Docket No. 50-423
B12983

Attachment 1

Millstone Unit No. 3

Natural Circulation System Comparison Report

August 1988

TABLE OF CONTENTS

1.0 INTRODUCTION

This Natural Circulation System Comparison Report has been developed to evaluate the plant systems and equipment that affect the natural circulation, boron mixing, cooldown and depressurization capabilities of Millstone Unit 3 relative to the requirements of Branch Technical Position RSB 5-1, Design Requirements for Decay Heat Removal Systems (Reference 1).

1.1 Background

Circulation of reactor coolant is a key function in the operation of the Millstone Unit 3 plant, including operations to place and maintain the plant in the hot standby operational mode and in performing operations to take the plant to cold shutdown. During normal plant operations, at least one reactor coolant pump (RCP) is normally operating to ensure forced circulation of reactor coolant for boron mixing, heat removal and pressure control considerations.

The loss of forced circulation constitutes an emergency plant condition. Under this plant condition, the plant protection systems will automatically trip the reactor and the plant will be placed in the hot standby operational mode under natural circulation conditions. The plant is designed to be maintained in this condition until forced circulation is restored and normal plant operations can be resumed. Natural circulation of reactor coolant is provided with the reactor core as the heat source and the steam generators as the heat sink. Steam release to maintain the reactor at hot standby is accomplished via the steam generator atmospheric power operated relief valves, or the safety valves if needed. The Millstone Unit 3 systems capabilities needed to support safety grade cold shutdown are evaluated in Section 5.4.7 of the Millstone Unit 3 Final Safety Analysis Report (Reference 2).

1.2 Description of the Diablo Canyon Power Plant Natural Circulation Test

On March 28 and 29, 1985, a boron mixing and cooldown test was performed at Diablo Canyon Unit 1. The test began with a trip from hot full power conditions at 2130 hours on March 28, and continued until 2245 hours on March 29 when cold shutdown conditions were achieved. In general, the test consisted of four basic periods as described below:

1) An initial period of approximately three hours during which the plant was stabilized at hot standby conditions prior to initiation of natural circulation.

2) A period of approximately four hours during which the plant was maintained at hot standby under natural circulation conditions. During this period, natural circulation was established and the boron mixing test was performed.

3) A period of approximately thirteen hours during which the plant was cooled down and depressurized from hot standby conditions to RHR system initiation conditions. During this period, plant cooldown and depressurization testing was performed.

4) A final period of approximately four and one-half hours during which the plant was cooled from RHR initiation conditions to cold shutdown conditions.

1.3 Report Structure

The final report for the Diablo Canyon natural circulation test is provided in the Diablo Canyon Units 1 and 2 Natural Circulation/Boron Mixing/Cooldown Test Final Post Test Report (Reference 3). This Millstone Unit 3 report is structured to compare the plant systems and equipment that affect the natural circulation, boron mixing, cooldown and depressurization capabilities of Millstone Unit 3 with the Diablo Canyon systems and equipment. This comparison is used to describe the applicability of the natural phenomena associated with the Diablo Canyon Unit 1 test to Millstone Unit 3.

Section 2.0 provides a general comparison between the systems and equipment of Millstone Unit 3 and Diablo Canyon.

Section 3.0 provides justification of the applicability of the Diablo Canyon test results to Millstone Unit 3.

2.0 COMPARISON OF DIABLO CANYON WITH MILLSTONE UNIT 3

This section compares the systems and equipment that affect natural circulation of Millstone Unit 3 to those of Diablo Canyon Unit 1 in sufficient detail to evaluate systems capabilities.

Reactor Coolant System

The general configuration of the piping and components in the reactor coolant loop is the same in both Millstone Unit 3 and Diablo Canyon. Both Millstone Unit 3 and Diablo Canyon have four loops for heat transfer. Each heat transfer loop contains a steam generator and a reactor coolant pump (RCP). The Diablo Canyon SG is a Model 51 while the Millstone SG is a Model F. The Diablo Canyon RCP is a Model 93A while the Millstone RCP is a Model 93A1. The hydraulic resistances and elevation differences are not significant and do not adversely affect the natural circulation flowrates. Also, one loop at each plant is equipped with a pressurizer.

Pressure control is available at both Diablo Canyon and Millstone Unit 3 using the normal pressurizer spray valves if the RCP's are running or the pressurizer auxiliary spray systems. If both the normal and auxiliary spray valves are unavailable, the pressurizer PORVs are available at each plant for RCS depressurization. At Millstone Unit 3, the pressurizer spray valves and auxiliary spray valves are not safety grade, however, the PORVs are safety-grade Class 1E solenoid operated valves. The PORV block valves are safety-grade and may be used to block PORV paths.

Auxiliary Feedwater System

The auxiliary feedwater systems at both Diablo Canyon and Millstone Unit 3 are capable of supplying cooling to all steam generators using the auxiliary feedwater pumps during the natural circulation cooldown. The systems will provide water to the SGs from large storage tanks. The condensate storage tank provides this water source at Diablo Canyon, while Millstone Unit 3 uses the Seismic Category I demineralized water storage tank. The auxiliary feedwater system at Millstone Unit 3 is a safety grade system. Alternate sources of auxiliary feedwater at Millstone Unit 3 include the condensate storage tank, service water system (safety grade source), and domestic water system.

Main Steam System

The steam generators at both plants have main steam pressure relieving valves (MSPRV) which are utilized for the plant cooldown. Millstone Unit 3 also has four main steam pressure relieving bypass valves (MSPRBV) to ensure a steam release path is available if the PORVs are not available. At Millstone Unit 3, the MSPRVs are air operated and have a safety function to close. The MSPRBVs, which are powered from Class 1E buses, provide the safety grade means of controlling steam release. (Reference 4) Rev. 1

Chemical and Volume Control System (CVCS)

Injection of boric acid into the RCS is required to offset xenon decay and the reactivity change which occurs during plant cooldown. The Diablo Canyon natural circulation cooldown test utilized the charging pumps to charge through the boron injection tank (at 20000 ppm boron) in the Safety Injection System. Subsequent charging was aligned from the volume control tank in the CVCS. The boron concentration in the volume control tank was adjusted to 2000 ppm to simulate charging from the refueling water storage tank (RWST).

At Millstone Unit 3, four weight percent boric acid is pumped from the safety grade boric acid tanks (at 6300 ppm boron) by the boric acid transfer pumps to the suction of the centrifugal charging pumps. These pumps are also safety grade and are powered from Class 1E buses. An alternate flow path from the boric acid tanks to the suction of the centrifugal charging pumps is available through the safety grade gravity feed valves. A backup source of boric acid is available from the RWST (at 2000 ppm boron). The borated water is then injected to the RCS via the normal charging line and the RCP seals. A back-up means for injection involves the use of the high pressure injection path through the SIS. The normal charging and the SIS boron injection paths each contain a Class IE solenoid operated throttling valve that permits variable control of the makeup flowrate.

To accommodate the borated water addition to the RCS, letdown capability is normally provided by the non-safety grade normal and excess letdown lines to the CVCS. If both the normal and excess letdown lines are unavailable, letdown is provided by the safety grade reactor vessel head vent letdown line to the pressurizer relief tank. Throttling control of the head vent letdown is provided by two redundant parallel safety grade Class 1E solenoid valves.

Residual Heat Removal (RHR) System

The RHR systems at both Diablo Canyon and Millstone Unit 3 are low pressure heat removal systems consisting of RHR pumps and heat exchangers. They are designed to lower the temperature of the RCS from 350°F to cold shutdown conditions.

3.0 APPLICABILITY OF THE DIABLO CANYON TEST RESULTS TO MILLSTONE UNIT 3

3.1 Natural Circulation

The Diablo Canyon natural circulation test evaluation verified that RCS natural circulation flow could be established, thereby permitting boron mixing and RCS cooldown/depressurization to RHR system initiation conditions. This phase of the test had no specific acceptance criteria and it was evaluated based on the results of the boron mixing and cooldown/depressurization phases of the natural circulation cooldown test.

The Diablo Canyon test results indicated that natural circulation flowrates were adequate to ensure that core decay heat removal, boron mixing and plant cooldown/depressurization were maintained throughout the test. The response of the RCS temperatures indicated stable natural circulation conditions throughout the test.

The Millstone Unit 3 plant and Diablo Canyon Unit 1 have been compared (Section 2.1) to ascertain any differences between the two plants that could potentially affect natural circulation flow. The general configuration of the piping and components in each reactor coolant loop is the same in both Millstone Unit 3 and Diablo Canyon Unit 1. The elevation head represented by these components and the system piping is similar in both plants. Steam generator units were also compared to ascertain any variation that could affect natural circulation capability by changing the effective elevation of the heat sink or the hydraulic resistance seen by the primary coolant. The longer tube bundle for Diablo Canyon Unit 1 would result in 5-10% higher driving head when compared to Millstone Unit 3. However, it can be concluded that there are no significant differences in the design of the steam generators in the two plants that would adversely affect the natural circulation characteristics.

To compare the natural circulation capabilities of Millstone and Diablo Canyon, the hydraulic resistance coefficients were also compared. The coefficients were generated on a per loop basis. The hydraulic resistance coefficients tabulated below are applicable to normal flow conditions. Although the hydraulic resistance coefficients would increase slightly for natural circulation conditions, the ratio of the total hydraulic flow coefficients is expected to remain applicable for natural circulation conditions since the individual hydraulic resistance coefficients for the two comparable plants would be affected in a similar manner. Therefore, the flow ratio per loop as reported below is expected to be valid for both normal flow and natural circulation conditions. Rev. 1

	Diablo Canyon $[ft/(gpm)^2]$	Millstone Unit 3 $[ft/(gpm)^2]$
Reactor Core & Internals	129.0×10^{-10}	115.1×10^{-10}
Reactor Nozzles	36.1×10^{-10}	26.6×10^{-10}
R.C. Loop Piping	20.9×10^{-10}	24.0×10^{-10}
Steam Generator	112.0×10^{-10}	118.0×10^{-10}
Total Hydraulic Flow Coefficient (HFC_{tot})	298.0×10^{-10}	283.7×10^{-10}

$$\text{Flow Ratio Per Loop} = \left[\frac{HFC_{tot}\text{ for Diablo Canyon}}{HFC_{tot}\text{ for Millstone}}\right]^{1/2} = 1.025$$

The general arrangement of the reactor core and internals is the same in Diablo Canyon and Millstone. The Diablo Canyon vessel inlet nozzle radius is significantly smaller than that of Millstone, as reflected by the higher coefficient for Diablo Canyon. The flow losses are otherwise very similar for the two plants. The coefficients indicated represent the resistance seen by the flow in one loop, excluding the resistance through the reactor coolant pump. The RCP flow resistances for the two Rev. 1

plants are on the same order of magnitude as the total hydraulic flow coefficients reported above and are comparable since the RCP impeller designs for the Diablo Canyon and Millstone 3 pumps are nearly identical. Accordingly, the flow ratio per loop as reported above would remain very close to unity when considering RCP flow resistance. Rev. 1

If the effect of the 5-10% increased natural circulation driving head for Diablo Canyon Unit 1 is taken into account, the flow ratio would change to approximately 0.99. Considering the slight differences and uncertainties in hydraulic losses and natural circulation driving heads, the natural circulation loop flowrate for Millstone Unit 3 is expected to be within three percent of that for Diablo Canyon. Slight differences in reactor power and decay heat levels between the two plants would not be expected to alter this conclusion.

3.2 Boron Mixing

The Diablo Canyon boron mixing test evaluation demonstrated adequate boron mixing under natural circulation conditions when highly borated water at low temperatures and low flowrates (relative to RCS temperature and flowrate) was injected into the RCS. It also evaluated the time delay associated with boron mixing under these conditions.

The acceptance criterion for this phase of the Diablo Canyon test was that RCS hot legs (loops 1 & 4) indicate that the active portions of the RCS were borated such that the boron concentration had increased by 250 ppm or more.

Boron injection was conducted at the Diablo Canyon test using the 20000 ppm boron solution contained in the boron injection tank (BIT). The BIT's contents were flushed into the RCS and within 12 minutes, natural circulation had provided adequate mixing to increase the boron concentration in the RCS by 340 ppm. Following injection, makeup to the VCT was set to provide 2000 ppm boron. This simulated suction of the charging pumps aligned to the RWST. The charging pump discharge was aligned to provide seal injection flow to each RCP and charging flow to one RCS loop. This alignment was continued throughout the remainder of the test causing the boron concentration to further increase.

For the Millstone Unit 3 plant, boron would be injected into the RCS from the 7000 ppm boron solution of the BATs through the RCP seals and the normal charging line, if available. Also, as noted previously, a safety grade backup means of boron injection is provided by the SIS flow path. This boron concentration (6300 ppm) at Millstone Unit 3 is less than that used for the successful Diablo Canyon test. The addition of a larger quantity of borated water over a longer time period will be required for Millstone Unit 3 to achieve a similar change in boron concentration. However, because natural circulation flow at Millstone Unit 3 is expected to be very similar to the flow obtained at Diablo Canyon, adequate mixing of the boron would also be provided for Millstone Unit 3.

A boron mixing calculation has been performed for Millstone 3 to determine the time necessary, under natural circulation conditions to achieve an increase in RCS boron concentration similar to that exhibited by Diablo Canyon Unit 1 during the natural circulation boron mixing test (i.e., 300 ppm). The calculation assumes the normal charging line plus the RCP seals provide the boron injection paths at a total boration rate of 120 GPM. The 6300 ppm BAT is assumed to be the source of the borated water. Also incorporated in the boron mixing calculation is a conservative estimate of boron mixing time under natural circulation conditions. The results of the calculation indicate that a time of approximately one (1) hour is needed to achieve a 300 ppm increase to the initial RCS boron concentration. The BAT is adequately sized to provide this quantity of borated water. Rev. 1

3.3 Reactor Coolant System Cooldown

The cooldown portion of the test demonstrated the capability to cool down the RCS to RHR system initiating conditions at approximately 25°F/hour using all four steam generators for natural circulation. The RHR system was then used to cool the RCS to cold shutdown conditions. Plant cooldown was controlled within Technical Specification limits. All active portions of the RCS remained within 100°F of the average core exit temperature. Also, both the steam generators and reactor vessel upper head were cooled to below 450°F when the core exit temperature was 350°F.

For Millstone Unit 3, cooldown capability will be similar to Diablo Canyon due to similarities in the design of the RCS, AFW, main steam and RHR systems. The upper head volume for Millstone Unit 3 is higher than that of Diablo Canyon Unit 1. However, the spray nozzle flow area for Millstone Unit 3 is significantly higher. The upper head region for Millstone Unit 3 is expected to cool at a rate comparable to or exceeding that of Diablo Canyon 1. RCS cooldown at a rate exceeding 25°F/hour would potentially be permitted for Millstone Unit 3. A 50°F/hour cooldown rate would be permitted if CRDM fans are operating. Initial plant cooldown will be accomplished via steam release from the main steam system. After RHR system initiation, the RHR system will be used to cool the plant down to cold shutdown temperatures.

The primary and alternate sources of auxiliary feedwater at Millstone 3 are listed in Section 2.0. Since the capacity of these auxiliary feedwater sources is comparable to the primary and alternate sources of auxiliary feedwater at Diablo Canyon, and sufficient auxiliary feedwater has been shown to be available at Diablo Canyon to perform a natural circulation cooldown to cold shutdown conditions, it can be concluded that sufficient auxiliary feedwater is available at Millstone 3 to perform a natural circulation cooldown to cold shutdown conditions. Rev. 1

3.4 Reactor Coolant System Depressurization

The depressurization portion of the test demonstrated the capability to control pressure in the RCS under natural circulation conditions. Pressure control capability included the ability to maintain adequate RCS pressure without operating the pressurizer heaters and the ability to significantly reduce RCS pressure when needed to initiate RHR system operation. Three methods of reducing pressure were demonstrated. During the RCS cooldown, pressurizer pressure exhibited a downward trend due to ambient heat losses from the pressurizer. This was followed by operator initiated RCS depressurization using the auxiliary spray. For auxiliary spray to be effective, the charging lines to the RCS loops must be isolated. Finally, depressurization was completed using a pressurizer PORV. Each method was determined to be effective in reducing RCS pressure.

For Millstone Unit 3, pressure control and depressurization capability will be similar to Diablo Canyon due to similarities in the design of the RCS and CVCS. Ambient heat losses will gradually reduce RCS pressure. Pressurizer PORVs or auxiliary spray will be effective in depressurizing the RCS when needed to permit RHR system initiation.

4.0 SUMMARY AND CONCLUSIONS

The Diablo Canyon Unit 1 Natural Circulation/Boron Mixing/Cooldown Test (Reference 3) demonstrated that the plant can safely be taken to cold shutdown under natural circulation conditions.

In order to apply the test results to Millstone Unit 3, a general comparison (Section 2.0) of the plant systems and equipment that affect natural circulation, boron mixing, cooldown and depressurization capabilities has been made between the Millstone Unit 3 and Diablo Canyon Unit 1 plants. The Section 3.0 evaluation demonstrates that the Millstone Unit 3 capabilities are comparable to those of Diablo Canyon Unit 1. Therefore it is concluded that Millstone Unit 3 meets the testing comparison requirement of Branch Technical Position RSB 5-1, Design Requirements for Decay Heat Removal Systems (Reference 1).

5.0 REFERENCES

1. Branch Technical Position RSB 5-1, Design Requirements for Decay Heat Removal Systems, Revision 2, July 1981.

2. Millstone Unit 3 FSAR Section 5.4.7, Residual Heat Removal System.

3. WCAP-11086, Diablo Canyon Units 1 and 2 Natural Circulation/Boron Mixing/Cooldown Test Final Post Test Report, March, 1986.

4. Millstone Unit 3 FSAR Section 10.3, Main Steam System.