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REPORT: "Reactor Coolant Flow Evaluation for the Oconee Nuclear Station Unit 1, dtd 8-23-73.

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August 23, 1973

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Mr. Angelo Giambusso
Deputy Director for Reactor Projects
Directorate of Licensing
U. S. Atomic Energy Commission
Washington, D. C. 20545

Re: Oconee Nuclear Station
Unit 1
Docket No. 50-269

Dear Mr. Giambusso:

Please find attached for your information a preliminary report concerning the evaluation of Reactor Coolant System flow at Oconee Nuclear Station Unit 1. This report is being transmitted to you at the request of Regulatory Operations, Region II.

Very truly yours,

William O. Parker Jr.
for A. C. Thies

ACT:vr

Attachment

cc: Mr. Norman C. Moseley, Director
Directorate of Regulatory Operations
Region II - Suite 818
230 Peachtree Street, Northwest
Atlanta, Georgia 30303

6616

OCONEE NUCLEAR STATION
UNIT 1
REACTOR COOLANT FLOW EVALUATION

Preliminary Report
August 23, 1973

Introduction

Oconee Unit 1 was designed for a minimum primary coolant flow rate of 131.32×10^6 pounds per hour. A greater flow rate than the minimum is expected, however. While this will afford excess DNB protection, a flow rate of 110.8% design flow has been specified by the Babcock & Wilcox Company as the upper limit to avoid core lift at the end of life.

A test was performed during the Power Escalation Sequence at the 75% full power plateau to verify that the magnitude of the primary system flow is within acceptable limits. The details of this test are delineated herein.

Evaluation

The basis of the flow calculation is a calorimetric around the two steam generators. Thermal-hydraulic data was monitored for an hour on July 29, 1973, properly averaged, and substitued into the heat balance equation described below to provide primary flow.

Figure 1 is a schematic of a steam generator with its associated coolant flow loops; the dotted line represents the control volume for the derivation of the calorimetric equation. Since the energy entering the volume must leave it in some form, the following balance for the A generator can be made.

$$W_P^A H_H^A + W_F^A H_F^A = W_P^A H_C^A + W_F^A H_S^A + K^A$$

A similar equation exists for the B steam generator. Both can be solved for primary coolant system flow and are presented below.

$$W_P = W_P^A + W_P^B$$

$$= \frac{W_F^A (H_S^A - H_F^A) + K^A}{H_H^A - H_C^A} + \frac{W_F^B (H_S^B - H_F^B) + K^B}{H_H^B - H_C^B}$$

Precision thermocouples and dead-weight gages were installed on the feedwater and steam lines to measure temperatures and pressures to calculate enthalpies. Precision manometers were used to measure the pressure drop across the calibrated Bailey flow nozzles for the feedwater and steam flow determination. The plant process computer was used to monitor the primary side temperatures and pressures and feedwater temperature.

Manometer readings were taken every two minutes for the duration of the test. Steam secondary side temperatures and feedwater pressures were recorded on a five minute interval while primary side temperatures and pressures and feedwater temperature were monitored on a 15 second basis. The data was averaged and the flow and enthalapies were calculated.

The heat loss term represents the surface radiation and/or convection from the surface of the piping and the steam generators. This term has minor significance but is included for completeness. Its magnitude is taken as 0.724 and 0.787 million BTU/hr for loops A and B, respectively.

Table 1 is a listing of the average values of the data collected during the test. The calculated enthalpies and flows are displayed in Table 2. The flow equation is shown below with the proper values inserted and the primary flow noted.

$$W_P = \frac{(1251.03 - 415.28)\ 4.0815 + 0.724}{609.00 - 561.31} \times 10^6$$

$$+ \frac{(1251.69 - 415.28)\ 3.9642 + 0.787}{609.27 - 561.20} \times 10^6$$

$$= 140.34 \text{ M lbm/Hr}$$

The error analysis for the above flow value is derived in Appendix A. The result of the error analysis yielded a band of $\pm$ 1.146 M lbm/Hr.

Since minimum design flow is 131.32 M lbm/hr at rated power which corresponds to 130.2 M lbm/hr at 75% power, the measured flow and experimental error is 107.8 $\pm$ .82 as expressed in percent.

Safety Analysis

The minimum RC system flow rate shall be the FSAR basis of the 100% (131.32 x 10^6 lb/hr, minimum design flow at rated power) plus 2.3% excess for bypass due to removal of 44 orifice plugs. This flow rate is established as the minimum flow rate to meet the DNBR requirements stated in the FSAR. Therefore, the minimum flow shall be 134.34 x 10^6 lb/hr at rated power.

The maximum reactor coolant system flow rate is 110.8% of the minimum design flow rate based on fuel assembly lift limitations. This 10.8% excess flow design limit is determined by utilizing experimental evidence of fuel assembly hydraulic resistance characteristics and the maximum expected flow rate for any fuel assembly based on flow distributions from the Vessel Model Flow Test. This maximum allowable flow rate is based on the more limiting end-of-life conditions.

The measured system pressure loss is lower than predicted and represents a design conservatism. Also, the modification of the reactor vessel and internals resulted in a reduction of the reactor vessel unrecoverable pressure loss. The reduction in reactor vessel pressure loss due to the internals changes is approximately 4 psi at the design flow rate. (Reference BAW-10037, Rev. 2, November 1972, "Reactor Vessel Model Flow Tests.") These two points account for the actual RC system flow rate being above minimum design flow rate.

Therefore, the reactor coolant system flow including possible measurement error for Oconee 1 is within acceptable limits.

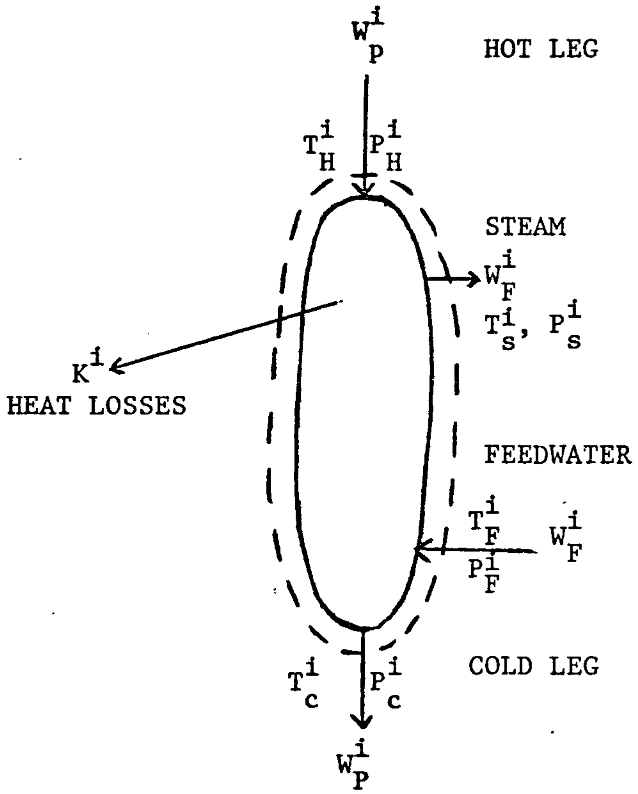
TABLE 1. AVERAGED DATA

		Loop A	Loop B
Main Steam,	Temperature, °F	590.34	590.80
	Pressure, psia	911.73	912.22
Feedwater,	Temperature, °F	436.47	436.25
	Pressure, psia	942.61	939.00
	ΔP, psi: Tap 1	35.64	35.25
	Tap 2	35.95	33.32
Hot Leg,	Temperature, °F	596.60	596.86
	Pressure, psia	2122.0	2141.7
Cold Leg,	Temperature, °F	560.997	560.945
	Pressure, psia	2089.4	2109.1

TABLE 2. HEAT BALANCE DATA

Enthalpies (BTU/lbm)	Loop A	Loop B
Main Steam	1251.03	1251.69
Feedwater	415.28	415.28
Hot Leg	609.00	609.27
Cold Leg	561.31	561.20
Feedwater Flow (M lbm/Hr)	4.0815	3.9642
Heat Losses	0.724	0.787

FIGURE 1. LOOP i STEAM GENERATOR



W_p = Total Primary Coolant Flow

W_p^i = Loop i Primary Flow

T_H^i = Loop i Hot Leg Temperature

P_H^i = Loop i Hot Leg Pressure

H_H^i = Loop i Hot Leg Enthalpy

T_c^i = Loop i Cold Leg Temperature

P_c^i = Loop i Cold Leg Pressure

H_c^i = Loop i Cold Leg Enthalpy

T_s^i = Loop i Steam Temperature

P_s^i = Loop i Steam Pressure

H_s^i = Loop i Steam Enthalpy

T_F^i = Loop i Feedwater Temperature

P_F^i = Loop i Feedwater Pressure

H_F^i = Loop i Feedwater Enthalpy

W_F^i = Loop i Feedwater Flow

K^i = Loop i Heat Losses

APPENDIX A

The basic flow equation from Figure 1 is as follows:

$$W_p = \frac{(H_S^A - H_F^A)\ W_F^A + K^A}{H_H^A - H_C^A} + \frac{(H_S^B - H_F^B)\ W_F^B + K^B}{H_H^B - H_C^B}$$

$$\text{or } W_p = W(X_1,\ X_2,\ \ldots .X_n)$$

$$\text{and } dW_p = \sum_{i=1}^{n} \frac{\delta W}{\delta Xi}\ dX_i$$

$$\text{Therefore } dW_p = \frac{H_S^A - H_F^A}{H_H^A - H_C^A}\ dW_F^A + \frac{W_F^A}{H_H^A - H_C^A}\left(\frac{\delta H_S^A}{\delta T_S^A}\ dT_S^A + \frac{\delta H_S^A}{\delta P_S^A}\ dP_S^A\right)$$

$$- \frac{W_F^A}{H_H^A - H_C^A}\left(\frac{\delta H_F^A}{\delta T_F^A}\ dT_F^A + \frac{\delta H_F^A}{\delta P_F^A}\ dP_F^A\right)$$

$$- \frac{(H_S^A - H_F^A)\ W_F^A + K^A}{(H_H^A - H_C^A)^2}\left(\frac{\delta H_H^A}{\delta T_H^A}\ dT_H^A + \frac{\delta H_H^A}{\delta P_H^A}\ dP_H^A\right)$$

$$+ \frac{(H_S^A - H_F^A)\ W_F^A + K^A}{(H_H^A - H_C^A)^2}\left(\frac{\delta H_C^A}{\delta T_C^A}\ dT_C^A + \frac{\delta H_C^A}{\delta P_C^A}\ dP_C^A\right)$$

$$+ \frac{dK^A}{H_H^A - H_C^A} + \frac{H_S^B - H_F^B}{H_H^B - H_C^B}\ dW_F^B + \frac{W_F^B}{H_H^B - H_C^B}\left(\frac{\delta H_S^B}{\delta T_S^B}\ dT_S^B + \frac{\delta H_S^B}{\delta P_S^B}\ dP_S^B\right)$$

$$- \frac{W_F^B}{H_A^B - H_C^B}\left(\frac{\delta H_F^B}{\delta T_F^B}\ dT_F^B + \frac{\delta H_F^B}{\delta P_F^B}\ dP_F^B\right) - \frac{(H_S^B - H_F^B) W_F^B + K^B}{(H_H^B - H_C^B)^2}\left(\frac{\delta H_H^B}{\delta T_H^B}\ dT_H^B + \frac{\delta H_H^B}{\delta P_H^B}\ dP_H^B\right)$$

$$+ \frac{(H_S^B - H_F^B)\ W_F^B + K^B}{(H_H^B - H_C^B)^2}\left(\frac{\delta H_C^B}{\delta T_C^B}\ dT_C^B + \frac{\delta H_C^B}{\delta P_C^B}\ dP_C\right) + \frac{dK^B}{H_H^B - H_C^B}$$

The differentials, dT_F^A, can be replaced by finite differences, ΔT_F^A, representing the measurement tolerances for each variable substituted. The measurement tolerances are given below:

Main Steam Temperature	± 0.5°F
Main Steam Pressure	± 1 psi
Feedwater Temperature	± 0.5°F
Feedwater Pressure	± 1 psi
Feedwater Flow	± 0.5%
RC Hot Leg Temperature	± 0.25°F
RC Hot Leg Pressure	± 25 psi
RC Cold Leg Temperature	± 0.25°F
RC Cold Leg Pressure	± 35 psi
Ambient Heat Losses	± 50%

The heat balance data from Table 2 is substituted for the feedwater flow and enthalpies. The values for the rate of change with respect to the differential are substituted for the partial derivation.

The terms of ΔW_p are the squared, summed, and the square root taken. The terms represent the error in feedwater flow, steam temperature, steam pressure, feedwater temperature, feedwater pressure, reactor coolant hot leg temperature, reactor coolant hot leg pressure, reactor coolant cold leg temperature, reactor coolant cold leg pressure, and ambient heat loss measurements.