NORTHEAST UTILITIES
THE CONNECTICUT LIGHT AND POWER COMPANY
WESTERN MASSACHUSETTS ELECTRIC COMPANY
HOLYOKE WATER POWER COMPANY
NORTHEAST UTILITIES SERVICE COMPANY
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June 16, 1989

Docket Nos. 50-213
50-245
50-336
50-423
A07218

Re: NRC Bulletin No. 88-04

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington DC 20555

Gentlemen:

References: (1) C. E. Rossi Letter to Licensees, dated May 5, 1988, Transmitting NRC Bulletin No. 88-04, "Potential Safety-Related Pump Loss."

(2) E. J. Mroczka Letter to U.S. NRC, dated June 30, 1988, Response to NRC Bulletin No. 88-04, "Potential Safety-Related Pump Loss."

(3) E. J. Mroczka Letter to U.S. NRC, dated January 10, 1989, Response to NRC Bulletin No. 88-04, "Potential Safety-Related Pump Loss."

(4) E. J. Mroczka Letter to U.S. NRC, dated May 3, 1989, Response to NRC Bulletin No. 88-04, "Potential Safety-Related Pump Loss."

Haddam Neck Plant
Millstone Nuclear Power Station, Unit Nos. 1, 2, and 3
Response to NRC Bulletin No. 88-04
Potential Safety-Related Pump Loss

Reference (1) requested licensees to evaluate safety-related centrifugal pumps to ensure that pump damage will not occur during normal or

IE11
1/1

emergency operation at or near shut-off head with inadequately designed minimum-flow lines. References (2), (3), and (4) reported the status of our investigation into the concerns of Reference (1). The purpose of this letter is to provide the final report to the NRC Staff on the analyses completed to address this issue.

Reference (1) requested an assessment of the potential for pump deadheading when pumps installed in parallel are operating simultaneously at minimum-flow through shared minimum-flow lines. The premise behind this request was that a stronger pump's minimum-flow could overpower and backup a weaker pump's minimum-flow at the point of junction of the shared lines. Analyses have concluded that such interactions are not a concern in our safety-related pumps. These analyses can be summarized as follows:

- Some parallel pump installations are protected from minimum-flow interaction by procedures which prevent their simultaneous operation.

- Most parallel pump minimum-flow installations contain individual restricting orifices (or throttle valves). The shared minimum-flow lines downstream of these orifices are generally larger than the individual pump minimum-flow lines. This configuration prevents pressure build-up on the downstream sides of the orifices, which precludes the type of minimum-flow interaction discussed in Bulletin No. 88-04. This point has been proven analytically for Millstone Unit No. 2 low pressure safety injection and high pressure safety injection pumps installed and operated in parallel. This point has been proven empirically at Millstone Unit No. 1 in a special test. This test measured low pressure coolant pump minimum-flows individually and while the pumps were operating together. No differences in minimum-flow were recorded.

It is important to note that the analytical and empirical techniques discussed above did indicate that pump interaction does occur through shared minimum-flow lines. However, the magnitude of this interaction was found to be small because of the pressure drop designed into the minimum-flow configurations analyzed. It was determined that minimum-flow of a weak pump could be reduced by 1 gpm or less by a stronger pump operating against it. Interactions of this low magnitude are expected regardless of pump degradation or worst case combinations of instrument error. These analytical and empirical results corroborate Reference (2) which stated that:

> "All pumps listed ... have minimum-flow lines containing flow restricting orifices or throttle valves. These flow restrictions are located such that a significant pressure drop occurs prior to the point at which the separate minimum-flow lines discharge to a common section of piping. This configuration should effectively preclude deadheading of any pumps."

The analytical approaches discussed above encompass all of the shared minimum-flow configurations requiring evaluation under NRC Bulletin No. 88-04. Therefore, no further individual pump interaction analyses are necessary.

Reference (1) also requested an assessment of the adequacy of the minimum-flow provided for safety-related pumps. The concept behind this request is that contemporary design philosophy calls for larger minimum-flows than originally provided. The following techniques were used to demonstrate that the minimum-flows provided for safety-related pumps at the three Millstone Units and Haddam Neck are appropriate.

- o Vendors were contacted for their evaluation, advice, and historical data.

- o Maintenance records for all pumps that are operated at minimum-flow were reviewed and evaluated. The objective was to find wear or failure trends indicative of chronic minimum-flow damage. No such patterns were discovered.

- o In-service testing (IST) data was reviewed and evaluated. The objective was to find trends which were indicative of pump degradation due to inadequate minimum-flow. No such trends were found. Instead, it was concluded that IST would identify and correct any chronic minimum-flow induced damage before it could lead to any significant degradation in pump performance or availability.

- o Special tests for certain critical pumps were conducted and evaluated to show that minimum-flow is sufficient to prevent overheating. In some cases, as applicable, analyses were performed to factor in higher minimum-flow water temperatures after a LOCA. Results in these special cases concluded that minimum-flows are adequate.

- o Vibration spectral plots for all pumps in question were evaluated. The objective was to look for evidence of impeller recirculation induced vibration spikes, or severe cavitation at minimum-flow. In all cases, it was concluded that vibration due to impeller recirculation and cavitation, if present, was within acceptable ranges. That is, such vibration will not lead to eventual failure of the pumps.

While it was generally found that the minimum-flows provided for our safety-related pumps are below the large minimum-flows suggested by the NRC staff in Bulletin No. 88-04, it was concluded that the minimum-flows provided are sufficient.

Extensive research to determine the possibility of minimum-flow related problems has therefore been completed. No evidence of minimum-flow related damage has been found and it is concluded that adequate minimum-flow exists for all normal, surveillance, and emergency conditions for all safety-related pumps at Millstone and Haddam Neck. Attachments 1 and 2 of Reference (4) have been updated to reflect the completed evaluations and are included herein as Attachments 1 and 2.

If there are any questions, please do not hesitate to contact us.

Very truly yours,
CONNECTICUT YANKEE ATOMIC POWER COMPANY
NORTHEAST NUCLEAR ENERGY COMPANY

E. J. Mroczka

E. J. Mroczka
Senior Vice President

C. F. Sears

By: C. F. Sears
Vice President

STATE OF CONNECTICUT)
) ss. Berlin
COUNTY OF HARTFORD)

Then personally appeared before me, C. F. Sears, who being duly sworn, did state that he is Vice President of Northeast Nuclear Energy Company and Connecticut Yankee Atomic Power Company, Licensees herein, that he is authorized to execute and file the foregoing information in the name and on behalf of the Licensees herein, and that the statements contained in said information are true and correct to the best of his knowledge and belief.

Lynn M. Sheridan
Notary Public

cc: W. T. Russell, Region I Administrator
M. J. Boyle, NRC Project Manager, Millstone Unit No. 1
G. S. Vissing, NRC Project Manager, Millstone Unit No. 2
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Docket Nos. 50-213
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ATTACHMENT 1

HADDAM NECK PLANT
MILLSTONE NUCLEAR POWER STATION, UNIT NOS. 1, 2, AND 3

NRC BULLETIN 88-04, "POTENTIAL SAFETY RELATED PUMP LOSS"
CUMULATIVE PUMP OPERATING TIME AT MINIMUM-FLOW,
MAINTENANCE HISTORY, AND ASSESSMENT OF POTENTIAL DAMAGE

JUNE 1989

NRC BULLETIN 88-04
CUMULATIVE PUMP OPERATING TIME AT MINIMUM-FLOW
MAINTENANCE HISTORY AND ASSESSMENT OF POTENTIAL DAMAGE

GENERAL COMMENTS

Centrifugal pumps are started against isolated discharge piping to prevent the possibility of runout and cavitation. Therefore, centrifugal pumps are limited to minimum-flow until their discharge paths are opened at each start-up. The estimation of cumulative pump operating time at minimum-flow is done primarily by estimating the number of times a pump is started in a given time period and how long it operates at minimum-flow during each start. Since mini-flow operation has not been limited by pump manufacturers, total time at shut-off/minimum-flow operation has not been restricted or logged for each pump start-up. The start frequencies were estimated by taking into consideration increased operation as a result of in-service testing requirements and tank charging as well as normal surveillance testing. These estimates are provided for each pump.

A pump's maintenance history can give an indication of the occurrence of damage due to cumulative operating time at shut-off/minimum-flow. This mode of pump operation generally results in higher operating temperatures and increased vibration. High temperature and vibration can produce the following types of pump damage:

- o Wear or scoring of wear rings.
- o Premature wear in bearings.
- o Erosion of impellers or pump casings.
- o Accelerated packing or seal deterioration, wear, or failure.
- o Blackening of lubricating oils due to the production of carbon particles.
- o Crack formation at mounting lugs.
- o Degradation of mounting pedestals.

If maintenance records indicate that these types of problems are occurring on a regular basis, one of several possible causes is a minimum-flow related problem in the affected pump. Conversely, if there is no history of these types of problems, it can be reasonably assumed that limited operation at the existing minimum-flow is not producing measurable damage. Normal maintenance is expected to correct or limit any damage accumulation due to minimum-flow in the latter case.

Millstone Unit No. 1

Estimated Cumulative Operating Time (at minimum-flow since start of commercial operations in 12/70):

- o 28 hours for the most used low pressure coolant injection pump (based on 648 starts in 18 years, 2.6 minutes at minimum-flow per start).
- o 9.4 hours for each core spray pump (based on 216 starts in 18 years, 2.6 minutes at minimum-flow per start).
- o 9 hours for each shutdown cooling (SC) pump (based on an estimated 36 minimum-flow tests in 18 years, 15 minutes at minimum-flow/test).

Maintenance History (only nonroutine maintenance, or maintenance that could be attributed to minimum-flow damage is listed here):

Low pressure coolant injection (LPCI) pumps (Note: All LPCI pumps had their supports upgraded in 7/87).

M8-75A

- o Sediment in oil on 4/21/86.
- o Disassembled, inspected, and overhauled in 1980, due to site engineering recommendation based on In-Service Testing (IST) vibration data.
- o This pump is the most frequently used pump. Its vibration has been increasing, although this increase has been small and has remained acceptable. It is judged to be from normal wear and other nonminimum-flow related phenomena.

M8-75B

- o Sediment in oil on 4/21/86.

M8-75C

- o Leaking cartridge seal in 7/88; checked motor bearing end play at the same time--nothing unusual recorded with work order.

M8-75D

- o In 11/77, the pump was disassembled, inspected, and overhauled when its discharge pressure dropped significantly. An eyebolt was found to be interfering with the pump's rotating parts.

- In 10/87, the pump started to approach its vibration IST limits. Rebalancing dropped vibration back into an acceptable range.

- In 8/88, the shaft cartridge seal leaked after a period of use for torus cooling, then it stopped leaking. The seal was repositioned and the coupling was realigned.

Core spray (CS) pumps (Note: Both CS pumps had their supports upgraded in 7/87).

M8-74A

- This pump has a history of lubricating oil leaks. (The pump is water lubricated. The motor bearings are oil lubricated.)

M8-74B

- This pump has a history of bearing cooling water to bearing lubricating oil leakage. Occurrences of this leakage were noted in 1982, 1985, 1986, and 1988. This pump also shows a history of increasing vibration. This increase is small and acceptable. It is judged to be from normal wear and other nonminimum-flow related phenomena.

Shutdown Cooling Pumps

M8-53A

- An oil leak at the pump was repaired on 4/7/81.

- A deteriorating pump/motor coupling was repaired on 1/14/86; both were loosening. Some damaged gasket material was replaced.

- The coupling was disassembled and inspected on 8/27/86, due to excessive grease leakage. It was noted that the wrong parts were installed. The correct parts were re-installed at this time.

- The pump was overhauled and inspected in February 1987. Previous coupling problems and vibrations appear to be the motivations for this inspection. Many new parts were installed. No damage or wear was noted.

M8-53B

- Pump was overhauled in November 1982.

- Re-tightened coupling bolts (1/14/86).

- o Removed and inspected motor/pump coupling on 8/27/86 due to excessive grease leakage. Re-installed the correct parts at this time after it was noted that parts with incorrect numbers were being used.

- o Disassembled and inspected pump on 8/29/86. Pump was found to be in satisfactory condition. It is believed the overhaul was performed to verify that the use of the wrong coupling did not damage the pump.

Assessment of Potential Damage

There are no indications that the pumps are being damaged due to operation at minimum-flow or inadequate minimum-flow.

The overhauls of the LPCI pumps performed in 1978 and 1980 did not reveal any of the following indications of minimum-flow induced wear:

- o Scoring of wear rings.

- o Premature shaft sleeve or bearing deterioration.

- o Flow induced erosion on the impeller or pump case.

- o Crack formation at mounting points.

The following potential symptoms of minimum-flow induced damage have been evaluated:

- o Mechanical cartridge seal failures on the "C" and "D" LPCI pumps - one failure per pump, during 18 years of service. This is not considered conclusive evidence of minimum-flow damage.

- o Sediment in lubricating oil--this is not considered symptomatic of minimum-flow damage because it is occurring on the oil lubricated motor end of these vertical pumps. The pumps are water-lubricated. Overheating at minimum-flow would occur at the pump, not at the motor bearings.

- o Degradation of the mounting pedestals--this problem may be due to vibration, which has been increasing on the most used, "A" LPCI pump and the "B" CS pump. However, this vibration may be due to transmission of vibration from downstream piping back to the pump, manual readjustments to the balancing (e.g., "D" LPCI in 1987), or improper mounting. (Stud embedment problems, aggravated by a cantilevered mounting design. Note that the mountings were modified in 7/87 to correct this problem[1].)

The cartridge seal, bearing oil/water contamination, and increased vibration discussed above could be indications of impeller recirculation at minimum-flow. If impeller recirculation is severe enough to induce vibration, it could produce seal and bearing cooling related damage. However, these results could be random, or due to other vibratory modes not associated with minimum-flow (e.g., vibrating piping driving the pump into a damaging vibratory mode). The most frequently used LPCI pump (the "A" pump) experiences the most vibration. The "D" LPCI pump has also had problems (vibration and otherwise). This could be the result of the 1977 incident in which an eyebolt was found to be interfering with operation of the pump.

The shutdown cooling pump maintenance history outlined above does not give any indications of persistent minimum-flow related problems.

In summary, it can be stated that there is no pattern of minimum-flow related pump damage in the unit's pumps after 18 years of operation. If pump vibration increases, a pump overhaul will be considered. Therefore, it is concluded that in-service testing of each of these pumps on a monthly basis will provide a means of identifying and correcting minimum-flow related damage before it can significantly degrade the availability or performance of these pumps.

Millstone Unit No. 2

Estimated Cumulative Operating Time (at minimum-flow since start of commercial operations 12/75):

- All of the Millstone Unit No. 2 ECCS pumps discussed in this section are estimated to have the same cumulative operating time at minimum-flow: 58 hours.

- The cumulative times for these pumps are the same because they receive the same in-service tests on the same test schedule. This testing has resulted in approximately 174 minimum-flow tests, with an average duration at minimum-flow of 20 minutes per test, in 13.5 years of commercial operation.

1. For additional details, see E. C. Wenzinger letter to E. J. Mroczka, "Routine-Inspection 50-245/87-12 (6/23/87 - 8/10/87)," dated August 24, 1987.

o The motor-driven auxiliary feed pumps can be run at shut-off/minimum-flow during steam generator filling. Cumulative time at minimum-flow due to this operational evolution has not been included in this evaluation due to the difficulty in obtaining accurate assessments of this time and the limited value of this information. This is based on the assessment that 58+ hours of minimum-flow operating time is enough to demonstrate adverse affects of inadequate minimum-flow. Also, evaluations of vibration spectral plots can assess the long-term impacts of minimum-flow operation regardless of cumulative operating time at minimum-flow.

Maintenance History (only non-routine maintenance, or maintenance that could be attributed to minimum-flow damage is listed here)

High Pressure Safety Injection Pumps

P-41A

o Pump overhaul in 8/76; machining of pump internals was done at this time.

o There are several notations of the need for motor oil between 1976 and 1979.

o An outboard thrust bearing was replaced in 7/78.

o The pump seized on 6/18/84 due to improper reassembly after overhaul. The pump was overhauled due to failure as a result of operation with suction inadvertently isolated.

o One instance of boric acid leakage at both ends of the pump shaft was reported on 9/26/87; repair was limited to cleanup.

P-41B

o Several instances of lube oil refill reported in 1979.

o Leaks and boron build-up on suction flanges; corrective action limited to cleaning (10/5/87).

P-41C

o Outboard pump thrust bearing failed and replaced (3/11/88).

Low Pressure Safety Injection Pumps

P-42A

o Repaired pump seal (3/76).

o Impeller nut fell off; pump disassembled to repair (10/16/86).

P-42B

- o Leaks at casing seam and boron build-up; special gaskets ordered (10/27/87).

Containment Spray Pumps

P-43A

- o Nothing of significance to this bulletin was identified.

P-43B

- o Abrasive pump sound during 8/09/85 shutdown led to pump disassembly; pump bearings and seals were replaced.

Auxiliary Feed Pump (Turbine Driven; P-4)

- o Required bearing oil in 1976.
- o Inboard pump packing leak was observed during operation (repaired on 4/25/83).

Auxiliary Feed Pumps (Motor Driven)

P-9A

- o Replaced pump shaft (3/11/78; P-9B's shaft was replaced at same time).
- o Repacked pump seals to stop leakage (2/22/80).
- o Water in outboard bearing compartment (10/10/85 and 12/5/85).
- o Shaft seal leak on 11/09/85.
- o Removed and overhauled on normal preventive maintenance schedule on 11/01/86.
- o Thrust bearings replaced due to excessive clearances after overhaul in 1989.

P-9B

- o Replaced thrust bearing (7/77).
- o Replaced pump shaft (3/11/78); P-9A's was replaced at the same time.
- o Installed new packing to stop leakage (3/23/80).

- o Adjusted packing to stop leakage (1/11/83 and 12/29/83).
- o Repacked seals (inboard and outboard - 1/4/84).
- o Seal leakage between pump and motor (6/18/84); tightened packing.

Assessment of Potential Damage

There are no indications that the pumps listed above are being damaged due to operation at minimum-flow or inadequate minimum-flow.

The high pressure safety injection (HPSI) pumps did have a significant amount of internal modification in the first year of operation (1975-1976). This work was primarily due to re-machining of the balancing drum and sleeve to achieve proper shaft thrust balance. Some thrust bearing replacements are also reported in this time period, which is to be expected if shaft thrust balancing is not correct. The incidence of thrust bearing replacement has gone down significantly since completion of this early hydraulic balancing effort (i.e., the "A" HPSI pump had a thrust bearing replacement in 1978; the "C" HPSI pump had a bearing replacement in 1988).

The thrust balancing achieved by properly sizing the balancing drum and sleeve of pumps like the HPSI pumps is achieved by building an internal minimum-flow into the pump. The space between the balance drum and sleeve provides a leakage path from the pump discharge chamber to the pump suction chamber (i.e., an internal recirculation/minimum-flow path). The early modifications to the HPSI pumps were additions of minimum-flow to that provided externally by the orificed minimum-flow lines.

The few incidents of flange leakage, shaft seal leakage and motor oil addition reported for the three HPSI pumps in their 13 years of operation are considered routine and insignificant.

The low pressure safety injection (LPSI), containment spray (CS) and turbine driven auxiliary feed (AF) pumps do not show any consistent patterns of maintenance that are symptomatic of minimum-flow induced damage. The few occurrences of leakage or overhaul appear to be random. Consequently, they are concluded to be of no significance to minimum-flow evaluations.

The maintenance histories of the two motor-driven AF pumps does indicate that seal leakage repairs are required sporadically. Since the frequency of these repairs varies from six months (1/4/84 to 6/18/84 for P-9B) to five years (2/22/80 to 11/9/85 for P-9A), it is not considered to be evidence of a minimum-flow related problem.

Both motor-driven AF pumps had their shafts replaced in 1978. Pump shaft replacement would not generally be associated with minimum-flow related problems unless seal or bearing problems due to inadequate minimum-flow resulted in shaft scoring, warping, etc. There is no evidence of bearing or seal problems before these shaft replacements. Also, these one time replacements have been followed by 10 years of trouble free operation. Therefore, this shaft replacement is considered to be of no significance to minimum-flow evaluations for these pumps.

In summary, it can be stated that there are no patterns of minimum-flow related pump damage in 13 years of maintenance history. The frequent in-service testing (IST) the subject pumps receive will lead to identification and correction of any minimum-flow related problems before they can result in significant damage.

Millstone Unit No. 3

Estimated Cumulative Operating Time (at minimum-flow since start of periodic testing in 11/85; commercial operations began in 4/86):

- 6.5 hours for the most tested charging pump (based on 13 minimum-flow tests at 30 minutes per test).
- 4.7 hours for either high pressure safety injection pump (based on 14 minimum-flow tests at 20 minutes per test).
- 15 hours for the most tested residual heat removal pump (based on 15 minimum-flow tests at one hour per test).
- 9.75 hours for the motor-driven auxiliary feed pumps (based on 39 minimum-flow tests at 15 minutes per test). The motor-driven auxiliary feed pumps can be run at shut-off/minimum-flow during steam generator filling. Cumulative time at minimum-flow due to this operational evolution has not been included in this evaluation due to the difficulty in obtaining accurate assessments of this time and the limited value of this information. This is based on the assessment that vibration spectral analyses will predict the long-term impacts of minimum-flow operation regardless of cumulative operating time at minimum-flow.
- 39 hours for the turbine driven auxiliary feed pump (based on 39 minimum-flow tests at 1 hour per test).

Maintenance History (only nonroutine maintenance or maintenance that could be attributed to minimum-flow damage is listed here):

Charging Pumps

3CHS*P3A

- Nothing significant to the subject bulletin was found.

3CHS*P3B

- o Motor bearing oil became dirty during a two-hour run; this run was during start-up of the plant (i.e., precommercial operations; date was 12/3/84).

3CHS*P3C

- o Pump seized during operation with suction valve shut (5/17/88); pump was replaced.

Safety Injection Pumps

3SIH*P1A

- o Water leaks at suction flange and casing joints during start-up program; also dirty motor oil (1/21/85).
- o Mechanical seal leakage (on shaft of pump) recorded on 7/15/88; seal replaced on 8/29/88.

3SIH*P1B

- o Mechanical shaft seal leakage reported on 8/29/88; no work performed at this time.

Residual Heat Removal Pumps

3RHS*P1A

- o Water contamination of motor bearing oil noted during plant start-up program (3/26/85); miscellaneous small oil leaks during start-up.

3RHS*P1B

- o Water contamination of motor bearing oil noted during plant start-up program (3/26/85).

Auxiliary Feed Motor-Driven Pumps

3FWA*P1A

- o No significant maintenance entries were found.

3FWA*P1B

- o The motor tripped for an unknown reason at startup (1/29/87). Electric checkout of motor and mechanical checkout of the pump did not disclose any problems. Pump performed normally after this faulty start and checks.

Auxiliary Feed Turbine Driven Pump

3FWA*P2

- Nothing of significance to Bulletin 88-04 was discovered in maintenance history.

Assessment of Potential Damage

There are no indications that the pumps are being damaged due to operation at minimum-flow.

None of the charging pump maintenance discussed above is indicative of excessive pump vibration or overheating.

The water leakage and dirty motor bearing oil reported during start-up for the safety injection pumps are considered to be normal occurrences related to installation and initial testing. The incidents of mechanical shaft seal leakage reported for both safety injection pumps may have significance. More operating/maintenance history is necessary before any association of this seal leakage with minimum-flow can be made.

The residual heat removal pump maintenance provided above is not considered to be related to pump operation at minimum-flow.

Nothing indicative of problems at minimum-flow was found in the maintenance histories of the auxiliary feed pumps.

In summary, it can be stated that there are no patterns of minimum-flow related pump damage at Millstone Unit No. 3 after approximately three years of commercial operation. It is also concluded that in-service testing of these pumps will identify and lead to correction of minimum-flow related damage, if it should occur, before it can significantly degrade pump performance and availability.

Haddam Neck Plant

Estimated Cumulative Operating Time (at minimum-flow since start of periodic testing in 1970 (for safety Class 1 items) and 1978 (for safety Class 2 and 3 items). Commercial operations began in January 1968.

- The auxiliary feed pumps are estimated to have cumulative operating times at minimum-flow of approximately 75.7 hr./each. This duration is based on an estimated 85 quarterly tests (resulting in 22.5 minutes at minimum-flow each) and 137 monthly operational availability tests (resulting in 20 minutes at minimum-flow each).

- The charging pumps are routinely tested at normal flow rates, not at minimum flow. Therefore, it can be assumed that these pumps have accumulated very little operating time at minimum-flow. For the purposes of analysis, it is estimated that each pump has accumulated ten hours or less of minimum-flow operating time.

- The high pressure safety injection pumps are estimated to each have approximately 63.5 hours of operation at minimum-flow. This duration is based on an estimated 85 quarterly minimum-flow tests (30 min/ea.) plus two additional monthly tests per year (30 min./ea.).

- The low pressure safety injection pumps are estimated to each have approximately 47.6 hours of operation at minimum-flow. This duration is based on an estimated 85 quarterly minimum-flow tests (22.5 min./ea.) plus two additional monthly minimum-flow tests per year (22.5 min./ea.).

- The residual heat removal pumps are each estimated to have 35.3 hours of operation at minimum-flow. This duration is based on an estimated 85 quarterly minimum-flow tests (20 min./ea.) plus two additional monthly minimum-flow tests every two years (20 min./ea.).

Maintenance history (only non-routine maintenance that could be attributed to minimum-flow damage is listed here):

Auxiliary Feed Pumps

P-32-1A

- Pump was disassembled and inspected for damage after unexplained debris was found in a pump discharge check valve. No significant damage (6/3/80).

- Pump overhauled (10/28/87) due to high vibration (in the alert range).

- Seal leakage was found and repaired (3/14/88).

- Pump disassembled and overhauled due to binding (5/23/88).

- Additional vibration testing performed to identify the source of vibration in the alert range (6/9/88).

- Coupling alignment is suspected as the source of excessive vibration. Coupling re-alignment performed on 7/11/88.

- Vibration is still a problem on 8/11/88. Coupling re-alignment is performed again. A thrust bearing is replaced.

- o Vibration is found to be in the action range (9/9/88). Dimension checks on coupling are performed. Coupling key is moved 90° from its original location as a possible cure. No further vibration problems have been encountered.

P-32-1B

- o Repacked a water supply seal on bottom of pump to stop leakage (2/4/76).
- o Pump is disassembled to check for possible debris damage after unexplained debris is found in a discharge check valve (6/3/80). No damage was found.
- o Replaced shaft cartridge seal and a thrust bearing (11/7/81).
- o Replaced shaft packing, sleeve, and bearing on 1/31/83.
- o Dark oil reported on both ends of pump. Oil is changed (12/22/87).
- o Adjusted packing to stop a shaft leak (3/14/88).

Charging Pumps

P-18-1A

- o A pump seal was removed, inspected, and reinstalled with a new O-ring; probably due to leakage (1/26/76).
- o Pump was replaced in the summer of 1984. Objective was to get a new pump in place with a modified rotating assembly. This modification was made to eliminate stress concentrations that were leading to shaft failures.
- o Pump shaft broke (5/22/85). Rotating assembly replaced at this time.
- o Found brass chips in motor bearing oil, esp. at coupling end (1/18/86).
- o Shaft breaks again on 7/9/86. Replaced with a reworked impeller at this time.
- o Noisy recirculation leads to measurement of minimum-flow (3/12/87). High-pitched noise observed at 102 gpm. Noise went away when orifice bypass throttle valve adjusted to produce 109 gpm total minimum-flow.

- o Found debris in lube oil filter (8/28/87). Identified as gasket material and possibly some Babbitt material. Gasket material replaced; oil changed.

- o Shaft breaks again (8/8/88). Pump disassembled and shaft is replaced.

P-18-1B

- o Pump motor bearing replaced on 6/16/75.

- o Replaced pump shaft on 1/10/83; done during pump overhaul.

- o Install new shaft cartridge seal, shaft housing sleeve (for seal), and locking collar (10/17/83).

- o Replaced outboard seal (7/10/80).

- o Motor bearing failure. Pump noise also reported. Start circuitry modifications and electrical tests seem to have been initiated because of this failure. A new motor was installed on 10/24/84.

- o Miscellaneous minor oil leaks (usually at sight glasses) reported from 1984 - present.

High Pressure Safety Injection (HPSI) Pumps

P-15-1A

- o Overhauled pump (5/25/73).

- o Misalignment of booster pump to this HPSI pump was producing an abnormal axial load. Problem was corrected (9/11/84).

- o Vibration and temperature readings checked with pump at minimum-flow (3/3/87). No problems reported.

- o Boric acid build-up on seal housing was found and cleaned up (4/14/88). A seal bolt was tightened to correct the problem.

- o Periodic problems with hold down bolt tightness on booster pump end.

P-15-1B

- o Overhauled pump (3/12/73).

- o Repaired seal water leaks (6/5/81).

- o Problems with loose hold-down bolts reported several times.

- o Vibration and temperature readings taken with pump at minimum-flow (3/3/87). No problems reported.

- o Vibration in the alert range recorded (9/6/88). Corrective action was the tightening of loose hold-down bolts.

Low Pressure Safety Injection (LPSI) Pumps

P-92-1A

- o Checked vibration during monthly ECCS IST (10/7/88). No problems recorded in work order history.

P-92-1B

- o Checked vibration during monthly ECCS IST (10/7/88). No problems recorded in work order history.

Residual Heat Removal (RHR) Pumps

P-14-1A

- o Replaced leaky gland seal (8/9/84). Rebuilt pump in the process of making this repair.

- o Pump found to be missing alignment jacking bolts and brackets (9/10/87). These were fabricated and installed at this time.

- o Repaired leaking fittings on gland seal cooler (12/23/87).

P-14-1B

- o High seal water temperature (3/5/81).

- o Black pump motor bearing oil reported during scheduled preventative maintenance (1/5/87). Oil drained and replaced.

- o Pump found to be missing alignment jacking bolts and brackets (9/10/82). These were fabricated and installed at this time.

<u>Assessment of Potential Damage</u>

<u>Auxiliary Feed Pumps</u>

These pumps demonstrate a history of maintenance that could be attributable tc cumulative damage occurring at minimum-flow. For example:

- o The P-32-1A pump has experienced vibration, binding, and seal leakage since June 1980.

- The P-32-1B pump has experienced darkened oil and frequent shaft seal replacements since June of 1980.

The key factor in this history seems to be the overhauls that both pumps received in 1980. These overhauls were performed to look for damage when debris was discovered downstream of the pumps in a discharge check valve. There is no evidence that debris damage was found.

There is evidence that vibration problems developed in P-32-1A from pump to motor coupling misalignment after the 1980 overhaul. The coupling changes made in September of 1988 should cure any persistent alignment problems and their resultant vibration.

The blackening of pump bearing oil reported for P-32-1B may not be attributable to pump heat-up at minimum-flow. The bearings on Worthington Model #3WTF pumps are supported away from the impeller retaining section of the pump casing. Therefore, they will not be heated directly by water churning at minimum-flow. The bearing heating that darkened the oil of P-32-1B in December of 1987 could be due to incorrect bearing preloading, cyclic bearing loading due to coupling misalignment, or bearing loading due to inadequate radial shaft support on the thrust bearing end of the pump (i.e., one end of pump is supported on a sleeve and a thrust bearing). These types of problems could also explain the frequent recurrence of shaft seal leakage on P-32-1B.

These problems may be caused by factors other than inadequate minimum flow, principally pump/driver alignment. Normal IST and maintenance has, and will continue to, maintain the pumps' reliability.

Charging Pumps

The charging pumps do not show any history of maintenance attributable to inadequate minimum-flow. This is logical considering that the charging pumps are provided with minimum-flows that are greater than 28 percent of rated design flow (note the maintenance entry that minimum-flow whine occurs when minimum-flows are set below 109 gpm).

The dominant failure mode reported for the charging pumps is shaft failure. This type of failure is not generally attributable to inadequate minimum-flow. Shaft failures explain some of the other maintenance reported for the P-18-1A and P-18-1B pumps.

The P-18-1B pump has demonstrated a history of motor problems. It is believed that one of the motor bearing failures reported for this pump is a random failure, while the second is attributed to a motor start circuitry problem.

The outboard shaft seal failure reported for P-18-1B in July of 1980 is considered to be a random occurrence.

In summary, there is no evidence of inadequate minimum-flow in the charging pump maintenance history.

HPSI Pumps

It appears that vibration in these pumps tends to loosen their hold down bolts. The vibration that is being experienced is primarily due to periods of operation at minimum-flow. This could be a manifestation of a minimum-flow related problem, or it could be a manifestation of a pump mounting problem. The latter seems more consistent with the maintenance entries reported. Vibration appears to start out in an acceptable range after pump overhaul. It increases as hold down bolts loosen. If minimum-flow was the cause of excessive vibration, it would be evident immediately after overhaul and consistently throughout the years.

The other maintenance items entered for these pumps are considered to be random and normal (i.e., not significant indicators with respect to NRC Bulletin 88-04).

In summary, the maintenance histories of the HPSI pumps do not indicate the presence of minimum-flow problems.

LPSI Pumps

There is no evidence of minimum-flow related problems in the LPSI pump maintenance histories.

RHR Pumps

There is very little in the maintenance history of the the RHR pumps that can be associated with problems at minimum-flow. The "A" pump has two occurrences of gland seal repairs (in 1984 and 1987). The "B" pump has one occurrence of blackened motor bearing oil. This was attributed to improper throttling of cooling water flow during a special test.

The two gland seal maintenance entries are considered insignificant in 21 years of operating history.

In summary, the maintenance history for the CY RHR pumps does not show evidence of inadequate minimum-flow.

Conclusions

There are no patterns of minimum-flow related damage in the charging, LPSI and RHR pump maintenance histories.

There are some patterns in the maintenance histories for the auxiliary feed and HPSI pumps that could be attributed to inadequate minimum-flow. However, there are other factors which could be leading to the indicated maintenance. Therefore, it can be stated that there are no clear-cut indications of minimum-flow related problems in the auxiliary feed and HPSI pumps.

These problems may be caused by factors other than inadequate minimum flow, principally pump/driver alignment. Normal IST and maintenance has, and will continue to, maintain the pumps' reliability.

Docket Nos. 50-213
50-245
50-336
50-423
A07218

ATTACHMENT 2

HADDAM NECK PLANT
MILLSTONE NUCLEAR POWER STATION, UNIT NOS. 1, 2, AND 3

NRC BULLETIN 88-04, "POTENTIAL SAFETY-RELATED PUMP LOSS"
ASSESSMENT OF PUMP SECTION XI TEST HISTORY

JUNE 1989

Millstone Unit 1

Core Spray (CS) and Low Pressure Coolant Injection Pumps

In general, there has been no significant change in the discharge pressure and flow of the LPCI and CS pumps in 18 years of periodic testing. The "D" LPCI pump has shown a slight increase in ΔP (Attributable to a decrease in dynamic suction pressure). This is explained by instrumentation accuracy (±2 percent) and readability, rather than a change in pump performance.

Vibration data for the LPCI and CS pumps is within in-service testing standards. However, the vibration of the "A" LPCI and "B" CS pumps (i.e., velocity in inches/second) has been increasing. This upward trend is presently believed to be due to the following, nonminimum-flow related factors:

- Flow-induced vibration in piping downstream of the pumps could be transmitted back to the pumps. Changes in this piping vibration increase pump vibration.
- Improper mounting stud embedment and pump grouting deterioration may have caused the "A" LPCI and "B" CS pumps to gradually go out of balance. (Note: mounting modifications for all LPCI and CS pumps were completed in 1987).
- The "A" LPCI pump seems to be the most used of all of the subject pumps. Its increased usage is leading to a gradual increase in imbalance or bearing wear.
- A pump that is balanced for smooth operation at rated flow will vibrate differently at minimum-flow. This is more of a reflection of vibratory harmonics that occur when the pump is operated off of its peak efficiency point than it is of the inadequacy of the minimum-flow provided. These vibrations may be due to hydraulic forces that have no bearing on pump degradation.

A special test of the LPCI and CS pumps was performed in December of 1988. This test was performed to look for the presence of impeller recirculation induced vibration. If this vibratory mode was found, it was to be assumed that minimum-flow is gradually contributing to pump wear and imbalance. If this vibratory mode was not encountered, it was to be assumed that the minimum-flows provided are acceptable for the subject pumps. Test results do not indicate the presence of damaging impeller recirculation induced vibration.

The special test demonstrated that pump interaction through shared orificed minimum-flow lines is not a problem where the orificed lines lead into a larger common header. This is because of the pressure drop imposed by the orifices as flow is reduced before entry into the larger common line.

In summary, the minimum-flows of individual LPCI pumps were not diminished when pairs of pumps were run together with flow routed through their shared minimum-flow lines.

Shutdown Cooling Pumps

Shutdown cooling pump test data is difficult to interpret because of differences in plant conditions during testing. Operational objectives during plant shutdown have led to tests at low reactor vessel level (i.e., low NPSH), high vessel level, at minimum-flow, and at full flow. Since the testing of these pumps is limited to shutdowns, the total number of tests performed to date is relatively small (it is estimated that there have been 36 tests per pump in 18 years of operation). Since the estimated 36 tests per pump have been performed at varying test conditions, the database for performance evaluation at any given condition is small. From this perspective, it is inappropriate to assign too much significance to the attempt at performance trending provided here.

The shutdown cooling pumps appear to be performing consistently. Discharge pressures and ΔPs have been acceptable most of the time in 18 years of testing. Requests for repairs are noted whenever these performance parameters have dropped below acceptance limits. However, major maintenance seems to be related to vibration rather than deterioration of performance parameters. Vibration has led to coupling repairs and overhauls in 1986 and 1987 (one pump overhauled in each year).

The shutdown cooling pumps did not have any significant internal damage at the overhauls discussed above. This implies that the pumps are not being damaged by operation at minimum-flow or any other condition. The vibration that has been experienced in these pumps has been attributed to coupling deterioration and misalignment, not inadequate minimum-flow. Also, this vibration has not been significant enough to produce any noticeable damage.

Conclusions

It is concluded that the minimum-flows provided for the LPCI, CS, and shutdown cooling pumps are not producing pump damage.

Millstone Unit 2

High Pressure Safety Injection (HPSI) Pumps

A span of seven years of ASME Code Section XI test data was reviewed. No significant changes in pump differential pressure, discharge pressure, or vibration were found. These parameters have remained within normal/acceptable ranges.

Some of the minimum-flow me surements recorded in early 1988 went out of the normal range. This cond..ion has not been observed in any subsequent tests. Therefore, it is believed that the minimum-flows went out of specified normal limits due to instrument inaccuracy; i.e., not due to any real decrease in flow.

Evaluation of vibration spectral plots was performed. This evaluation supports the conclusion that the HPSI pumps have adequate minimum-flow (based on the stability observed in key pump performance parameters).

In summary, it is concluded that there have been no noticeable decreases in HPSI pump performance parameters due to normal operation and periodic testing at minimum-flow in 13.5 years of service.

Low Pressure Safety Injection (LPSI) Pumps

A span of seven years of test data was reviewed. No significant changes in minimum-flow differential pressure, discharge head, or vibration were found. These pump performance parameters remained stable and within normal limits.

An analysis of the LPSI pump vibration spectral plots was performed. This evaluation supports the conclusion that the LPSI pumps have adequate minimum-flow (based on the stability observed in key pump performance parameters).

It is concluded that there has been no significant degradation of LPSI pump performance due to normal operations or periodic testing at minimum-flow in 13.5 years of service.

Containment Spray (CS) Pumps

A span of seven years of test data was reviewed. No significant changes in differential pressure, discharge head, or vibration were found. These pump performance parameters remained stable and within normal limits.

Minimum-flow for both pumps dropped below normal limits, but not into the alert range, in February 1988. Since minimum-flow has been back within its normal range on all subsequent tests, this minor deviation on both pumps in the same month is not considered to be indicative of minimum-flow damage; i.e., instrument error.

An evaluation of vibration spectral plots was performed. This evaluation supports the conclusion that the containment spray pumps have adequate minimum-flow. This premise is based on the consistency in the vibration level of the pumps over seven years of service.

It is concluded that there has been no noticeable deterioration in containment spray pump performance. This implies that periodic testing at minimum-flow is not damaging the pumps.

Auxiliary Feed Pump (Turbine Driven)

A span of seven years of data was examined. Pump vibration at minimum-flow remains within acceptable/normal limits. However, vibration has been increasing gradually. It is standard site engineering practice to recommend overhaul when a pump's operating parameters drop out of the normal/acceptable ranges into the alert range. This practice will correct any minimum-flow problem that may exist before pump performance or availability can be significantly affected.

Differential pressure dropped out of the acceptable/normal range at two tests in 1982. This performance parameter has been in the acceptable range for all subsequent tests. Since the ΔP decrease (1-3 psig which is approximately .3 percent of the acceptable minimum ΔP of 1101 psig), was not significant enough to enter the alert range, and was not observed in subsequent tests, it is not considered indicative of minimum-flow induced damage accumulation.

All other performance parameters remained in normal/acceptable ranges.

An evaluation of the auxiliary feed pump's minimum-flow test spectral plots was performed. This evaluation did not disclose any minimum-flow related problems.

It is concluded that there has been no significant degradation of the turbine-driven auxiliary feed pump's performance or availability due to periodic testing at minimum-flow.

Auxiliary Feed Pumps (Motor Driven)

Test data spanning seven years was sampled and examined. Differential pressure has remained within normal/acceptable limits without significant changes.

Pump P-9A has one vibration data point that is slightly above the normal range, but within the acceptance range in October 1988. This is not considered a significant indication with regard to minimum-flow adequacy.

An evaluation of the vibration spectral plots for these pumps at minimum-flow was performed. This evaluation did not change the conclusion that the minimum-flow provided for these pumps is acceptable.

In summary, there is no evidence of any minimum-flow related damage in these pumps after 13.5 years of service and minimum-flow testing.

Millstone Unit 3

General

In general, it can be stated that the three years of test data available for these pumps may not be sufficient to notice any degradation due to operation at minimum-flow.

Safety Injection, Charging, and Residual Heat Removal

The safety injection, charging, and residual heat removal pumps have not shown any deterioration in performance parameters (e.g., differential pressure and minimum-flow). Vibration measurements for these pumps have remained within in-service testing standards. These pumps are tested at minimum-flow.

Auxiliary Feed Water (Motor Driven)

These minimum-flow tested pumps have shown some excessive vibrations at vane pass and running speed frequencies. The occurrence of these vibrations has not been consistent in the three years of monthly testing performed to date. However, the few incidents of excessive vibration have been considered significant enough to justify an evaluation of increasing minimum-flow and other performance improvements. Final results of these analyses are not in. Preliminary results indicate that minimum-flow modifications are not required.

A critical bushing within these pumps is being monitored (by means of special instrumentation) for signs of deterioration that could produce increased vibration and rotor failure. These problems are related to bushing material, not minimum-flow.

Auxiliary Feed Water (Turbine Driven)

This pump did experience excessive vibration during two consecutive minimum-flow tests in 1986. This pump is also being evaluated as described above (for the motor-driven auxiliary feed pumps). The high vibrations experienced have been attributed to bad transducer cables.

The pump experienced low discharge pressure at one test in 1988. Apparently, it passed based on backup instrumentation readings.

Vibration - Evaluation of Multi-Spectra Plots

The vibration data collected during minimum-flow testing of the subject pumps may not span enough time to provide meaningful data on the possibility of slowly accumulating minimum-flow damage.

It is difficult to make projections from one minimum-flow test. Ideally, minimum-flow vibration spectra would be compared to full flow vibration spectra over a period of time. This method would point out any increases in vibratory amplitudes due to the slow accumulation of pump damage. It would also show that certain vibratory modes are characteristic of a pump. The presence of these vibratory modes at minimum-flow is less of a concern when it is known that these modes are observed at design flow. Also, the availability of full-flow vibratory spectra makes it easier to identify cavitation in minimum-flow vibratory spectra. Without the benefit of all this data, only the following limited observations can be made.

- Charging pump data does not seem to indicate the presence of any minimum-flow problems.

- Safety injection pump data may indicate the presence of cavitation at minimum-flow. More test and maintenance history will be required to conclude whether cavitation is present or not. Both safety injection pumps had shaft seal repairs in 1988. This type of maintenance could be due to cavitation induced vibration.

- The residual heat removal pumps show their highest vibratory amplitude points at running speed, which is normal. There are lower amplitude spikes at harmonics of vane pass. There is also indication of cavitation in the rough "grass" in the low amplitude regions of the vibratory spectra. There is nothing in maintenance history of these pumps to indicate any minimum-flow problems.

- The auxiliary feed pumps (turbine and motor driven) have their highest amplitude vibratory modes at vane pass and vane pass harmonics. This could be indicative of impeller recirculation. The fact that these peak points have a higher amplitude and frequency than the normal spikes at run speed implies that damage could be occurring at minimum-flow. These pumps are the subject of special evaluation for these reasons as described above.

Conclusions

Three years of test experience may not be enough to assess the impact of running these safety-related pumps at minimum-flow.

The auxiliary feed pumps do show some indications that some damage may be accumulating due to operation at minimum-flow. NNECO does not believe there is a serious problem with the minimum-flows provided for these pumps. Engineering evaluations of these pumps are continuing.

Charging pump test data does not indicate the existence of minimum-flow problems.

Residual heat removal pump test data implies the possibility of cavitation and impeller recirculation induced vibration due to minimum-flow. The existence of cavitation and damaging impeller recirculation is not supported by maintenance history to date.

The safety injection pumps may be experiencing cavitation at minimum-flow. More test and maintenance history will be required for conclusions on this possibility to be made.

Haddam Neck

Auxiliary Feed (AF) Pumps

Test data spanning close to eight years was reviewed. AF pump differential pressure and discharge pressure has fluctuated over the years. This makes any trending of these pump performance parameters difficult. It is important to note that the variations noticed are due to changes in steam pressure applied to the turbine driver for these pumps. That is, variations in turbine inlet steam pressure change pump speed. Changes in pump speed affect pump pressure. Therefore, the fluctuations noted are not considered significant with respect to NRC Bulletin No. 88-04.

AF pump minimum-flow is not measured during in-service testing (IST). However, the AF pumps are in-service tested at minimum-flow.

AF pump vibration at different monitoring points has occasionally gone into the alert range. Vibrations have dropped back into normal ranges in subsequent tests (due to maintenance or overhaul). This type of vibration history is not considered to be indicative of chronic minimum-flow problems. These variations in vibrations are relative to a baseline, which is considered by the manufacturer to be exceptionally low.

An evaluation of the vibration spectral plots for these pumps at minimum-flow was performed. This evaluation supports the conclusion that the auxiliary feed pumps have adequate minimum-flow.

Charging Pumps

Test data from January 1982 to May 1989 was reviewed. Differential pressure and discharge pressure have varied. This appears to be due to testing at different points on the pump curve. That is, the pump performance curve at low flows has enough of a slope to produce a 2.2 psig change in discharge pressure per 1 gpm change in rated flow. Accumulation of small differences in charging flow and recirculation flow (5-6 gpm and 5-15 gpm, respectively in recent data) can shift the operating point 22-45.5 psi on the performance curve. This shift, plus instrumentation error can easily explain the range of pressures recorded. These types of variations in pump performance are not considered significant with respect to NRC Bulletin No. 88-04.

The charging pump minimum-flow has not always been a measured parameter. It has been measured periodically since late 1983. Minimum-flow has varied significantly. This is partially due to adjustments of throttling valves in the minimum-flow path. Repeatability error in the instrumentation used to measure minimum-flow can also be credited for some of the variation in minimum-flow observed over time. The history of minimum-flow test data is not considered significant to Bulletin No. 88-04 because of the magnitude of CY's charging pump minimum-flow. The most recent test data indicates that the "A" pump's minimum-flow is 72 gpm (20.5 percent of rated flow) and the "B" pump's minimum-flow is 149 gpm (41.4 percent of rated flow). It is important to note that the charging pumps are tested at a low flow greater than minimum-flow.

Charging pump vibration has been decreasing over the time interval examined. This is certainly indicative that low-flow operation is not producing damage. Most of the vibration readings that exceed alert limits are in the motors for these pumps, not in the pumps themselves. This implies that vibration is probably not due to the hydraulic action present inside the pumps.

An evaluation of the vibration spectral plots for these pumps was performed. This evaluation supports the conclusion that the charging pumps have adequate minimum-flow.

High Pressure Safety Injection (HPSI) Pumps

Almost eight years of test data was reviewed. HPSI pump differential pressure and discharge pressure have been increasing in the time period reviewed. This is not indicative of damage accumulation due to inadequate minimum-flow.

HPSI pump minimum-flow is not measured during in-service testing. However, the HPSI pumps are tested at minimum-flow during IST.

HPSI pump vibration has occasionally been in the alert range. However, the out of range vibration has always been reduced to normal levels by maintenance (usually just tightening of loose mounting bolts). This vibration history is not considered indicative of inadequate minimum-flow.

An evaluation of the vibration spectral plots for these pumps at minimum-flow was performed. This evaluation supports the conclusion that the HPSI pumps have adequate minimum-flow.

In March of 1987, a special test was performed to measure HPSI pump heat-up and vibration at minimum-flow. This test concluded that pump temperature leveled off at approximately 180°F after 15 minutes at minimum-flow. Vibration at minimum-flow was within acceptable limits. These results are indicative that minimum-flow is adequate for the HPSI pumps.

Low Pressure Safety Injection (LPSI) Pumps

Test data for seven years was reviewed. LPSI pump discharge pressures and differential pressures have not degraded in this time period.

LPSI pump minimum-flow is not measured during in-service testing. however, the LPSI pumps are in-service tested at minimum-flow.

A few motor vibration data points for both pumps went into the alert range in 1983. It appears that these problems were corrected without major maintenance. All subsequent vibration data has been consistently within normal acceptance limits. This vibration history does not indicate the presence of any chronic minimum-flow problems.

An evaluation of the vibration spectral plots for these pumps at minimum-flow was performed. This evaluation supports the conclusion that the LPSI pumps have adequate minimum-flow.

Residual Heat Removal (RHR) Pumps

In-service test (IST) data from January 1982 to May 1989 was reviewed. The ΔP of these pumps seems to have dropped by approximately 7-8 psid. This seems to be due to a change in test procedures. RHR tests are now run with suction pressures approximately 16 psig higher than in 1982. This tends to increase pump discharge pressure by only 5-8 psig. The result is that ΔP decreases by the 7-8 psid mentioned above. This type of change is not indicative of degrading pump performance.

RHR pumps are tested at minimum-flow during IST, but minimum-flow is not measured and recorded.

RHR pump vibration has remained well within its normal ranges for all tests since 1982. This consistency in vibration is indicative of a lack of chronic minimum-flow problems.

An evaluation of the vibration spectral plots for these pumps at minimum-flow was performed. This evaluation corroborates the conclusion that minimum-flow is adequate for these pumps.

Conclusion

It is concluded that the minimum-flows provided for these pumps are not producing pump damage.