4A.2 REACTOR COOLANT PUMP TESTING AT PUMP MANUFACTURER

Each reactor coolant pump (RCP) was tested at Byron Jackson Division of Borg-Warner Corporation. The objective of these tests was to assure compliance to the specification and reliability of the pumps. Tests were performed for each pump impeller with motors and cases assigned as follows:

	Unit 1	Unit 2
Motor	1S-77P-108	4S-79P-520
Pump Case	0445	0445
Impeller	681-N-0437	681-N-0441
Impeller	681-N-0438	681-N-0442
Impeller	681-N-0439	681-N-0443
Impeller	681-N-0440	681-N-0444

Tests performed were as follows:

a. Cold Performance Characteristics
b. Hot Performance Characteristics
c. Cavitation Tests
d. Spin-Down Characteristics
e. Airborne Noise Levels and Vibration
f. Pump Motor Cooling Water Pressure Drop
g. Start-Stop Cycle Summary
h. Reliability Test

The test of hot performance characteristics is the only test significant for assessing the expected flow at full power. This is the only test discussed in this report.

4A.2.1 TESTS PROCEDURES AND RESULTS

Each impeller was installed in the test loop (Figure A) with water temperature of 550°F and a suction pressure of 2250 ± 50 psig. Flow rates were varied over the range of 50,000 gpm to 130,000 gpm by throttling the flow. Pump performance parameters of suction and discharge pressure, flow rate, volts, amperes, kilowatts, and speed were measured at approximately nine equal increments of flow. Pump pressure was measured at the pump suction and discharge. From the test data collected, performance curves were plotted showing head, efficiency, and brake horsepower versus flow rate. For each flow rate, the differential pressure (ΔP) across the pump case was measured to provide a reference ΔP versus flow curve to be used in establishing the Reactor Coolant System (RCS) flow.

Flow in the Byron Jackson test loop was established by measuring the ΔP across a venturi in each of four parallel pipe paths.

4A.2.2 ASSESSMENT OF MEASUREMENT UNCERTAINTY

Figure B shows the effect of measurement uncertainties on the calculation of flow for a single RCP. The figure assumes that there is a true flow of 92,500 gpm [flow used for loss-of-coolant accident (LOCA) analysis] in both the Byron Jackson test loop and the Calvert Cliffs RCS. The true pump case ΔP will then be identical in both loops and is approximately equal to 85 psi. Measurement uncertainties for the Byron Jackson and post-core load hot functional tests are then applied to result in the calculation of the highest possible flow. It is this flow which must be measured in the RCS to assure that for the worst case combination of error, the flow is not less than 92,500 gpm.

Venturi ΔP. The ΔP produced by the venturi is within ± 1% of the theoretical ΔP when the venturi is constructed according to the Hydraulic Institute Code. This relation was checked for the Palisades pump tests by weighing the volume of water pumped in a given time interval. The assignment of 1% error is conservative in that it assumes that each of the four parallel venturis has a maximum error in the unconservative direction.

Venturi ΔP Measurement. The meters measuring the venturi output have an accuracy of 0.5% full scale (FS). With a total flow of 92,500 gpm, this is equivalent to an accuracy of 2.5% of reading.

Calculated Test Loop Flow. There is no error assigned to this calculation. As flow is proportional to the square root of the ΔP, the error in flow is less than the error in ΔP. The calculated test loop flow is 94,100 gpm with both venturi and venturi ΔP errors assumed to be in the positive direction.

Measured Pump Case ΔP (In Test Loop). The meter used to measure pump case ΔP had an accuracy of ± 0.5% FS. This is equivalent to ± 0.75 psi. The worst case flow error will result if this error is applied to produce a higher than true reading. The pump case ΔP is thus assumed to be 85.75 psi.

Effect of Variation in Pump Case Dimensions. Each pump impeller was individually tested. The impellers were tested in one of the St. Lucie pump cases. The pump casings are castings made from the same mold; therefore, there is no reason to expect that any of the casings would be dimensionally different in any significant aspect from the test casing. To verify this, measurements were made of the minimum flow area in the diffuser region for four Unit 2 pumps and four St. Lucie pumps. The results were as follows:

Pump No.	Minimum Diffuser Flow Area (in^2)	Deviation From Reference Case
21A	776.0	-3.2%
21B	798.5	-.4%
22A	789.1	-1.6%
22B	813.0	+1.4%
0445	801.8 (reference case)	--
0446	789.2	-1.6%
0447	772.3	-3.7%
0448	767.0	-4.3%

NOTE: Unit 1 pumps were not available for measurement without disassembly.

A conservative estimate of the effect of variations in diffuser areas can be made by calculating the increase in diffuser pressure drop resulting from a reduction in the flow area. Under the conservative assumption that all Unit 1 pumps have a flow area which is 5% less than the reference case, this will result in a generated head which is 2.3' less than that produced for the reference case. The apparent increase in flow is equivalent to 840 gpm. The apparent flow has been increased by 840 gpm to 94,940 gpm.

Measured Pump Case ΔP (In RCS). The meter which will be used to measure RCP case ΔP will have an accuracy of ± 0.5% FS. Once the pump case ΔPs have been measured in the reactor coolant loop, a more precise determination of the case ΔPs can be obtained in the plant calibration laboratory by measuring the input ΔP required to duplicate the meter reading at full flow. The input ΔP can be accurately measured using a mercury manometer. Using this technique, an accuracy of ± 0.5% of reading is obtainable. Applying this error in the negative direction results in the highest value of perceived flow. In the reactor pump case, ΔP is thus assumed to be 84.57 psi.

Effect of Test Temperature. The pumps were tested at 550°F. This approximates the full power operating condition for the pump. There is, therefore, no possibility of dimensional changes affecting the pump output. The test procedure for determining RCS flow makes allowance for changes in coolant density at 100% power conditions versus the test condition at Byron Jackson.

Combination of Measurement Uncertainties. Uncertainties in measurement of test loop flow cause the perceived flow to be 94,940 gpm/pump. The perceived pump case ΔP is 85.75 psi. It is this point which is plotted on the pump capacity curve rather than 92,500 gpm and 85 psi. When reactor plant pump case ΔP measurements are made, the maximum possible difference in ΔP (85.75 - 84.57 = 1.18 psi) represents an additional flow allowance which must be included. The magnitude of this flow allowance is a function of the slope of the pump capacity curve at the pump operating point. For the worst case pump this is equivalent to 1125 gpm. The flow which must be measured to assure 92,500 gpm is thus 94,940 + 1125 gpm = 96,100 gpm.