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ATTACHMENT 5

SAFETY EVALUATION TO JUSTIFY OPERATION WITH LOSS OF JET PUMP FLOW INDICATION FOR QUAD CITIES UNITS 1 AND 2

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1. INTRODUCTION

Loss of flow indication from jet pump No. 7 at Quad Cities Unit 1 has occurred due to failure of a sensing line inside the vessel. An evaluation was made to determine the effect of this failure on plant operation and safety. Loss of flow indication for up to three jet pumps was also evaluated for Quad Cities Units 1 and 2. The scope of the evaluations includes the following:

1. The effect on core flow measurement accuracy under two-loop and single-loop operation for the loss of jet pump flow indication from:

   a) Jet pump No. 7 only (to be allowed at all times under proposed Tech Specs),

   b) Jet pump No. 7 plus one additional jet pump (to be allowed until the next cold shutdown under proposed Tech Specs), and

   c) Jet pump No. 7 plus two additional jet pumps (to be allowed for up to 12 hours following the loss of indication from the third jet pump under proposed Tech Specs).

   For Quad Cities Unit 2, any single tap jet pump can be substituted for Jet Pump No. 7.

2. The effect on the ability to detect a jet pump failure using the surveillances as described in current Tech Specs.

3. The effect on the ECCS performance analysis.

2. CONCLUSIONS

2.1 Core Flow Measurement

Jet Pump No. 8 should be used to simulate the flow of Jet Pump No. 7 in the core flow measurement system. Similarly, if flow indication is lost in additional jet pumps, they should be simulated by their partner jet pump on the same riser. Loss of flow indication for Jet Pump No. 7 was found to have a negligible effect on the overall core flow measurement accuracy. Loss of flow indication for a calibrated (double-tap) jet pump results in an increase of about 0.17% in the overall core flow measurement uncertainty for two-loop operation and 0.34% for single-loop operation. Based on these changes, plant operation with loss of flow indication in up to three jet pumps is acceptable as long as each jet pump is on a different riser and no more than one calibrated jet pump per loop is affected.

2.2 Jet Pump Integrity Surveillance

Current plant instrumentation is adequate to detect whether any jet pump displacement is occurring which might impact jet pump integrity. The plant Technical Specifications on jet pump integrity should be modified to replace the core plate ΔP versus core flow criterion with monitoring of individual jet pump flows. This change is necessary because the existing criterion may not be met if displacement occurs in the jet pump which has lost flow indication.

2.3 Effect on ECCS Performance Analysis

Any leak from up to three jet pumps to the downcomer annulus through the instrument line would be too small to have an effect on the ECCS performance analysis.

3. CORE FLOW MEASUREMENT

3.1 Brief Description of Measurement System

On typical jet pump BWR plants like Quad Cities Units 1 and 2, there are a total of 20 jet pumps. All of the jet pumps are provided with a single tap (ST) diffuser-to-plenum ΔP transmitter. The total core flow passing through 20 jet pump diffusers is determined by the single-tap ΔP transmitter of each jet pump. The ΔP signal from each individual jet pump is electronically square rooted to obtain a signal proportional to flow and then summed with other jet pump flows to obtain the jet pump loop flows (i.e. sum of 10 jet pump flows) and the total core flow (i.e. sum of two loop flows).

In addition, four of the jet pumps are provided with a double-tap (DT) diffuser-to-diffuser ΔP transmitters. These four jet pumps (No's 1, 6, 11, and 16), are laboratory-calibrated prior to installation at the plant, and are referred to as calibrated or double-tap jet pumps. During initial plant startup, the flow through these four calibrated jet pumps is calculated from the double-tap measurement system, and two calibration constants per loop are developed. The average of these two calibration constants for a loop is then used to calibrate the 10 single-tap instruments in the loop, so that the loop flow indicators and core flow recorder read correctly. This calibration process is conducted periodically throughout the life of plant to compensate for instrument drift and other changes in the recirculation system operating characteristics.

3.2 Simulation of Lost Jet Pump Flow Signal

Since there is no accurate flow signal from jet pump No. 7 for Unit 1 due to the severed instrument line, a substitute signal is needed. The substitute signal should be accurate enough to prevent a significant increase in core flow measurement uncertainty, convenient for input into the core measurement system, and enable surveillance for jet pump integrity. The single-tap flow signal from the other jet pump on the same riser (i.e. No. 8) will best meet the objectives which are mentioned above. Therefore, these evaluations are based on the assumption that jet pumps with no flow indication will be simulated by their respective partner jet pump on the same riser.

The simulation is based on data collected during previous jet pump surveillance tests at the plant. The data is analyzed to establish the relative difference between the flows of the jet pump on the riser. The failed sensed flow is then:

$$W_{(failed)} = W_{(jet\ pump\ on\ the\ same\ riser)} * (K)$$

where K and its uncertainty are established from plant historical data. The simulation is implemented by wiring the unfailed signal to the summer input for the failed sensing line and adjusting the summer input signal scaling for that input which corresponds to the value of K.

3.3 Measurement Uncertainty Analysis

The core flow measurement system accuracy depends on many factors. The major contributors to the uncertainty, assuming no system faults, are:

1. The differential pressure measurement instruments for both the single- and double-tap system.

2. The recirculation pump flow measurement which is used to determine the calibration constants for the double-tap jet pumps.

3. A sampling uncertainty due to only four of the twenty jet pumps being calibrated.

4. Uncertainties in establishing the calibration constants for the double-tap jet pumps.

5. Changes in the recirculation system performance during the fuel cycle due to changes in the core pressure drop. This affects the jet pump M-ratio (suction flow/drive flow) which causes the calibration constant to change.

6. Instrument drift during the fuel cycle until another calibration is performed.

7. Differences from jet pump to jet pump since their M-ratio can vary due to the drive flow manifold distribution to the jet pumps.

8. The accuracies of the core flow measurement system square rooters and summers.

GE Nuclear Energy has developed a probabilistic model to calculate the total core flow uncertainty by considering the above plus many other less significant contributors.

If an instrument sensing line is severed, additional uncertainties are introduced due to:

1. Uncertainty in the value of K used in the simulation as defined in Section 3.2.

2. One less single-tap flow measurement which increases the uncertainty in the summation process. The uncertainty of 19 measurements is higher than the uncertainty of 20 measurements.

3. For the double-tap system, additional uncertainties are introduced if there is one less calibrated jet pump measurement. The uncertainty of 3 measurements is higher than for 4 measurements. In addition, the sampling uncertainty increases since the sample ratio changes from 2 out of 10 calibrated jet pumps per loop to 1 out of 10 in one of the loops.

By modifying the original model for normal operation, an incremental uncertainty due to the severed sensing line can be calculated.

3.4 Effect on Core Flow Measurement Uncertainty

Using the method as described in Section 3.3 and the jet pump surveillance test data for Unit 1 provided by CECo (Reference 1), the total active coolant flow uncertainties were calculated to be the following for the indicated conditions:

	2-Loop	1-Loop
1. Normal Operation:	2.01%	5.00%
2. Loss of Jet Pump No. 7 only:	2.01%	5.00%
3. Loss of Jet Pump No. 7 plus one DT Pump:	2.18%	5.34%
4. Loss of Jet Pump No. 7 plus one ST & one DT pump:	2.19%	5.36%
5. Loss of Jet Pump No. 7 plus one DT pump per loop:	2.34%	5.64%

Loss of two DT pumps in one loop was not specifically evaluated, but would result in a much higher uncertainty than calculated for case 5. As can be seen from the above results, the incremental uncertainty due to the ST pump is negligible since the flow of the jet pump is simulated by its partner on the same riser. However, the loss of a calibrated jet pump signal has a more significant effect on the accuracy for the reason discussed in Section 3.3.

The total core flow uncertainties for Unit 2 were also calculated based on historical jet pump data supplied by CECo (Reference 2). The differences in the measured data between each jet pump pair on the same riser were found to be very small as was the case for Unit 1. Consequently, the contribution to the total core flow uncertainty due to the loss of flow indication in a Unit 2 ST jet pump is also insignificant. The contribution of DT jet pumps to the total core flow uncertainty is based on laboratory calibration prior to installation and is thus independent of the individual plant data. Therefore, the total Unit 2 core flow uncertainties for the various conditions listed above will be essentially identical to Unit 1, except that Jet Pump No. 7 can be replaced by any ST jet pump.

The changes in total core flow uncertainties for single-loop operation with loss of flow indication in up to three jet pumps have also been evaluated and are summarized in the above table. These changes are larger than for two-loop operation because the core flow measurement system is calibrated to measure core flow when both loops of jet pumps are operating in forward flow. For single-loop operation, the jet pumps in the inactive recirculation loop will experience reverse flow.

3.5 Effect of Accuracy on Safety Limits Calculation

3.5.1 Two-Loop Operation

The accuracy required for the core flow measurement system is 2.5%. This requirement comes from the General Electric Thermal Analysis Basis (GETAB) which assumed a core flow uncertainty of 2.5% in the derivation of the Safety Limit Minimum Critical Power Ratio (MCPR). As can be seen from the results presented in Section 3.4, the loss of flow indication from one ST jet pump plus two DT jet pumps (one from each loop) still meets this requirement.

3.5.2 Single-Loop Operation

A bounding value of 6% core flow measurement uncertainty has been conservatively applied in the GETAB calculations for single-loop operation. The predicted total core flow uncertainty for Quad Cities Units 1 and 2 during single-loop operation with all jet pump flow instrumentation assumed operable is 5% (Reference 3). For all cases summarized in Section 3.4, the worst case (Case 5) still meets the 6% requirement.

3.5.3 Conclusions

Based on the above results, it is concluded that plant operation with loss of flow indication in up to three jet pumps is acceptable as long as each jet pump is on a separate riser and no more than one DT jet pump per loop is affected. This conclusion applies to Quad Cities Units 1 and 2 under both two-loop and single-loop operating conditions.

4. JET PUMP INTEGRITY SURVEILLANCE

The loss of an accurate flow signal from any jet pump makes it necessary to review the Technical Specifications that depend on that flow signal to diagnose a jet pump integrity problem (i.e., displacement of the removable portion of the jet pump). The current Technical Specifications require simultaneous occurrence of the following two conditions to indicate loss of jet pump integrity:

(a) The recirculation pump flow differs by more than 10% from established speed-flow characteristics, and

(b) The indicated core flow is more than 10% greater than the core flow value derived from established core plate ΔP-core flow relationships.

These criteria are evaluated in the following paragraphs to determine if changes are needed when flow indication from one or more jet pumps has been lost.

4.1 Recirculation Pump Speed-Flow Characteristics

Since this ratio does not depend on the jet pump flow signals, it remains valid.

4.2 Indicated Versus Actual Core Flow

Data from a BWR where a jet pump beam failed was evaluated and it was determined that the following differences between the actual core flow and core flow indicated by the core flow measurement system would be expected to occur:

<u>Effect of Failure in Partner to Jet Pump with Lost Flow Indication</u>

When the jet pump displaced, the flow of the other jet pump on the same riser dropped by 45% and reverse flow occurred through the jet pump that displaced. The reverse flow through the diffuser was approximately 142% of the normal forward flow. The 142% flow was indicated as 167% flow in the core flow measurement system since the system was calibrated for forward flow rather than reverse flow. Since the core flow measurement system did not detect this as reverse flow, it added the 167% rather than subtracting it.

When the failed jet pump flow is used to simulate the flow for the jet pump which has lost flow indication, large core flow measurement uncertainties will result. Core flow measurement uncertainties would be introduced due to adding 167% rather than subtracting 142% for the failed jet pump, and showing a flow of 167% rather than 55% of normal for the intact jet pump. This would lead to an uncertainty of 21% of rated core flow.

<u>Effect of Failure in Jet Pump with Lost Flow Indication</u>

When the failed jet pump flow is simulated by its partner jet pump, the core flow measurement uncertainty will not be as large as the previous case. Core flow measurement uncertainties would be introduced due to adding 55% rather than subtracting 142% for the failed jet pump. This would lead to an uncertainty of 9.9% of rated core flow.

Consequently, the 10% indicated versus actual core flow criterion is marginal for detection of a displacement of the jet pump with lost flow indication. Consequently, the Technical Specifications should be modified to assure detection of a displacement.

4.3 Alternatives

Continued use of the pump flow versus pump speed is acceptable because this indication does not depend on the jet pump flow signals. However, the use of the total core flow versus core plate ΔP may be misleading in determining whether jet pump integrity is maintained. If the failure occurs on a jet pump that has a failed instrument line, then the change in core flow for the corresponding core plate ΔP may be less than 10%. Therefore, it is recommended that this requirement be removed from the Technical Specifications.

The individual jet pump flow deviation pattern will clearly indicate jet pump displacement since the indicated flow of the jet pumps on the affected riser change by 45% and 67%. Therefore, monitoring of the individual jet pumps is recommended as an alternative to core plate ΔP versus core flow for evaluating jet pump operability with loss of flow indication in one or more jet pumps. This method requires that if the ratio of the indicated jet pump flow of any individual jet pump to the mean flow of all jet pumps in that loop with intact instrument lines differs by more than 10% from the characteristic value for that jet pump, then the jet pump may be failed.

With these changes, a jet pump would then be considered inoperable due to possible failure if both the pump speed versus pump flow and the individual jet pump flow deviations occur simultaneously.

4.4 Other Considerations

Plant operation with loss of flow indication for two jet pumps on the same riser is not permitted. If this should occur, there is no way to ensure that jet pump integrity is being maintained for the affected jet pumps. Maintenence of jet pump integrity is required to demonstrate that the core can be reflooded to two-thirds core height following a large recirculation line break loss-of-coolant accident.

4.5 Summary

The current Technical Specifications for Quad Cities Units 1 and 2 are marginal with regard to detection of displacement of a jet pump which has lost flow indication. To remedy this concern, replacement of the core plate ΔP versus core flow requirement with a requirement to monitor individual jet pump flows is recommended.

5. EFFECT ON ECCS PERFORMANCE ANALYSIS

The diffuser upper pressure taps are located at approximately the same elevation as the bottom of the active fuel. To minimize the signal noise and to account for any differences in the velocity distribution at the diffuser entrance, there are three 0.125 inch diameter holes at the diffuser entrance to measure the static pressure in the diffuser. A manifold connects these taps and the instrument line is connected to this manifold inside the vessel. If the jet pump instrument line should break inside the vessel, it would establish an additional leakage path through these taps to the downcomer annulus which would allow water intended for core cooling to leak into the downcomer and delay core reflooding.

The design basis loss-of-coolant accident (LOCA) for Quad Cities Units 1 and 2 is a recirculation suction line break with a single failure of a DC power source which disables the High Pressure Coolant Injection (HPCI) System, one Core Spray (CS) System and two of the four Low Pressure Coolant Injection (LPCI) pumps. In this case, core cooling is accomplished by the one remaining Core Spray System that injects inside the core shroud plus the two remaining LPCI pumps. During reflooding, the leak through the instrument line would start to occur when the water level reaches the bottom of the active fuel. Leakage would continue as the water level rises to the jet pump suction elevation which is at approximately two-thirds of the core height. This additional leakage was calculated to be less than 3 gallons per minute through the three 0.125 inch pressure taps in any one diffuser. Even if three diffusers were leaking at this rate, the total flow loss would amount to much less than 1% of the total ECCS flow available. Previous sensitivity studies have shown that a leakage increase of this magnitude has no effect on ECCS performance limits. Consequently, no changes to the current ECCS performance limit calculations are necessary.

6. REFERENCES

1. Jet pump surveillance test data for Quad Cities Unit 1, dated September 18, 1972.

2. Jet pump base data for Quad Cities Unit 2, QTP 1130-S5, Rev. 3, May 1980.

3. Dresden Nuclear Power Station Units 2 and 3 and Quad Cities Nuclear Power Station Units 1 and 2 Single-Loop Operation, NEDO-24807, December 1980.

ATTACHMENT 6

SUMMARY AND

JUSTIFICATION FOR CORRECTIVE ACTION ON

UNIT ONE JET PUMP SEVEN

February 28, 1989

1803H/

On October 31, 1972, Quad-Cities Unit One Jet Pump Number 7 instrument line failed. The failure of the instrument line prevented the use of flow indication directly from Jet Pump 7. The proposals listed below were evaluated to determine the best corrective action to be pursued.

1. Repair of the damaged instrument line.

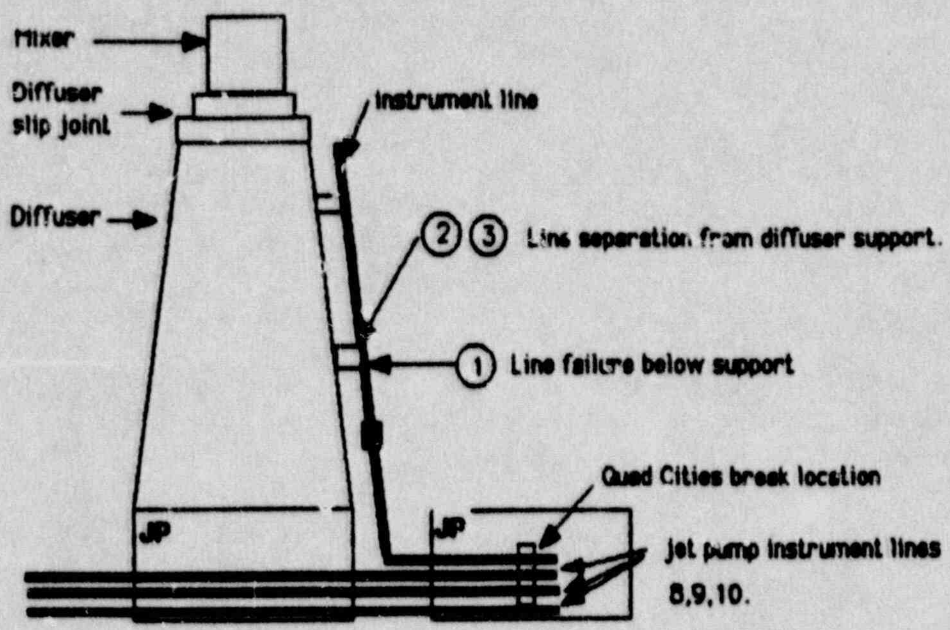
2. Replace the jet pump upper section.

3. Justify operation with the failed instrument line.

Repair of the Damaged Instrument Line

Commonwealth Edison and General Electric had expended considerable effort to develop a method of repairing the failed instrument line in early 1975. A full scale mock-up was constructed by General Electric to test numerous tooling designs that could repair the instrument line. Based on this work, it was demonstrated that repair was not feasible due to the limited access to the area and the close proximity of other instrument lines which could be easily damaged.

In the early 1980s, three BWRs experienced jet pump instrument line failures. These failures occurred on the middle to upper diffuser section of the jet pump (as shown below).



General Electric has performed repairs on broken jet pump instrument lines with proven techniques and available tooling. The "Type 1" break shown above was repaired using shrinkable Nickel/Titanium Alloy Coupling to replace the broken section. The "Type 2, 3" breaks shown above were repaired using replacement mechanical band clamps to secure the instrument line back on the diffuser section.

The Quad-Cities instrument line break on jet pump 7 is similar to the Type 1 break above. This type of break took a General Electric team seven - 24-hour shifts to complete at a total cost of approximately three million dollars. In addition, it must be noted again that Quad-Cities instrument line break is in a more restricted area. The repair work on the instrument line for jet pump 7 could lead to instrument line failures for jet pumps 8, 9 and 10 due to the close proximity of these lines.

1803H/

Replace the Jet Pump Upper Section

Another proposed fix recommended by General Electric was to provide a new jet pump upper section with a new instrument tap location. The tap and fittings, along with the instrument line would be shop attached. This new instrument line would be routed from the jet pump vertically up the interior side of the reactor vessel wall, run circumferentially around the vessel wall for approximately 90°, and then be routed out of the vessel via the existing control rod drive hydraulic system return line.

Because of flow induced vibration, the vertical portion of the instrument line would have to be supported at intermediate points. However, because of limited access and undeveloped underwater welding techniques, it is not presently felt to be possible to attach the line directly to the vessel wall. Therefore, a vertical support, with the instrument line attached, would have to be developed.

The horizontal section of the instrument line would likewise have to be supported by the installation of brackets on the vessel wall. It has been proposed to accomplish this through the use of a lead-lined gondola which has a circular window which could be sealed against the vessel wall for radiation exposure control. A welder could be lowered into the gondola to weld pads and brackets on the vessel clad to support the proposed instrument line. This method has been completely speculative to date.

This replacement method of repair as described above may represent a possible solution, but it is not felt to be a viable method for several reasons:

(A) It is undesirable to make the postulated modifications to the vessel internal clad and to the control rod drive return line.

(B) It is undesirable to have one instrument sensing line routed as described above because of its vulnerability to future damage during vessel maintenance work.

(C) The postulated gondola and other repair methods have never been tried and appear to have many drawbacks.

(D) The personnel radiation exposure related to this repair would be very large.

(E) The costs associated with this repair appear to be far greater than the benefits to be gained.

Justify Operation With the Failed Instrument Line

This method involves a technical evaluation to determine the effects of the failed instrument line on plant operation and safety. This evaluation examined the effect of the failed instrument line on the accuracy of the flow measurement. The effect and ability to detect a jet pump failure using the surveillance as described in current Technical Specifications and the effect on the Emergency Core Cooling System performance analysis. The analysis shows that continued operation with a failed jet pump instrument line is acceptable as long as minor changes are made to Quad-Cities Technical Specifications.

CONCLUSIONS

Based on the factors discussed above, safety, cost and further damage to existing jet pump instrument lines, Quad-Cities believes the prudent course of action is to pursue the Technical Specification change. The analysis (Attachment 2) shows that operation with one failed jet pump instrument line is acceptable. See Attachment 3, Proposed Changes to Technical Specifications for Quad-Cities Unit One Facility Operating License DPR-29; Attachment 4, Summary of Changes; Attachment 5, Safety Evaluation; and Attachment 6, Evaluation of Significant Safety Hazards Consideration Jet Pump Instrumentation.