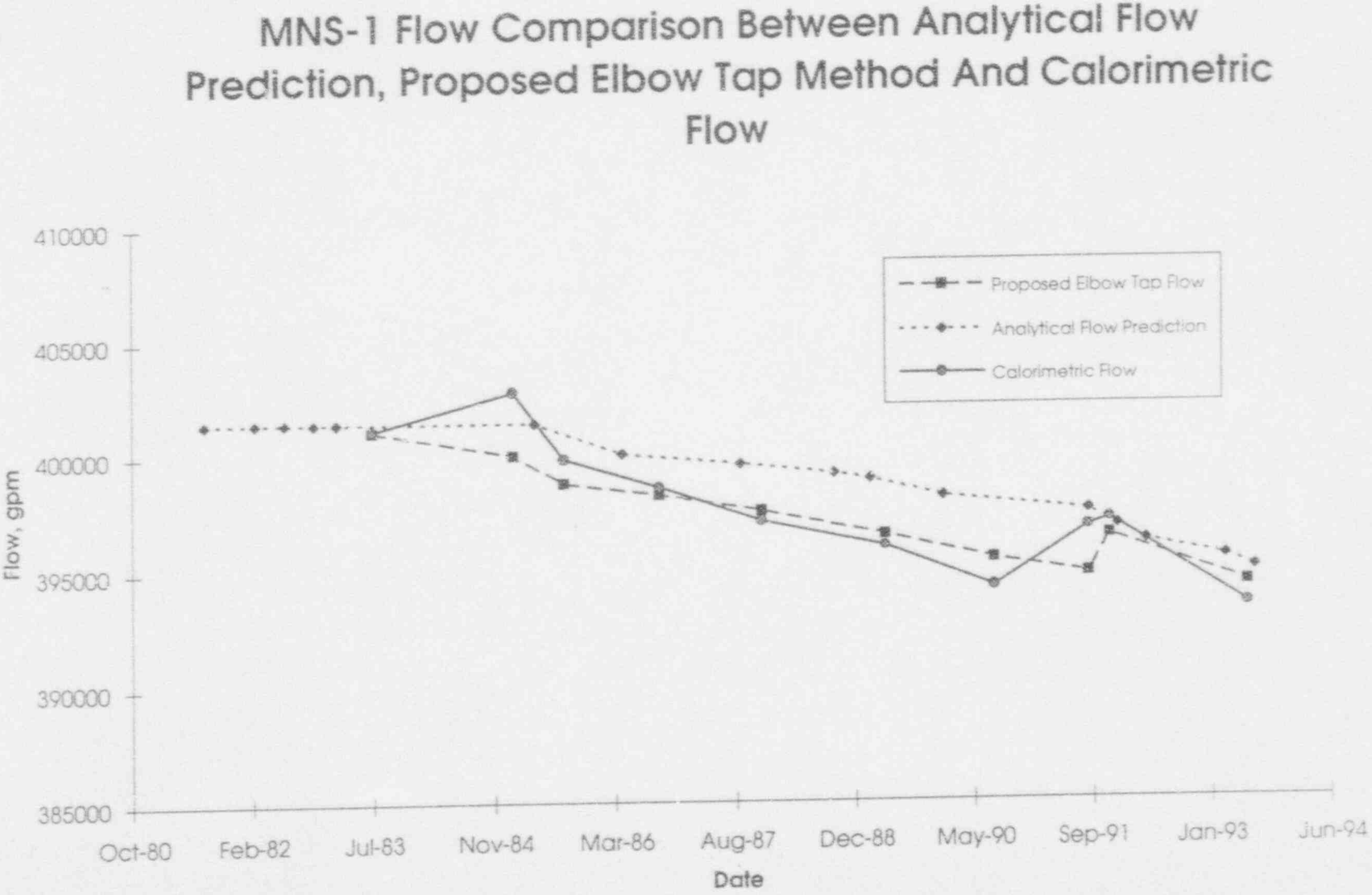

MNS-1 Flow Comparison Between Analytical Flow Prediction, Proposed Elbow Tap Method And Calorimetric Flow
410000
405000
400000
395000
390000
385000
Flow, gpm
Oct-80
Feb-82
Jul-83
Nov-84
Mar-86
Aug-87
Dec-88
May-90
Sep-91
Jan-93
Jun-94
Date
Proposed Elbow Tap Flow
Analytical Flow Prediction
Calorimetric Flow

Figure 1

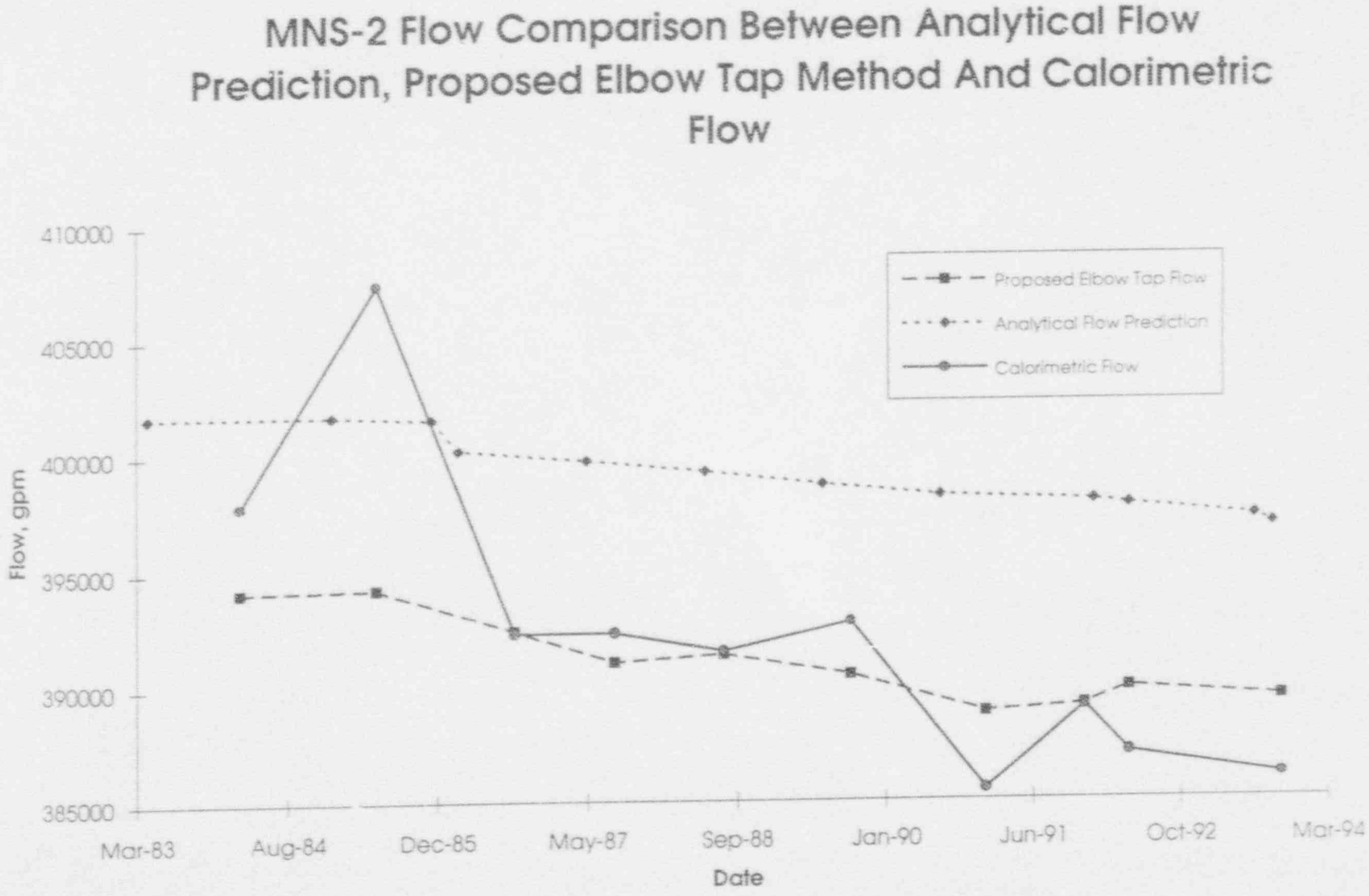
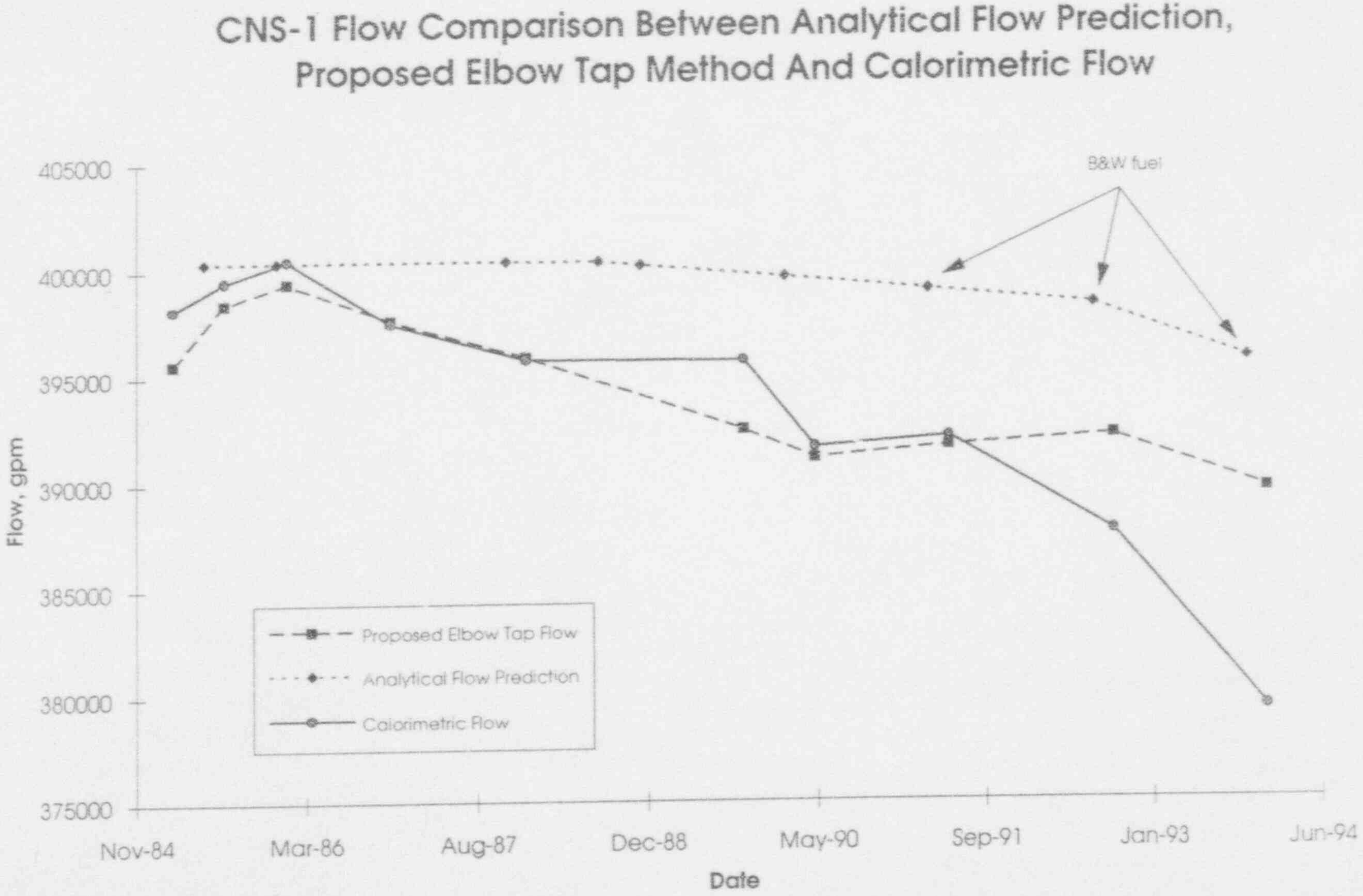

MNS-2 Flow Comparison Between Analytical Flow Prediction, Proposed Elbow Tap Method And Calorimetric Flow
Proposed Elbow Tap Flow
Analytical Flow Prediction
Calorimetric Flow
Flow, gpm
410000
405000
400000
395000
390000
385000
Mar-83
Aug-84
Dec-85
May-87
Sep-88
Jan-90
Jun-91
Oct-92
Mar-94
Date

Figure 2



CNS-1 Flow Comparison Between Analytical Flow Prediction, Proposed Elbow Tap Method And Calorimetric Flow

Figure 3

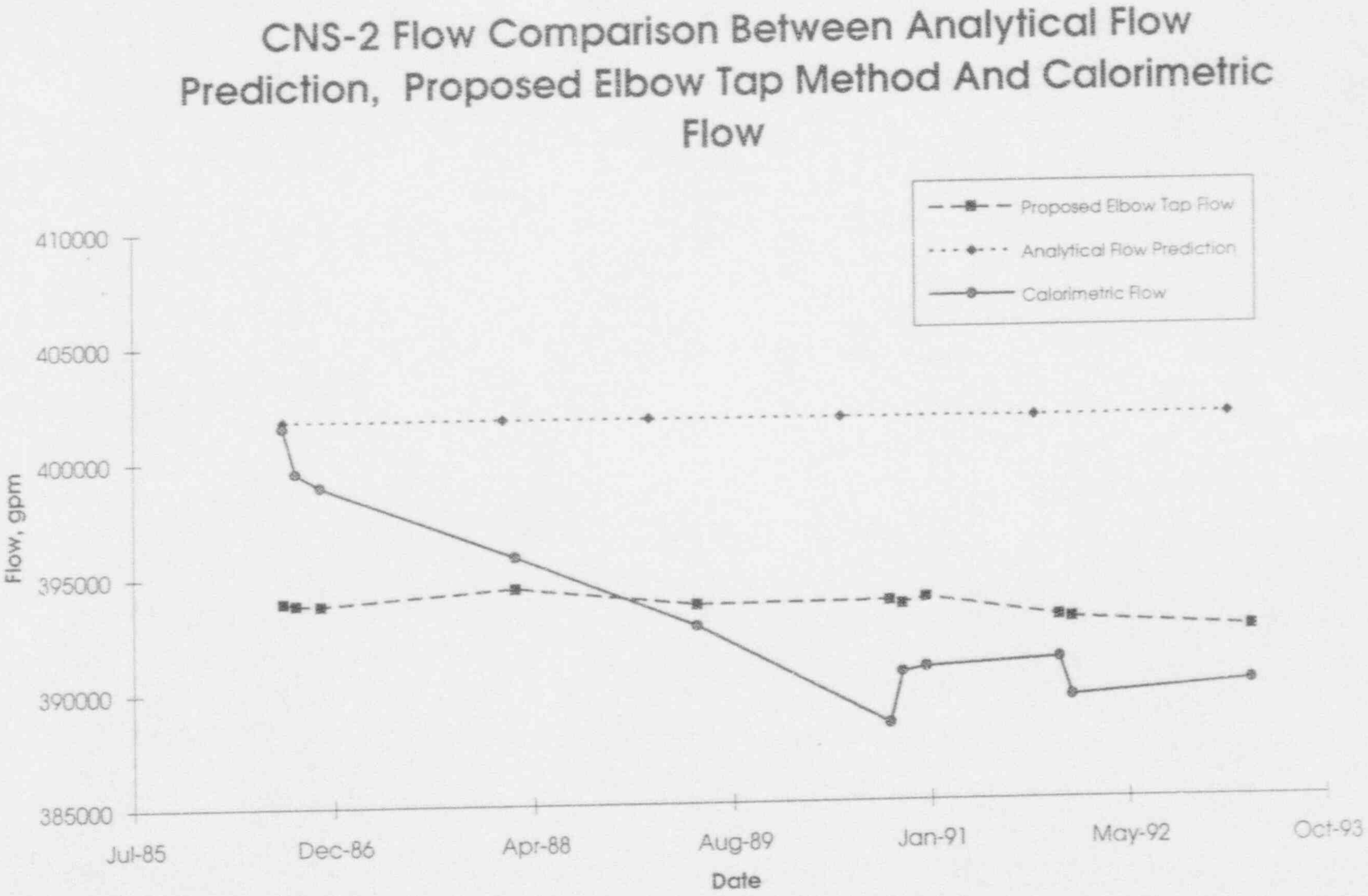

CNS-2 Flow Comparison Between Analytical Flow Prediction, Proposed Elbow Tap Method And Calorimetric Flow
Proposed Elbow Tap Flow
Analytical Flow Prediction
Calorimetric Flow
Flow, gpm
410000
405000
400000
395000
390000
385000
Jul-85
Dec-86
Apr-88
Aug-89
Jan-91
May-92
Oct-93
Date

Figure 4

QUESTIONS ON PROPOSED TS CHANGE FOR CATAWBA/MCGUIRE RCS FLOW-RATE MEASUREMENT

Reference: Previous questions and sample calculation.

1. For question A1, one part asked for the amount of hot leg streaming in past reloads. You provided a list of hot and cold leg temperatures. Hot leg streaming is associated with low leakage core loading and could correlate with your RCS flow rate results. To help understand the effect of this, please provide information on the core loading which indicates the relative degree (high, medium, low) of low leakage core loading (distribution of radial peaking factor) for the information in Tables 1 to 4 and Figures 1 - 4 of attachment 3.

2. For question A2, you answered that your new method of measuring RCS flow rate does not use a particular calorimetric from a past cycle to produce elbow tap coefficients, but that valid calorimetric data from previous measurements will be used to determine an averaged set of elbow tap coefficients to reasonably and conservatively represent the final coefficient values for each elbow. Usually, a flow meter is calibrated over a wide range of flow rates. Often, the flow coefficient can vary with Reynolds number when the flow rate is below the threshold value. How do you quantify the accuracy of the elbow tap for ranges of flow appreciably (10%) below where there has been data to base it on?

3. For question A3, you provided information indicating that the flows calculated by the calorimetric heat balance have been in the range of 407,363 gpm to 378,285 gpm, or a variation of about 28,078 gpm (6.89%). You indicated that the primary function of the elbow tap in the existing Technical Specification is to provide a flow indication for the Reactor Protection System such that a reactor trip will occur at 90% loop flow. As such, the elbow tap flow meters were designed to provided an accurate flow indication over the range from 100% to 90% flow.

   (a) Provide the relationship used to obtain the flow rates for ranges below 100% flow and also what you expect the accuracy to be when at 90% flow, a flow rate for which you have no data to base the calibration on. Do you have an added uncertainty for flow rates below 100%?

   (b) In Tables 17 and 18 for McGuire and Tables 20 and 21 for Catawba you show the uncertainty associated with the precision calorimetric including a bias value. Please explain how the values used are obtained and what they are based on. For these tables explain how the Sensor Calibration Accuracy (CSA) is obtained.

4. Reference 1 presents the general method for assessing uncertainties. Figure 3, measurement error, taken from Reference 1, shows that the measurement error is composed from the effect of the sensing path from the sensing element to the measurement output of the desired value. This error is shown to be composed of the effects of normal distribution and a bias. Figure 4 from Reference 1 is a schematic of components used for direct measurement of a quantity and includes output transmission, signal conditioning and readout, A/D conversion and digital computation.

The process of obtaining statistical accuracy of the measurement includes the effects of all the elements used in arriving at the end result.

For question B1, you were asked what flow measurement uncertainty (FMU) value you were using for your new method of measuring RCS flow rate and to submit the analysis for the FMU. Our question was anticipating a FMU analysis modified from that submitted previously for Catawba by WCAP-11308 (Ref. 1). You have modified the cold leg elbow tap results from the previous FMU analysis to account for the reactor trip setpoint changes. The analysis should be further modified to include the added uncertainty from your new method of averaging the results of the previous calorimetrics. The previous FMU analyses have been based on statistical analysis to obtain a 95/95 probability/confidence level, using a statistical approach similar to that described in Reference 1.

Since you are adding a new element into the previous method of measuring RCS flow rate, an uncertainty value needs to assigned to this new element. This element is the process of averaging the previous values of the flow coefficient, K to arrive at the new value of K. For example, the new value of K could be obtained by choosing (1) only certain inputs near the first operating cycles, or (2) only certain inputs near the last operating cycles. The flow calculated by either of these two methods would give different values. You have chosen to use the average of values ranging from the early to late cycles. The method of selecting the data for calculating the flow coefficient effects the final accuracy and needs to be analyzed and quantified to determine the particular FMU for your method.

5. For question C2a, you discussed fouling at the taps. For the flow pattern in the elbow, the flow near the tap on the outside radius flows at a oblique angle towards the tap as it turns inside the pipe which could effect the accuracy of the reading with a possible velocity pressure component. Also there are possible effects (such as a turbulance and erosion) on the accuracy of the flow reading on the inner radius tap location from eddies . It is understood that you do not plan to make further calorimetric heat balances for measuring the primary side flow rate. Please comment on the continued long range (20 plus years) operation with no further calibration to check for changes (fouling or any other effects such as frictional changes) that can affect the calibration of the elbow taps. How do you plan to check for effects that can effect the calibration with time.

6. For question C2c, you stated that the elbow taps are considered to be independently calibrated from past historic data. Please comment on the accuracy of this calibration for 100% flow rate and also its accuracy over ranges where it not based on data.

7. For question D1c, you provided Figures 1 - 4 of Attachment 3.

   The plot for the calorimetric flow rate has generally close agreement with your proposed elbow tap method, except for the data point taken after December 88. However, the calorimetric flow rate deviates sharply

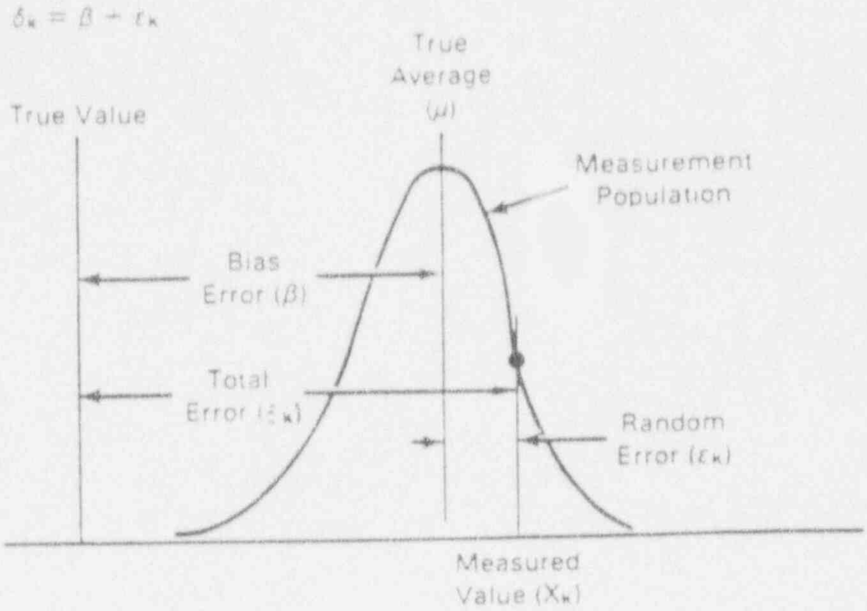


Figure 3 Measurement error

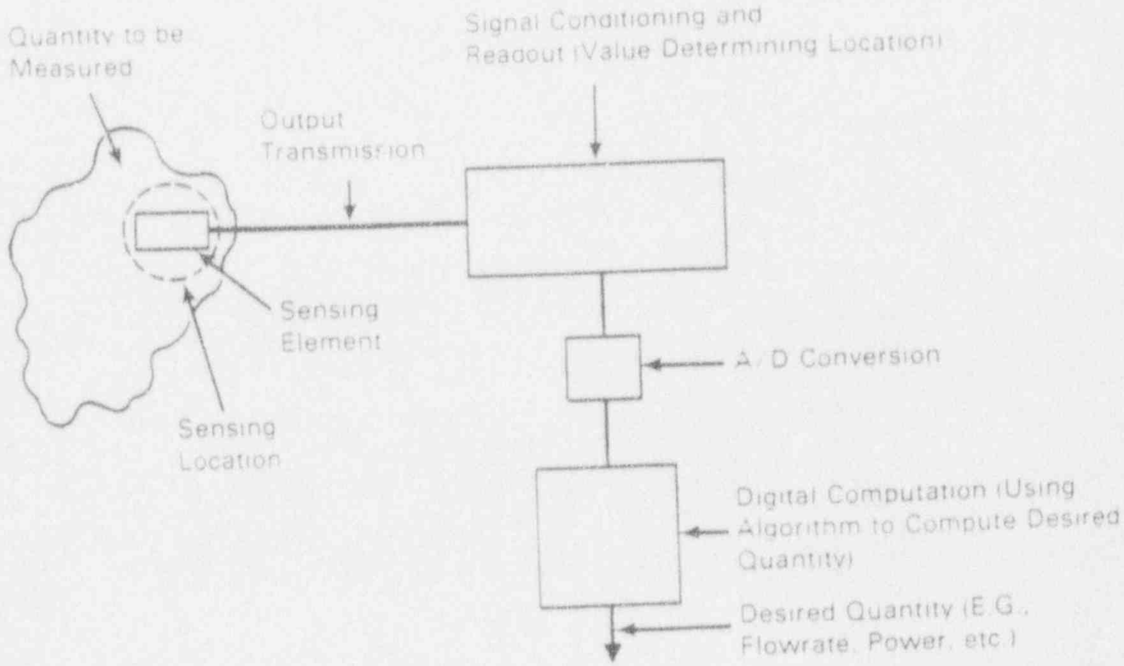


Figure 4 Illustrative schematic of components used for direct measurement of a quantity

lower from your proposed method for the data taken after September 91.

(a) Please explain the reason for the greater deviation experienced for Figure 3 for data taken after September 91. Is this from an increased radial peaking profile in your low leakage core loading? If so, do you have plans for further increases in this profile?

The data in your Table 11 indicates that for Catawba Unit 1, the percent of steam generator (SG) tube plugging increased from 4.03 % in August 92 to 7.91% in November 93. The November 93 SG percent tubes plugs value is is almost double the value of August 92.

(b) Please provide information on the effect of this large increase in SG tube plugging on the RCS flow rate and also the effect of hot leg streaming for this cycle on RCS flow rate. Is this reduction in RCS flow rate for this current cycle mostly due to SG tube plugging rather than from hot leg streaming? If so, is this not is a realistic reduction in flow rate, rather than a false indication from an inaccurate hot leg reading?

Reference

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