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AUDIT OF FORT CALHOUN PROCEDURES AND TRAINING THAT ADDRESS THE PRESSURIZED THERMAL SHOCK ISSUE

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1.0 INTRODUCTION

This review reports the results of an audit of the Fort Calhoun Generating Station of the Omaha Pacific Power District relative to interim concerns on the issue of Pressurzied Thermal Shock (PTS). The current status of the generic PTS issue, Fort Calhoun's general plant operating characteristics and pertinent control room instrumentation are included.

1.1 SHORT-TERM OBJECTIVES AND SCOPE OF REVIEW

On June 8, 9, and 10, 1982, a multi-disciplinary audit team visited Fort Calhoun Station to evaluate certain aspects of the 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?

This general question was applied to the applicable procedures and to operator training. In addition, since the procedures and training refer to control room instrumentation, the control room instrumentation that is relevant to PTS events was also evaluated. As noted in the Nuclear Regulatory Research (NRR) division 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 scope of the review (analysis of training and procedures), the resolution of various technical questions on PTS (e.g., thermal-hydraulic analyses, fracture mechanics, and probabilities) was not part of the audit team charter. However, a brief analysis of thermal-hydraulic concerns at Fort Calhoun is included for perspective relative to training and the procedures. Also, implementation of any recommendations (see Section 5) is subject to coordination and consistency with the longer term generic program (Unresolved Safety Issues, Item A-49: - USI A-49).

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 NRC staff has committed to the Commission to have developed an interim initial position on PTS 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 that have been identified as having the highest reference temperature for nil ductility transformation (RTNDT). 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 should be initiated before the NRC generic resolution and acceptance criteria are adopted. The final submittal in the June recommendations by the NRC staff to the Commission will have available the findings and recommendations addressed in Sections 4 and 5 of this report, as well as the findings of other audit teams formed for related investigations (such as fluence reduction at the vessel wall).

1.3 FORT CALHOUN GENERAL CHARACTERISTICS

The Fort Calhoun nuclear steam supply system is a Combustion Engineering PWR, two loop design. It operates at 500 MW(e) maximum and during six cycles (cores) has accumulated about 1950 effective full power days (EFPD) and has generated in excess of 66 3/4 million MW-hr. The reactor vessel design includes a thermal shield between the core barrel and the vessel wall. The shield extends from the bottom plate to the top of the core. Reactor power is controlled by chemical shims augmented by control rod assemblies. The reactor and plant output are controlled by a combination of reactor average temperature compared to a reference temperature based on turbine demand, pressurizer pressure and level control, and steam generator level control systems. The reactor core is protected by the Reactor Protective System and the Safety Injection Actuation System (SIAS). The latter provides borated water (chemical shim) to the primary system under potential accident conditions to mitigate the consequences by keeping the core covered under all plausible events. The system includes three High Pressure Safety Injection Pumps (HPSI pumps) at a shut-off head of 1380 psig; two low pressure safety injection pumps (LPSI) at a shut-off head of 200 psig; two shutdown cooling heat exchangers; four safety injection tanks (SIT), 5500 gallons each and pressurized to 250 psig for passive injection at lower RCS pressures; the system high pressure (8) and low pressure (4) injection valves for system isolation during normal operation and automatic make-up upon demand. The LPSI also provide shutdown cooling through the reactor core and shutdown cooling heat exchangers during cold or refueling shutdown.

Included with the SIAS in the Engineered Safeguards System are systems, when conditions demand, for containment isolation (CIAS), for containment cooling and depressurization (CSAS), for ventilation isolation (VIAS), and for longer term emergency cooling, the recirculation actuation system (RAS).

The charging pumps (three) in the Chemical and Volume Control Systems in the RCS are also available for low flow injection (40 gpm each) but at high discharge pressure (2500 psig). Suction for all emergency injection including the charging pumps when their normal suction source (Volume Control Tank) approaches depletion is the large Safety Injection and Refueling Water Tank (SIRWT) maintained at a capacity of at least 283,000 gallons of borated water. If this source approaches depletion, pump suction is transferred automatically to the containment sump by the RAS (HPSI pumps only as the LPSI pumps are turned off automatically at this step.)

Upon initiation of SIAS by pressurizer pressure low pressure of 1725 psig (or containment high pressure), flow from the injection headers supplied by the HPSI pumps begins when RCS pressure reaches about 1375 psig. The passive system (SIT), injects at an RCS pressure of 250 psig. The coolant flow from the LPSI pumps is injected when RCS pressure reaches about 185 psig. On the secondary side two (of three) Main Feedwater Pumps (MFWP) maintain level in each of two steam generators (S/Gs) commensurate with the steaming rate and power demand. Level control in the S/Gs is maintained by a three element, level dominant signal, controlling positions of the feedwater regulating valves from the MFWPs. The shell side of each S/G is protected by five appropriately sized code safety valves set at proper lift pressures. Two air operated relief valves upstream of each MSIV dump to atmosphere on demand from the control room. Each S/G steam output is isolated when needed by a Main Steam Isolation Valve (MSIV) actuated by low S/G pressure (or CIAS). Two feedwater isolations valves in each S/G feedwater line, one of which closes automatically upon a CIAS, can completely isolate the secondary side of each S/G.

A steam dump and bypass system comprising of five control valves with associated controls and instrumentation provide a path to a heat sink (condenser) following a reactor and turbine trip. In case the condenser is unavailable, a valve which dumps to the atmosphere from a common header is located downstream of one of the MSIV's.

The Fort Calhoun control room displays to the operators the following major parameters that are needed for monitoring PTS events:

Parameters	Display
RCS Pressure	One wide-range and one narrow-range strip recorder.
RCS Temperature	One wide-range strip recorder for Loop A and one for Loop B; eight hot-leg, narrow-range meters; eight cold-leg, narrow-range meters.
Pressurizer Pressure	Two narrow-range strip recorders and one low-range meter.
Pressurizer Level	One full-range meter that displays in percentage units.
Reactor Head Temperature	No reactor head thermocouples.
Core Exit Temperatures	These can be called up and printed out on the control room computer; the computer can also assign these readings to a strip recorder for determination of trend information.

Parameters	Display
Subcooling Margin	Digital readout on subcooling margin monitor in degrees Fahrenheit based on RCS pressure and hot leg temperature. This monitor only works down to 465°F, because the temperature reading is taken from a narrow-range meter. Below that temperature, the subcooling margin has to be determined manually.
Cooldown Rate	There is no display of instantaneous cooldown rate. The cooldown rate has to be extrapolated from strip recorders that are used to monitor RCS temperature.
Safety Injection Flow	Flow meter for each injection line.
Charging System Flow	Flow meter.
Steam Generator Level	0 to 100 percent meter and 0 to 100 percent strip recorder.
Steam Generator Steam/ Feed Flow	Steam/feedwater flow strip recorder.
Trend Monitors	Three auxiliary strip chart recorders which can be programmed to record any of the above.

Except for the subcooling margin monitor, the parameter displays in the control room were judged to be adequate to help the operators monitor a PTS event. Since the subcooling margin monitor interfaced with a narrow-range temperature indicator that only registers down to 465°F, this monitor would not be useful to the operators when RCS temperature falls below that temperature.

2.0 SHORT-TERM CRITERIA USED FOR FORT CALHOUN AUDIT

The criteria for procedure and training reviews were based on transient and accident analyses. The analyses and audit criteria are discussed below.

2.1 TRANSIENT AND ACCIDENT ANALYSES

Overcooling events in PWRs may occur as a result of steam line breaks (SLB), feedwater system manfunctions, steam generator tube rupture (SGTR), or loss-of-coolant accidents (LOCA). 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 presents an overview of overcooling events at the Fort Calhoun Station. Termination criteria for primary and secondary injection systems are also discussed.

2.1.1 Fort Calhoun Overcooling Events Summary

A review of the operating history has resulted in the identification of two overcooling events that could have led to exceeding the cooldown limit if not mitigated by automatic plant controls or operator action. These events are discussed individually below. One event, in 1974, was the result of excess feedwater flow to the steam generators causing overfill and cooldown of the primary system. The second in 1977 was inadvertent activation of SIAS due to operator error during normal cooldown, thus accelerating the cooldown. Termination of the SIAS prevented the RCS temperature from falling below the PTS cooldown limit of >100° from this event.

In the former event however, all three criteria that identify PTS were judged to have occurred, namely a cooldown rate >100°F/hr (actual estimate was 330°F/hr), an event duration of >10 minutes (actual duration was estimated to be 19 minutes), and total temperature decrease of more than 100°F (actual decrease estimated to be 107°).

2.1.2 Termination Criteria

- SI Termination: At Fort Calhoun, the HPSI pumps can be throttled. Procedures for emergencies where the possibility of RCS overpressurization exists instruct the operator to throttle HPSI flow to prevent RCS overpressurization. The following must be considered:

  Pressurizer level above heater cutoff and responding to charging pump flow.

  All RCS hot and cold leg temperatures at least 50°F below saturation temperature for current RCS pressure.

  Core cooling is being provided by natural or forced circulation.

  Core power is stable and within specifications.

  T_{AV} is stable and boron concentration is adequate and confirmed.

  Control rods fully inserted or boration is sufficient for stuck rod.

  CVCS boration path is demonstrated to be operable.

  If LPSI was initiated, has it run at least 20 minutes with significant flow from either HPSI or LPSI?

  SIRWT level O.K.

- Charging Pump Termination: During an uncontrolled heat extraction, charging pumps are stopped as a follow-up action.

  In a loss of cooling accident, the charging pumps remain on until the boric acid tank inventory is exhausted.

  During a steam generator tube rupture with Pressurizer Pressure Low Signal (PPLS) blocked, charging pumps can be operated manually only as needed to maintain pressurizer level.

  During a steam line rupture with loss of offsite power, the charging pumps are stopped to avoid overpressurization of the RCS.

- Main Feedwater Termination: In an uncontrolled heat extraction, main feedwater pumps are immediately stopped.

In a steam line rupture, feedwater to the affected steam generator is stopped as soon as it is determined which one is affected.

In other emergencies, main feedwater is left on but flow is automatically cut back to 5 percent whenever a reactor trip occurs.

- Auxiliary Feedwater Termination: During a transient, auxiliary feedwater will be throttled to the steam generators to maintain level for heat rejection. If there is a tube rupture, AUX feedwater to the affected generator will be stopped after the MSIV for that generator is closed.
- Reactor Coolant Pumps: Reactor coolant pumps are manually tripped any time safety injection occurs and are not restarted until safety injection has been stopped.

2.1.3 Thermal Hydraulic Analysis[a]

1. CEN-189 Generic PTS Analysis (Small Break LOCA)

In CEN-189,[1] only the scenario of small break LOCA with concurrent loss of feedwater was analyzed. The break sizes ranged from zero to 0.01 ft^2, all located in the pressurizer. Maximum and minimum HPI flow were used as the bracket for PTS analysis. Two alternatives were provided for the operator action: 1) PORV opened at 10 minutes, or 2) feedwater restarted at 30 minutes. The cases of zero break size with the maximum conservative high-head pump flow and restoration of feedwater at 30 minutes (Case 6) was selected for a more detailed thermal-hydraulic evaluation.[2] It indicated that the margin of the temperature/pressure combination to the potential PTS region is small. The critical factor in the case is the operator action and the time of action. For the scenario of operator restarting feedwater flow at 30 minutes, if this action is delayed further, the steam generators will dry out, and the natural circulation in the primary loop may not be sustained (due to loss of heat sink). This leads to the loss of a main driving force for downcomer mixing of cold-leg and HPI flows. However, the possibility of operator confusion on the

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(a) Submitted by Shaw Bian, Thermal and Fluid Engineering Section, Engineering Physics Department, Battelle-Northwest.

corrective actions is low in this case because it is consistent with the procedure of preventing the core from uncovering in a LOCA situation.

2. Steamline Break Transients for Fort Calhoun

Two types of overcooling transients were analyzed for the Fort Calhoun plant:(3) 1) double-ended main steamline break (MSLB) and 2) small streamline break (one atmospheric dump valve upstream of main steam isolation valve stuck open). In both cases, the transients start at hot zero power (HZP). Zero decay heat, RCP trip at SIAS actuation and total mixing of cold-leg and high pressure injection flows are assumed. The operator terminates the charging and HPI pumps at 30 minutes for MSLB and at 90 minutes for small SLB.

The initial HZP condition is conservative due to the fact that at HZP, the steam generators have the largest water inventory which leads to a maximum cooldown in an SLB event.

The tripping of RCP early in the transient is conservative because of the higher system pressure and lower downcomer temperature (less mixing) caused by the tripping. Regarding the mixing of the SI fluid and cold-leg coolant, the assumption of total mixing is reasonable as long as the loop circulation is maintained.

The time allowed for operator action, i.e., 30 minutes for terminating the charging and HPI pumps in an MSLB accident, could be insufficient. More analyses are needed to give the sensitivity of the pressure-temperature behavior to the action time.

REFERENCES

1. CE-189 "Evaluation of Pressurized Thermal Shock Effects Due to Small Break LOCA's with Loss of Feedwater for the Combustion Engineering NSSS" Combustion Engineering, Inc., December 1981.

2. L. T. Pedersen et al., "PNL Technical Review of Pressurized Thermal Shock Issues," Pacific Northwest Laboratory, to be released, (1982).

3. G.S. Vissing to all Licensees Represented by CE Owners Group, "Summary of Meeting with CE Owners Group, Omaha Public Power District, Baltimore Gas and Electric Company and Maine Yankee Atomic Power Company Concerning the PTS Issue," NRC, March 12, 1982.

2.2 CRITERIA FOR PROCEDURE REVIEWS

All Fort Calhoun emergency procedures (EPs) were reviewed for relevance to PTS issues, as were relevant operating procedures (OPs) and operating instructions (OIs). The list of the relevant EPs, OPs, and OIs is presented in Section 3.1.

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. Finally, the CE Owner's group is in the process of writing new technical guidelines for mitigating emergency events using a functional approach as required by NUREG-0899. The NRC is currently reviewing their submittal, and following its approval, Fort Calhoun will be totally rewriting its EPs. This is expected to occur in late 1982 or early 1983. 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. Safety 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 CRITERIA FOR TRAINING PROGRAM REVIEW

The audit team used the criteria developed by the NRC staff as a standard for all plant PTS audits. These criteria cover 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.

Within the general criteria, more specific criteria were used in reviewing detailed training material such as lesson plans and in preparation for interviews with the training staff and operating personnel.

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 Omaha Public Power Distrit (OPPD) on the PTS issue and that OPPD had responded that additional training was underway.
3. Operators should understand that a rapid reduction in reactor vessel temperature 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 steam line 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).

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

3.0 DESCRIPTION OF AUDIT

Prior to the plant visit, PNL reviewed the Fort Calhoun 150-day response and a more recent package supplementing that response [letter from W. C. Jones (OPPD) to R. A. Clark (NRC) dated 5/17/82]. The audit of procedures and training relating to PTS is described below.

3.1 PROCEDURES

During the plant visit, the audit team reviewed the current version of appropriate Fort Calhoun EPs, OPs, and OIs. Instructions relating to possible PTS events were discussed with the individual responsible for writing these documents. The bases for PTS related instructions were discussed in the course of working through various transient and accident scenarios. The audit team then visited the control room to review instrumentation and available pressure/temperature curves that had been referred to in the procedures and to determine the legibility and currency of the control room procedures. The following OPs, OIs, and EPs were included in the audit:

Procedure Number	Procedure Title
OP-2	Plant Startup from Cold Shutdown to Hot Standby
OP-3	Plant Startup from Hot Standby to Minimum Load
OP-7	Reactor Startup
OP-8	Reactor Shutdown
OI-RC-3	Reactor Coolant System Startup
OI-RC-4	Reactor Coolant System Normal Shutdown
OI-RC-7	Reactor Coolant System Pressure Control
EP-5	Loss of Coolant Accident (PPLS unblocked)
EP-5A	Loss of Coolant Accident (PPLS blocked)
EP-6	Uncontrolled Heat Extraction
EP-29	Steam Line Rupture with a Complete Loss of Off-Site AC Power
EP-30	Steam Generator Tube Leak/Rupture (PPLS unblocked)
EP-30A	Steam Generator Tube Rupture (PPLS blocked)
EP-32	Emergency Shutdown
EP-35	Reset of Engineered Safeguards.

3.2 TRAINING

The review of the training at Fort Calhoun on the subject of PTS began with the Manager of Training describing their current programs. This issue has been recently added to their training curricula for RO and SROs as a topic for separate treatment. In addition, a senior engineer from their Engineering Services Department at Omaha Public Power District has given two hour seminars for the licensed RO's and SRO's for each of the six shifts. One of these seminars had been video-taped as a further training aid. The audit team reviewed this video presentation on PTS. Each trainee receives a lecture syllabus which parallels the presentation and each trainee takes a written exam. The syllabus and the examination were reviewed as were the separate test results for the four licensed staff members who were interviewed.

Training for the Shift Technical Advisors (STA's) is the responsibility of an onsite technical support group in the Engineering Department. The content of the training appears more extensive and the length of time devoted to the issue is longer than that received by the licensed personnel. The instructor currently is an STA who because of his prior training and experience functions as the formal training officer for STAs. An in-depth review of the training for STAs on the issue (PTS) was completed as a part of the interview of an STA who is the current training instructor coordinator for STAs.

Interviews were conducted with the following personnel four of whom were licensed and two were STAs. The audit team were given the roster of all six shifts and a choice of candidates to interview. The majority of those selected by the audit team were from two shifts on duty during the visit, one of which was in the normal one week training cycle. They were:

SRO	Shift Supervisor
SRO	Sr. Control Room Operator
RO	Control Room Operator
RO	Control Room Operator
STA	Training Coordinator (STA's)
STA	Shift STA

Each interview was conducted by an experienced examiner qualified by NRC to examine RO and SRO candidates. Each interview was conducted in a manner somewhat similar to the oral examination for license. The candidates were expected to create at least one recognized scenario that might lead to a PTS event, select and use the appropriate procedures, both operating and emergency, and identify the involved instruments, controls and equipment in the control room that would be used to mitigate the event and terminate the potential for repressurization at the conclusion of the interview. Each interviewee reviewed a portion of the written test, not for the answers which he had already successfully supplied but for the rationale and applicability of questions.

3.2.1 Operator Interviews Resulted in the Following Findings Regarding Training

- It was apparent that all operators and STAs interviewed had been recently trained on this issue. All showed a basic understanding of PTS.
- All recognized the events that could lead to a PTS, the instrumentation and information sources available to the operators and real time sequences that could develop.
- There were minor differences in responses as to how to identify a potential PTS event.
- Operators were all satisfactorily aware of the appropriate Emergency Procedures and the steps that involved potential PTS consequences even though these procedures are directed almost entirely to keeping the core cooled and covered.

4.0 KEY FINDINGS FROM THE FORT CALHOUN AUDIT

Findings regarding the procedures and operator training are presented below. Comments regarding control room instrumentation are provided in the procedures section.

4.1 COMPARISON OF PROCEDURES WITH THE AUDIT CRITERIA

1. Procedures should not instruct operators to take actions that would violate NDT limits. The only manner in which the procedures could be construed to be instructing the operators to take actions that would violate NDT limits is with regard to instructions about the subcooling margin. In all but two of the EPs, operators are instructed to maintain a subcooling margin of at least 50°F. A subcooling margin of over 200°F would violate the NDT curve (their procedures refer to the NDT curve as the "cooldown curve" or "cooldown rate curve"). In the other two EPs, the subcooling margin was given as at least 50°F, but not greater than 200°F. This would keep the operators from violating the NDT curve. Thus, it would be important to specify both the lower and upper bounds of the subcooling margin in all of the EPs. In addition, while not instructing the operators to violate the NDT curve, two of the OIs and several of the EPs provided inconsistent data regarding maximum RCS pressure for low temperature conditions. The correct numbers should be determined and used consistently throughout the OIs and EPs. Future procedures may not necessarily establish P-T limits by subcooling margin, but may use other criteria.

2. Procedures should provide guidance on recovering from transient or accident conditions without violating NDT or saturation limits. All of the relevant EPs were specific about not violating the saturation curves by providing a minimum subcooling margin. In some cases, as discussed in (1) above, a maximum subcooling margin was specified. The maximum subcooling margin was chosen so as to be consistent with the NDT curve. Therefore, if both maximum and minimum subcooling

margins are specified so that the operators have an acceptable operating band, then the above criterion is met. As discussed in Section 1.3, however, the subcooling margin monitor does not work below 465°F, so more aid is needed for the operators regarding this parameter. In addition, there are several places in the EPs where the operator is referred to the subcooling margin monitor, even though it is possible that at that place in the event the RCS temperature is below 465°F. Although this might be misleading, all of the operators that we interviewed were well aware of the subcooling monitor limitations. Finally, whenever an EP referenced the saturation curve, the curve was provided at the back of that specific EP as it should be. However, the NDT curve was only available in the Technical Specifications and at the end of EP-35, even though several other procedures referenced it. The NDT curves should also be provided in these procedures.

3. Procedures should provide guidance on recovering from PTS conditions. The procedures instruct the operator that if the NDT curve is violated, RCS pressure shall be decreased to bring the pressure within the NDT limits. The procedures also state that vessel integrity takes precedence over subcooling considerations.

4. PTS procedural guidance should have a supporting technical basis. The procedural guidance on PTS is based on plant-specific analyses and on studies conducted by Combustion Engineering. Their NDT curves are updated yearly on the basis of these analyses.

5. High pressure injection and charging system operating instructions should reflect a consideration for PTS. The procedures recognize the fact that high pressure safety injection and the charging pumps are the primary sources of pressure, especially when the RCS temperature is below normal operating temperatures and even more so when the RCS temperature is below the minimum temperature for full pressurization. In these conditions, these two systems have the capability to fill the pressurizer to a water solid condition. Thus, the procedures instruct the operator to throttle these systems or to use them intermittently to preclude overpressurization.

6. Feedwater (FW) and/or auxiliary feedwater (AFW) operating instructions should reflect PTS concerns. Termination of FW is dependent upon the type of event and reflects PTS concerns. In addition, the use of AFW in either the normal AFW header or the emergency feedwater header reflects a concern for PTS events.

7. An NDT curve and a saturation curve should be provided in the control room. Both curves are available in the control room. However, some of the EPs refer to the "attached" NDT curve, which was not attached to that procedure. In addition, while the saturation curve is presented at the back of each relevant procedure, two different curves are used and they have reversed axes. The NDT curve also has its axes reversed from the more commonly used saturation curve. From an operator's standpoint, the NDT curve and the saturation curve with the 50°F subcooling curve included would be most useful if they were presented on one graph, because they would then indicate (without the need for further processing on the operator's part) the acceptable operating band. Finally, the NDT curve presented in the EPs was not the latest NDT curve for Fort Calhoun. However, the NDT curve in the Technical Specifications, which was available in the control room, was the latest curve.

4.2 COMPARISON OF TRAINING WITH AUDIT CRITERIA

1. Training should include specific instruction on NDT vessel limits for normal mode of operation. The Operator Requalification Pressurized Thermal Shock lecture outline includes a discussion of the PTS issue in general and NDT vessel limits. All interviewees showed good understanding in this area.

2. Training should include specific instructions on NDT vesssel limits for major transients and accidents. The requalification training deals with PTS concerns for major transients and accidents. A decision tree for determining whether a PTS incident had occurred was included in the course handout. All interviewees knew the vessel RT NDT and understood NDT cooldown limits.

3. Training should particularly emphasize those events known to require operator response to mitigate PTS. Operators are taught that if they follow procedures they will not reach a PTS condition. It is emphasized that SI termination criteria in the EPs should be closely observed when PTS is concerned. The operators were instructed to regain pressure and temperature control as rapidly as possible, to control cooldown rate to less than 100°F/hr, and to avoid repressurization that could lead to a PTS condition.

Specifically, operator requalification training addressed the seven more specific training program criteria as follows:

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. The training material covered the NDT shift and the reason for it. The interviewees knew the RT_{NDT} + 100°F temperature and that radiation had caused the shift.

2. Operators should be aware that NRC has sent letters to Omaha Public Power Distrit (OPPD) on the PTS issue and that OPPD had responded that additional training was underway. Operators interviewed were well aware of the NRC's current emphasis on PTS training at Fort Calhoun.

3. Operators should understand that a rapid reduction in reactor vessel temperature can raise the possibility of crack propagation, particularly if pressure rises after the temperature reaches its lowest value. The training material stressed the importance of avoiding repressurization during cooldown. The operators interviewed knew this and that repressurization could lead to crack propagation. They also knew that there is a possibility of undetected cracks to propagate from a PTS event.

4. Operators should be aware of the types of events which are known to involve PTS (such as steam line breaks and secondary side malfunctions). The training materials covered causes of PTS events and the operators interviewed understood which ones they are, namely stuck open safety valve, steam line break, small break LOCA, and steam generator tube rupture.

5. Operators should appreciate that other safety limits (such as core cooling and shutdown margin) must also be balanced with the PTS limits. The PTS training covered the fact that keeping the core covered, cooled, and subcritical in an emergency still is first priority. The operators interviewed knew this and seemed reasonably confident that they could do so without violating the NDT curve.

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. The operators interviewed were aware of how to determine subcooled margin, cooldown rate, and RCS temperature and pressure. They knew which controls and systems to use to control these variables during an emergency.

7. Operators should understand the basis for current emphasis on PTS, specifically, that more severe transients have occurred than expected (Rancho Seco, Crystal River). The training material covered PTS events at Rancho Seco and Calvert Cliffs. Operators interviewed were aware that PTS events have occurred at other plants.

4.3 SUMMARY OF FINDINGS

4.3.1 Procedures

- Procedures were generally found to be adequate when compared with audit criteria.
- Procedures were based on plant specific analysis, which was performed by Combustion Engineering.

- Procedures were designed to provide a well-defined path through accidents, including the guidance needed to prevent PTS and guidance on what to do if the NDT curve had been violated.
- Procedures specify minimum subcooling margins and maximum cooldown rates. In some cases they provide maximum subcooling margins, which correspond to the NDT curve.
- Two different subcooling curves are presented in the EPs. Although they provide the same (correct) information, they have reversed axes.
- The NDT curve in EP-35 was an outdated curve.
- Maximum RCS pressures for low temperature conditions are presented in a slghtly inconsistent manner throughout the OIs and EPs.
- The procedures refer to the subcooling margin monitor at times when the monitor may not be useful because of its temperature limitation (i.e., does not operate below 465°F).

4.3.2 Training

4.3.2.1 Training Material

The review of training material and training evaluation test questions resulted in the following findings:

- the lecture outline for PTS traning covered all the areas identified by audit criteria
- operator evaluation included a fifteen-question written exam which was fairly comprehensive. One written PTS question will be included in the requalification exam.

4.3.2.2 Operator Interviews

Operator interviews resulted in the following findings regarding training:

- All had been recently trained on the PTS issue and were cognizant of its potential and its priority in emergency core cooling and other rapid cooldown events.

5.0 RECOMMENDATIONS

1. Maximum RCS pressures for low temperature conditions are presented in OI-RC-3 and OI-RC-4. The numbers are slightly inconsistent between OIs and this inconsistency carried through in some of the EPs. We recommend that these be made consistent throughout.

2. Minimum and maximum subcooling temperatures are presented in several of the EPs, which is good practice for handling PTS events. In other places, only minimum subcooling temperatures are given. We recommend that the procedures be made consistent throughout using both the minimum and the maximum specifications.

3. Two different saturation curves are presented in the EPs, which have reversed axes. The curve with the 50°F subcooling curve is the most useful. We recommend that all the saturation curves include the 50°F subcooling curve and that all of these curves be presented consistently throughout the procedures.

4. The NDT curve is referred to in the EPs, but the curve is only presented in EP-35, and it is an outdated curve. We recommend the new curve be inserted, and the curve should be presented in each EP that refers to it. In addition, we recommend that the saturation curves and the NDT curve be presented on the same graph, so that the operator can tell at a glance what the allowable operating band is.

5. Until the subcooling margin monitor is upgraded to be used below 465°F, a label should be affixed to remind the operator not to use it below 465°F.