ENCLOSURE A

EVALUATION OF POTENTIAL SAFETY-RELATED PUMP LOSS FOR SAN ONOFRE UNIT 1 IN RESPONSE TO NRC BULLETIN 88-04

EVALUATION OF POTENTIAL SAFETY-RELATED PUMP LOSS FOR SAN ONOFRE UNIT 1 IN RESPONSE TO NRC BULLETIN 88-04

In the bulletin, the NRC asked that we respond to following items. Our responses are provided below.

NRC Action 1

"Promptly determine whether or not its facility has any safety-related system with a pump and piping system configuration that does not preclude pump-to-pump interaction during miniflow operation and could therefore result in dead-heading of one or more of the pumps."

SCE Response

All safety-related systems were reviewed to identify those with two or more pumps operating in parallel. All pumps that do not use miniflow lines were eliminated from the evaluation as not being within the scope of NRC Bulletin 88-04. The designs of the miniflow lines were then reviewed to determine which safety-related pumps shared miniflow lines. The pumps that did not share miniflow lines were not evaluated for dead-heading concerns, but were evaluated for adequacy of miniflow capacity (see response to NRC Action 3).

Table 1 lists the safety-related pumps with miniflow lines, and summarizes the evaluations for potential pump-to-pump interaction. For those pumps with shared miniflow lines, typically there are individual orifices downstream of each pump which provide sufficient pressure drop to preclude pump-to-pump interaction. However, the Residual Heat Removal Pumps (RHR) share a common miniflow line, do not have individual orifices for pressure reduction, and therefore fit the criteria for potential pump interaction resulting in dead-heading. The RHR pumps are discussed in more detail in the response to NRC Action 2.

Response to NRC Action 1 (continued):

TABLE 1
TABULATION OF SAFETY-RELATED PUMPS WITH MINIFLOW LINES

Safety-Related Pumps w/miniflow	Miniflow Lines	Evaluation of the Potential for Dead-Heading
Safety Injection Recirculation (CRS-G-45A & B)	Individual	Not Applicable.
Safety Injection (SIS-G-50A & B)	Shared	Interaction precluded by orifices in miniflow lines as well as pressure drop in 2" miniflow lines (miniflow lines join just before RWST nozzle).
Charging (VCC-G-8A & B)	Shared	Interaction precluded by separate orifices in miniflow lines.
Component Cooling Water (CCW-G-15A, B, & C)	Shared	Separate orifices in miniflow lines; also pumps not run on miniflow during testing, normal operation, or post accident modes.
Auxiliary Feedwater (AFW-G-10,-10S,&-10W)	Individual	Not applicable.
Refueling Water (CRS-G-27N & -27S)	Shared	Interaction precluded by individual orifices in miniflow lines.
Residual Heal Removal (RHR-G-14A & -14B)	Shared	See response to NRC Action 2.
Main Feedwater (FWS-G-3A & -3B)	Shared (in safety injection mode)	Interaction precluded by individual orifices in miniflow lines.
	Individual (in feed-water mode)	Not applicable.

NRC Action 2

"If the situation described in Item 1 exists, evaluate the system for flow division taking into consideration (a) the actual line and component resistances for the as-built configuration of the identified system; (b) the head versus flow characteristics of the installed pumps, including actual test data for "strong" and "weak" pump flows; (c) the effect of test instrument error and reading error; and (d) the worst case allowances for deviation of pump test parameters as allowed by the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code) Section XI, Paragraph IWP-3100."

SCE Response

We have reviewed the SONGS-1 safety-related pumps that share miniflow lines and concluded that with the exception of the RHR pumps, the piping system precluded the type of pump-to-pump interaction during miniflow operation that could result in the dead-heading of one or more of these pumps. In the case of the RHR pumps, a review of the RHR operating procedures determined that RHR pump operation is not likely to result in dead-heading either of the RHR pumps during miniflow operation. This is based on an evaluation of the following:

a) Actual line and component resistances,

b) Head versus flow characteristics of installed pumps,

c) Effect of test instrument error and reading error, and

d) Deviation of pump test parameters.

The design and operating modes of the SONGS-1 safety-related pumps with shared miniflow lines, including discharge headers, were reviewed in detail, using P&IDs, System Descriptions, Pump Curves, and Operating Procedures. The In-Service Testing program and test data required by ASME Section XI were reviewed to determine proper pump performance.

<u>(a) Actual Line and Component Resistances</u>

With the exception of the RHR pumps, safety-related pumps at SONGS-1 that share miniflow lines or miniflow discharge headers have separate orifices for each pump's miniflow line. Reviews of the orifice designs confirmed
that the major portion of the pressure drop for all miniflow lines occurs at the orifices. Therefore, the resistive effects of the common lines are negligible with respect to

those of the separate miniflow lines discharging to a common tank. Interaction will not occur in such a design, because a single pump can not provide significant pressure to the discharge of the parallel pump. A list of all safety-related pumps with miniflow lines along with a summary of the reviews discussed above is provided at the end of the response to NRC Action 1.

As previously stated in the response to NRC Action 1, only the RHR pumps have a shared miniflow line without separate orifices. The pump operating instruction requires the stopping of one RHR pump if RHR flow is < 800 gpm (approximately 73% of rated flow) with both RHR pumps in operation. Therefore, operating practices protect the pumps from dead-heading.

(b) Head Versus Flow Characteristics of Installed Pumps

The pressure drops at the orifices (as discussed in item (a) above) preclude one pump from applying significant additional discharge head to the parallel pump. Therefore, the flowrate of the lower performing pump is not significantly reduced.

(c) Effect of Test Instrument Error and Reading Error

Due to the orifices discussed above, test instrument error and reading error are not of significance with respect to the potential for dead-heading.

(d) Deviation of Pump Test Parameters

Similar to (b) and (c) above, deviation of pump test parameters is not of significance due to the pressure drops at the orifices.

Conclusion

We conclude that none of the SONGS 1 safety-related pumps with miniflow lines are subject to dead-heading due to pump-to-pump interaction.

NRC Action 3

"Evaluate the adequacy of the minimum flow bypass lines for safety-related centrifugal pumps with respect to damage resulting from operation and testing in the minimum flow mode. This evaluation should include consideration of the effects of cumulative operating hours in the minimum flow mode over the lifetime of the plant and during the postulated accident scenario involving the largest time spent in this mode. The evaluation should be based on best current estimates of potential pump damage from operation of the specific pump models involved, derived from pertinent test data and field experience on pump damage. The evaluation should also include verification from the pump suppliers that current miniflow rates (or any proposed modifications to miniflow systems) are sufficient to ensure that there will be no pump damage from low flow operation. If the test data do not justify the existing capacity of the bypass lines (e.g., if the test data do not come from flows comparable to the current capacity) or if the pump supplier does not verify the adequacy of the current miniflow capacity, the licensee should provide a plan to obtain additional test data and/or modify the miniflow capacity as needed."

SCE Response

We have evaluated the adequacy of all of the safety-related pumps minimum flow bypass lines. We examined the operation, maintenance, and in-service test (IST) histories to evaluate the cumulative effects of pump operation in the minimum flow mode over the life of the plant and during postulated accident scenarios. The results of our evaluation indicate that with the exception of the main feedwater pumps (MFP), which might sustain some accelerated wear, all of the SONGS-1 safety-related pumps have adequate miniflow rates. Over the remaining life of the plant, IST and normal maintenance are expected to ensure continued operational readiness for service during post-accident operation.

In the case of the main feedwater pumps, based on recommendations from the MFP vendor, we elected to increase the SI mode minimum flow rate to provide additional miniflow margin for the pump and reduce the potential for accelerated wear. We have tested the MFPs and verified the adequacy of the increased miniflow. We have also performed a post-test inspection and found no indications of wear to the thrust bearing or disc.

The following discussion provides background information in support of our conclusion that all of the SONGS-1 safety-related pumps have adequate miniflow rates. Also refer to Enclosure B, item 2 for further details regarding operating experience, miniflow modes of operation, and the maintenance history of each of the subject pumps.

BACKGROUND DISCUSSION

SONGS 1 safety related pumps have provided reliable service for many years. That history provides an adequate basis for assessing miniflow acceptability. For the specific SONGS 1 pumps in question, all except the Main Feedwater Pumps (MFP) have been operated in the miniflow mode for longer cumulative periods of time than would be required for safety related functions. Since sufficient operating experience for these pumps exists, and the associated IST and maintenance records are available and have been reviewed, it is concluded that additional input from the vendors is not required for these specific pumps.

Operating Experience

To verify that there is sufficient operating experience for miniflow assessment, the operating experience for each of the pumps in the miniflow mode was compared to the required time durations for safety-related miniflow operation following a design basis accident. In addition to the In-Service Test (IST) operating times, some of the pumps have been occasionally operated in the miniflow mode at other times. In each case, except for the Main Feedwater Pumps, it was found that the actual miniflow operation times to date exceed the time period required for safety-related operation during an accident condition. The IST records confirm that pump vibrations and temperature rises during testing have not shown degrading trends.

Maintenance Histories

The maintenance histories of the pumps can give an indication of the occurrence of damage due to cumulative operating time at miniflow conditions. This mode of pump operation can result in higher operating temperatures and increased vibration. Higher temperatures and vibration can produce the following types of pump damage: (1) wear or scoring of wear rings, (2) premature wear in bearings, (2) erosion of impellers or pump casings, (4) accelerated packing or seal deterioration, wear, or failure, (5) blackening of lubricating oils due to production of carbon particles, (6) crack formation at mounting lugs, and/or (7) degradation of mounting pedestals.

If there is no history of these types of problems and if the IST records do not indicate degrading trends, it can be reasonably concluded that operation at the existing miniflow is not producing measurable damage.

The maintenance records from approximately 1984 to the present were reviewed. Over approximately the same time period, all of the pumps except the Main Feedwater Pumps were operated in the miniflow mode for time durations exceeding the requirement for post-accident operation. The IST and maintenance history data provide assurance that the pumps have not experienced damage attributable to low flow rates.

Main Feedwater Pumps

Unlike the other pumps discussed above, the Main Feedwater Pumps (MFP) miniflow operational experience in the safety injection mode is limited. The vendor, Byron-Jackson (BJ), was contacted to identify the miniflow rates necessary to ensure no damage as a result of pump operation at or near shutoff head conditions. Their recommended values are summarized below:

(1) 1800 gpm for continuous operation

(2) 1350 gpm for intermittent operation up to an accumulation of 1500 hours,

(3) 1200 gpm for up to 60 hours.

Additionally BJ evaluated MFP operation at low flow (372 gpm) for the required 6 hours of post-accident operation following a small break LOCA. BJ concluded that the pump "should operate satisfactorily at 372 gpm for 6 hours and not sustain any damage, which would affect hydraulic performance or mechanical integrity except for possible accelerated wear caused by recirculation erosion. Even if additional wear should occur,the pump should still perform its safety injection function."

In support of their assessment, BJ referred to the special features inherent in the SONGS 1 MFP design which make the pumps especially resistant to damage in the minimum flow mode: (1) rotating element design for minimum shaft deflection, (2) hydrodynamic bearings, (3) grooved pump wearing surfaces, (4) impeller vane to volute tongue clearance sized to minimize the effect of pressure pulsation, and (5) wear ring clearance sized to preclude contact during transient operation.

The existing miniflow rate in the safety injection mode was calculated to be approximately 350 gpm. This flowrate was calculated after the Byron-Jackson evaluation, and for that reason is slightly different than the 372 gpm flowrate provided for their evaluation. However, since the difference is small, it is expected that there would be no significant impact to their assessment in view of the special pump features discussed above.

Modifications to the Main Feedwater Pump SI Mode Miniflow Lines

To minimize the potential for accelerated wear caused by recirculation erosion, the following changes have been made during the Cycle 11 outage:

(1) The existing miniflow orifices were modified to increase the miniflow from its previous 350 gpm to approximately 525 gpm.

(2) Bypass orifices were installed on each miniflow line that would be manually valved in by the operator after 30 minutes of miniflow operation during a small break LOCA event. This would increase the available miniflow capacity from 525 gpm to approximately 1200 gpm.

Additional Main Feedwater Pump Miniflow Information

In addition to the safety injection mode, the MFP is operated in the condensate miniflow mode. As indicated in Enclosure B, there is ample operational history which demonstrates that the existing miniflow of approximately 1000 to 1100 gpm has not caused damage associated with low flowrate operation. Therefore, the BJ recommendations listed above are conservative with respect to actual SONGS-1 experience.

For additional details regarding the MFP miniflow, see item 3 of Enclosure B.

Conclusion

Based on our review of the operating experiences and maintenance histories, it is concluded that all of the SONGS-1 safety-related pumps have adequate miniflow rates.

NRC Action 4

"Within 60 days of receipt of this bulletin, provide a written response that (a) summarizes the problems and the systems affected, (b) identifies the short-term and long-term modifications to plant operating procedures or hardware that have been or are being implemented to ensure safe plant operations, (c) identifies an appropriate schedule for long-term resolution of this and/or other significant problems that are identified as a result of this bulletin, and (d) provides justification for continued operation particularly with regard to General Design Criterion 35 of Appendix A to Title 10 of the Code of Federal Regulations (10 CFR 50), 'Emergency Core Cooling' and 10 CFR 50.46, 'Acceptance Criteria for Emergency Core Cooling System for Light Water Nuclear Power Reactors.'"

SCE Response

(a) An evaluation of the designs and operating modes of safety-related pumps with miniflow lines showed that there is no credible potential for damage:

The RHR pumps are precluded from potential dead-heading by an Operating Instruction, "Residual Heat Removal Operation," which requires the stopping of one RHR pump if RHR flow is < 800 gpm with both RHR pumps in operation. This precludes deading the weaker RHR pump.

The miniflow rate for the Main Feedwater Pumps in the safety injection mode has been increased (as discussed in the response to NRC Action 3).

All other safety-related pumps with miniflow lines have acceptable flow rates as discussed above in the response to NRC Action 3.

(b) The safety injection mode miniflow orifices for the Main Feedwater Pumps have been replaced during the Cycle 11 outage as discussed above. Operating procedures have been revised to provide for operator action to open the miniflow bypass valves after 30 minutes following a safety injection signal if the Safety Injection and Main Feedwater pumps have not been stopped. In addition, the miniflow bypass isolation valves are locked closed valves and have been added to the valve locking program. No other short term or long term modifications to plant operating procedures or hardware are planned.

(c) There are no remaining problems which require long-term resolution. Therefore, schedules are not required.

(d) No justification for continued operation is required.

NRC Action 5

"Within 30 days of completion of the long-term resolution actions, provide a written response describing the actions taken."

SCE Response

No additional long-term resolution actions are planned.

NRC Action 6

"An evaluation of your actions in response to this bulletin should be documented and maintained at the plant site for a minimum of two (2) years. That evaluation should, as a minimum, address the piping system configuration in accordance with Item 1 above, each of the four factors discussed in Item 2, pertinent test data and field experience on minimum flow operation, and verification of the adequacy for current miniflow capacity by the pump manufacturer."

SCE Response

The engineering evaluation for the actions taken have been documented and will be permanently maintained at Southern California Edison in the Corporate Document Management system.

ENCLOSURE B

RESPONSE TO NRC COMMENTS REGARDING
SONGS UNIT 1 RESPONSE TO NRC BULLETIN 88-04

RESPONSE TO NRC COMMENTS REGARDING SONGS UNIT 1 RESPONSE TO NRC BULLETIN 88-04

NRC COMMENT 1

"The licensee could not obtain concurrence from pump suppliers that existing miniflow rates are acceptable. In its response, the licensee did not provide a plan to obtain additional test data and/or modify the miniflow capacity as requested by Item 3 of the Bulletin."

SCE RESPONSE

SONGS 1 safety related pumps have provided reliable service for many years, and that history provides an adequate basis for assessing miniflow acceptability. For the specific SONGS 1 pumps in question, all except the Main Feedwater Pumps (MFP) have been operated in the miniflow mode for longer cumulative periods of time than would be required for safety related functions. Since sufficient operating experience for these pumps exists, and the associated IST and maintenance records are available and were reviewed, it is concluded that additional input from the vendors is not required for these specific pumps.

A review of the miniflow data for all pumps except the MFPs in the safety injection (SI) mode is provided in the response to Comment 2. For the pumps other than the MFPs, it was concluded that the miniflow rates are acceptable and physical modifications to increase the flow rates are not required.

The Main Feedwater Pumps are discussed in the response to Comment 3. Unlike the other pumps discussed above, MFP miniflow operational experience in the safety injection mode is limited. The vendor (Byron Jackson) was contacted for an evaluation of the adequacy of the estimated miniflow rate. For the short period of time (approximately 6 hours) for which miniflow in the Safety Injection mode is required, the vendor concluded that "the pump should operate satisfactorily at 372 gpm for 6 hours and not sustain any damage, which would affect hydraulic performance or mechanical integrity except for possible accelerated wear caused by recirculation erosion. Even if additional wear should occur, the pump should still perform its safety injection function."

To minimize the potential for accelerated wear caused by recirculation erosion, two modifications have been made to the miniflow piping: (1) the miniflow orifices were modified to increase the miniflow to approximately 525 gpm, and (2) bypass lines were added which can be valved in after 30 minutes and which provide approximately 1200 gpm miniflow (the vendor has stated that 1200 gpm is adequate for up to 60 hours of operation). These modifications provide assurance that the Main Feedwater Pumps can perform their safety related function. For additional information regarding the Main Feedwater Pump SI mode miniflow modifications and also regarding the evaluation of the condensate mode miniflow, see the response to Comment 3.

NRC COMMENT 2

"Based on its review of IST data, the licensee concluded that miniflow rates are acceptable for all safety-related pumps except the feedwater pumps. Typically, a pump is operated over a period of 15 to 30 minutes for collecting IST data. This is not judged to provide a meaningful indication of how the pump would perform when operated in miniflow for considerably longer periods of time."

SCE RESPONSE

To verify that there is sufficient operating experience for miniflow assessment, the operating experience for each of the pumps in the miniflow mode was compared to the required time durations for safety related miniflow operation following a design basis accident. In addition to the IST operating times, some of the pumps have been occasionally operated in the miniflow mode at other times. In each case, except for the MFPs in the SI mode, it was found that the actual cumulative miniflow operation times to date exceed the time period required for safety related operation during an accident condition. The IST data provides adequate experience for miniflow assessment. IST records confirm that pump vibrations and temperature rises during testing have not shown degrading trends.

The maintenance histories of the pumps can give an indication of the occurrence of damage due to cumulative operating time at miniflow conditions. This mode of pump operation can result in higher operating temperatures and increased vibration. Higher temperatures and vibration can produce the following types of pump damage: (1) wear or scoring of wear rings, (2) premature wear in bearings, (3) erosion of impellers or pump casings, (4) accelerated packing or seal deterioration, wear, or failure, (5) blackening of lubricating oils due to production of carbon particles, (6) crack formation at mounting lugs, and/or (7) degradation of mounting pedestals.

If there is no history of these types of problems and if the IST records do not indicate degrading trends, it can be reasonably concluded that operation at the existing miniflow is not producing measurable damage. The maintenance records from approximately 1984 to the present were reviewed. Over approximately the same time period, the pumps were operated in the miniflow mode for time durations exceeding the requirement for post-accident operation. The IST and the maintenance history data provide assurance that the pumps have not experienced damage attributable to low flow rates. Therefore it can be concluded that the pumps are adequate to provide miniflow service during post-accident operation. Figure 1 is a flow chart showing the procedure used for pump miniflow evaluation.

Tables 1 through 8 provide details regarding the operational time durations and maintenance data for each pump. With other miniflow operational time periods considered in addition to miniflow time periods during IST, it is concluded that the favorable operating experience for these pumps has provided sufficient positive data to make additional testing unnecessary.

NRC COMMENT 3a

"In the case of the feedwater pumps (G-3A and G-3B), the licensee performed a calculation to demonstrate the adequacy of miniflow rates for the safety injection mode of operation. The licensee's methodology was deficient in the following respects:

a. The licensee assumed that a 700 gpm miniflow rate was adequate. The validity of this assumption was not established."

SCE RESPONSE

The calculation has been revised to incorporate the Cycle 11 design changes as discussed in items 3b and 3c below. The previous assumption regarding miniflow is no longer applicable to the calculation. The following is a discussion of the updated miniflow evaluation and the Cycle 11 design changes.

Design Basis Operation of the Main Feedwater Pumps

During a large break loss of coolant accident (LBLOCA), the safety injection flow to the core must be maximized to ensure that limits on peak clad temperature (PCT) are maintained. Consequently, miniflow under these conditions must be limited. Safety analyses assume a maximum miniflow rate of 700 gpm diverted back to the RWST during the injection phase of a LBLOCA. During the LBLOCA, pump minimum flow requirements are not a concern since total flow through the pumps will approach 10,000 gpm. However, the amount of flow diverted back to the RWST must be limited to <700 gpm to avoid impact to the safety analyses. The maximum time that these pumps would be required to operate under these conditions would be 30 minutes. Both trains of SI and MFP would trip on RWST low level.

During the small break loss of coolant (SBLOCA) scenario, RCS pressure could remain at or slightly below the design shutoff head for the MFPs. In this case it will take longer for the RWST level to reach the SI/MFP trip set point. Calculations show that for the worst case SBLOCA, operation of the MFP, at or near shutoff head conditions, could be as long as 6 hours.

Pump Vendor Evaluation

Byron-Jackson (BJ) was contacted to identify the miniflow rates necessary to ensure no damage as a result of pump operation at or near shutoff head conditions. Their recommended values are summarized below:

(1) 1800 gpm for continuous operation,

(2) 1350 gpm for intermittent operation up to an accumulation of 1500 hours, and

(3) 1200 gpm for up to 60 hours.

Additionally BJ evaluated MFP operation at low flow (372 gpm) for 6 hours of operation. BJ concluded that the pump "should operate satisfactorily at 372 gpm for 6 hours and not sustain any damage, which would affect hydraulic performance or mechanical integrity except for possible accelerated wear caused by recirculation erosion. Even if additional wear should occur, the pump should still perform its safety injection function."

In support of their assessment, BJ referred to the special features inherent in the SONGS 1 MFP design which make the pumps especially resistant to damage in the minimum flow mode: (1) rotating element design for minimum shaft deflection, (2) hydrodynamic bearings, (3) grooved pump wearing surfaces, (4) impeller vane to volute tongue clearance sized to minimize the effect of pressure pulsation, and (5) wear ring clearances sized to preclude contact during transient operation.

Existing Design Miniflow Rate

Using the existing miniflow orifice size as discussed in item 3c below, the maximum safety injection miniflow was calculated to be approximately 350 gpm. This flowrate was calculated after the BJ evaluation, and for that reason is slightly different than the 372 gpm flowrate provided to BJ for evaluation. However, since the difference is small, it would be expected that there would be no significant impact to their assessment.

In the condensate miniflow mode, the MFP flow rate is approximately 1000 to 1100 gpm. There is extensive operational experience under these conditions. Inspections performed on the pump in 1986 confirmed that there was no accumulated damage attributable to miniflow during all of the years prior to 1986. After the inspection, the West MFP was run for 48 hours continuously on miniflow. The subsequent MFP thrust bearing assembly inspection indicated no unusual wear. Since that time the pumps have logged additional time on condensate miniflow. IST and maintenance histories do not indicate any degrading trends.

We conclude that the BJ recommendations listed above are conservative with respect to actual SONGS-1 operating experience in the condensate miniflow mode, and the existing miniflow of 1000 to 1100 gpm has proven to be adequate.

Cycle 11 Design Changes

To minimize the potential for accelerated wear caused by recirculation erosion, the following changes have been made:

(1) The existing miniflow orifices were modified to increase the miniflow from its current 350 gpm to approximately 525 gpm. This was done to provide miniflow above the vendor evaluated 372 gpm and at the same time limit the amount of injection flow diverted from the core during a LBLOCA.

(2) Bypass orifices were installed on each miniflow line that would be manually valved in by the operator during a SBLOCA. If after 30 minutes of operation, following a SBLOCA, the SI/MFPs have not tripped on RWST low level and the SI reset criteria cannot be satisfied, then the operators will valve in the bypass orifices. This will provide approximately 1200 gpm miniflow for each MFP to support extended operation at or near shutoff head conditions.

Testing

Following the implementation of the above design changes, sufficient miniflow is provided to support the recommendations of the pump vendor and at the same time provide for operation of the MFP within the limits of the current safety analyses. Installation of the bypass orifices provides for miniflow rates which meet the minimum vendor requirements for up to 60 hours of miniflow operation.

The 525 gpm orifices provide sufficient flow to assure minimal accelerated wear of the MFP during the first 30 minutes of the limiting SBLOCA. To confirm that this miniflow would be acceptable, the MFPs were tested at approximately 525 gpm following implementation of the design changes. The test was conducted for 30 minutes. After the test, visual inspection of the pump thrust disc, bearing shoes, and thrust bearing assembly of Pump S1-FWS-G-3A was performed, and no indications of wear to these components was noted.

NRC COMMENT 3b

"The licensee assumed a clean piping system for determining pressure drop. Given the vintage of San Onofre Unit 1 and the fact that the system contains carbon steel components, this is not a realistic assumption."

SCE RESPONSE

The flow rate calculation has been revised to account for the replacement of the miniflow orifices, and for addition of the new bypass orifices. The revised calculation includes a sensitivity study regarding the pressure drop in the carbon steel portion of the system. It was found that the pressure drop across the miniflow orifices is the dominant contributor to the overall pressure drop. A postulated increase in pressure drop of up to 50% in the carbon steel piping resulted in a flow rate reduction of less than 5%. It is concluded in the calculation that the pressure drop in the carbon steel piping does not have a significant impact on the flow rate.

NRC COMMENT 3c

"No design information was available for the miniflow orifices. The licensee used ultrasonic techniques to establish orifice geometry and concluded that the orifice consists of an eleven inch long section of pipe where the inside diameter was reduced slightly compared to the nominal pipe diameter. This is not a standard orifice design and should be investigated by the licensee. The feedwater system miniflow orifice is significantly different for this design consisting of many 1/8 inch diameter holes. The fact that the pressure drop across the feedwater miniflow control valves is twice the pressure drop across the safety injection miniflow control valves tends to discredit the assumed safety injection miniflow orifice geometry. Additionally, if the assumed geometry is correct, it is questionable that such an orifice could prevent dead heading between two feedwater pumps."

SCE RESPONSE

The orifice configuration was investigated prior to their replacement. Orifice RO-897 was radiographed, and the results showed that there was an insert inside the pipe with a 3/4" diameter through hole. This was confirmed with a visual inspection of the orifice through the blind flange on the tee fitting just above the orifice.

The impact of incorporating the correct orifice geometry into the previous miniflow rate calculation was assessed, and it was determined that the safety injection flow rate would have been approximately 350 gpm as discussed in item 3a above. However, the orifices have been replaced (also as discussed in item 3a above). The new orifices are provided with pressure taps, and are calibrated to allow flow measurement with approximately 1 % accuracy. After installation, the new orifice meters were used to verify that the actual flowrate is approximately 525 gpm for the miniflow orifices, and a total of approximately 1200 gpm with the bypass orifices open.

The previously existing miniflow orifices as well as the new replacement orifices provide sufficient pressure drop to ensure pump dead heading would not occur. The resistive effects of the common lines are negligible with respect to those of the separate orifices. Dead heading due to pump interaction is precluded by the low back pressure in the common portion of the miniflow line.

NRC COMMENT 4

"Information supplied by the licensee in its letter dated May 4, 1990, indicates that certain components in the safety injection miniflow flowpath are carbon steel. Included among these are the miniflow orifices and miniflow control valves. Carbon steel components may not be suitable for this application and this condition should be evaluated by the licensee."

SCE RESPONSE

The original material for the miniflow lines was carbon steel. When the miniflow control valves CV-875A and B were later relocated, the majority of the piping inside of the Turbine Building was rerouted. Stainless steel was used for the replacement piping. The four inch carbon steel line to the RWST was retained, as was a small amount of carbon steel piping adjacent to the relocated miniflow control valves and orifices.

Piping:

A nonconformance was evaluated in 1989 regarding the piping schedule and material of the carbon steel miniflow piping. The range of UT readings for the 3" carbon steel pipe was found to be 0.397" to 0.478". This was satisfactory considering the piping mill tolerance. The range of wall thicknesses for schedule 160 is 0.382" to 0.492". Similarly, the UT readings for the 4" pipe were found to fall within the range of 0.313" to 0.340", while the expected mill tolerance range is 0.295" to 0.379" for schedule 80.

We conclude that although the use of carbon steel material in a borated water environment is not normal practice, pipe wall thickness UT measurements indicate negligible effects from corrosion (if any) since the time the subject piping was installed (over 20 years). Therefore, continued use of carbon steel pipe for this application (low temperature service) is acceptable, and it is expected that the wall thicknesses will remain acceptable over the balance of the plant life.

Miniflow orifices:

The miniflow orifices were replaced as discussed in item 3c above. The new orifices are made of stainless steel, and are therefore no longer a concern. (Note: Replacement of the orifices also involved replacement of some of the adjacent 3"carbon steel piping with stainless steel. After replacement, the old piping was cut at various locations, and the inside surfaces were visually inspected. A thin layer of crud was found in some areas, but no evidence was found of any significant pitting, flaking, or wall thinning. This is consistent with the results of the UT inspection discussed above.)

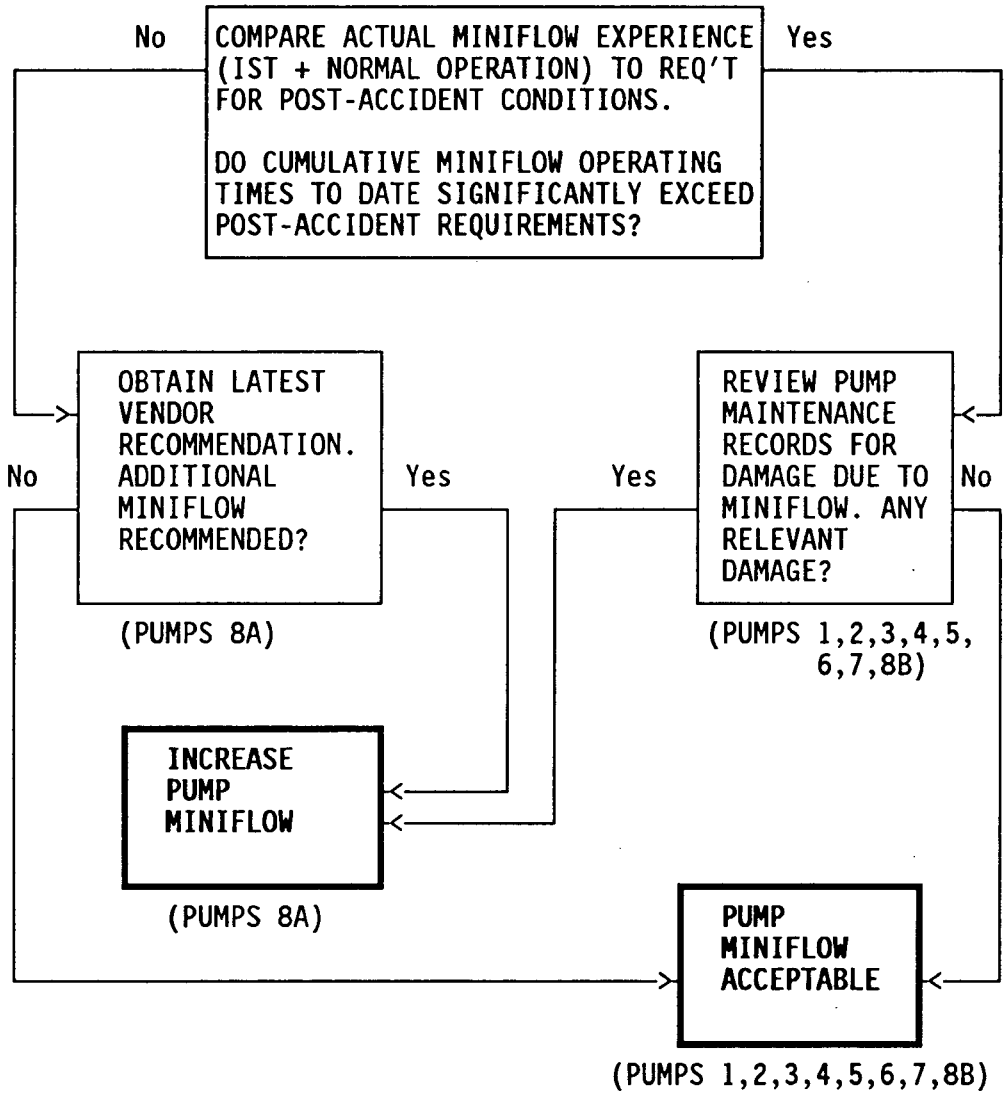
Miniflow control valves:

Regarding miniflow control valves CV-875A & B, these valves have required maintenance in the past for various reasons, but none of the reasons appear to be attributable to cold borated water service. For example, recent stem bending problems were evaluated and were found to be due to misadjustment of the diaphragm adjusting bolts and improper sizing of the diaphragm register fit. Similarly, seat leakage of CV-875B was evaluated and it was concluded that the existing spring was undersized and required additional preload for seating. During maintenance on the valves, no evidence of potentially unacceptable corrosion has been noted.

Although possible replacement of these valves is being considered for the future because of items such as those discussed above, use of carbon steel has not been determined to be the root cause and would not be the reason for replacement. Furthermore, lack of corrosion in the attached carbon steel piping as evidenced by UT readings and visual inspections as described above provides additional assurance that internal corrosion is not a significant problem.

FIGURE 1

FLOWCHART FOR EVALUATION OF MINIFLOW FOR SONGS 1 SR PUMPS



SAFETY RELATED PUMPS WITH MINIFLOW:

1 - S. I. RECIRC. (CRS-G-45A&B)
2 - S. I. (SIS-G-50A&B)
3 - CHARGING (VCC-G-8A&B)
4 - CCW (CCW-15A,B,&C)
5 - AUX FEED (AFW-G-10,10S,&10W)
6 - REFUELING WATER (CRS-G-27N&S)
7 - RHR (RHR-G-14A&B)
8A- FW (SI MODE) (FWS-G-3A&3B)
8B- FW (FW MODE) (FWS-G-3A&3B)

TABLE 1

EVALUATION OF MINIFLOW FOR SONGS 1 SR PUMPS

PUMP: SAFETY INJECTION RECIRCULATION (CRS-G-45A&B)

MANUFACTURER	CHEMPUMP (Model GPS-50L-46H-3S)
REQUIRED TIME DURATION FOR MINIFLOW POST-ACCIDENT	5 minute warm-up only.
IST	Quarterly test: Run dry for a few seconds. Biennial test: With water in sump, run 5 min with temp discharge line to sump. Then close valve to temporary line, and measure shut off head.
RECENT MAINTENANCE HISTORY	No maintenance problems related to pump vibration, bearing temperatures, or discharge pressure.

EVALUATION: Pump does not run during normal plant conditions. Shut off pressure testing confirms pumps will operate adequately during 5 minute post-accident warm-up. IST and maintenance histories show no damage or degrading trends due to testing.

CONCLUSION: **PUMP MINIFLOW HAS PROVEN TO BE ADEQUATE BASED UPON ACTUAL OPERATING EXPERIENCE.**

TABLE 2

EVALUATION OF MINIFLOW FOR SONGS 1 SR PUMPS

PUMP: SAFETY INJECTION (SIS-G-50A&B)

MANUFACTURER	WORTHINGTON (DRESSER) (Model 12 LNS-32)
REQUIRED TIME DURATION FOR MINIFLOW POST-ACCIDENT	Up to 6 hours.
IST	IST performed quarterly, with pump running at least 5 min. Also, once per year, bearing temperatures are measured -- 3 times approx 10 min apart. Readings must be within 3%. Estimated that G-50A and G-50B have been tested on miniflow approximately 12.9 and 13.4 hours cumulative respectively since June 1981. In addition, Technical Specifications require monthly testing
RECENT MAINTENANCE HISTORY	Majority of maintenance orders related to packing. Cause of problem apparently packing itself.(Original packing was teflon, which later was replaced with Garlock 98. Later replaced with mechanical seals approximately 9/86.) High IST vibration measurements taken for G-50A on 11/27/89. Bearings and shaft (G-50A) subsequently replaced Review of maintenance order history starting 8/84 indicates no previous bearing replacement. Bearing and impeller inspections found no damage attributable to miniflow operation.

EVALUATION: See pages 15 through 18.

TABLE 2 (continued)

EVALUATION (SIS-G-50A & G-50B)

SI Pump Design Requirements

Each SI Pump is designed to supply 10,500 gpm of borated water from the RWST to one feedwater pump at a minimum developed head of 245 feet, which is sufficient to prevent feedwater pump cavitation at the highest safety injection flow rate. During the small break loss of coolant accident (SBLOCA) scenario with the MFP operating on miniflow, the SI Pump flow rates would be 500-600 gpm for 30 minutes, followed by 1200-1300 gpm for 5-6 hours. SI Pump miniflow operation is not anticipated for any other operating conditions other than SBLOCA.

Vendor Assessment of Short Duration Miniflow

The vendor (Dresser) was contacted regarding assessment of miniflow rates for short duration service. For long term continuous service, Dresser recommended a flowrate of 5000 gpm. However, the SONGS 1 SI pumps are required to operate at reduced flow rates for only very short time durations as discussed above. Dresser was unable to determine miniflow requirements for these short time durations. The following is an excerpt from their letter:

"There are many uncontrolled variables which can effect predicted life when operating at flows below those given to be the onset of recirculation such as piping/system design, suction pressures/temperatures, pump power levels, specific operating profile, etc. Currently, it is not practical to quantify the effects of all factors influencing suction recirculation largely due to an insufficiently documented data base and overall problem complexity."

Operating History of G-50A and G-50B

Since the vendor indicated that they do not have sufficient data to specifically assess the SONGS 1 SI Pump requirements, the actual operating histories of the pumps have been reviewed and evaluated as test data.

The miniflow during IST is approximately 90-100 gpm. Therefore, the IST low flow condition is much more severe than the SBLOCA conditions described above. As noted above in Table 2, the pumps have been run on miniflow for IST for over 12 hours each since June 1981. This amounts to over twice the SBLOCA requirement described above.

There are other times when the pumps have been run continuously at low flow rates for extended periods of time such as:

1) On 2/11/85, G-50B was run continuously for 2 hours and 17 minutes on miniflow for packing adjustment and run in.

2) Per Technical Specification, monthly SI line sampling and recirculation is required when the reactor is critical. The SI pumps are run for approximately 1/2 hour in this mode each month. Since the return purge line to the Refueling Water Storage Tank is a 2" line, the flowrate for this condition is less than the lowest SBLOCA scenario flowrate (i.e., both MFPs operating on miniflow and bypasses closed for the first 1/2 hour).

3) During the testing of the Cycle 11 MFP miniflow modifications on 1/28/91, the SI Pumps were run continuously for approximately 2 hours 21 minutes (G-50A) and 2 hours 46 minutes (G-50B). The SI pump flow rates during this test corresponded to various modes of operation during the SBLOCA scenario. There were six (6) test conditions during this time period:

For test condition 1 (approximately the first 1/2 hour of the test), both MFPs were running with the miniflow bypasses closed. The SI pump flow rates for this condition are approximately 600 gpm.

During test condition 2, both MFPs remained running with the MFP miniflow bypasses open (SI pump flow rates approximately 1300 gpm).

For test conditions 3 and 4, the East MFP was run alone with the miniflow bypass open and closed respectively.

Similarly, test conditions 5 and 6 were run for the West MFP alone and the miniflow bypass orifices open and closed respectively.

In summary, there exists extensive operational history for these pumps at reduced flow conditions.

Maintenance History

The maintenance histories of the SI Pumps for the time period of 1984 to the present include the following relevant items:

G-50A

6/84-- Packing loose

11/84-- Packing leaked

5/85-- Packing leaked

3/86-- Pump repacked

6/86-- Packing leaked (replaced)

7/86-- Pump discharge flange leaked (tightened)

9/86-- Packing replaced with mechanical seal

Cycle 11 outage-- Pump bearings, mechanical seals, and shaft replaced (1990).

G-50B

8/84-- Pump packing glands were loose

1/85-- Pump repacked

3/86-- Pump repacked

6/86-- Packing leaked

9/86-- Packing replaced with mechanical seal

8/88-- Stuffing box gasket leaked

Cycle 11 outage-- Pump bearings and mechanical seals replaced (1990).

Note regarding pump seals & G-50A shaft:
Replacement of the pump packing with mechanical seals has proven effective. During the time period from 9/86 until the Cycle 11 outage, it is estimated that the SI pumps have been run for IST and for the monthly SI line recirculation for a total running time of more than twice the 6 hours required for SBLOCA, and at flow rates significantly less than would be required for SBLOCA (as described above). The seals remained in good condition.

G-50A shaft was replaced (1990) because the maximum runout was measured at .088″ versus the .003″ value recommended by the vendor. The probable cause for this deviation is that a previous maintenance effort may have applied excessive heat and thereby causing the shaft distortion.

Inspections

During the maintenance work listed above, the pumps have been partially disassembled at various times, and additional relevant problems have not been found. (See page 3 for a discussion of the types of damage that could be attributable to cumulative miniflow operation.) During the Cycle 11 outage, impeller and bearing inspections found no damage attributable to miniflow operation.

Conclusion

Based upon the above operating experience, the SI Pumps have proven to be capable of performing their safety related function in the miniflow mode.

TABLE 3

EVALUATION OF MINIFLOW FOR SONGS 1 SR PUMPS

PUMP: CHARGING (VCC-G-8A&B)

MANUFACTURER	PACIFIC PUMPS (2″ Type Z 12 Stages)
REQUIRED TIME DURATION FOR MINIFLOW POST-ACCIDENT	Qualification for Post-accident miniflow operation not required. N. Charging Pump operation at low flowrate for extended periods of time during Safe Shutdown operations is possible. However, a 3″ bypass line to the RWST is available to carry the balance of the flow.
IST	Pumps tested quarterly; bearing temperatures recorded at least once per year. Flowrate through FI-1112 measured, but there is also the additional flow of 72 gpm miniflow and 24 gpm for Seal Injection.
RECENT MAINTENANCE HISTORY	G-8A Rebuild pump (3/85) G-8B • Replace mech seal gasket (6/88) • Replace rotating element with new design (12/87) • Replace mech. seals (12/85)

EVALUATION: Normal and maximum pump flow rates are 136 and 213 gpm respectively. Flow rates during testing are approximately 40 + 72 + 24 = 136 gpm (normal flowrate). Although the best efficiency point (BEP) is 345 gpm, actual operating experience confirms normal flowrate is acceptable. The pumps are not required to operate in the miniflow mode during post accident conditions.

CONCLUSION: PUMP MINIFLOW IS ADEQUATE:

(1) Post-Accident miniflow operation not req'd.
(2) Pumps are typically not run on miniflow alone during normal operation or IST.

TABLE 4

EVALUATION OF MINIFLOW FOR SONGS 1 SR PUMPS

PUMP: **COMPONENT COOLING WATER (CCW-G-15A, B, & C)**

MANUFACTURER	PACIFIC PUMPS (6 x 14 Type DS)
REQUIRED TIME DURATION FOR MINIFLOW POST-ACCIDENT	Miniflow mode not required post-accident.
IST	Quarterly tests not run in miniflow mode, therefore possibility of insufficient flow during testing is not a concern.
RECENT MAINTENANCE HISTORY	Replaced mechanical seals, no maintenance history related to pump vibration, bearing temperatures, or discharge pressure

EVALUATION: Pumps are typically not in miniflow mode during testing, normal operation, or post-accident conditions. Maintenance experience has been very good.

CONCLUSION: **PUMP MINIFLOW HAS PROVEN TO BE ADEQUATE BASED UPON ACTUAL OPERATING EXPERIENCE.**

TABLE 5

EVALUATION OF MINIFLOW FOR SONGS 1 SR PUMPS

PUMP: AUX FEED (AFW-G-10, -10S, & -10W)

MANUFACTURERS	G-10: WORTHINGTON;3-WTL-86 G-10S: PACIFIC; SIZE 2, TYPE BJTC G-10W: PACIFIC; Size 3, TYPE JHF
REQUIRED TIME DURATION FOR MINIFLOW POST-ACCIDENT	Not required. Pump discharge valves open after pressure reaches set points. FCVs 2300A, B, & C are preset to 100% open; operators adjust valve settings to equalize flow to each Steam Generator.
IST	G-10W is tested with flowrate of 165 gpm miniflow to aux feed storage tank (monthly test). G-10 and G-10S are also tested in miniflow mode once per month, but without flow measurement. Additional tests of G-10 and G-10S at full flow is performed each time the plant enters Mode 3, 4 or 5.
RECENT MAINTENANCE HISTORY	G-10: Rebuild pump -- low pressure pressure output.(11/85) G-10S: Overhaul pump (11/85) G-10W: No maintenance history related to pump vibration, bearing temperatures, or discharge press.

EVALUATION: Miniflow mode is used primarily for IST testing. Maintenance and IST histories indicate use of miniflow has not caused damage or degrading trends to pumps. Safety related operation in the miniflow mode is not required.

CONCLUSION: PUMP MINIFLOW HAS PROVEN TO BE ADEQUATE BASED UPON ACTUAL OPERATING EXPERIENCE.

TABLE 6

EVALUATION OF MINIFLOW FOR SONGS 1 SR PUMPS

PUMP: REFUELING WATER (CRS-G-27N & -27S)

MANUFACTURER	WORTHINGTON (Model 4HN112)
REQUIRED TIME DURATION FOR MINIFLOW POST-ACCIDENT	Not required.
IST	Pumps are tested on miniflow quarterly (time required > 5 min.). Once per year bearing temperatures are measured which requires approx 30 min running time on miniflow.
RECENT MAINTENANCE HISTORY	G-27N: • Missing bolt on bearing cover (1/86) • Realigned motor after mechanical seal replacement (4/88) • Replaced mechanical seal (5/86) G-27S: No maintenance history related to pump vibration, bearing temperatures, or discharge pressure.

EVALUATION: Results of IST over a number of years (since at least 1982) indicate highly reliable performance. Miniflow configurations are similar, and G-27S has no history of maintenance problems. Safety related operation in miniflow mode not required.

CONCLUSION: **PUMP MINIFLOW HAS PROVEN TO BE ADEQUATE BASED UPON ACTUAL OPERATING EXPERIENCE.**

TABLE 7

EVALUATION OF MINIFLOW FOR SONGS 1 SR PUMPS

PUMP: RESIDUAL HEAT REMOVAL (RHR-G-14A & G-14B)

MANUFACTURER	PACIFIC PUMPS (6″ Type SVC)
REQUIRED TIME DURATION FOR MINIFLOW POST-ACCIDENT	Miniflow used primarily for line warming only.
IST	NPSH would not be adequate with MOV-813 &-814 closed. Therefore, pumps are tested only when RHR is in service. (during final stages of plant cooldown & cold shutdown).
RECENT MAINTENANCE HISTORY	G-14A: • Replace mech. seal (6/89) • Install new pump due to oil leaks (1/86) • Rewind motor (8/84) G-14B • Replace oil seals (5/88) • Replace pump and motor due to oil leaks. (9/86)

EVALUATION: Pump miniflow mode used primarily for line warming only. Miniflow mode not needed for testing, normal operation, or post-accident conditions. Pumps have never failed during startup of the RHR system in entire operating history of SONGS1.

CONCLUSION: **PUMP MINIFLOW HAS PROVEN TO BE ADEQUATE BASED UPON ACTUAL OPERATING EXPERIENCE.**

TABLE 8

EVALUATION OF MINIFLOW FOR SONGS 1 SR PUMPS

PUMP: MAIN FEEDWATER (FWS-G-3A & -3B)

MANUFACTURER	BYRON-JACKSON (10x10x17 2 stage DVMX; 10500 GPM)
REQUIRED TIME DURATION FOR MINIFLOW POST ACCIDENT	Not required in the Feedwater Mode. Required for up to 6 hours in the SI Mode. (See response to comment 3.)
IST (Performed in Feedwater Mode)	Pumps tested under Mode 1 full flow conditions. When not in Mode 1, pumps are sometimes tested on miniflow to provide assurance pump will perform properly in Mode 1.
FUNCTIONAL TEST OF SI SYSTEM	FW pumps run in SI mode approx 5 minutes for each test.
RECENT MAINTENANCE HISTORY	See attached pages for relevant history related to pump vibration bearing temperatures, or discharge pressure.

EVALUATION: (1) Miniflow for SI mode has been increased during Cycle 11 as described in response to comment 3.

(2) Miniflow in the Feedwater mode is estimated to be approximately 1000-1100 gpm. There is no indication that the pumps have been damaged. To provide verification, the West (G-3B) pump was tested on miniflow for 48 hours in 9/86, followed by a thrust bearing assembly inspection to verify that damage did not occur. Since that time, it has provided additional miniflow service without damage as evidenced by the IST and maintenance records.

CONCLUSION: PUMP MINIFLOW IS ADEQUATE IN THE FEEDWATER MODE BASED Upon ACTUAL OPERATING EXPERIENCE. MINIFLOW IN THE SI MODE HAS BEEN INCREASED AND IS ADEQUATE AS DESCRIBED IN THE RESPONSE TO COMMENT 3.

TABLE 8 (continued)

RECENT MAINTENANCE HISTORY (FWS-G-3A & G-3B)

East Pump (G-3A)

1) Thrust bearing failure due to seal water contamination of lube oil supply on 2/11/85 was caused by overloaded drain cavities (excessive seal water flow prior to pump startup & operational delays between commencing seal flow and starting feed pumps). **Not caused by miniflow.**

2) Removed thrust bearing upper housing to take relative axial measurement between shaft & thrust disc (6/22/87). Looseness was observed, but the looseness was due to improper setting of the clearances during the last reassembly (9/86). **Not caused by miniflow.**

West Pump (G-3B)

1) Pump shaft failure 5/1/85. The cause was hypothesized to be stresses induced by axial vibration of shaft due to improper alignment. **Not caused by miniflow.**

TABLE 8 (continued)

2) Pump shaft failure 9/4/86. Failure in same threaded area as in 5/1/85. Failure was caused by loss of thrust disk assembly preload, followed by thread-to-thread fretting.

After repair, the West MFP was run for 48 hours (Mode 5), & then the thrust bearing assembly was inspected. No indications of unusual wear were found. Although the special pump design features noted in the response to comment 3 tend to minimize vibrations, it was noted during the 48 test that low frequency vibration was occurring in the pump due recirculation effects. It was observed that the vibration was occurring on the pump as an assembly and was not due to the shaft moving relative to the casing or bearings. Therefore, it was concluded that bearing and pump internal wear will not be accelerated due to these vibration levels.

3) Outboard journal bearing exceeded normal temperature limits (5/90) due to momentary lack of adequate lubrication. **Not caused by miniflow.**