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William A. Josiger
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May 12, 1989
IP3-89-036

Docket No. 50-286
License No. DPR-64

William J. Russell
Regional Administrator
U.S. Nuclear Regulatory Commission
Region I
475 Allendale Road
King of Prussia, PA 19406

Subject: NRC Bulletin No. 88-04, "Potential Safety - Related Pump Loss"

1. NRC Bulletin No. 88-04: Potential Safety Related Pump Loss, dated May 5, 1988.

2. Letter IP3-88-046, NYPA to Russell, Authority's Response to NRC Bulletin 88-04, dated July 13, 1988.

Dear Mr. Russell:

Reference (1) requested addressee response to the affected pump loss issues presented and licensee justification if applicable for continued operation. Reference (2) provided the Authority's response to the immediate issues presented and provided a justification for continued operation for Indian Point 3. Reference (2) also asserted that the Authority would 1) evaluate the Residual Heat Removal(RHR) system for flow division with respect to Reference (1) Action 2 Items and 2) evaluate the adequacy of the minimum flow bypass lines with respect to damage resulting from operation and testing in the low flow mode for the Safety Injection (SI), Residual Heat Removal(RHR) and Recirculation pumps at Indian Point 3 in accordance with Reference (1) Action 3 Items. This letter with Attachment I provides the Authority's response to the remaining Action Items per Reference (1). Attachment II provides a justification for continued operation pending completion of the remaining long term issues. The Authority confirms that the submittal of this letter with the actions detailed provides compliance with all applicable actions requested per Reference (1).

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Should you or your staff have any questions regarding this matter, please contact Mr. M. Peckham of my staff.

Sincerely

William A. Josiger
Resident Manager
Indian Point Unit 3
Nuclear Power Plant

State of New York
County of Westchester
Subscribed and sworn to before me this

16th day of May 1989

Lorrie A. Hafner

cc: Document Control Desk (original)
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Resident Inspector's Office
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ATTACHMENT I
NRC BULLETIN 88-04
RESPONSE

RESPONSE

The Authority initiated an evaluation with Westinghouse Electric Corporation to determine the adequacy of the existing minimum flow lines for all operating modes, of the Emergency Core Cooling System (ECCS) Pumps. At Indian Point 3, these pumps are as follows:

Safety Injection Pumps - Pacific Pump Model 2.5" JTCH
Residual Heat Removal Pumps - Ingersoll Rand Model 8X20W
Recirculation Pumps - Ingersoll Rand Model 24APK3

For the above pumps, the extent of the evaluation included the thermal and mechanical minimum flow requirements as well as an evaluation of the potential for dead-heading during minimum flow operations.

The evaluation of both the dead heading issue (Action Item 2) and the low flow concerns (Action Item 3) utilizing the Bulletin criteria is summarized as follows:

ACTION ITEM 2 (dead heading issue)

High Head Safety Injection Pumps

The high head safety injection (HHSI) configuration at Indian Point 3 consists of three centrifugal pumps in parallel with a common suction header. The miniflow lines are constructed such that each pump has an individual recirculation line which joins a common miniflow line shared by the other pumps. In this configuration the piping resistance of the mini-flow circuit is essentially concentrated in the individual pump miniflow lines. This resistance is in the form of a multistage high pressure breakdown orifice sized to reduce the pump discharge pressure from approximately 1500 psi to 100 psi at the prescribed minimum flow condition. Consequently, the resistance of the common portion of the miniflow line is very low. As a result, the fluid pressure at the junction points (common lines) is very low relative to the pump discharge pressure upstream of the miniflow orifices. The orifice backpressure at the junction point does not increase to result in a reduction of the individual pump flowrates when all three pumps operate simultaneously in parallel. Essentially the junction point in the common miniflow line acts as a receiver tank or as a common suction header serving the three pumps.

The presence of check valves in the pump discharge lines downstream of the recirculation connections is also significant in preventing a stronger pump from shutting off the weaker pump by blocking the stronger pump from forcing flow through the miniflow line of the weaker pump as well as its own miniflow line.

It is concluded that the potential for a stronger HHSI pump to dead-head a weaker pump does not exist because 1) the line resistances for the miniflow lines are distributed mainly in the non-common portion of the line (i.e., the high pressure breakdown orifices), and 2) the placement of check valves in the pump discharge line downstream of the recirculation connections.

Residual Heat Removal Pumps

The Residual Heat Removal (RHR) pump portion of the low-head safety injection configuration at Indian Point 3 consists of two RHR pumps in parallel with common suction and discharge headers. RHR pump minimum flow is provided by a common line which takes flow downstream of the pumps and RHR heat exchangers and returns it to the pump suction. Because of changes in operational philosophy which resulted in the symptom based Emergency Operating Procedures (EOPs) the RHR pumps with their shared mini-flow configuration are now vulnerable to the dead-heading concern. The windows of vulnerability for the dead-heading of the RHR pumps at Indian Point 3 were previously discussed in Reference (2). The comprehensive evaluation performed while addressing the low flow issues showed that the Reference (2) scenarios and JCO still apply.

The Authority is currently in the process of designing a modification for the RHR mini-flow lines which will mitigate existing pump to pump interaction (dead-heading). This modification will be completed prior to completion of the 7/8 Refueling Outage.

A Justification for Continued Operation (JCO) is provided in Attachment II.

Recirculation Pumps

The containment recirculation pump portion of the low-head safety injection configuration at Indian Point 3 consists of two recirculation pumps in parallel which have a common discharge header. Recirculation pump minimum flow is provided by both an individual miniflow line which takes flow upstream of each pump's discharge check valve and a common recirculation line which takes flow from the discharge header. All three lines return the miniflow back to the recirculation sump.

Unlike the HHSI and RHR pumps, the recirculation pumps do not receive an automatic start signal following a design basis event. The recirculation pumps are manually started during the switch over to cold leg recirculation. Initially, plant emergency operating procedures require only one recirculation pump to be started. The second recirculation pump would only be started if all three emergency diesel generators were available. With this configuration, injection flow to the reactor core would be established prior to the start of the second pump. This configuration would desensitize the system to the dead-heading issue since the pumps would be in the steeper portion of the head/flow curve.

Although the recirculation pumps share a common miniflow line, it is concluded that the potential for a stronger pump to dead-head a weaker pump does not exist because 1) the presence of individual pump miniflow lines upstream of the pump discharge check valves would prevent a stronger pump from forcing flow through the miniflow line of the weaker pump, and 2) the manual start feature would enable the system to be set up for core injection prior to a second pump being started.

ACTION ITEM 3 (low flow concerns)

High Head Safety Injection Pumps

The results of the thermal (flow required to prevent fluid inside the pump from reaching saturation conditions) minimum flow evaluation for the High Head Safety Injection (HHSI) pumps indicated that the required thermal minimum flow was substantially below the actual pump flow for each mode of operation. The actual minimum flow was found adequate to prevent pump overheating, cavitation, and potential short term failure.

The results of the mechanical (flow required to prevent pump mechanical damage at off design flow rates) minimum flow evaluation for the HHSI pumps indicated that the calculated nominal mechanical minimum flow was lower than the actual minimum flow for each mode of operation. Therefore, no indication exists for unusual or accelerated wear as a result of low flow operation.

Based on these results, no changes to plant hardware or procedures are necessary.

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Residual Heat Removal Pumps

The results of the thermal minimum flow evaluation for the RHR pumps indicated that the required thermal minimum flow was substantially below the actual pump flow for each mode of operation. The actual minimum flow was found to be adequate to prevent pump overheating, cavitation, and potential short term failure.

The results of the mechanical minimum flow evaluation for the RHR pumps indicated that the minimum flow rate was adequate for all operational modes except for mid loop operation at Indian Point 3.

The Authority will implement procedural and surveillance enhancements to mitigate long term mechanical minimum flow degradation for mid-loop operation of the RHR pumps. Those enhancements will be completed prior to the next anticipated mid-loop operation of the RHR pumps during the 7/8 Refueling Outage.

Recirculation Pumps

The results of the thermal minimum flow evaluation for the recirculation pumps indicated that the required thermal minimum flow was substantially below the actual pump flow for each mode of operation. The actual minimum flow was found adequate to prevent pump overheating, cavitation, and potential short term failure.

The results of the mechanical minimum flow evaluation for the recirculation pumps indicated that the minimum flow rate was adequate for all operational modes except for surveillance testing, where the calculated mechanical minimum flow was found to be 203 gpm and the actual minimum flow 160 gpm. Since long term mechanical minimum flow damage is a cumulative phenomenon of numerous hours of operation and since the Recirculation Pumps are only operated for approximately 1 hour a year, changes to surveillance procedures to mitigate the long term concerns are not required.

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JUSTIFICATION FOR CONTINUED OPERATION

BACKGROUND

One of the concerns noted in the Bulletin was the adequacy of presently installed safety-related pump minimum flow capacity. Pump minimum flow requirements have been based on thermal rise considerations. Specifically, operation on miniflow should not result in reaching saturation conditions within the pump. The actual flow required to meet this criteria is typically between 5% and 10% of pump flow at the best efficiency point.

The Authority provided the results of the evaluations performed for all ECCS Pump miniflow concerns in Attachment I. Reference was made to the changes necessary to mitigate the RHR pump interactions and low flow concerns based on Bulletin 88-04. Pending completion of necessary modifications and procedural changes, a Justification for Continued Operation (JCO) is provided based on the ability of the RHR pumps to meet their required safety functions.

EVALUATION

The ability of a pump to operate at low flow rates for various time periods depends on various pump characteristics; suction conditions, shaft design, bearing design, etc. To preclude damage, sufficient flow must be provided to prevent both short term and long term failures. Short term failures can be caused by thermal effects, long term failures can be caused by mechanical effects. Based on pump performance history and satisfactory surveillance results, long term wear mechanisms have not had a significant detrimental affect on the RHR pumps. During the time period until modifications and procedural changes are completed, significant degradation from long term mechanisms is not expected. In addition, the RHR pumps are not expected to operate at low flows or on miniflow alone, for long periods of time, while performing their safety functions. Therefore, for this evaluation and JCO, only short term failures for the pumps in question will be considered.

In order to prevent short-term, thermal related catastrophic pump failures, "thermal minimum flow" considerations should be addressed. "Thermal minimum flow" is the flow required to prevent fluid inside the pump from reaching saturation conditions

JUSTIFICATION FOR CONTINUED OPERATION

which could eventually lead to overheating, cavitation, vibration, and potential catastrophic pump failure.
As a centrifugal pump operates at reduced flows, the temperature rise of the fluid passing through the pump is increased due to the pump inefficiency. The pump hydraulic efficiency decreases as the pump flow is reduced. The calculation of the "thermal minimum flow" depends on pump horsepower, efficiency, developed head, and pump suction conditions (NPSH, temperature, pressure). The "thermal minimum flow" is based on pump temperature rise and system NPSH. The pump fluid temperature rise is given by the following equation:

$$Tr = H/(778 \times Cp \times Eff)$$ where:

Tr= pump temperature rise

Cp= fluid specific heat

Eff= Pump efficiency

H = pump developed head

Solving the above equation for efficiency, and utilizing the pump performance curves, the minimum flow required to prevent saturation conditions in the pump suction can be determined. The pump nominal minimum flow should be greater than this calculated "minimum thermal flow" value to prevent cavitation and to assure no short-term failure due to thermal effects.

The following provides an evaluation of the RHR pumps relative to their ability to perform their safety related functions.

Residual Heat Removal Pumps

The Residual Heat Removal (RHR) pumps are used as part of the ECCS to inject water into the RCS following a large break LOCA during the ECCS injection phase of the transient. RHR minimum flow is provided by a common line which takes flow from downstream of the pumps and residual heat exchangers and returns it to the pump suction. Because of this common piping arrangement, the RHR system is subject to the pump-to-pump (dead-heading) interaction problem described in the Bulletin. This problem could cause the stronger of the two pumps to dead-head the weaker pump during low flow, parallel pump operating conditions when the pumps are operating only on minimum flow. The dead-heading could cause a total loss of minimum flow through the dead-headed pump. An evaluation on a similar pump at another

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Westinghouse plant demonstrated that the dead-headed pump could operate for approximately 10 minutes without failure. Continued operation in a dead-headed condition, however, could cause thermal related pump damage.

Following a large break LOCA, the RCS depressurizes and the RHR pumps inject water from the RWST into the RCS cold legs. As the RCS pressure is considerably below the shutoff head of the RHR pumps the pumps will inject into the RCS and do not need to operate on the minimum flow loop.

Following a small break LOCA, the RCS pressure typically remains above the shutoff head of the RHR pumps causing the RHR pumps to operate on minimum flow. Because the RCS pressure does not fall below the shutoff head, however, no credit is taken for RHR injection to mitigate the small break LOCAs.

Long term cooling, following LOCA events, is provided by ECCS recirculation. During this phase of ECCS cooling, the recirculation pumps take suction from the recirculation sump inside containment and return water to the RCS either directly or via the SI pumps. The RHR pumps provide a backup capability to provide this recirculation function, but are not required to meet post-LOCA long term cooling requirements.

In summary, the possibility for pump-to-pump interaction while the RHR pumps are operating on minimum flow, will not affect the ability of the ECCS to mitigate LOCA events. The ability to meet the requirements of GDC 35 and 10 CFR 50.46 are, therefore, not affected by the RHR pump-to-pump interaction issue.

The RHR pumps, however, do provide the ability to cool the reactor following many postulated accident events. This ability is credited in the radiological consequences analyses performed for the non-LOCA and Steam Generator Tube Rupture event presented in FSAR Chapter 14. For these scenarios, if an "SI" signal is generated during the event, the RHR pumps will start and operate on miniflow. If both pumps start, pump-to-pump interaction could cause the weaker pump to dead-head with subsequent damage likely. The remaining pump will continue to operate on miniflow. Within approximately 30 minutes, the operating pump would be shutoff until it was needed for RHR cooling.

An evaluation has been performed by Westinghouse to determine the

JUSTIFICATION FOR CONTINUED OPERATION

ability of one pump to operate on minimum flow during the early part of these non-LOCA transients. The evaluation considered the suction conditions present in the system. The required "thermal minimum flow" was calculated by Westinghouse to be approximately 50 gpm. The nominal available miniflow is approximately 450 gpm and, therefore no short-term catastrophic failure due to adverse thermal effects are expected for this situation. It is considered unlikely that the stronger RHR pump, which had run successfully for some period of time at the beginning of the transient, would fail to operate when required during the controlled process of placing the plant onto RHR cooling several hours later during the recovery from the postulated events. Therefore, at least one RHR pump should be available to provide RHR cooling during the long term recovery following non-LOCA transients.

Summary and Conclusion

The above evaluation for pump minimum flow capabilities indicates that the Indian Point 3 Residual Heat Removal pumps will be able to perform their safety functions considering the available minimum flows, without causing any undue damage to the pumps. It is therefore concluded, that the RHR pumps are adequate to meet minimum flow capabilities, as designed, and continued operation is acceptable while modifications are under development and implementation to further mitigate any Bulletin 88-04 concerns.