ENCLOSURE

PACIFIC GAS AND ELECTRIC COMPANY

DIABLO CANYON POWER PLANT UNIT 1

RCS NATURAL CIRCULATION, BORON MIXING, AND COOLDOWN TEST

PRELIMINARY POST-TEST REPORT

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Contents

1. INTRODUCTION

Following the Hosgri Seismic Evaluation, Pacific Gas and Electric Company (PGandE) performed an evaluation of the systems and equipment required to achieve and maintain Hot Standby and Cold Shutdown of Diablo Canyon Units 1 and 2 following a safe shutdown earthquake. As part of this evaluation, PGandE committed to perform a natural circulation, boron mixing, and cooldown test to demonstrate the plant's capability to achieve cold shutdown conditions following a safe shutdown earthquake. A Diablo Canyon Power Plant (DCPP) Unit 1 Test Procedure for the subject test was developed by PGandE, and reviewed by the NRC. NRC comments resulting from this review were transmitted to PGandE in October 1979. The test procedure was subsequently modified to address NRC comments and to include pre-test and post-test reports. A pre-test report was then developed to outline the bases, objectives, and evaluation/acceptance criteria for the test. The pre-test report and the test procedure have been the subjects of several NRC meetings to resolve comments on the subject test.

The DCPP natural circulation, boron mixing, and cooldown test was performed at DCPP Unit 1 on March 28 and 29, 1985. The test was performed per Revision 4 to Test Procedure No. 42.7, "Natural Circulation Boron Mixing Test." The applicable version of the Pre-Test Report was Revision 2, "Diablo Canyon Natural Circulation Pre-Test Report."

This Preliminary Post-Test Report describes the test and test results relative to the test objectives and evaluation/acceptance criteria. A final post-test report is under preparation to systematically evaluate the test results and describe how they will be used in reviewing the plant emergency operating procedures.

2. TEST OBJECTIVES

The objectives of the test were to:

- o Establish natural circulation conditions using core decay heat
- o Confirm that adequate mixing of borated water added to the reactor coolant system (RCS) prior to cooldown can be achieved under natural circulation conditions
- o Verify that the RCS can be borated to the Cold Shutdown concentration
- o Maintain Hot Standby conditions under natural circulation conditions for at least 4 hours
- o Determine if cooldown and depressurization of the RCS from normal hot standby to cold shutdown conditions can be accomplished using only safety-grade equipment
- o Evaluate the effect of a charging valve failure during the use of auxiliary spray for depressurization

- Obtain reactor vessel head cooldown rates (both metal and water)
- Verify that adequate water volume is available in the condensate storage tank to cool down the plant

3. TEST DESCRIPTION

Unit 1 was tripped from hot full power conditions at 2130 hours on March 28, 1985. Unit trip was initiated by manually initiating a turbine trip. The unit was then stabilized at Hot Standby conditions. Natural circulation was established by tripping the reactor coolant pumps at 0028 hours on March 29. The boron mixing/maintaining hot standby conditions phase of the test commenced when stable natural circulation conditions were established at 0048 hours. Boron injection was initiated at 0052 hours, terminated at 0113 hours, and boron mixing verified during the remainder of this phase of the test. The cooldown/depressurization test phase was initiated at 0450 hours. Cooldown/depressurization to residual heat removal (RHR) system initiation conditions was achieved and RHR system operation initiated at 1805 hours. The cooldown/depressurization phase was continued until Cold Shutdown conditions were achieved at 2245 hours.

4. TEST RESULTS

The test was structured to collect data for evaluation of the various phenomena associated with a natural circulation cooldown. An initial assessment of the test results has been performed to evaluate if the test objectives and evaluation/acceptance criteria were satisfied. The results of this initial assessment and a brief discussion of the data justifying these results are summarized in the following subsections.

4.1 Decay Heat/Natural Circulation

The objective of the natural circulation evaluation was to verify that RCS natural circulation flow conditions would permit boron mixing and RCS cooldown/depressurization to RHR system initiation conditions.

This objective had no specific evaluation/acceptance criteria since it would be evaluated based on the results of the boron mixing and cooldown/depressurization phases of the natural circulation cooldown test.

The test results indicated that adequate natural circulation flow rates to ensure core decay heat removal, boron mixing, and plant cooldown were maintained throughout the test. The response of RCS temperatures indicated stable natural circulation flow conditions throughout the test. The RCS hot leg/cold leg differential temperature was approximately 15-20°F under natural circulation conditions.

4.2 Boron Mixing

The objectives of the boron mixing portion of the test were to:

- o Demonstrate boration without letdown. This included the demonstration of boron mixing under natural circulation conditions when highly borated water at low temperatures and low flow rates is injected into the RCS.

- o Evaluate the delay time associated with boron mixing under natural circulation conditions.

The evaluation/acceptance criterion was that RCS hot legs 1 and 4 samples must indicate that the active portions of the RCS (excluding pressurizer) are borated such that mixed RCS boron concentration has increased by 250 ppm or more.

During the boron mixing phase of the test, a charging pump was aligned to deliver the contents (900 gallons of 21,000 ppm borated water) of the boron injection tank (BIT) to each of the four RCS cold legs. To ensure that the BIT's contents were flushed to the RCS cold legs, the charging pump was aligned to the BIT for approximately 20 minutes with a total flow rate of approximately 150 gpm.

Six minutes after the initiation of the boron injection, a pressurizer power-operated relief valve (PORV), PCV-456, actuated due to high pressurizer pressure. This occurred nine times until, after injecting for approximately 19 minutes, letdown was established to minimize PCV-456 actuation.

The test results indicate that the objectives and evaluation/acceptance criterion were satisfied. Initially, RCS boron concentration increased to approximately 1224 ppm (340 ppm increase) and mixed very quickly to a final value of approximately 1186 ppm (300 ppm increase). Approximately 12 minutes after the delivery of the BIT's contents, the RCS boron concentration was within 20 ppm of the final RCS boron concentration.

4.3 Cooldown

The objectives of the cooldown portion of the test were to:

- o Demonstrate the capability to cool down the RCS to RHR system-initiating conditions using all four steam generators for natural circulation, and evaluate reactor vessel head and steam generator cooling under these conditions

- o Demonstrate the capability to cool down the RCS to Cold Shutdown conditions once the RHR system has been placed in service

The evaluation/acceptance criteria were:

- o Plant cooldown on natural circulation can be controlled within Technical Specification limits

- All active portions of the RCS were cooled down uniformly within $\pm 100°F$ of the average core exit thermocouple temperature

- Steam generators and reactor vessel head were cooled down to $\leq 450°F$ (saturation pressure ≤ 407 psig) when the average core exit thermocouple temperature is 350°F

- The RHR system was capable of cooling down the RCS to Cold Shutdown conditions

The test results indicated that these objectives and evaluation/acceptance criteria were satisfied. The test demonstrated the capability to cool down the RCS to RHR system-initiating conditions and the capability for the RHR system to cool the RCS to Cold Shutdown conditions. Data were collected on reactor vessel head and steam generator cooling. Plant cooldown was controlled within Technical Specification limits. All active portions of the RCS remained within 100°F of the average core exit temperature and both the steam generators and reactor vessel upper head were cooled to below 450°F when core exit temperature was at 350°F.

4.4 Depressurization

The objective of the depressurization portion of the test was to demonstrate the capability to significantly reduce pressure in the RCS under natural circulation conditions. The evaluation/acceptance criterion was that pressure in the RCS should be lower than RHR system initiation pressure (425 psig).

The test results indicated that the objective and evaluation/acceptance criterion was satisfied. During the test, pressurizer pressure trended down (due to ambient heat losses) from normal operating pressure to approximately 1300 psig at 1400 hours. Depressurization was initiated with the pressurizer auxiliary spray which reduced pressure at a rate of approximately 8 psi/minute to approximately 700 psig at 1515 hours. During the depressurization portion of the test, charging valve 8146 was opened. This caused the depressurization rate to drop to almost 0 psi/min. This action was taken to determine the effect of a charging valve failure during auxiliary spray depressurization. Auxiliary spray was then terminated (since letdown was isolated) and the pressurizer PORV was used to complete depressurization to approximately 375 psig at 1550 hours.

4.5 Reactor Vessel Head Cooldown

The objectives of this portion of the test were to:

- Monitor upper head bulk water temperature

- Monitor upper head metal temperature

The evaluation/acceptance criterion of the upper head bulk water temperature was such that a 50°F subcooling could be maintained during cooldown and depressurization. A 100°F limit between the average core exit thermocouples and the upper head bulk water temperatures had been imposed as an administrative limit.

The upper head bulk water temperature remained cooler than the RCS during Hot Standby and cooldown conditions until 0845 hours when a control rod drive mechanism (CRDM) fan was secured. Upper head water temperatures relative to RCS temperatures started increasing until, at approximately 1230 hours, the upper head was approximately 15°F higher than the RCS. Between 1230 and 1330 hours, the RCS cooldown rate was increased to approximately 25°F/hr. This increase in cooldown rate combined with securing a CRDM fan caused the ΔT between the RCS and the upper head water to increase to about 40°F. Between 1400 and 1517 hours, cooldown was terminated while Operations personnel depressurized the RCS. This caused the upper head/RCS water temperature ΔT to decrease to less than 0°F. At 1517 hours, cooldown was re-established and the same upper head cooldown trend (i.e.,ΔT increasing slightly) could be observed. This continued until about 1835 hours, when all of the CRDM fans were secured. This caused upper head/RCS water temperature ΔT to increase to about 20°F. At 2015 hours, three CRDM fans were re-energized and the upper head/RCS ΔT never exceeded 20°F during the remainder of the cooldown. It should be noted that these different fan combinations were taken to obtain additional information on the cooling effects of CRDM fans.

Since no vessel head metal cooling limitations were identified, no specific evaluation/acceptance criteria were identified for this aspect of the cooldown test. A 100°F limit between the average core exit thermocouples and the upper head metal temperatures had been imposed as an administrative limit. The magnetic thermocouples' (T/Cs) temperature profiles indicated that vessel head metal temperatures remained below hot leg and cold leg temperatures as long as the CRDM fans remained on. Once the CRDM fans were secured, the T/C at the top dead center of the RV head indicated metal temperatures reaching hot leg temperature equilibrium and then lagging hot leg temperature during the cooldown. The remaining T/Cs decreased in their cooldown rate but never approached hot leg temperature conditions.

The test results indicated that the objectives were satisfied. Data were collected for both upper head water and metal temperature. An initial assessment of the upper head water temperature data has been performed by comparing them to upper head cooling analyses that has been performed by the Westinghouse Owners Group as part of the Emergency Response Guideline development activity for natural circulation. This assessment has confirmed that the test results show upper head cooling rates due to CRDM fans that exceed the rates predicted by the analyses. The upper head cooling is dependent on the number of fans running. Through controlling the number of fans running and the RCS cooldown rate, the RCS and the

upper head can be cooled down at approximately the same rate. During the majority of the plant cooldown (i.e., between 0450 and 1300 hours), the RCS and the upper head were within +20°F of each other and were cooling at approximately the same rate (20°F per hour). The maximum differential temperature occurred at 1400 hours when upper head temperature exceeded RCS temperature by approximately 40°F.

4.6 Condensate Storage Tank Capacity

The objective of the test was to verify that the condensate storage tank (CST) had adequate water volume to cool the plant.

Test results indicate that the CST has adequate capacity to cool down the plant. CST level was 91% at the beginning of the test and decreased to 61% by the end of the test. This correlates to a usage of approximately 126,000 gallons during the test which is much less than the 400,000-gallon capacity of the tank.

Because decay heat decreases exponentially with time and the water usage during the cooldown occurred over a period of approximately 18 hours (including 4 hours at Hot Standby), these data indicate that the CST has enough capacity to cool down the plant for extended periods of time. A more detailed evaluation of these results will be provided in the Final Post-Test Report.

5. FINAL POST-TEST REPORT

The Final Post-Test Report will provide a more detailed description of the test and test results, interpretation/application of the test data, and the use of the test data in revising the emergency operating procedures. Completion of the Final Post-Test Report is scheduled for December 1985.

Attachment

ATTACHMENT

TO

DIABLO CANYON UNIT 1

RCS NATURAL CIRCULATION, BORON MIXING, AND COOLDOWN

PRELIMINARY POST-TEST REPORT

CHRONOLOGY OF EVENTS AND OPERATOR ACTIONS

Time	Plant Status/Actions
Plant Trip from 100% Power:	
2130:	Plant operating at 100% power. Operators initiated the plant trip from 100% power [Ref. Test Procedure (T.P.) 43.4] by manually initiating a turbine trip.
2140:	Reactor is shut down and plant is in hot standby conditions. Operators are securing the plant secondary side. Relief valves on the #2 feedwater heaters have lifted. Operators are attempting to reseat the reliefs. Waiting for steam generator levels to return to 44% narrow range level.
2150:	Operators are beginning their Class I equipment alignment per T.P. 42.7.
2230:	Operators are attempting to relatch the main turbine to minimize steam leakage on the secondary side.
2300:	Steam Generator levels at 44% narrow range level.
2330:	Main Turbine has been relatched. Vital power breaker for pressurizer heater 1-3 will not energize.
2400:	Vital power breaker for pressurizer heater 1-3 had a blown fuse. pressurizer heater 1-3 is aligned to vital power.
0015:	All Class I equipment aligned. Total RCP seal injection flow is approximately 50 gpm.
Natural Circulation/Boron Mixing Phase:	
0028:	Operators are tripping the reactor coolant pumps.
0048:	Natural circulation conditions have been established.

0052: Injection with the boron injection tank (BIT). Flow rate is approximately 150 gpm.

0058: Power-operated relief valve (PORV), PCV-456, opening to relieve excessive pressurizer pressure. PCV-456 actuated nine times from 0058 to 0110 hours.

0111: Operators establishing letdown to lower the pressurizer level, and minimize PORV actuation.

0113: Terminated boron injection. RCS boron concentration increased from 886 ppm to 1186 ppm. Continuing with the 4-hour stabilization period at hot standby. RCS temperature steadily drifting downward due to Operators trying to maintain the secondary side under hot conditions.

0200: Operators are minimizing steam losses on the secondary side by securing 50% of the condenser steam jet air ejectors.

0415: Operators lowering pressurizer level by initiating letdown.

0440: Operators demonstrated that RCP seal injection flow can be controlled by manually throttling the isolation valve downstream of FCV-128. After the demonstration, the reciprocating charging pump was placed in service. This would give Operators better control of RCP seal injection flow during the remainder of the test thereby minimizing or preventing RCP seal damage due to high seal injection flow.

0450: Plant has been at hot standby natural circulation conditions for at least 4 hours. Operators are setting the volume control tank (VCT) makeup control system to provide 2000 ppm makeup to the VCT. This will simulate the charging pumps aligned to the RWST.

Cooldown/Depressurization Phase:

0450: Operators are isolating letdown and commencing cooldown using the 10% atmospheric steam dumps. Cooldown rate is approximately 20°F/hr.

0533: Initiated letdown to lower pressurizer level and lower primary/secondary system differential pressure.

0833: Isolated letdown.

0845: Secured CRDM fan 1-1 per Westinghouse request.

0957: Initiated letdown to lower pressurizer level.

1319: All 4 loops' hot leg temperatures are less than 350°F. Plant declared in Mode 4.

1356: Charging valve 8146 and auxiliary spray bypass valve 8148 open. No appreciable depressurization in the RCS.

1402: Closed charging valve 8146. Depressurization rate is 8.0 psi/min.

1515: Operators are opening PORV PCV-456 to depressurize the RCS. Also, isolating letdown.

RHR Initiation:

1805: Operators are initiating the RHR system. RHR Pump 1-2 placed in service.

1831: Secured the remaining CRDM fans.

2015: Operators are re-energizing the CRDM fans (three only).

2245: RCS temperature below 200°F. Plant is in Mode 5.