ABB
ASEA BROWN BOVERI

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LD-93-048

Docket No. 52-002

Attn: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Subject: System 80+™ Reactor Systems Branch Review

Dear Sirs:

Enclosed with this letter are responses to supplementary questions from Mr. Sun of the Reactor Systems Branch. It is our understanding that, in general, this information need not be printed in CESSAR-DC and that Mr. Sun will contact us if any specific paragraphs need to be extracted and printed in CESSAR-DC. It is also our understanding that this information is adequate to close these issues.

If you have any questions, please call me or Mr. Stan Ritterbusch at (203) 285-5206.

Very truly yours,

COMBUSTION ENGINEERING, INC.

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The following are responses to questions asked of ABB-CE at a meeting with Mr. Summer Sun of the NRC in Windsor, Ct. on February 3, 1993. These responses were faxed to Mr. Sun on February 16, 1993. The fax included the following attachments:

1) Proposed modification to the draft System 80+ Emergency Procedure Guidelines - Functional Recovery Section for Continuing Actions for Inventory Control.

2) RAI 440.58

3) CE letter S-PSD-469 dated September 30, 1980, High Pressure Safety Injection Special Test.

4) RAI 440.71

NRC Question No. 1

The EPG's for System 80+ should be reviewed and revised as necessary to discuss the use of the SCS pumps for Injection mode for a Beyond-Design-Bases event. This is a follow-up" item to ABB-CE's response to DESR open item 6.3.3-1.

ABB-CE's Response

The draft version of the EPG's was reviewed for inclusion of the SCS operation as part of the Safety Injection System. It was found that this operation was implied as part of the Safety Function for RCS Inventory Control in the success path IC-2. The structure of the Functional Recovery Guide in the EPG's establishes what systems are to be used for recovery and in proper priority. The first system is the CVCS which provides inventory control for breaks smaller then a SBLOCA. For all other breaks, the SIS is used as it is designed to exceed the inventory control requirements for all Design-Bases-Events. However, at the end of the SIS section for inventory control, page 10, the EPG's provide a section entitled "Continuing Actions for Inventory Control" which would cover Beyond-Design-Bases events. Listed in the section, as item c iii, is the following contingency action for the case if the SIS fails to maintain RCS inventory:

"c) The feasibility of restoring function to a success path by:

iii) use of alternate components to implement a success path."

This would include the use of the SCS pumps as an alternate source of injection. However, to clarify the intent, an item c. v. (see attachment 1) will be added stating:

"v. Align the SCS pumps, once the RCS is depressurized, to inject borated water from the IRWST to the DVI's."

NRC Question No. 2

Document in the appropriate place that power will be removed from the SCS isolation valves during leak testing.

ABB-CE's Response:

This comment was evaluated base on the requirement for when and how the SCS RCS isolation valves need to be leak tested. A review of the ASME code for Operation and Maintenance of Nuclear Power plants was preformed, in conjunction with the operational requirements of the SCS, to provide a bases. The results being that the power should not be removed from the SCS RCS isolation valves during leak testing. The following is provided to support this statement.

ASME OM Code-1990 requires that the leak testing shall be done with valves pressurized from the normal pressure side (i.e, reverse pressurization is not allowed for these valves). To perform testing during power operation, which meets the Code requirement, the interlocks that prevent the SCS valves from opening and overpressurizing the SCS (P-103, P-104, P-105 and P-106) would have to be over-ridden. This is necessary so that SI-656, SI-655, SI-654 and SI-653 can be opened so that leak testing of SI-651 and 652 can be performed. This would put the SCS in a position with only a single isolation valve between the RCS and the SCS and as such power removal from the valve operators would not be recommended.

However, ASME OM Code-1990 also allows an alternative test. Leak testing can be performed at reduced pressures. The results would be extrapolated to the maximum differential pressure across the valve. For the SCS isolation valves, this means that they could be tested during shutdown cooling when there is no potential of overpressurizing the SCS. This is also consistent with the SCS design requirements i.e., the system has two identical trains, each capable of providing the necessary DHR. The current Technical Specification, LCO 3.4.11, allows the isolation of one train for up to eight hours. This would provided adequate time to leak test the SCS isolation valves. As a result, leak testing should be performed during shutdown cooling and power should not be removed from the valve's motor operator so that the train of SC being tested can be restored rapidly if needed.

NRC Question No. 3

Now that the auto-closure interlocks have been removed from the Shutdown Cooling suction isolation valves, what (if any) TS have been, or should be, added? Review the San Onofre TS for applicability to this issue.

ABB-CE's Response:

The San Onofre shutdown cooling system design is not similar to System 80+. San Onofre's design uses a single hot leg suction connection, then splits to provide redundant isolation protection. After the isolation, the suction line combines, has a single LTOP relief valve and containment penetration before splitting to the two shutdown cooling pumps.

System 80+ provides two totally separate, redundant trains of shutdown cooling. Each sized to meet the cooling and LTOP relief requirements. Therefore, they are not similar and requirements are not directly applicable.

However, a review of the Technical Specifications for both System 80+ and San Onofre was performed. The review showed that many changes have been made to the System 80+. The following is a summary of the major changes made for System 80+ related to LTOP:

a) For System 80+, two LTOP relief valves shall be operable in modes 4, 5 and 6 where San Onofre requires one. (the "Action" requirements of LCO 3.4.11 allows one to be inoperable for short term to facilitate testing). Each LTOP valve for System 80+ is equivalent to the one provided in the San Onofre Shutdown Cooling System in that it is designed to relieve the anticipated mass and energy addition transient associated with LTOP. Therefore, System 80+ has twice the relieving capability plus the Technical Specifications requirement to have the valves operable.

b) For System 80+, two division of Rapid Depressurization isolation valves shall be open during modes 4, 5 and 6. This provides a vent path of 9.794 sq. in. vs. the 5.6 sq. in. requirement for San Onofre.

Based on the system design and the Technical Specifications changes, System 80+ does not require any further modifications as a result of the deletion of the auto-closure feature for the suction isolation valves.

NRC Question No. 4

Provide the bases for the 12000 hour operation for the SI pumps.

ABB-CE's Response:

The requirement for 12,000 hours of continuous operation comes from the ABB-CE Project Specification for which Ingersoll-Rand has agreed to for the ANPP and YGN 3 & 4 contracts. The actual requirement is stated as "At runout conditions (runout flow plus bypass flow) they [the HPSIPs] shall be suitable for operation for a minimum of 12,000 hours." Ingersoll-Rand has stated that the seal life is a function of (a) the number of hours of operation below the design point, (b) the

number of hours of operation above the design point and (c) the number of starts/stops. Ingersoll-Rand's justification for agreeing to the 12,000 hour requirement is based on data presented in the literature for pumps with mechanical seals.

NRC Question No. 5

Discuss the issue of the miniflow rate for the SCS pumps.

ABB-CE's Response:

The issue of maximum miniflow for the SCS pumps was addressed in RAI 440.58. A copy provided as attached 2 for reference.

NRC Question No. 6

ABB-CE's response to DSER OI 6.3.3-1 addressed Safety Injection Pump minimum flow requirements. What test data exists to support the minimum flow established for System 80+? How long were the pumps operated at the minimum flow rates? What data exists regarding the 45 hours provided in the response?

ABB-CE's Response:

ABB-CE does not have the results from the test performed on the HPSIP. The statement made in DSER OI 6.3.3-1 was based on the report prepared summarizing the special test. The intent of the test was to:

a) Verify satisfactory pump operation at maximum runout conditions;

b) Verify pump operability at shut-off head and minimum bypass flow;

c) Confirmation of pump performance consistent with the manufacturer's curve.

The report prepared for this test did not include specific time limits that were used to establish steady flow prior to taking the results. However, it did express the time for minimum flow operation, as endorsed by the manufacture, as:

"Operation of pumps at 35 gpm minimum flow is to be limited to one hour every month for 5 years. At the end of this period, the bearings are to be replaced. During this five year period, the pumps may operate at 35 gpm for one month. If this occurs, the bearings are to be replaced after the one-month period."

The 35 gpm has since been revised to a minimum flow of 85 gpm. This provides the 60 hours for intermittent use and 720 of continuous operation at minimum flow. Attachment 3 is provided for documentation of the test.

The 45 hours presented in DSER-OI 6.3.3-1 was based on a review of testing performed at Arkansas on the HPSI pump. The test required:

1) Three ISI tests per year for 30 minutes each and
2) One bearing temperature equilibrium test at three hours both over a pump life of ten years.

NRC Question No. 7

Review NRC Bulletin 88-04.

ABB-CE's Response:

A review of NRC Bulletin 88-04 was provided in RAI 440.71. The response is attached as attachment 4 for reference.

The following questions were asked in a telephone call with Mr. Mike Volodzko (ABB-CE) on February 26, 1993.

NRC Question No. 8

In response to DSER Open Item 5.4.3.4-1 ABB-CE indicated that the SCS pumps are designed to operate for a minimum of 12,000 continuous hours. What is the basis for this operability period? In addition, in response to RAI 440.30, ABB-CE indicated that the SIS pumps are capable of operating for 5 years between scheduled maintenance cycles. Why is the SCS operability period different from that of the SIS pumps?

ABB-CE's Response

In addition the bases given in the response to NRC Question No. 4, the 12,000 hours operability for the SCS pumps is based on the consideration of the following factors:

1.) ABB-CE's judgement of how long a SCS pumps needs to operate continuously post accident;

2.) the amount of redundancy available in the SCS and CSS pumps to perform decay heat removal by producing flow through the reactor core and SCS or CSS heat exchangers; and

3.) the life expectancy of the SCS and CSS pump seals and bearings based on vendor information and experience.

It is ABB-CE's judgement that having a SCS pump with the (minimum) capability of continuously operating for 12,000 hours after an accident is sufficiently long to allow conditions in containment to stabilize and for decay heat to decrease to very low values. In addition, when accounting for the redundancy available in the SCS and CSS pumps (a total of three redundant pumps and heat exchangers) it is ABB-CE's position that the capability exists to conduct decay heat removal using safety grade components for at least 35,000 hours without maintenance, and for an indefinite period of time thereafter when accounting for maintenance to these pumps.

Based on discussions with Ingersoll Dresser Pump Company, the 12,000 hours is consistent with the capabilities of these pumps based on seal life expectancy and experience. This can be illustrated by an evaluation of the SCS pump design. First, the pump bearings are located in the motor, which removes them from the harsh RCS fluid environment. The design of the pump motor/bearings is consistent with what is used extensively throughout the pump industry. The only unique facet of the SCS pump design is the forged pump housing. This difference from standard pump designs (cast housings) does not impact pump durability. Lastly, the seal material for the SCS pump seals is consistent with pump seals used extensively in similar environments.

The discussions given in response to RAI 440.30 regarding the SIS pump operability represent a typical value based on the performance of similar pumps in boiler feedwater applications rather than a minimum operability time, as in the case of the SCS pump discussed above. ABB-CE believes that the SCS pumps are capable of operating beyond the minimum time required in our specification if necessary.

NRC Question No. 9

What is the miniflow requirements for the SCS pumps?

ABB-CE's Response

The miniflow rate requirement for the SCS pumps will be consistent with the other safety system pumps, approximately 3% to 5% of runout flow rate.

NRC Question No. 10

The response given to NRC Question No. 1 is, in general, acceptable. However, what are the conditions and limitations for using the SCS pump for injection for Beyond-Design-Basis events? Is it safe to operate the pump in this mode? What is the maximum pressure against which the SCS pumps will be used?

ABB/CE's Response:

The response provided to NRC Question No. 1 from the Feb. 3rd meeting was not intended to provide a complete EPG write-up covering the use of the SCS pumps but rather to indicate the location in the EPG where the use of the SCS pumps during Beyond-Design-Basis events (BDBE's) would be addressed.

In developing the procedure guideline for SCS pump use during BDBE's consideration will be given to the performance capabilities and limitations of the pump. In particular, the procedures will be written to reflect the shutoff head of the pumps and to account for the temperature limitations of the pumps and the SCS.

The following question was asked during a telephone call with Mr. Mike Volodzko (ABB-CE) on March 5, 1993.

NRC Question No. 11

Expand the discussion of the 45 hours for SI pump testing presented in DSER OI 6.3.3-1, and provided in response to NRC Question No. 11, to account for the actions requested in NRC Bulletin No. 88-04. In particular, evaluate the adequacy of the minimum flow bypass lines for the SIS, CSS and SCS pumps with respect to damage resulting from operation and testing in the minimum flow mode and 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.

ABB/CE's Response:

The 45 hours is based on tests performed on the HPSI pumps at Arkansas. The Arkansas testing program followed the requirements of the ASME Code, Section XI, and each HPSI pump was tested at shutoff conditions (full miniflow) for 45 hours over a period of ten years. The 45 hours involved two types of tests, In-Service Inspection tests and bearing equilibrium temperature tests. The ISI tests were performed quarterly on each pump, with each test lasting 30 minutes.

A three-hour bearing temperature equilibrium test was performed once a year during one of the ISI tests. The duration of each test was agreed to by the utility and the pump vendor. Based on this data, the System 80+ SI pump bearing and seals are expected to withstand at least 45 hours of miniflow operation for a period of ten years before maintenance is needed on the pumps. The System 80+ testing program will follow the requirements of the ASME OM Code.

With regard to the actions requested in NRC Bulletin No 88-04, the effect of cumulative operating time at minimum flow is accounted for by the fact that ASME OM Code-1990, Subsection ISTB, Inservice Testing of Pumps in Light-Water Reactor Power Plants, requires that

(a) inservice tests be conducted nominally every three months;

(b) inservice tests be conducted with the pump operating at specified test reference conditions;

(c) pressure, flow rate and vibration be determined and compared with corresponding reference values;

(d) if deviations are detected from the reference values and fall within the alert range, the frequency of testing be doubled until the cause of the deviation is determined and the condition corrected;

(e) if deviations are detected from the reference values and fall within the required action range, the pump be declared inoperable until the cause of the deviation has been determined and corrected.

ABB-CE believes that the minimum flow rates specified for the SIS, CSS and SCS pumps provide a reasonable balance between (a) accounting for the time spent in the minimum flow mode during testing and during a postulated accident and (b) overly conservative bypass flow requirements which increase the power and size of these pumps. While the minimum flow rate requirements for these pumps may not preclude maintenance or replacement of pump parts over the lifetime of the plant because of inservice tests, the ability of these pumps to perform their intended safety function is not compromised in view of these tests and the original design specifications.

ATTACHMENT 1

COMBUSTION ENGINEERING EMERGENCY PROCEDURE GUIDELINES	TITLE FUNCTIONAL RECOVERY GUIDELINE
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CONTINUING ACTIONS FOR INVENTORY CONTROL

If the acceptance criteria are NOT met, Then RCS Inventory Control is still in jeopardy. The operator must continue to attempt to establish RCS Inventory Control while pursuing other jeopardized safety functions. Evaluate further actions using the following:

a) Rate of change of inventory and potential for damage to the RCS
b) The urgency of other jeopardized safety functions
c) The feasibility of restoring function to a success path by:
   i) restoring the vital auxiliaries necessary to operate components or systems in the success paths
   ii) manual operation of valves
   iii) use of alternate components to implement a success path.
   iv) depressurizing/cooling the RCS to increase or establish HPSI flow. ~~to increase or establish LPSI flow, or, in an extreme case, to allow the SITs to discharge.~~
   v) Align the SCS pumps, once RCS is depressurized, to inject borated water from the IRWST to the DVI's.

Question 440.58

Discuss provisions of pump protection available for SCS pumps from potential low flow or no flow operating conditions.

Response 440.58

The design of the System 80+ Shutdown Cooling System (SCS) has eliminated the potential for pump low flow or no flow operation without the occurrence of multiple failures. Chapter 5, Section 5.4.7 of CESSAR-DC defines the functional design bases for the SCS such that the pumps are required to operate in support of the following conditions:

a) shutdown cooling,
b) transfer of coolant to the CVCS for purification during the shutdown cooling mode,
c) transfer of coolant from the fuel pool back to the IRWST following refueling operations,
d) backup to the Containment Spray System (CSS) for IRWST heat removal during accident conditions.

Most notable is the deletion of the low pressure safety injection function on receipt of a Safety Injection Action Signal. The result is that the SCS pumps now operate in a closed loop environment where the pump's head is only a function of the line losses. The static pressure in the RCS will not change the pump's head as in an open loop system, where the operating point is determined by the system back pressure. Therefore, from the functional bases requirements, none of the design modes will require the pumps to be operated in a low flow, no flow condition.

As described in CESSAR-DC Section 5.4.7.2.2.E, each of the SCS pumps is provided with a mimimum flow (miniflow) recirculation line to provide pump protection. The miniflow lines are routed from the pump discharge back to the pump suction; see CESSAR-DC Figures 6.3.2-1A and 6.3.2-1B. The miniflow lines have no remotely actuated valves; a locally operated manual valve that is provided in each line to allow pump maintenance is locked open during all plant operating modes. A heat exchanger is provided in each miniflow line to remove pump heat in the event of a closed pump discharge path due to operator error.

Each of the SCS pumps is provided with a low shutdown cooling flow alarm. The alarm setpoint is established based on the flow rate required for shutdown cooling operations. An alarm will alert the operator to low flow conditions that may lead to a loss of shutdown cooling due to either a loss of adequate pump suction or the closure of a system valve. Instrumentation that would alert the operator to a low flow condition due to closure of the SCS suction line isolation valves is discussed in the response to NRC question 440.54.

ATTACHMENT (3)

HPSI SPECIAL TEST REPORT

A test of selected [illegible] Pressure Safety Injection ([illegible]) System features for San Onofre Unit 2 was conducted during the period of August 4 to 9, 1980. CE has reviewed the test data with regard to the principal test objective. This summary report provides the results of that review.

The principal test objective was to provide engineering and technical information which would provide early validation of the engineering assumptions used to develop the HPSI flow shown in Table 6.3-2A of Amendment 17 of the SONGS Units 2 & 3 FSAR.

It is CE's assessment that the test results confirm the ability of the HPSI system to provide flow consistent with the Table 6.3-2A of FSAR Amend. 17

The test was conducted in accordance with SCE test procedure 2ST-225-01, titled "HPSI Special Test". The test was designed to provide specific engineering information regarding components and the overall system performance. The test was scheduled to precede the normal preoperational system testing. Quality control provisions for the special test were generally the same as those used in the preoperational program. The specific issues addressed in the test program are listed below. Each item was reviewed separately as part of the overall evaluation to confirm HPSI system performance.

The specific items of interest can be divided into component issues and system issues. Component issues are associated with the HPSI pump. They are:

1) Verification of satisfactory pump operation at maximum runout conditions;

2) Verification of pump operability at shutoff head and minimum bypass flows;

3) Confirmation of pump performance consistent with the manufacturer's curves.

System issues are:

1) Establish as-built system resistance for each possible combination of pump and header;

2) Establish leg balance characteristics for each header;

3) Confirm system performance for the Emergency Core Cooling System (EC(Small Break Analysis.

Pump Runout Limits

Maximum flow for small breaks is achieved by permitting operation at maximum flows in a runout condition. Engineering review had shown that the potential pump runout point was greater than the runout point listed in the pump specifications. Header valves or leg orifices are provided in the design to limit the total system flow. Since it was desirable to take advantage of rather than limit the extra flow, the test program was designed to provide the pump manufacturer with sufficient information to enable them to endorse pump operation at flow rates greater than the originally specified values.

One HPSI pump (P017, was instrumented for continuous monitoring of vibrations and inlet and discharge pressure oscillations. During the test, pump flow was gradually increased to maximum runout while the pump vendor representative was monitoring the pumps behavior. Subsequently, the othe HPSI pumps were also run at maximum flow.

After review of the test results, the pump manufacturer endorsed pump operation at 1000 gpm. This represents an 18% increase from the existing specification flow of 850 gpm. The existing system configuration will not permit the pump to operate at 1000 gpm. Maximum flows are expected to be approximately 935-950 gpm including design minimum bypass flow.

Minimum Flow Operation (Miniflow)

During the development of the test program there were concerns expressed that the design minimum flow of 35 gpm might be too low. The test program was expanded to include observations of minimum flow. Provisions were made to increase the minimum flow above the design value in order to establish the necessary level of minimum flow should the design value prove inadequate.

Minimum flow testing covered a range of flows fr.. 115 gpm to 35 gpm. The tests showed that the minimum flow orifices used to control minimum flow were oversized. The range of flows for all pumps was found to be 99-115 gpm with the original orifices. Throttling was required to test the pumps at the design value of 35 gpm.

Minimum flow operation at 35 gpm has been endorsed by the pump manufacturer, but the following conditions have been imposed:

> Operation of pumps at the 35 gpm minimum flow is to be limited to one hour every month for five years. At the end of this period, the bearings are to be replaced. During this five-year period, the pumps may operate at 35 gpm for one month. If this occurs, the bearings are to be replaced after the one-month period.

These conditions permit periodic inservice inspection testing under ASME Section XI and sufficient operation at the end of the cycle for successful operation in the event of a LOCA.

Overall Pump Performance

The HPSI pump may operate at several different points on its characteristic curve during a small break LOCA as the pressure in the reactor coolant loop decreases with time. This is in contrast with the large break LOCA where the system operates at the runout point thoughout the event.

Since the major emphasis of this test program was to confirm HPSI pump performance assumptions used in the small break LOCA analysis, the test program included 6 point checks of the pump characteristic curves. System resistance was varied by throttling the header valves to obtain the 6 points ranging from runout to shutoff (i.e. pump operating on minimum bypass flow). More extensive data was collected on pump P017 as part of the vibration study.

Suction and discharge pressures were recorded during twenty minute runs at each flow condition. Flows were recorded by diverse methods. It

is concluded that the field performance is consistent with vendor shop tests. Figures 1 to 3 provide comparisons between the pump characteristic curves established by the vendor and those established by field testing.

As Built System Resistance

The resistance of complex piping systems is normally predicted by summing resistances of individual components whose resistances have been defined under controlled conditions. Interaction between individual components introduces an inherent uncertainty in these predictions. Initial system interface resistance requirements are specified conservatively low, and the system design has provisions for throttling so that runout flows may be limited to component specifications during final system testing. This procedure, followed in the design of the HPSI system, resulted in the expectation that testing would potentially yield higher flows.

Calculations showed a system resistance of 1225 ft which would permit total flows of approximately 910 gpm. To limit the flows to 850 gpm would require an increase in system resistance to 1570 ft. To confirm the maximum available flow for use in the small break analysis it was necessary to establish the as-built system resistance by test and to have pump operation endorsed at the flow rates permitted by the as-built system. The four potential system configurations that may be used in the safety analysis with the maximum tested flow and system resistance are shown in Table 1 . The flow rates and resistances in Table 1 compare favorably with the predicted values mentioned above. However, no significant additional margins were established by the tests.

Leg Balance

Each HPSI train consists of one pump with discharge piping which splits into four essentially parallel paths to deliver safety injection flow to the four reactor coolant loop cold legs. The safety analysis assumes spillage of the flow entering a broken cold leg. Therefore flow to the core is represented by flow from three legs. For a given total system flow maximum utilization is achieved if the individual leg flows are balanced. To achieve balance by design is difficult but provisions are provided in the system design for field adjustment. SCE has elected to use orifices for balance so that the header isolation valves could always go to a full open position.

The simplest balance criterion is a plus or minus flow tolerance on each leg. This breaks down if one is attempting to maximize flow and one leg is low and the other three are equal. The balance exercise could be time consuming particularly when orifices are used. From a functional point of view it is sufficient that the flow from the lowest three legs be greater than some fixed value as determined by the safety analysis. It is preferable to separate the balance criteria from the total flow requirement.

The balance criterion that has been chosen is that the sum of the lowest three legs divided by0.75 must be within a specified tolerance of the total flow. This provides maximum flexibility on the absolute values for each leg and has the potential to minimize the number of adjustments required for balance.

The total system and individual leg flow rates were measured. The difference between the total measured flow rate and the balanced flow

Table 1

Max. Pump Flows (without miniflow)

	HPSI Header #1		HPSI Header #2	
HPSI Pump →	P017	P018	P019	P018
Max. Flow (gpm)	920	939	934	938
System Headloss (ft)	1169	1184	1172	1204

Table 2

Leg Balancing

Pump No.	Total[1] Flow (gpm)	Leg Balancing Criterion (gpm)
P017	920	16
P018 (hdr.#1)	939	13
P019	934	6
P018 (hdr.#2)	938	5

(1) without miniflow

rate calculated by the above criterion ranged from [illegible] to 5 gpm. The results provided in Table 2 . Prior to testing, a target value of 11 gpm had been considered reasonable. It was decided that the maximum value of 16 gpm would not require adjustment.

ECCS Flow for Small Break

For the small break LOCA the safety injection system operates in the wide open configuration, but high back pressure reduces system flow. It has been established that for the limiting small break the back pressure range of interest is 1100 psia to 600 psia. When establishing the flow capability for the safety injection system, instrument error(for pressure and flow), pump degradation, and leg balance considerations are conservatively used to adjust best estimate performance(either predicted or tested).

Best estimate performance as established by the field tests for each system configuration is given in Table 3 below.

Table 3-Test Performance(Best Estimate)

RCS Pressure PSIA	Header 1		Header 2	
	Pump P017	Pump P018	Pump P019	Pump P018
1100	414	416	416	420
900	524	527	529	531
600	662	670	673	675
runout	898	916	921	923

It is clear that the minimum system flow rate is provided by pump P017 and header No.1 . However the spread is minimal, indicating a well balanced design.

Table 4 represents ECCS requirements. These flow rates must be met if the analysis presented in Amendment 17 of the FSAR is to remain applicable. Column A represents flows required from the HPSI System if flow from the charging system is also credited. Column B represents flow required from the HPSI system if no charging flow is assumed.

Table 4 - ECCS Requirements

RCS Pressure psia	HPSI System Flow A (gpm)	HPSI System Flow B (gpm)
1100	373	400
900	487	514
600	627	654
14.7 runout	860	887

Pump 017 discharging through header 1 was used to establish the minimum performance for comparison with that used in the ECCS analysis. Uncertainties from instrument error, pump head degradation, and leg balance are subtracted from the measured test results to produce conservatively low performance data for ECCS analysis. Table 5 represents a summary of flows derived for different values of these factors. Column A represents our selection of a reasonable set of parameters based on the test equipment utilized in this program. It is not expected that the pump will experience 3% degradation with its service requirements. It is clear that the performance in Column A, Table 5, exceeds that required by Column A Table 4 . Columns B through D of Table 5 show the sensitivity of the various parameters. In these columns the pump head degradation has been reduced to 1%. Column B does not provide sufficient flow to eliminate the use of the charging system. Column C shows the sensitivity of leg balance and Column D shows the sensitivity of flow error. Neither Column C nor D shows significant change from Column A.

CONCLUSIONS

The special HPSI test was conducted to provide validation of HPSI system performance before the normal pre-operational system testing. Three specific component issues and three specific system issues were examined as part of the overall system performance review. HPSI pump operation has been endorsed by the vendor over the range 35-1000 gpm, with restrictions applied to operation at the minimum flow. As-installed pump performance curves were shown to be consistent with the manufacturer's curves. Overall system resistance and leg balancing characteristics were determined. In summary, the test program demonstrated that the HPSI system in conjunction with the charging system has the capability to provide sufficient flow to support the FSAR Amendment 17 analysis.

Table 5

Factors Affecting Pump Flow Data

	A	B	C	D
Pump Head Degradation - %	3	1	1	1
Pressure (± psi)	6.25	6.25	6.25	6.25
Flow (± gpm)	10	10	10	20
Leg Balance (gpm)	17	17	44	17
Minimum flow at shutoff (gpm)	45	45	45	45

RCS pressure - psia	HPSI Pump Flow (gpm)			
1100	378.9	394.8	382.7	386.6
900	495.5	507	491.5	498
600	640.2	647.7	628	638
14.7 (runout)	881	885	858	875

Question 440.71

Discuss the percentage of safety injection (SI) flow capacity (in terms of best efficiency flow) for the SI pump minimum flow recirculation required to protect against hydraulic instability or impeller recirculation problems during extended SI pump low flow operations. (Reference NRC Bulletin 88-04, May 5, 1988)

Response 440.71

The SI pump characteristics and the Safety Injection System have been designed to prevent the hydraulic instability and impeller recirculation problems reported in the NRC Bulletin 88-04. In developing the system, the design has addressed the potential sources delineated in the NRC Bulletin and includes the following resolutions:

1) Shape of the Pump Curve: According to the NRC Bulletin, the primary cause of hydraulic instability is due to the shape of the typical centrifugal pump curve with low specific speed. Specifically, system operation of the pump near dead head conditions yields performances that flatten out or exhibit a downward concavity, producing a reduction in head with a reduction in flow. This phenomenon is significantly more prevalent with low head, high flow, low specific speed pumps. The System 80+ Safety Injection Systems pumps are high head, low flow, high specific speed pumps whose performance curves do not flatten out as the they approach low flows. Therefore, hydraulic instability is not a concern for this system design.

2) Train to Train Cross Connection: The arrangement of the Safety Injection System miniflow recirculation lines precludes pump to pump interaction of the kind discussed in the NRC Bulletin 88-04. The only cross connects provided in the System 80+ SIS arrangement ties two discharge recirculation lines together down stream of an orifice and a check valve, and then provides a path to the vented IRWST. There is no plausible operating configuration which would cause the operation of one SI pump to cause other SI pumps to operate at a low flow rate that is lower than the minimum flow required for pump protection. Therefore, cross connection of trains in the SIS with parallel pump operation is not a concern for hydraulic instability or impeller recirculation.

3) Design Value for Recirculation Flow: The third concern addressed in the NRC Bulletin 88-04 was the determination of the proper miniflow that should be provided to protect the pump against suction and/or discharge tip recirculation. The NRC has recommended that a flow rate in the range of 25% to 50% of best efficiency flow should be used as a guide in establishing the miniflow rate. This range also corresponds to both the pump vendors recommended flow and also corresponds to the defined onset of impeller recirculation as delineated in common pump handbooks. This range, however, does not relate to specific pumps and applications nor to the point where significant performance degradation would occurs. Therefore, in the interest of optimizing the Safety Injection System design, i.e., limiting the size of the pumps, motors, piping and the operating cost

associated with the higher motor BHP, ABB-CE has, in conjunction with pump vendors and utilities, performed an extensive investigation into the specific pump to be used for this application. The results yielded that the minimum flow for the Safety Injection pumps need not be as high as recommended, but should be in accordance with previously established values of 85 to 105 gpm or 9.7% to 12% of BEF efficiency flow. This flow has been shown to protect the pumps from damage associated with operation at low flow for the specific application of Safety Injection.