UNITED STATES
NUCLEAR REGULATORY COMMISSION
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Docket No. 50-251

MEMORANDUM FOR: Gus C. Lainas, Assistant Director
for Operating Reactors
Division of Licensing

FROM: Joel J. Kramer, Deputy Director
Division of Human Factors Safety

SUBJECT: PRESSURIZED THERMAL SHOCK AUDIT REPORT
TURKEY POINT PLANT, UNIT 4

We have completed our audit of the Turkey Point Plant, Unit 4 procedures and training on pressurized thermal shock (PTS) and the audit report is enclosed. The audit report should be forwarded to the licensee for information. Based on the results of the audit, we feel the Turkey Point operations personnel are capable of dealing with PTS.

The audit was conducted by personnel from Battelle Corporation.

Joel J. Kramer

Joel J. Kramer, Deputy Director
Division of Human Factors Safety

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Audit Report

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Audit of Turkey Point Procedures and Training for Pressurized Thermal Shock

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1 INTRODUCTION

1.1 Short-Term Objectives and Scope of Review

On July 13, 1982, an interdisciplinary audit team visited Turkey Point 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 Turkey Point 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) and NRC staff concurrence.

A visit to Turkey Point took place on July 13-15, 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 Turkey Point 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. 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 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.

1.3 Turkey Point Configuration

Turkey Point Units 3 and 4 are twin three-loop Westinghouse PWRs each rated at 2200 MWt (666 MWe). Normal pressurizer level is controlled by the chemical and volume control system which contains three positive displacement pumps. The safety injection system (SI) utilizes medium head pumps which will initially discharge the boron injection tank (BIT) into the cold legs of the reactor coolant system. There are four pumps which are used for the two plants. Interconnection between plants is possible.

The SI pumps have a shut-off head of 1400 psig and have a rating of 450. gpm at 867 psig. The SI system also contains three accumulators which discharge at 650 psig and two low head pumps (RHR) rated at 3000 gpm at 165 psig.

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 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 three turbine-driven pumps for the two reactors. Each pump can supply 100% auxiliary flow for one reactor and the third pump is a spare. Steam generator pressure control is performed by the steam dump system which includes 4 valves with a total full load steam flow capacity of 40%, one atmospheric dump on each steam generator with a total flow of 10% and the main steam code safety relief valves.

The Turkey Point Nuclear Station control room board contains the controls and displays necessary for the operation of Units 3 and 4. The following table contains the major parameters available to an operator at Turkey Point that would assist in monitoring PTS events.

Parameters	Display
RCS Pressure	Wide and low range meters and narrow range recorder
RCS Temperature	T-hot - wide range recorder
	T-cold - wide range recorder
	These temperatures could also be displayed 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
Reactor Water Level	Inadequate core cooling system will be added during the steam generator outage in 1982

2 SHORT-TERM CRITERIA USED FOR TURKEY POINT 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 or any situation which leads to the injection of cold water into the reactor. 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 Turkey Point events that occurred since the plant was built. A summary of the thermal-hydraulic analyses available for evaluating pressurized thermal shock events is provided in Section 2.1.4.

2.1.2 Turkey Point Cooling Events Summary

A detailed review of the operating history of Turkey Point has identified no events that resulted in exceeding the cooldown rate limit of 100 F/hr. One event was identified that could have led to exceeding the cooldown rate limit if not mitigated by automatic plant controls and protective functions and operator action and one over-pressurization occurred when the reactor coolant system was in a cold condition.

2.1.2.1 Event 1: December 2, 1971

Prior to plant startup three code safety relief valves were blown free from the unit three "A" loop main steam line. The "A" loop steam generator had no feed water flow at the time of the event. The RCS cooled from 547 F to 490 F. Further cooldown was prevented by operator action. The cooldown rate was not exceeded and pressure temperature relationship was within limits. The levels in the pressurizer and loops "B" and "C" steam generators were recovered and a normal cooldown was initiated approximately one hour after the event started.

2.1.2.2 Event 2: November 29, 1981

Prior to heatup with the reactor coolant system (RCS) in a water solid condition and the RCS temperature and pressure 110 F and 310 psig respectively, two over pressure conditions developed for which the overpressure mitigating system (OMS) failed to operate. The cause of the problem was found to be a failed summator on the OMS circuitry coupled with a pressure transmitter which was unintentionally left isolated. The peak pressure and duration were 1100 psig for two minutes during the first occurrence and 750 psig for one minute on the second.

2.1.3 Termination Criteria

2.1.3.1 Reactor Coolant Pumps (RCPs)

The RCPs do not trip automatically on a reactor trip or safety injection (SI) actuation. The emergency operating procedures (EOPs) include instructions to manually stop all RCPs once high head safety injection (SI) pump operation has been verified and reactor coolant system (RCS) pressure is at or below 1400 psig. This criteria does not apply for controlled depressurization steps in the EOPs.

2.1.3.2 Feedwater

The main feedwater pumps trip automatically on SI actuation. This causes auxiliary feedwater (AFW) pumps to start.

2.1.3.3 Charging Pumps

The charging pumps trip on SI actuation. The steam generator tube rupture (SGTR) EOP instructs the operator to restart all charging pumps just prior to depressurization steps (to maintain pressurizer level). Charging pumps are not restarted in loss of reactor coolant or loss of secondary coolant procedures.

2.1.3.4 SI Termination During Loss of Reactor Coolant

SI must remain in operation until all of the following conditions are met.

- RCS pressure > 1400 psig and increasing
- Pressurizer (Pzr) level > 50%
- RCS subcooling > 30 F
- AFW flow ≥ 570 GPM or
  At least one SG level in the narrow range

A caution is included which states:

> CAUTION: RCS pressure may be in excess of the plant pressure temperature (PT) curve limits. Refer to the PT curves and verify that the current plant conditions are below and to the right of the 100 degree per hour cooldown curve. IF THE PT CURVES ARE BEING VIOLATED, CAREFULLY REDUCE RCS PRESSURE TO A VALUE THAT WILL NOT VIOLATE THE PT CURVES, BUT DO NOT ALLOW SUBCOOLING TO DROP BELOW 30 F.

2.1.3.5 SI Termination During Loss of Secondary Coolant

In this procedure, RCS cold leg temperature determines the termination criteria. If T cold is less than 350 F, all of the following criteria must be met for SI termination:

- RCS pressure > 700 psig and stable or increasing
- Pzr level > 20% and rising
- RCS subcooling > 60 F
- AFW flow isolated to faulted SG(s)

- AFW flow ≥ 57[redacted] GPM or
  SG level in the narrow range in at least one non-faulted SG.

If T cold is greater than 350 F, all of the following criteria must be satisfied before SI is stopped:

- RCS pressure > 1400 psig and stable or increasing
- Pzr level > 50%
- RCS subcooling > 60 F
- AFW flow isolated to faulted SG(s)
- AFW flow ≥ 570 GPM or
  SG level in the narrow range in at least one non-faulted SG.

A caution is included which states:

> CAUTION: RCS pressure may be in excess of the plant pressure temperature (PT) curve limits. Refer to the PT curves and verify that the current plant conditions are below and to the right of the 100 degree per hour cooldown curve. IF THE P.T. CURVES ARE BEING VIOLATED, CAREFULLY REDUCE RCS PRESSURE TO A VALUE THAT WILL NOT VIOLATE THE PT CURVES, BUT DO NOT ALLOW SUBCOOLING TO DROP BELOW 60 F.

2.1.3.6 SI Termination During Steam Generator Tube Rupture

The following termination criteria apply after the RCS has been depressurized to match the steam pressure in the faulted SG. All of these conditions must be met:

- RCS pressure has increased by at least 200 psi (after shutting the spray valves or verified closure of Pzr PORVs)

- Pzr level indication has returned

- RCS subcooling > 40 F

2.1.4 WCAP-10019 Vessel Integrity Analyses

The analyses provided in WCAP-10019 are typical of FSAR-type design bases events. However, the boundary conditions have been selected to enhance the overcooling. Maximum safety injection and feedwter flows are assumed, minimum water temperatures are used, and heat sources are either omitted or are conservatively underestimated. Large and small LOCAs have been addressed, as well as large and small steam line breaks. In addition, the Rancho Seco overcooling event was included. Westinghouse indicates that the dynamics of this event would be similar to a low probability small steam line break (including additional failures). Operator action is identified for two events

presented in WCAP-100[redacted] For the isolatable LOC[redacted] (a stuck open PORV), it is assumed that the operator isolated the break in 30 minutes. For the large steam line break, it is assumed that auxiliary feedwater to the faulted steam generator and makeup injection flow to the RCS is terminated within 10 minutes.

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 audit team used training criteria developed by the staff as a standard for all plant PTS audits. The criteria covers 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 for 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 FPL on the PTS issue and that FPL 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 that more severe transients have occurred than expected (Rancho Seco, Crystal River).

FPL was asked 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.

3 KEY FINDINGS OF THE TURKEY POINT 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 Turkey Point, PNL reviewed the procedures listed in 3.3.1, the Turkey Point training outline which included a description of past events and the Turkey Point 150 day response dated 1982. During the plant visit, PNL reviewed the training schedule and interviewed key members of the training staff. Procedures which dealt with PTS were reviewed against the audit criteria. Past Turkey Point potential events and potential overcooling transient scenarios used in the FPL simulations (as reported in WCAP-10019) 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.

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 follow-up or recovery steps in the emergency procedures. Several interview aids were used 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.

3.2 Training

3.2.1 Introduction

The audit of Turkey Point'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 (only 1 licensed)
- 1 Nuclear Watch Engineer (SRO)
- 1 Nuclear Plant Supervisor (SRO)
- 2 nuclear control operators (RO)

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. The requalification training deals with NDT vessel limits and their use during transients. The lectures included 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 does cover these topics. The emphasis is on preventing PTS and includes using the PORVs to prevent over pressurization, termination criteria for SI, 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 PTS subject and MPT curve adequately. The operators are taught that if they find the plant in a potential PTS condition they are to stabilize at that point and 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.

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 and Emergency Procedures.

0202.2 Unit Start-up - Hot Shutdown Power Operation

0205.2 Reactor Shutdown - Hot Shutdown to Cold Shutdown Condition

20001 (E-1) Loss of Reactor Coolant

20002 (E-2) Loss of Secondary Coolant

20003 (E-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 within the acceptable region on the MPT graph. This may involve SI termination or operating the PORVs.

(3) Procedures should provide guidance on recovering from PTS conditions. The procedures provide instructions for maintaining the RCS within conditions allowed by the NDT curve and also cover cases where a PTS event has occurred before the operators are able to begin to control plant conditions. The procedures do not give guidance to the operator given that the cooldown rate has been exceeded, however, these recovery procedures are also 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 Westinghouse and reported in the 150 day response (WCAP-10019).

(5) High pressure injection and charging system operating instructions should reflect a consideration for PTS. The subcooling criteria for SI termination reflect PTS

concerns by use of notes and cautions.

(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 generators 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 give the operator guidance on preventing a PTS event. The guidance deals with such items as terminating SI and use of the PORVs.

3.4 Summary

Six individuals were interviewed. They ranged in experience from a shift supervisor to a 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 and include instructions on how to recover from a situation where the plant is operating outside the acceptable zones on the P-T diagrams.

4 RECOMMENDATIONS

Based on the findings presented in Section 3, the Turkey Point audit team has no recommendations.

REFERENCES

(1) WCAP-10019 "Summary Report on Reactor Vessel Integrity for Westinghouse Operating Plants".

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

(3) Licensee 150 - Day Response to NRC on PTS, Florida Power and Light Company, Turkey Point Nuclear Station, December, 1981.