DCS MS-016

AUG 27 1982

Ms. Judith M. Barrows
Safe Power for Maine
P. O. Box 2204
Augusta, Maine 04330

Dear Ms. Barrows:

In response to your letter of August 6, 1982, I have enclosed the report of the audit of procedures and training for pressurized thermal shock (PTS) at the Maine Yankee Atomic Power Station. The audit was held May 25 to 27, 1982. The audit report has just been received from our consultant, Pacific Northwest Labs, has not yet been reviewed by our staff, and therefore does not represent the NRC's position. In addition, I have enclosed the summaries of two recent meetings on the subject of PTS as well as NUREG/CR-2837, PNL Technical Review of Pressurized Thermal Shock Issues.

I trust this information is responsive to your request.

Sincerely,
Original signed by

Robert A. Clark for

G. C. Lainas, Assistant Director
for Operating Reactors
Division of Licensing

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Enclosure 1

Audit of Maine Yankee Procedures and Training for Pressurized Thermal Shock

CONTENTS

1 INTRODUCTION

1.1 Short-Term Objectives and Scope of Review

On May 25, 1982, an interdisciplinary audit team visited Maine Yankee Nuclear Station to evaluate certain aspects of the Pressurized Thermal Shock (PTS) issue. The question that the audit team focused on was:

> ARE CORRECTIVE ACTIONS REQUIRED THAT MUST BE INITIATED BEFORE THE LONGER TERM PTS PROGRAM PROVIDES GENERIC RESOLUTION AND ACCEPTANCE CRITERIA?

Emergency procedures and operator training were the only areas in which the Maine Yankee audit team applied the above general question. As noted in the NRR March 9, 1982 presentation to the Commission:

> "...we will undertake a program to verify that existing operating procedures contain the steps necessary to prevent and/or mitigate PTS events, and to verify that operator education/training programs regarding PTS are acceptably thorough."

Due to the limitation of the review to training and procedures, the resolution of various technical questions on PTS (thermal-hydraulic analyses, fracture mechanics, probabilities) was not part of the audit team charter. Also, implementation of any recommendations (see Section 4) is subject to coordination and consistency with the longer term generic program (USI A--49).

A visit to Maine Yankee took place on May 25-27, 1982, during which time the audit team evaluated procedures and training. The key findings of the group are discussed in Section 3. In preparation for the Maine Yankee audit the audit team used the general criteria addressed in Section 2.

1.2 Current Status of the Generic PTS Issue

Efforts to pursue an integrated PTS program involving a variety of technical areas are continuing under USI A-49. The summer of 1983 is the current schedule for finalizing the generic regulatory requirements for PTS along with required corrective actions if the generic requirements are not met. Key issues are yet to be resolved and extensive programs exist to provide the foundation for the generic regulatory requirements.

Before the above effort resulting in regulatory requirements is completed however, the staff has committed to the Commission to have developed an interim initial position for the summer of 1982 (June). The interim initial position will consist of NRC evaluation of the safety of continued plant operation (and initial corrective actions required) for the eight plants previously identified as representative of plants having the highest RTNDT. Technical assistance is being provided by a PNL multi-disciplinary team. PNL has been contracted to work with the staff to provide recommendations regarding the June 1982 initial position on the safety of continued operation and to recommend any additional corrective actions that PNL believes should be initiated before the NRC generic resolution and acceptance criteria are adopted. The June recommendations by the NRC staff to the Commission will also consider the findings and recommendations addressed in Sections 3 and 4 of this report, as well as other audit teams formed for related investigations (such as fluence reduction at the vessel wall).

1.3 Maine Yankee Configuration

The Maine Yankee Nuclear Station is a single unit 2630 MWt, 790 MWe Combustion Engineering (CE) design. The Reactor Coolant System (RCS) configuration is a three loop, three cold and hot leg design utilizing C.E. shell and "U" tube steam generators. Plant control is by the Reactor Regulating System (RRS) which matches reactor power and feedwater flow with turbine demand. Typical power operations are conducted with all control rods at their fully withdrawn position and reactor control is by boration or dilution of the reactor coolant. Plant transients are mitigated by the Reactor Protective System (RPS) and the Engineered Safety Feature System (ESFS) which, if necessary, actuates the Emergency Core Cooling System (ECCS) for long term core subcriticality and decay heat removal.

The ECCS includes the Safety Injection System (SIS) which incorporates High Pressure Safety Injection (HPSI) pumps, passive Safety Injection Tanks (SIT) and Low Pressure Injection Pumps (LPSI). The HPSI pumps also provides Reactor Coolant Pump (RCP) seal injection and normal RCS makeup which is injected only into the cold legs of loop 2 and 3. A safety injection actuation signal (SIAS) is activated at a RCS pressure of 1585 psig and the system is realigned for injection into all three cold legs with the pump suction receiving its supply from the refueling water storage tank. The three passive SITs have a liquid volume of 11,200 gallons each will inject if the RCS pressure falls below the 230 psig nitrogen over pressure in the tanks. Although the LPSI pumps are started on a SIAS the pump shutoff heat prevents injection until the RCS falls below 186 psig. RCS pressure control is accomplished by the pressurizer spray, the pressure heaters, the power operated relief valves (PORV) and pressurizer code safety relief valves.

Feedwater is delivered from the condenser hotwell to the steam generator by 3 condensate pumps (two operate during normal operation and the third is an installed spare) and two motor driven main feedwater pumps. A closed secondary cycle of two trains of six stages of feedwater heaters is utilized and incorporates two heater drain pumps which discharge to the suction side of the main feed pumps. The auxiliary feedwater system consists of one turbine-driven and two motor-driven pumps. The system is normally aligned to take suction from the Demineralized Water Storage Tank (DWST). Steam generator pressure control is performed by the steam dump and bypass system which includes 12 valves with a total full load steam flow capacity of 50% and the main steam code safety relief valves.

The Maine Yankee Nuclear Station control room is an L shaped bench board configuration and contains the controls and displays necessary for the operation of the plant. The following table contains the major parameters available to an operator at Maine Yankee that would assist in monitoring PTS events.

Parameters	Display
RCS Pressure	Wide, narrow and low range meters

RCS Temperature	T-hot - narrow range meter and recorder T-cold - wide range meter and recorder These temperatures could also be read on a CRT
In-Core Temperature	Read on a CRT
Subcooling Monitor	Digital readout showing subcooling margin in either temperature or pressure - uses in-core temperature signals

2 SHORT-TERM CRITERIA USED FOR MAINE YANKEE AUDIT

2.1 Transient and Accident Analyses

2.1.1 Introduction

Overcooling events in PWRs may occur as a result of steam line breaks (excessive steam flow), feedwater system malfunctions, or loss-of-coolant accidents. Multiple failures and/or operator errors can result in more severe overcooling events. Of particular concern are those events in which repressurization of the primary system occurs following the severe overcooling. This section summarizes our review of the Maine Yankee events that occurred since the plant was built. Aside from the primary mission of the audit team to examine procedures and training, a summary of the thermal-hydraulic analyses available for evaluating pressurized thermal shock events is provided in Section 2.1.3.5.

2.1.2 Maine Yankee Cooling Events Summary

A detailed review of the operating history of Maine Yankee has resulted in no identification of events that have resulted in exceeding the cooldown rate limit of 100 F/hr. Two events were identified that could have led to exceeding the cooldown rate limit if not mitigated by automatic plant controls and protective functions or operator action.

2.1.2.1 Event 1: January 14, 1977

A transistor failed in the steam dump valve temperature controller causing the twelve steam dump valves to open. The operator terminated this transient by closing the main steam excess flow check valves and non-return valves. The average reactor coolant system temperature decreased 43 F. Subsequently, plant design change number 10-73 eliminated the transistor in question and the potential that this single failure would cause another transient.

2.1.2.2 Event 2: February 4, 1973

During testing and adjustment of the turbine governor valves, these valves opened, resulting a rapid increase in steam flow. Automatic operation of the excess flow check valves and prompt operator response minimized the effects of this event. Average reactor coolant system temperature decreased 20 F.

2.1.2.3 Summary of Events

In summary, the operating history included only two initiating events that resulted in the potential for overcooling and both involved large steam loads being imposed on the plant, but neither event caused excessive cooldown.

2.1.3 Maine Yankee Termination Criteria

2.1.3.1 Reactor Coolant Pumps (RCPs)

The RCPs are tripped when the primary system pressure falls to 1585 psig and the control and shutdown rods have been fully inserted for five seconds.

2.1.3.2 Feedwater

The main feedwater condensate and heater drain pumps will automatically trip on a safety injection actuation signal coincident with low steam generator pressure. The auxiliary feed pumps will automatically start on low steam generator level coincident with low steam generator pressure but with a 5 minute time delay to preclude excessive cooling and potential reactor restart due to the moderator temperature coefficient.

2.1.3.3 HPSI Termination During LOCA

The HPSI System must remain in operation until all of the three following conditions are met:

a. RCS indicated subcooling is equal to or greater than 50 F on the MCB T(sat) meter or core exit thermocouples vs. pressurizer pressure.

b. Indicated pressurizer level equal to or greater than 50%

<u>and</u>

c. Water level in at least one steam generator:

Narrow range equal to or greater than 50% or

Wide range equal to or greater than 365"

2.1.3.4 <u>HPSI Termination During Steam Supply System Rupture</u>

The HPSI termination criteria for this event are the same as for HPSI termination during a LOCA (see above).

2.1.4 <u>Thermal-Hydraulic Analysis</u>

<u>CEN-189 Vessel Integrity Analysis</u>

Transients were analyzed where the initiating event is the simultaneous occurrence of a small break and a total loss of feedwater. In addition, during these transients, actions are taken to prevent core uncovery, either by opening two PORVs 10 minutes after the accident or by restoring auxiliary feedwater 30 minutes after the accident.

A total of eight SBLOCA and LOFW transients were evaluated. These transients were expected to result in severe pressurized thermal shock conditions. The break location is at the pressurizer and the transients span the range of break sizes from zero or very small breaks to 0.01 ft^2. Most of the analyses were performed for a composite reference plant which envelopes all C-E operating plants and is adequately representative of other plants being evaluated. In addition, one separate analysis was performed with high-head high pressure safety injection pumps which conservatively envelope the pumps of the Maine Yankee Plant. Minimum injection water temperature was assumed in all cases.

The amount of HPSI flow was found to significantly influence the thermal-hydraulic response to the transients. Two rates of HPSI flow were evaluated for the reference plant: (1) minimum flow assuming one HPSI train and charging pumps and (2) maximum flow assuming the largest HPSI and charging pump flow of C-E 2700 MWt class plants. A comparison of downcomer fluid temperatures and systems pressures for the eight transients indicates that the lowest downcomer fluid temperatures and highest pressures were calculated for the cases of zero (or very small) initial break size, maximum HPSI flow, and a LOFW that is restored by the operator at 30 minutes. The recovery of auxiliary feedwater was conservatively assumed to occur at maximum flow rate at a feedwater temperature of 40 F.

The degree of mixing of the cold HPSI and charging pump water with the hot water in the cold leg and downcomer is an important parameter. Mixing of cold HPSI water was evaluated based on a hot water entrainment model that was developed for the present study. The model assumes the cold liquid mixes with the hot loop flow at the injection location, moves without mixing along the bottom of the cold leg and mixes in the downcomer with the surrounding hot fluid. The downcomer mixing prediction of the model was compared against experimental data and showed very good agreement.

2.2 Criteria for Procedural Reviews

The procedures to be reviewed were selected based on the perceived likelihood of conditions occurring that might subject the reactor vessel to pressurized thermal shock conditions and based on the potential consequences of less likely transients. Such procedures selected included normal startup and shutdown, steam generator tube rupture, steam supply system rupture, and loss of coolant accidents.

The audit criteria for the content of procedures was somewhat flexible to account for operator knowledge and to identify which procedures must be used to respond to a given transient. In addition, detailed operator knowledge of actions for preventing or mitigating PTS could offset some weaknesses in procedures. With this in mind, the following criteria were established for the procedures audit:

(1) Procedures should not instruct operators to take actions that would violate NDT limits.

(2) Procedures should provide guidance on recovering from transient or accident conditions without violating NDT or saturation limits.

(3) Procedures should provide guidance on recovering from PTS conditions.

(4) PTS procedural guidance should have a supporting technical basis.

(5) High pressure injection and charging system operating instructions should reflect a consideration for PTS.

(6) Feedwater and/or auxiliary feedwater operating instructions should reflect PTS concerns.

(7) An NDT curve and saturation curve should be provided in the control room. (Appendix G limits for cooldowns not

exceeding 100 F/hr).

2.3 In-Plant Training Program

The effort of the audit team to determine the effectiveness of Maine Yankee Atomic Power Company (MYAPCO) training in PTS began by selecting training criteria which would be used in evaluating the training material, interview Maine Yankee shift personnel, and assessing the evaluation MYAPCO made after completion of the training. The criteria developed into three general areas:

(1) Training should include specific instruction on NDT vessel limits for NORMAL modes of operation.

(2) Training should include specific instruction on NDT vessel limits for transients and accidents.

(3) Training should particularly emphasize those events known to require operator response to mitigate PTS.

More specific criteria were also developed to aid in the review of the training program and in preparation of interviews with operating personnel. These included:

(1) Training in NDT limits should include the knowledge that irradiation adversely affects fracture toughness properties of the reactor vessel. Operators should know that the vessel and welds will lose ductile material properties and trend toward embrittlement.

(2) Operators should be aware that NRC has sent letters to MYAPCO on the PTS issue and that MYAPCO had responded that additional training was underway.

(3) Operators should understand that a rapid reduction in reactor vessel temperature/pressure can raise the possibility of crack propagation, particularly if pressure rises after the temperature reaches its lowest value.

(4) Operators should be aware of the types of events which are known to involve PTS (such as MSL breaks and secondary side malfunctions).

(5) Operators should appreciate that other safety limits (such as core cooling and shutdown margin) must also be balanced with the PTS limits.

(6) Training should emphasize the instrumentation available to observe key parameters as they approach limits. Strategies/options which are under operator control should be emphasized.

(7) Operators should understand the basis for current emphasis on PTS, specifically more severe transients have occurred than expected (Rancho Seco, Crystal River).

MYAPCO was requested to furnish an outline of their training program on PTS and the lesson plan which was used in the training classes. They were also questioned on the method used to evaluate the effectiveness of the training sessions.

Preparation for review of the training program included a review of MYAPCO correspondence with the Commission, including a report on vessel integrity of Combusion Engineering operating plants (CEN-189), normal and emergency procedures furnished by MYAPCO, and the technical specifications. An interview plan was developed which used the general training criteria and the specific subjects that were included in the MYAPCO training material.

Each interview was preceded by a discussion of the reason for the audit and acknowledgment that the individual could use all material available in the control room, particularly the followup or recovery steps in the emergency procedures. Several interview aids were prepared to provide the operators a point of reference for discussion and to allow them to predict responses or execute recovery strategies to mitigate PTS or challenges to other limits.

3 KEY FINDINGS OF THE MAINE YANKEE AUDIT

The following is a description of how the audit was conducted and the key findings resulting from the audit.

3.1 Description of Audit

Prior to the plant visit to Maine Yankee, PNL reviewed the procedures listed in 3.3.1, the Maine Yankee training outline which included a description of past events and the Maine Yankee 150 day response dated Jan. 1982. During the plant visit, PNL reviewed the training schedule, interviewed key members of the training staff and an individual responsible for writing procedures. Procedures which dealt with PTS were reviewed against the audit criteria. Past Maine Yankee PTS events, potential events and potential overcooling transient scenarios used in the MYAPCO simulations (as reported in CEN-189) were reviewed along with the procedures and these served as a basis for interviews with plant operating personnel to determine the effectiveness of the training program and operator knowledge on PTS. Six operations people were interviewed.

3.2 Training

3.2.1 Introduction

The audit of Maine Yankee's training program consisted of a review of the PTS training outline which included a lecture on the minimum pressure temperature (MPT) curve, a description of the requalification program and a detailed training schedule and syllabus. We also interviewed two key members of the training staff and the following licensed operations personnel:

- 2 STAs

- A shift supervisor (SRO)

- 2 control operators (SRO)

- An assistant control operator (ACRO) non-licensed

3.2.2 Comparison of Training with Audit Criteria

(1) Training should include specific instruction on NDT vessel limits for NORMAL mode of operation. The Periodic Training Requalification includes a discussion of the PTS issue and NDT vessel limits as they apply to both normal and off-normal operations. All interviewees showed good knowledge in this area.

(2) Training should include specific instructions on NDT vessel limits for major transients and accidents. A segment of the requalification training deals with NDT vessel limits and their use during transients. The lectures included a discussion on material properties and the changes that are caused by fast neutron irradiation. These topics are covered in shift training when there are changes to procedures which have PTS implications. All interviewees were questioned in this area and demonstrated a good understanding.

(3) Training should particularly emphasize those events known to require operator response to mitigate PTS. Training in the classroom, on shift and on the generic simulator at C-E does cover these topics. The emphasis is on preventing PTS and includes throttling HPSI or

using the PORVs to prevent over pressurization, termination criteria for HPSI, use of P-T diagrams and how to establish and maintain subcooling margins and not exceed cooldown rates.

3.2.3 Summary on Training

The training program appears to have covered the PTS subject and MPT curve adequately. The operators are trained so if they find that plant in a potential PTS condition they are to stabilize the plant at that point and then slowly work the plant to a more desirable condition of pressure and temperature. The training program involves continuous requalification training which is designed to ensure that operators are constantly aware of PTS rather than being retrained only once a year. The area that was found to be weak deals with acquainting the operators with past PTS events that have occurred in the industry, e.g., Rancho Seco and Crystal River. These events were not listed in the training syllabus.

Both the review of the training program and interviews with the supervisors, STAs and control operators indicated that they had a good understanding of PTS. They demonstrated a knowledge of transients that could result in PTS and a generally good understanding of how to avoid PTS.

3.3 Procedures

3.3.1 Procedures Audit

Our audit included a review of selected procedures as discussed in Section 2.2, discussions with a licensee representative on the instructions relating to PTS and the basis for these instructions, and an audit of the control room copy of the procedures to determine its legibility and currency. Our audit included the following Operating Procedures (OP), Emergency Procedures (EP), and Casualty Procedures (CP):

1-1 Controlling Procedure for Unit Heat-up

1-5 Controlling Procedure for Unit Shutdown

2-70-2 Loss of Reactor Coolant

2-70-4 Steam Supply System Rupture

2-70-3 Steam Generator Tube Rupture

3.3.2 Comparison of Procedures With the Audit Criteria

(1) Procedures should not instruct operators to take actions that would violate NDT limits. The procedures that were audited generally did not appear to contain instructions that would cause an operator to violate NDT limits.

(2) Procedures should provide guidance on recovering from transient or accident conditions without violating NDT or saturation limits. The procedures direct the operators to stay on the 50 F subcooled curve on the MPT graph. This may involve throttling HPSI or operating the PORVs.

(3) Procedures should provide guidance on recovering from PTS conditions. While the procedures provide instructions for maintaining the RCS within conditions allowed by the NDT curve, the procedures do not cover cases where a PTS event has occurred before the operators are able to begin to control plant conditions. Procedures are written for a single failure and it would take multiple failures to get into a PTS event. The procedures also do not give guidance to the operator given that the cooldown rate has been exceeded. Thus, there are no written instructions in the procedures to

tell the operator how to recover from a PTS condition. These recovery procedures are adequately covered in the training course and the licensed operators were knowledgeable of the appropriate action.

(4) PTS procedural guidance should have a supporting technical basis. The procedural guidance on PTS is based on analyses and studies conducted by C-E and reported in the 150 day response (CEN-189).

(5) High pressure injection and charging system operating instructions should reflect a consideration for PTS. The 50 F subcooling criterion for HPSI termination reflects PTS concerns. The HPSI pump discharge has flow control valves that can throttle the flow without violating termination criterion.

(6) Feedwater (FW) and/or auxiliary feedwater (AFW) operating instructions should reflect PTS concerns. Instructions are provided in the steam generator tube rupture and the loss-of-coolant procedures to terminate FW/AFW flow to the faulted steam generator. These procedures also provide instructions to maintain steam generator levels in the nonfaulted steam generator within a defined band.

(7) An NDT curve and a saturation curve should be provided in the control room. These curves are provided in the control room.

3.3.3 Findings on Procedures

In general, the procedures do give the operator guidance on preventing a PTS event. The guidance deals with such items as terminating HPSI.

3.4 Summary

Six individuals were interviewed. They ranged in experience from a shift supervisor to an assistant control operator. They all exhibited an understanding of the basic PTS issue and why PTS was a concern to their plant. We presented a number of detailed scenarios which involved the potential for over-cooling or over-cooling with repressurization and all interviewees knew what to do. The people we interviewed in the control room were able to describe the right actions and demonstrate that they knew the location and functions of the displays and controls involved in their actions. The training program covers PTS subjects in the classroom, during shift training and in the simulator. The procedures are generally adequate in their coverage of PTS. The only subject that is not preesntly covered in the procedures is that of how to recover from a situation where the plant is operating outside the acceptable zones on the P-T diagrams. Recovery from unacceptable zones is, however, covered in the training program. The training program did not adequately cover past PTS events in the industry.

4 RECOMMENDATIONS

Based on the findings presented in Section 3 the Maine Yankee audit team recommends the following:

(1) The PTS training program should provide a thorough discussion of major past industry-wide PTS events.

REFERENCES

(1) CEN-189 "Thermal-Mechanical Report - Effect of HPSI on Vessel Integrity for Small Break LOCA Event with Extended Loss of Feedwater".

(2) NUREG-0737, "Clarification to the Action Plan", 1980.

(3) Licensee 150 - Day Response to NRC on PTS, Maine Yankee Atomic Power Company, Maine Yankee Nuclear Station, December, 1981.

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FROM: Judith M. Barrows

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