Incident Investigation Team Report

96-002

"Plant Shutdown Due To Circulating Water and Essential Service Water Intake Icing"

Wolf Creek Nuclear Operating Corporation

Issued February 28, 1996

INCIDENT INVESTIGATION REPORT

96-002

"Plant Shutdown Due To Circulating Water And Subsequent Essential Service Water Intake Icing"

Wolf Creek Nuclear Operating Corporation (WCNOC)

signed copy on file	2/28/96	signed copy on file	2/28/96
IIT Team Leader Engineering Subcommittee	Date	IIT Team Leader Operations Subcommittee	Date

Approved By: signed copy on file 2/28/96

Incident Investigation Team (IIT) Leader Date

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INCIDENT INVESTIGATION REPORT 96-002

"Plant Shutdown Due To Circulating Water And Subsequent Essential Service Water Intake Icing (IIT 96-002)"

TEAM LEADER: [name deleted]

TEAM MEMBERS: See Appendix "A" for Team Assignment

ASSESSMENT PERIOD: This Incident Investigation Team investigation activities occurred from February 3, 1996, through February 17, 1996. Follow-up activities and report development continued into the week of February 26, 1996.

I. EXECUTIVE SUMMARY:

This report documents the findings of the Incident Investigation Team (IIT) (96-002) and gives recommended corrective action and the recommended enhancements for the various areas evaluated. The basic report and its recommendations concern the Essential Service Water (ESW) trash rack frazil ice formation and the Circulating Water (CW) traveling screens freezing problems. In addition the report addresses a number of issues found during the IIT such as the initial misalignment of valves during the operation of the ESW system.

The inherent root cause of this event is the inadequate design of the CW and ESW systems to operate in the cold environment existing on January 30, 1996, through February 1, 1996. This report addresses the recommended corrective action to preclude this event in the future.

II. INTRODUCTION:

At 0337 hours on January 30, 1996, Wolf Creek Generating Station (WCGS) was manually tripped following ice build-up on the Circulating Water (CW) traveling screens. Ice build-up on the Essential Service Water (ESW) trash racks later caused the loss of the "A" ESW pump on two separate occasions. Twice during this event the Wolf Creek Nuclear Operating Corporation (WCNOC) declared a Notification of Unusual Event (NUE).

The Vice President Plant Operations, through letter WO 96-0024, chartered an Incident Investigation Team (IIT) to investigate the plant shutdown due to CW intake icing, the ESW intake icing, and subsequent events relating to these conditions. The WCNOC Nuclear Safety Review Committee (NSRC) Chairman was appointed as the team leader. The first team meeting was conducted at 0800 hours on February 3, 1996. The team was split into two groups, one to evaluate engineering and design issues, and the other to investigate Operations and Emergency Planning issues. The Manager Support Engineering was appointed to lead the Engineering Team and the Manager Training was appointed to lead the Operations Team. Consultants were brought in from both Bechtel Engineering and Sargent & Lundy (S&L), respective designers of the ESW, Ultimate Heat Sink (UHS) and Train Systems. Personnel were also brought in from Cooper Nuclear Station, Callaway Nuclear Station, and the Institute Of Nuclear Power Operations. Additionally, a Hydraulic Engineer from the United States Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, participated in the investigation. See Appendix "A" for a listing of the team composition and expertise.

Specific concerns associated with the Turbine Driven Auxiliary Feed Water Pump (TDAFWP) and the failure of some control rods to fully insert were not included in this investigation. Incident Investigation IIT 96-001 was chartered with investigating the TDAFWP concerns and the control rod problems are being investigated under significant **PIR 96-0268**.

III. DESCRIPTION OF EVENT:

Overview:

On January 30, 1996, Wolf Creek Generating Station (WCGS) initiated a plant shutdown due to the loss of all CW because of ice build up on the traveling screens. To gain a broader perspective of this event, this description will encompass specific events occurring prior to, during, and subsequent to this plant shutdown.

Historical Developments:

In August of 1975 S&L performed calculations (Calc WR-WC-DT-3) for determining flow rates for the CW warming lines. During April and May of 1976, Bechtel performed an evaluation on the potential for frazil ice formation at the WCGS ESW pumphouse. As a result of this evaluation Bechtel changed the location of the warming line from in front of the pumphouse to inside the pumphouse. Bechtel also instructed the individual performing the evaluation to assume that the Service Water (SW) would enter the ESW Screenhouse through the warming line at 35°F (Calc K-20-01-F), when lake water temperature is sub-cooled to less than 32°F. The Bechtel calculation (Calc K-20-01-F) also determines a flow of 4000 gallons per minute (gpm) is required through the warming line to prevent frazil ice formation. A later Bechtel calculation (Calc M-EF-13) determined the actual flow through the warming lines will be 4413 gpm with valves EF HV-39, 40, 41, and 42 closed, and EF HV-37, and 38 open. This calculation assumes the line would be full.

STN GP-001, Revision 0, "Plant Winterization," is released in October 1985. Initially it does not contain any steps to winterize either the CW Screen House (CWSH) or the ESW Pumphouse. These were added to the procedure in Revision 3 (1990) in response to PMR 2149 modifications. These modifications were to allow SW flow through the warming lines when the ESW system is not in operation to control Microbiologically Induced Corrosion (MIC). In October 1988, with regards to the CWSH side, the setup includes putting the traveling screens in "manual slow".

STN GP-001 was initiated on September 22, 1995, and the steps associated with the CWSH and the ESW pumphouse were completed on October 30, 1995. During winter conditions the shift crews begin receiving briefings when the temperatures are predicted to be extremely low, aimed at heightening awareness of problem areas created by the cold weather.

On January 24, 1996, maintenance was performed on the TDAFWP. It was confirmed that Maintenance personnel had removed the packing gland follower, and that it was not reinstalled correctly.

January 29, 1996:

Preventive Maintenance (PM) was performed on the CWSH traveling screens and the "B" CW Pump Motor. The work on the traveling screens was completed successfully around 1430 hours. The lead mechanic has indicated that there was a little ice on the traveling screens, and on the screen cover backsplash, but nothing out of the ordinary for that time of year and the existing weather conditions. He also noted that the ice on the lake was closer in toward the pump fore bays than he had previously seen, but it did not raise any undue concern in his mind. The traveling screens were left in the "as-found" condition which was, all running in "manual slow speed."

The PM work on the "B" CW Pump Motor was completed successfully at about 1500 hours. However, the electricians had noticed that there was a bushing on a potentiometer that might be a potential problem. The supervisor was contacted, and it was agreed that the pump would be left "tagged out" until the following day. They would then pull a spare from the warehouse to compare with the installed problem part. The "A" and "C" CW Pumps were not affected by the PM on "B," and thus were running the entire time. They were also running when the electricians left the CWSH that afternoon.

January 30, 1996:

At 0000 hours the plant status was as follows: MODE 1, Power level 98.3% with Reactor Coolant System (RCS) Average Temperature at 584.6°F and RCS Pressure at 2235 psig. The lake elevation was at 1086' (Technical Specification (T/S) Limit for UHS is 1070'). The lake temperature was between 32.2°F and 32.8°F (CW inlet temperature). The air temperature was 8°F with wind speeds of 16 MPH. The "B" Component Cooling Water (CCW) pump was carrying all the CCW loads. The "A" and "C" SW pumps were supplying SW, and, as noted above, the "A" and "C" CW pumps were running with the "B" pump tagged out. The CWSH traveling screens were in the manual mode on slow (per Procedure STN GP-001).

Icing Event Description:

At 0149 hours on January 30, 1996, the following sequence of events began. The control room receives CWSH trouble alarms. At 0154 hours the site watch reports high differential pressure (ΔP) in bay #3. A couple of minutes later (0158 hours) Annunciator (ANN) 5A, CWSH alarms. The Shift Supervisor (SS) instructs the operator to immediately start "A" & "B" ESW, at 0159 hours, based on a drop in SW pressure and an increase in load temperatures.

The operator is directed to do this without the System Procedure (SYS) due to the need for urgency. Thus, the following actions were accomplished without the use of the procedure. The "B" ESW Pump is started at 0159 hours, followed by the "A" ESW Pump at 0211 hours. At approximately the same time (0200 hours) the site watch reports traveling screens in "A" and "C" CWSH bays are frozen. Operators open ESW return to SW isolation valves EF HV-39, -40, -41 and -42. They close ESW to UHS isolation valves EF HV-37 and -38, aware that the valves will still be 90% and 67% open, respectively, by design.

The site watch notes that the traveling screens in CWSH "B" bay are clear of ice, but the pump is "tagged out" and not running at 0223 hours. He places the traveling screens in "manual fast" to prevent freezing, and, at the direction of the Control Room, clears the "tag out". The "B" CW Pump and the Low Flow SW Pump are started and the "A" CW Pump and the "A" SW Pump are secured due to low bay level. Two minutes later, 0225 hours, the site watch reports bay "B" traveling screens are frozen and level in bay "B" and "C" are decreasing. The CW valves are throttled to stop level decrease.

The SS contacts the Manager Operations at 0212 hours, to apprise him of the situation and to request additional support. In addition, support is requested from Mechanical Maintenance (MMA) at 0200 hours, plant support at 0238 hours, Electrical Maintenance at 0312 hours and Reactor Engineering at 0326 hours.

The Operators start the standby condenser vacuum pumps at 0252 hours in response to decreasing condenser vacuum. With the decrease in condenser vacuum and the continued degradation of the CWSH conditions, the decision is made to begin decreasing

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turbine load at 1/2% per minute (0255 hours) by manually inserting rods and borating.

With CW bay levels still decreasing, the SS and the Supervising Operator (SO) discuss a plan of action for tripping the plant (0334 hours). At 0335 hours the SW Pressure Low Alarm comes in and the site watch reports auto start of the electric fire pump. Also, the low flow SW pump is making a lot of noise.

System Operations is contacted, the plant announcement is made and the reactor is manually tripped at 0337 hours. The Operators enter Emergency Operating Procedure (EMG) E-0, "Response To Reactor Trip Or Safety Injection," and begin monitoring the Critical Safety Function trees, break condenser vacuum and remove CW from service. The following control rods failed to fully insert: H2 (12 steps), F6 (18 steps), K6 (6 steps), K10 (6 steps), and H8 (12 steps).

The Auxiliary Feedwater started on Lo Lo Steam Generator (S/G) Level and the Operators manually initiate the Main Steam Isolation Signal at 0338 hours.

At 0341 hours the Control Room transitions from the EMG E-0 and then entered EMG ES-02, "Reactor Trip Response." In the process of the transition it was discovered that the Control Room did not have a copy of EMG ES-02 on hand. Fourteen minutes later, (0355 hours) the Operators begin emergency boration, using ES-02 and Off Normal Procedure (OFN) BG-009, "Emergency Boration."

AT 0430 hours the Control Room Operators begin Attachment "A" of General Operating Procedure (GEN) 00-005, "Minimum Load To Hot Standby," in accordance with EMG ES-02. AT 0432 hours the SS makes the event notification to the Nuclear Regulatory Commission (NRC) per 10CFR50.72, Reactor Protection System (RPS) actuation. At 0439 hours operators halt emergency boration, all rods having settled on the bottom of the reactor without operator action. Emergency boration is halted with concurrence of the Reactor Engineer, but without completion of a shutdown margin calculation (Surveillance Procedure (STS) RE-004, "Shutdown Margin Determination") as required by OFN BG-009.

At 0503 hours Security reports that the TDAFWP is spraying water on the wall. The turbine building watch confirms that the TDAFWP is leaking about 20-25 gpm from the shaft gland packing. At 0505 hours, MMA is notified. Operations personnel use the Motor Driven Auxiliary Feedwater Pump (MDAFP) to control S/G levels. The TDAFWP is secured and declared inoperable at 0514 hours. The plant enters T/S 3.7.1.2, and is in a 72 hour Limiting Condition for Operations (LCO).

The SS instructs Chemistry to obtain a sample to determine the Dose Equivalent Iodine (DEI) so the Emergency Action Levels (EALs) can be reviewed. At 0528 hours Chemistry reports DEI at 2.16μC/gm. This is high enough to enter T/S 3.4.8, but not high enough to require notifications.

The Operations shift change occurs at 0700 hours. The oncoming Reactor Operator (RO) recognizes that the ESW valve lineup is improper, but takes no immediate action to correct the condition.

At 0747 hours operators secure the "A" ESW Pump [place the pump in "Pull-To-Lock" (PTL)] due to low discharge pressure and high strainer ΔP. Operations enters OFN-33, "ESW Malfunctions," and the plant enters T/S 3.7.1.2, 3.7.4 and 3.8.1.1. This puts the plant in a 6 hour LCO. The SO continues working GEN 00-005, Attachment "A," before beginning GEN 00-006, "Hot Standby To Cold Shutdown." The TDAFWP is tripped locally at 0750 hours and AL HV-36 is closed to reduce condensate loss from the TDAFWP inboard packing seal. About fifteen minutes later the SO directs the ESW line-up to be corrected using SYS EA-120, "Service Water System Startup." Operators also start SGK04B and secure SGK04A to provide more heat to the "B" Train ESW.

<u>Notification Of Unusual Event (NUE):</u>

At 0845 hours the Emergency Plan pagers are activated, but the recording on the Automatic Dialog System (ADS) states that there is no emergency. A minute later, and after consultation with the Shift Engineer, the Manager Operations, the Vice President Plant Operations, and the Manager Emergency Planning on the EALs, the SS declares a NUE due to "A" ESW and TDAFWP being out of service. This is done in accordance with the Emergency Action Level (EAL) Administrative Tree 1, 2.

A report comes in that the "D" S/G Safety valve ABV045 is lifting at 0900 hours. The current S/G pressure is 1100 psig and the Safety valve setpoint is 1185 psi. Operations declares ABV045 inoperable and enters T/S 3.7.1.1.

Electrical Maintenance sets up temporary heaters for both "A" and "B" ESW fore bays at 0925 hours. At 1013 hours Operations authorizes Emergency Temporary Modification (TMO) 96-005-NG and TMO 96-004-NG to install heaters from spare breakers in NG056 and NG06E. System Engineering determines this does not render either train inoperable, and this is verified by the Call Superintendent per Step 6.8 of Administrative Procedure (AP) 211-001, "Temporary Modifications."

At 1107 hours operators commence cooling down the RCS to 350°F per GEN 00-006 (T/S 3.7.1.2). At this point the plant was a little over three (3) hours into the six (6) hour LCO. This delay is due to the SO having difficulty completing Attachment "A" of GEN 00-005.

The site watch reports that the CW Warming Line Valve 1CW002 is open. Operators close the valve at 1211 hours. They also close NG06E HF1 to supply temporary heaters at ESW. About ten (10) minutes later, in response to reports that five (5) traveling screen panels have buckled on the "A" CW screen, the Low Flow and "A" SW pumps, and the "A" CW pump, are put in PTL. Operators close breaker NG05E GF2 to supply temporary heaters.

The SS logs that operations has failed to reach MODE 4, RCS less than 350°F, as required by T/S 3.7.1.2. Operations continues the cooldown, while the SS prepares an RER and PIR at 1347 hours.

Operations commences boration of the RCS at 1433 hours. The RCS will be borated to 900 parts per million (PPM) to facilitate Rod Drop Testing, if needed.

The SS notifies the Call Superintendent, at 1521 hours, of having missed the 6-hour limit to be in Hot Shutdown (MODE 4). Ten minutes later (1531 hours) WCGS enters MODE 4. The "A" ESW Pump is started and placed in service per SYS EF-200, "Operation Of The ESW System," at 1543 hours.

The operators secure "A" Reactor Coolant Pump (RCP) to allow oil addition at 1645 hours. The "A" Train containment coolers are filled, vented and placed in service with the ESW flow through them at 1704 hours.

By 1710 hours the System Engineers have established that ABV 045 was not leaking. The evidence of steam was due to entrainment of steam from the S/G Atmospheric Relief Valves (ARV's). The S/G Safety Valve is determined to be operable per System Engineering recommendations and Operations exits T/S 3.7.1.1

NUE Terminated:

At 1745 hours the NRC requests continuous Emergency Notification System (ENS) communications be maintained through the night. Per discussions with the Manager Operations, the Vice President Plant Operations and the System Engineer, the ESW "A" Train can be considered fully operable for the following reasons: 1) The system is filled and vented and running properly; 2) Supplemental heating is available and functioning (one diesel fired heater per train, ducted and tented to the back of the ESW and two electric heaters per train in the pump room ducted to the fore bays); and, 3) Continuous Fire Watches stationed to observe fore bay levels, watch for icing and to monitor diesel fired heaters. Per an engineering evaluation, as long as the ESW strainer ΔP's are within allowable values (i.e., not alarming) the ESW system is operable. The contingencies taken above are to ensure ESW ΔP's remain in the normal range. Currently ESW "A" and "B" Trains are fully Operable. The PSRC reviewed and concurred, prior to implementation, with the above discussed actions and decisions. Continuous ENS communications were maintained throughout the night per NRC request. Based on this reasoning, the NUE is terminated at 1758 hours.

Shift Turnover occurred at 1900 hours with the plant in MODE 4; "A" and "B" ESW Pumps running, "A" and "B" MDAFP are running, "B" RHR Pump is in service, "A" RCP is Out Of Service, "B", "C", & "D" RCPs are running.

At 1923 hours the Operators secure "A" ESW Pump due to fluctuating discharge pressure and flow. The Plant enters T/S 3.7.1.2, 3.7.4 and

3.8.1.1; which require the plant to be in Cold Shutdown (<200°F within 30 hours). Ten minutes later the site watch reports that the level of the "A" ESW After Bay is 10' lower than normal. At 1931 hours the NRC Resident and the ENS are notified that the "A" ESW has been secured. The SS and the Shift Engineer (SE) review the EAL's. No EAL is made at this time (1936 hours) since the "B" ESW is still operating properly, and with the plant in MODE 4 no Auxiliary Feedwater (AFW) is required.

At 2002 hours the Site Watch notifies the SS that the level in the "B" ESW fore bay is slowly decreasing. The SS, the SE and the Manager Operations discuss the potential for the loss of the "B" ESW. If "B" ESW is lost both Emergency Diesel Generators (EDG) will be inoperable which will require a NUE declaration. The SS directs the SO to commence the cooldown using the "B" RHR system at 2012 hours, and to cooldown to 200°F at 2019 hours. By 2021 hours the "B" ESW fore bay Level is recovering. The thought is that the recovery may be due to hotter water returning through the warming line. The fore bay level is at 1077.'

At 2024 hours the Call Superintendent directs the SS to cool the plant down to 190°F.

The operators place the "A" EDG master transfer switch in "Local" as the "A" EDG is inoperable at 2041 hours. The Site Watch reports to the SS that the "A" ESW fore bay level is normal, and that he will be rolling the traveling screens in slow speed. About fifteen (15) minutes later, 2058 hours, with the "A" ESW traveling screens rotating freely in slow speed, the site watch reports that the "B" ESW fore bay level is fluctuating below normal level, but still greater than T/S Level. This leads to a discussion between the SS, the SE and the Call Superintendent (at 2100 hours), that if the "B" fore bay level decreases below 1070', or if the pump cannot be run, the proper EAL will be a Site Area Emergency (SAE) from Block 7 of the Safety System Functions Chart. At 2128 hours the site watch reports that both "A" and "B" ESW fore bay levels are equal with Lake Level.

At 2141 hours operators isolate ESW flow to the "A" containment coolers to allow venting of the "A" Train ESW. In the meantime the Superintendent of MMA updates the SS on status of maintenance on

"C"/"D" CWSH traveling screens. Once all of the "A" Train ESW high points, with the exception of containment, are vented, the "A" ESW pump is started at 2214 hours. Fourteen (14) minutes later, at 2227 hours, operators secure the "A" ESW pump due to fluctuating discharge and pressure. The discharge pressure went to 0 psig and the flow decreased. The site watch says the level is about 12' below where it was when the pump was started.

At 2325 hours the clearance order on the "A" RCP is restored.

<u>January 31, 1996:</u>

The operators start the "A" RCP at 0047 hours. At the same time, the Call Superintendent is directed to leave the control room to man the Technical Support Center (TSC). The Outage Shift Manager notifies the Engineering team to move to the TSC, along with the Outage Control Center (OCC) at 0103 hours. A manual callout of ERO Team "A" personnel is initiated at 0208 hours.

The SS authorizes Clearance Order 96-175-EF to allow diver inspection of the "A" ESW fore bay at 0238 hours. At 0357 hours MMA reports, via the TSC, that "C" and "D" CWSH traveling screens are working properly and rotating in slow speed. About a hour later (0454 hours) the "D" CWSH traveling screens are turned off. The "A" ESW Train is filled and vented outside containment and containment coolers "A" and "C" are isolated.

<u>Second NUE:</u>

At 1000 hours the SS declares a NUE using Administrative Tree 1.2. This was due to the excessive ice build-up in the "A" ESW fore bay. Thirty-five minutes later, 1035 hours, follow-up notifications to the county and state are initiated. These are done at approximately 30 minute intervals.

The diver exits the ESW fore bay around 1255 hours. At 1435 hours MMA initiates sparging air to "A" ESW return line using a temporary air compressor. The air is introduced into a vent line on the chemical injection line. A little more than an hour later, 1548 hours, the divers re-enter the "A" ESW fore bay. At 1610 hours the TSC informs the control room that the effect of the air sparge has moved the ice block 2'

back from the trash racks. The plan is to do the following things: 1) Disconnect the air sparge to connect a flange to the ESW chemical injection spool piece to inject heated water from a portable tanker (truck) heater; 2) Then reconnect the air sparge to the ESW vent line and force heated water and air into the ESW warming line. Once this is accomplished TMO 96-006 will be implemented which will direct SW return to the UHS via the "A" ESW warming line.

Thirty minutes later the decision is made to not implement TMO 96-006. This decision is made because of the flange configuration. Since there is no isolation valve on the truck or the flange, the modification would require the warming lines to be closed to change trucks. A telecon is held between the TSC staff and the NRC, to update the NRC on the plant status and plans of action.

At 1730 hours, the control room starts hourly logging the ESW return temperatures on a local Fluke temperature meter. Inputs for the meter are from Valves EF HV-37 and EF HV-38. (Between 1730 hours, on January 31, 1996, and 1005 hours, on February 2, 1996, the temperatures ranged between 39.9°F and 41.1°F for HV-37, and between 56.0°F and 57.2°F for HV-38.)

By 1821 hours Maintenance resumes injecting air into the ESW vent line. They will follow this with injection of hot water from the tanker heater. Thirty minutes (1932 hours) after they went into the "A" ESW fore bay, the divers are out. At 2000 hours Operators secure the hot water flush of "A" ESW to allow the truck to be refilled. The TSC notifies the SS that the ice under the water at the "A" ESW is cleared.

At 2100 hours, SW flow to "A" ESW is established in accordance with TMO 96-006. However, when the Operator attempts to close EA HV-6 electrically. It does not close the all the way. The site watch is instructed to manually shut the valve. (Action Request (AR) #12238 is initiated) The SW pressure is 104 psig. The watch at the ESW sees more turbulence in the "A" ESW fore bay. It appears that two of the warming line valves, EF-V264 and EF-V262, are leaking by. At 2113 hours, Operators close EF-V318, secure the air purge of the "A" ESW fore bay and the venting header, and disconnect the air hose.

The Outage Shift Manager informs the SS at 2123 hours, of a discussion held previously between representatives from Wolf Creek, the NRC, the State, the County and Federal Emergency Management Administration (FEMA). The decision was made that if a SAE declaration was made based on loss of functions needed to maintain Hot Shutdown (i.e., Loss of all ESW), and no release occurred, that John Redmond Reservoir (JRR) would not be evacuated. "NOTE A" on EPP 01-10.1 would be applicable in this situation only.

At 2148 hours Operations recommence hot water flush to "A" ESW fore bay. The SS directs the SO to take the plant to MODE 5 at 2205 hours. At 2248 hours, Operations makes the announcement that the plant is in MODE 5. This allows the exiting of T/S 3.7.4 on the "A" ESW pump. The control room directs the watch at ESW to open both "A" warming valves, EF-V262 and EF-V264 at 2303 hours. The watch reports to the TSC that on opening the valves he did not hear any flow. The air sparge is realigned to go through EF-V318, and the watch reports that warming line flow can be seen in the "A" fore bay.

<u>February 1, 1996:</u>

The SS approves TMO 96-008 to establish air sparging to the ESW fore bays at 0120 hours. TMO 96-007 is also approved at 0230 hours. This TMO adds a hot water connection and sparging air to the ESW warming lines. At 0243 hours Operators open EA-HV6 and start the "A" ESW pump. Both discharge pressure and flow are normal. After starting the "A" pump, operations closes out TMO 96-006. About an hour later (0351 hours) the watch reports that Maintenance has commenced putting bubbling air on the bar grill on the "B" ESW fore bay. This is slowly breaking up the ice in the "B" fore bay. There is no ice in either the fore or after bay of the "A" ESW.

At 0527 hours the "A" and "C" Containment Coolers are vented and ESW flow through them is reestablished. Maintenance commences hot water flush of the "B" ESW fore bay at 0811 hours. About an hour later, 0910 hours, the "B" ESW hot water sparging is secured for about thirty-seven minutes and then restarted at 0947 hours. At 1140 hours the hot water injection at the ESW fore bays is secured. No further hot water injection will be done for now, however the system will remain in hot standby. The air sparging to the "A" ESW warming line is also

secured at 1200 hours and EF-V318 is closed. About a half hour later EF-V262 and EV-V264 are closed to install new flanges at the "A" ESW. These valves are open again by 1340 hours.

At 1358 hours the divers enter the fore bay at the CWSH to inspect the "F" screen. They are entering the area between the screen and the trash rack. The divers are aware that a pump is running in the fore bay. Maintenance installs TMO 96-009-ZC. This puts air sparging on the lake side of each of the CW Traveling Screens.

The "B" CW pump is started at 1650 hours with the traveling screens in manual slow and the discharge valve is throttled to achieve 21.5 psig discharge pressure. At 1702 hours, the watch station at the CWSH reports that the level in the "B" fore bay initially dropped about two inches, then stabilized. The fore bay level will be continually monitored until ANN 6B, "CWSH Screen Bloc" is cleared. An AR has been submitted. The Operators open 1CW 002, CW warming line valve at 1708 hours. Forty minutes later "C" and "D" CWSH traveling screens are placed in "Auto" per an On-The-Spot-Change (OTSC) to SYS SW-121, "Circulating Water Screen Wash System."

At 2300 hours Mechanics lower the sparging header in the "A" ESW fore bay from its present position of about 15' below the water level to the bottom of the fore bay. The "A" ESW pump parameters were monitored during this evolution to verify that pump performance would be acceptable with the sparging header at any elevation in the fore bay. Ten minutes later it is returned to its original level. No changes were observed on the "A" ESW pump discharge pressure or current. The System Engineer reports that with the sparging header on the bottom of the fore bay the observed turbulence was the same as, or greater than the turbulence with the header at the (-)15 foot level. This indicates that the air supplied through the sparging header is not being ingested into the ESW pump, at 2310 hours.

The Outage Shift Manager reports that the day shift completed a temporary procedure to collect data on the ESW pump. All measured parameters were found to be acceptable. These parameters were measured to ensure "A" ESW was operated properly. STS EF-100A, "ESW System Inservice Pump A Test And ESW A

Service Water Cross Connect Valve Test," is current and will not need to be performed as a prerequisite to calling "A" ESW operable.

February 2, 1996:

The ESW sparging headers are placed on the bottom of "A" ESW fore bay at the direction of the System Engineer at 0200 hours. Operations personnel complete venting of the "A" Train ESW via selected vents (per SYS EF-203, "Fill And Vent Of A(B) Train ESW," - partial procedure performed). The OCC had requested this action be taken. The only air found was about a 1/2 second release from GK V71. This information is forwarded to the OCC.

At 0800 hours the SS, the SE, the SO, the Superintendent of Operations and the System Engineering Supervisor review the AP 28-001, "Evaluation Of Nonconforming Conditions Of Installed Plant Equipment," operability evaluation of the ESW system. The SS signs concurrence with the evaluation, but will hold on making an operability call until after the Plant Safety Review Committee (PSRC) has reviewed the evaluation.

Termination Of The Second NUE:

At 1005 hours with the review, and approval of the "A" ESW Operability evaluation per AP 28-001 by the PSRC, the SS reviews the contingencies, actions taken and the present status of the ESW fore bays and declares the "A" ESW Operable. T/S 3.7.4 and T/S 3.8.1.1 are exited and the NUE is terminated.

The ESW fore bays are free of ice and there is a tent installed over the grating of the fore bay. Two air compressors are located at the ESW with one in service supplying air sparging to the "A" ESW fore bay. The second compressor is idling in standby. If ice formation is detected in the fore bays while the pumps are secure, they will be started and maintained running until ice free conditions are restored.

At 1005 hours on February 2, 1996, the second NUE was terminated.

IV. ANALYSIS OF EVENT:

The IIT was established to perform an analysis of the icing event by initially addressing the questions posed by the Vice President Plant

Operations in letter WO 96-0024, dated February 2, 1996. This was followed up by root cause analysis of the icing event, contributing causes, and a related event concerning the failure to meet a T/S Action Statement cooldown time. In addition, questions posed by the NRC Augmented Inspection Team (AIT) were also addressed. Questions posed by the NRC in regard to how close the operability margin associated with "B" ESW Pump was during the event and the adequacy of the first operability determination of ESW Pump "A" will be addressed at the end of this section.

This Section will summarize the questions addressed as well as discuss the evaluations and their conclusions. Corrective Actions will be summarized in the Recommended Corrective Action Section and the Recommended Enhancement Section.

QUESTIONS/ANSWERS:

How will ESW operability be assured under the icing conditions experienced during this event? What are the proposed temporary modifications, administrative controls, and compensatory measures that will be used to anticipate and mitigate the ESW intake icing conditions?

A comprehensive and critical review was performed of the Engineering Evaluation performed for Work Package (WP) 109199 Task 1 dated February 2, 1996, to mitigate the ESW intake icing conditions. The Engineering Team found the Evaluation to be thorough, conservative and reflected good Engineering judgment. However, it was evident from the review that those involved with the Evaluation did not fully understand the mechanisms that initiate frazil ice formation and the root cause for it. **PIR 96-0367** was initiated to document the IIT review of the Operability Evaluation. With the knowledge gained from conducting this investigation, the IIT Engineering Team has recommended enhancements to System Engineering for incorporation into the WP 109199 Task 1 to ensure frazil ice blockage of the ESW intake trash racks does not occur. Incorporation of these enhancements gives additional assurance for frazil ice mitigation into the ESW Pumphouse:

1. Verify proper valve and system lineup to maximize warming flow to the ESW fore bays whenever ESW pumps are running.

2. Install temporary heating equipment to the ESW screen bay area to reduce the likelihood of ice formation to the traveling screens.

3. Provide a means to clean the front of the ESW trash racks. This can be accomplished by installing temporary air sparging in each fore bay to "broom" the front of the trash rack and/or by use of a trash rack rake.

4. To provide early detection of active frazil ice formation while the ESW pumps are running, immerse a metal chain several feet into the trash rack fore bay water and monitor for ice accumulation.

5. Install tents over the grating of the fore bay to provide wind protection to personnel assigned to monitor ESW fore bay conditions and to prevent surface ice formation. This is to assist in detection and cleaning of the trash racks should frazil ice begin to form.

6. Station a dedicated cognizant individual at the ESW pumphouse while the ESW pumps are operating. This individual will: 1) Monitor the sparging air compressors, 2) Monitor the tents, and 3) Watch for formation of ice on the traveling screens, screen wash discharge, and trash racks. Notification of the Control Room should occur immediately upon compressor failure, tent degradation or detection of ice formation.

7. Install high intensity lights for observing and cleaning of trash racks and traveling screens.

Actions 1 through 7 above will be performed on both ESW trains when:

1) Actual lake temperature is 33°F and decreasing, as measured at the intake of the ESW Pumphouse.

2) An ice cover does not exist from the ESW UHS to the Owner Controlled Area Boundary.

NOTE: In evaluating whether a substantial ice cover does exist, a small amount of open water adjacent to the pumphouse structure is not of concern.

What is the justification for using these temporary modifications to provide for system operability?

The justification for the use of temporary modifications is based upon the design deficiency to provide adequate warming line heat as determined through the root cause investigation. Use of the above temporary measures adequately compensates for the inability of the design to mitigate the affects of frazil ice by providing:

1. Indication of the changing environmental conditions necessary to take actions
2. Early detection of any frazil ice ingress
3. A means to remove the frazil ice should it begin to accumulate on the trash racks.
4. Protection for personnel performing work and surveillance activities during frazil ice conditions.

Performance of these measures within the WCNOC procedural control program and from the experience gained from the icing event provides assurance that these temporary measures are adequate compensation until the design deficiency can be corrected.

Is the installed warm-up line adequate to mitigate the icing conditions experienced? If so, why didn't it prevent the icing condition from occurring?

The ESW warming line is inadequate to mitigate the icing conditions as experienced. The system hydraulics will not provide 4000 gpm at 35°F minimum as originally designed. **PIR 96-0263** was initiated to document the "A" ESW pump

becoming inoperable due to low water level in the fore bay due to icing.

A design calculation performed in 1976 specified a warming line flow rate of 4000 gpm for the prevention of frazil ice. This was determined using valid, conservative methods, but assumed that the temperature of the warming line flow would be at least 3°F above freezing. During the time that the icing occurred the estimated actual warming line temperature rise from Train "A" was on the order of 1°F. This situation is due to the only substantial heat load on Train "A" being the "A" Train Containment Coolers. CCW Heat Exchangers are the only other significant heat load to ESW in addition to the Containment Coolers. During the event the CCW Heat Exchanger "B" was valved in to reject heat to "B" Train ESW in addition to the "B" Train Containment Coolers. Although, a greater amount of heat input was being delivered to the "B" Train ESW, than "A" Train ESW, neither train was delivering the amount of heat specified by the original design to the ESW Pumphouse warming lines. **PIR 96-0316** was initiated to document the design deficiency and to develop corrective actions.

Using present day United States Army Corps of Engineers minimum recommendations, the flow required to prevent frazil ice for a warming line flow temperature of 1°F above freezing would be 2,700 gpm. Using this methodology the 4000 gpm design flow rate might have been adequate even with the lower than assumed warming temperature.

The UHS and warming lines are open ended piping runs to the UHS and ESW Pumphouse respectively. The piping diameters and elevations are such that portions of these lines operate with partial pipe flows due to the low driving head and with the dry portions not vented. This condition was apparently not foreseen by the piping designer, and makes the calculation methodology used for sizing the warming line inadequate and resulted in a much lower than required flowrate. **PIR 96-0334** was initiated to document the lower than required flowrate and

to develop corrective actions. The warming line flow rate during an accident line-up for the piping as-built configuration cannot be readily calculated or measured with a high degree of certainty, but is estimated to be about 2500 gpm.

The "B" Train ESW warming line was operating with a known nonconformance. Valve EFV-0263 is one of two manual butterfly valves in series located in the "B" ESW warming discharge line at the ESW Pumphouse. From previous work history, EFV-0263 was mechanically frozen in the 50% open position. Engineering had been quoted in company correspondence that this nonconformance was acceptable for system operation as the partial open position did not affect flow appreciably. However, no formal disposition by Engineering of this nonconformance could be found. Furthermore, had the "B" ESW been operating as the original design intended, the pressure drop across this partially open valve could have impeded flow by approximately 600 gpm. **PIR 96-0430** was initiated to document the nonconformance and provide corrective actions. The IIT Engineering team concluded from the hydraulic analyses and partial pipe fill conditions that the partially open butterfly valve EFV-0263 actually had negligible affect to further reduce the flow. However, **PIR 96-0438** was initiated to ensure that the outstanding repair activities for the four warming line valves, EFV-0262, 0263, 0264 and 0265 be completed in order to accommodate the corrective actions being developed to alter the ESW System hydraulic characteristics for satisfactory warm as well as cold weather operation.

During the approximately six hour period preceding the first time "A" ESW pump had to be secured due to the ice blockage, ESW return to SW return cross tie isolation valves were open and the ESW return to the UHS valve was throttled. This caused some of the ESW return flow to be diverted from UHS through the normal SW discharge line. It is estimated that this caused warming line flow to be reduced to about two thirds of what it would have been, or about 1700 gpm. This flow

diversion merely hastened the icing event on "A" ESW trash rack and did not change the eventual outcome.

Is there a need for any additional operator training or any changes to operating procedures?

The following recommendations are made based on needs identified during interviews, investigation, and root cause analysis.

a) Simulator Training on MODE 3 to 4 cooldown in 6 hours. **PIR 96-0370**

b) General Operating Procedures (GEN) 00-005 and 00-006 needs clarification for "rapid cooldown." **PIR 96-0369**

c) Recommendation to include Reactor Engineers in selected simulator scenario's. **PIR 96-0416**

d) include frazil ice formation in applicable training material. **PIR 96-0415**

e) Review clarity of management's expectations for communications when crew composition changes. **PIR 96-0371**

f) Contingency Plans should be incorporated into the winterization procedure. **PIR 96-0376** and **PIR 96-0398**

g) The Alarm Response Procedure (ALR's) should be reviewed with emphasis on actions required where expeditious actions may be required. In these cases specific steps could be added to minimize the references to separate procedures. **PIR 96-0375**

h) Review guidelines for Axial Flux Control. **PIR 96-0362**

i) Review clarity of management expectations for verification after performing urgent system line-ups. **PIR 96-0373**

j) Review clarity of management expectations for procedure adherence when completing GENS for rapid cooldown. **PIR 96-0372**

k) Enhance Control Room crew communications. **PIR 96-0374**

l) Review the adequacy of the Shutdown Margin (SDM) computer program. **PIR 96-0406**

m) Evaluate Auxiliary Boiler Trips for reliability of boiler. **PIR 96-0417**

n) Delete Technical Specification Clarification 88-003 which promulgated incorrect frazil ice formation. **PIR 96-0366**

o) Procedure SYS SW-121 needs revision to delete requirement to operate the traveling screens in slow for cold weather operations. **PIR 96-0376 and 96-0482**

p) STN GP-001 needs revision to require controlotron setup and zero adjustment prior to opening the CW warming line valve each winter season. **PIR 96-0316, and 96-0482**

q) SYS SW-121 needs revision to provide guidance on the use of air bubblers to assist in breaking up surface ice around the CW traveling screens. **PIR 0398, 96-0316, and 96-0482**

r) ALR 00-006C needs revision to eliminate requirement to place traveling screens in fast if icing conditions are encountered. **PIR 96-0399**

s) EPP 01-4.1 needs revision to ensure that minimum staffing requirements for the TSC/OSC activation are clear, concise and consistent with the Radiological Emergency Response Plan (RERP). **PIR 96-0428**

Is Wolf Creek's Cold Weather Protection Plan adequate?

To answer this question two approaches were pursued.

First, operations personnel were interviewed to determine if they felt that the program was adequate and to determine the reasoning behind their answer. The responses received provided their reasoning for believing the program was adequate. In addition to the preparatory actions taken at the beginning of the cold weather season, frequent reminders were provided at shift briefings when the weather was anticipated to

be severe. These were usually directed at areas of known or expected vulnerability; areas with vent ducts and uninsulated piping, specific areas with a history of freezing problems, etc. This was being done during shift briefings at this time because of the low temperatures being experienced. When questioned about possible concerns with the CW and ESW System, the answer was always in the negative. Despite equally cold conditions having occurred in the past, no problems of this kind had ever occurred previously. In addition, it was documented that questions had been previously directed to engineering concerning potential problems with "frazil icing". Per a 1990 Engineering Letter, NP 90-2162, to Operations, frazil ice was not a concern since the ESW pumphouse is heated and the traveling screens are enclosed by the building structure. **PIR 96-0366** was initiated to address the error in judgment regarding frazil ice potential and to develop corrective actions. Furthermore, **PIR 96-0377** was initiated to find and remove documentation referring to frazil ice as not being a credible event.

The second approach was to review STN GP-001 including the history of revisions. A review was also done of SYS EA-120, which is used for the winterization alignment of the ESW system.

ESW and CW winter alignments were added to STN GP-001 in Revision 3 released in 1990. No changes were found in the section dealing with the winterization of the Circulating Water Screenhouse (CWSH) from the time it was included (Rev. 3), until the revision in use at the time of the icing event. Changes were found in the section dealing with the winterization of the ESW pumphouse. Most of the changes made in this section during the life of the procedure did not affect the basic warming valve line-ups. However, for several years the procedure carried a "Note" dealing with the throttling of certain valves in the ESW (EF) system to maintain system ΔP and temperature across the CCW heat exchanger. The 'Note' was eventually deleted when the requirement to throttle for system ΔP was removed. These changes were also reflected in SYS EA-120. These basic activities of the procedure for winterization of the CWSH and

ESW pumphouse appear to have been adequate within the constants of the postulated winter conditions and the assumed system performance with respect to the design basis heat transfer and flow conditions. These conclusions were also verified with a review of the winterization portions of SYS EA-120.

In addition to this review of the procedures and interviews with operations personnel, the team reviewed Quality Evaluation (QE) Surveillance Reports K15-003 S-3056 and K15-003 S-3130. These surveillances covered the implementation of the Plant Winterization program for the winter of 1994 and 1995. While there was no specific mention of the CWSH or the ESW pump houses, the overall conclusion of the reports was that the actions taken, as part of STN GP-001, were satisfactory and adequate.

It should also be noted that no other equipment covered by STN GP-001 encountered freezing problems during the period surrounding this event. Thus, our conclusion is that the conditions that occurred within the CWSH, and the ESW pumphouse, were not due to inadequacies in STN GP-001, but attributable to other considerations.

Was there equipment, either individually or in combination, that was degraded or out of service that had an impact on the event or could have provided better mitigation?

A review of the Equipment Out of Service log, plant logs, and Operator interviews were utilized.

The "B" CW Pump (preventive maintenance)and the "B" SW Pump (seized bearing) were both out of service. As the traveling screens were freezing this limited the crews ability to shift pumps away from the most problematic bay. Even though the crew was switching pumps, with all three Circulating/SW Pumps available, the crew could have rotated pumps more effectively in conjunction with shutting down the plant. It took 34 minutes to get the "Danger-Do-Not-Operate" Tags removed from the "B" CW Pump. The crew noted decreasing condenser vacuum and increasing return temperatures on the Main Lube

Oil Systems. The Low Flow SW Pump was reported to be making cavitation sounds, and the Electric Fire Pump started on low pressure. The potential loss of these systems caused great concern for the ability of the unit to remain on the line. Significant equipment damage in the Turbine building was a certainty if SW was lost for a prolonged period. These facts led to the crew decision to trip the unit at 0337 hours on January 30, 1996. Even though a plant trip was inevitable, the status of the CW and SW system impacted the mitigation strategies.

The most significant post trip problem was the combination of the TDAFWP and the loss of the "A" ESW pump. These events, coupled with the very real possibility of losing the "B" ESW would result in lose of primary safety related cooling systems. In that condition, secondary means of cooling remain available.

Is the design of the Circulating and Service Water Systems, and their auxiliary equipment adequate for the climatic conditions?

No. The IIT has determined that CW Traveling Screens are not adequately protected from the environmental conditions. **PIR 96-0265** was initiated to address ice buildup on the CW Traveling Screens.

The CWSH is provided with a 42" Warming Line supplied from the CW Discharge Header and routed to the area just in front of the structure's trash racks. The line delivers 34,000 gpm of water heated 30°F above lake temperature, during 3 CW Pump operation, and 30,000 gpm of water heated to 40°F above lake temperature, for two pumps. Therefore, even though the flow is less, more heat is actually transferred to the Circulating Intake Bay during 2 pump operation than in 3. The head pressure which drives the warming line flow is a factor of Circulating Discharge Weir water level. This level varies by less than 3' between 2 and 3 pump operation. Thus the change in warming line flow between 2 and 3 pumps is relatively minor. Since throttling of the CW Pump discharge valves to prevent pump runout does not reduce the weir level by any significant amount, this practice actually helps increase the heat input to the bay by increasing the condenser outlet temperature even

more. Simple heat balance calculations show that there is sufficient warming line heat input to prevent frazil ice during either mode of CW Pump operation with the plant on-line. These calculations were verified by measuring the warming line flow rate during two pump operation using an ultrasonic flow meter. The lack of any substantial build-up of ice on the trash racks also indicates that the Warming Line's design is adequate.

Traveling Screen Operation:

The CW Traveling Screens are a series of stainless steel wire mesh basket assemblies with 3/8" openings. The traveling screens are chain driven by a two speed motor (1800/450 RPM). In the Manual slow mode of operation, one complete basket cycle takes 36 minutes. Fast speed can complete the cycle in 9 minutes. While operating in Manual slow, as procedurally required, the traveling screens are exposed to the environment for approximately 7 minutes during the 36 minute cycle. While exposed the traveling screens are backwashed by sprays supplied by SW at near lake temperature. This spray, when exposed to the environmental conditions present on January 30, 1996, caused an initial ice build-up on the steel mesh. As the traveling screens continued through their cycle they were exposed to the water coming into the CW Bay. This incoming water was believed to be warmed sufficiently to prevent ice buildup on the trash racks in front of the traveling screens, yet near enough to freezing that the initial ice build-up caused a rapid growth of ice to block the traveling screens completely. **PIR 96-0376** documents the "Manual slow" mode of Traveling Screen operation as a causal factor to the ice blockage of the CW Traveling Screens. **PIRs 96-0399** and **96-0482** also address additional procedural controls in regard to the CW Traveling Screens.

Is the design of the Ultimate Heat Sink, (UHS), adequate for the climatic conditions? Was the potential for this situation to occur recognized in the plant design basis? Why is there a level indication installed in the "B" ESW fore bay and not the "A" fore bay?

The design was found to be deficient in providing adequate warming line heat to the ESW Pumphouse intake to prevent frazil ice blockage. The design of the UHS by itself was not found by the IIT Engineering Team to be a contributor to the deficiency other than the source of the frazil ice. During the original design, the potential for frazil ice was recognized, but was thought to be addressed adequately by the design of the ESW warming line and the spacing of the trash rack bars.

Spacing of the trash rack bars influences the ability of frazil ice to "bridge" and thus block flow through the trash rack. Reference literature included in the design calculations at the time of the ESW Pumphouse and warming line design development recommended four inches between trash rack bars to prevent frazil ice "bridging". The design chosen was to use three inches center to center of bars based on the potential of foreign material ingress into the ESW Pump suction. Therefore, the three inch center to center bar spacing criteria chosen was non-conservative in regard to frazil ice blockage.

More recent evaluation on frazil ice formation has found that the size of the spacing actually will not prevent bridging (4" versus 3") but will significantly delay the formation of a bridge. Although the 3" versus 4" was non-conservative at the time with the knowledge available, it is not significant to the recommended corrective actions to preclude recurrence of this event at WCGS.

The design basis of the water level indicator in the "B" ESW Fore bay is to monitor the UHS level. The ESW Pumphouse structure provides a convenient location to mount and maintain the sensor. It was not designed with the intent to monitor ESW Pump suction water level. **PIR 96-0329** was initiated to address the current provision of ESW Fore bay water level indication.

The instrument operates by sending out a series of ultrasonic pulses, transmitted and received. When the pulses "bounce" (reflect) off of the water surface, the instrument calculates a level by comparing the difference in the transmitted time versus the received time. If the return signal is interfered with, the

proper time and pattern will not be achieved and a false indication will result. Per the vendor, Sensall Instruments, Inc., surface turbulence or something in the water at the water surface, such as frazil ice, may cause this type of erratic response.

Data was gathered and analyzed for approximately 1 year on the operation of both "A" and "B" pumps. Normal operation of the UHS level indicator was observed.

Accounts of eyewitnesses at the ESW Pumphouse during the event, were that the fore bay level varied approximately 8' to 10.' It is believed that the trend of level indicated by the level instrument follows the pattern of actual level. The minimum and maximum spikes observed appear to be from turbulent water, including frazil ice mixtures, in the fore bay. However, the periods of instability for the level instrument coincide with the securing of "A" ESW Pump.

AR 12261 was initiated to investigate the operation of the instrument. As stated in the Technical Manual, turbulence affects the operation of the instrument as well as electrical interference. Results of the AR revealed that the electronics of the instrument operated within specification. However, turbulence at the water surface incurred by the "B" ESW Pump operating caused water level fluctuations of several inches, and prevented instrument indications to come within tolerance. Thus, it is concluded that the trend was indicative of the fore bay level fluctuation, and that the high and low spikes observed were caused by the signal being reflected in an uneven pattern.

Recommendations for ESW Fore bay level indication is addressed in **PIR 96-0316**.

Were surveillances and/or preventive maintenance procedures adequate and up to date?

A determination was made early in the review that Preventive Maintenance (PM) activities had been conducted in the CWSH on January 29, 1996, the day prior to the event. WP 107621 covered MPM SW-001, PM of the "B" CWSH Traveling Screens. An interview was conducted with the lead mechanic. He stated that while they did notice a small amount of ice on the traveling screens, and some on the backsplash of the screen cover, this was not unexpected considering the temperature and had been seen previously. Only one of the traveling screens was stopped for some minor adjustments. Though not part of the procedure, the traveling screens are taken to fast speed to expedite inspection. Each screen was done in turn and then returned to slow speed. This information was provided to the engineering team to evaluate the potential impact on ice formation on the traveling screens. The mechanic remarked that the only thing of notice to him was how close the lake ice was to the fore bay. He also remarked that he had thought about it a lot since the event, trying to think if there was anything that would have indicated a potential problem. However, he could not recall anything. They completed the PM sometime between 1400 hours and 1500 hours.

This practice for conducting PM's was evaluated by Engineering for the potential of icing to have initiated upon the traveling screens. It was determined that it did not. Due to the short duration of the speed change and no evidence of ΔP change across the traveling screens following the work, it was concluded that PM activity had no significance towards the event.

The other PMs being worked that day were on the "B" CW Pump Motor. One was an electrical check-out of the motor (WP107587, to perform MPM E00P-05) and the second was a sampling of the motor's oil (WP 107586, to perform MPM OS-001).

An interview was conducted with the lead electrician performing the pump motor PMs. He stated that the PMs were completed satisfactorily around 1500 hours on January 29, 1996. They had noted, however, a potential problem with a bushing on a potentiometer in the control circuit. The electrician contacted his supervisor to confirm the decision to leave the motor tagged out and do a comparison of the part with one in the warehouse the next day. The electrician was called in early the next morning to clear the tag due to the icing event.

In an interview with Maintenance Planning personnel, the PM schedule was reviewed for equipment in both the CWSH, and the ESW Pumphouse. The review showed that with the completion of the PMs noted above, all PM's were up-to date as of the date of the event. In all other respects the PM's appeared to be adequate.

A review was also done for all applicable Surveillances. Several were found for the ESW system. STS EF-001 is the ESW Valve Check surveillance. It was last completed on January 24, 1996. This surveillance manipulates valves in the system to ensure their operability. Included in these are EF HV-51, -52, -59, & -60. The procedure notes that for normal operation these valves are open, but may be throttled during cold weather, and can be opened at the operator's discretion. The other valves manipulated by this procedure that are involved in the winterization procedure are EF HV-39, -40, -41, -42. For the latest completion of this STS, EF HV-51 and -52 were listed as "Open," and EF HV-59 and -60 were listed as "Closed." This was determined to be a correct line-up for the valves. The remainder of the valves were returned to their proper 'as-found' condition.

STS EF-100A and -100B, "Inservice Pump A(B) And A(B)/Service Water Crossconnect Valve Test," were completed on October 18, 1995, and January 3, 1996, respectively. As the title implies, this test ensures operability of the ESW pumps and the associate crossconnect to the SW system.

The last Surveillance reviewed was STS EF-201A and -201B, ESW Inservice Valve Test. This ensures the operability of all the major valves in the system. Both surveillance's were last completed on December 17, 1995.

When asked why these procedures were done during the winter rather than the spring or fall, the Maintenance Planner noted that our outages come in the spring or the fall, every other year. Performing the tasks in the winter unloads the amount of work that might have to be done during an outage. This coupled with the need to fit things within the thirteen week rolling schedule are the determining factors for when the maintenance and surveillance's are performed.

In conclusion, the team found that all PM and surveillances for the equipment involved in this event were both adequate and current. Valve EF-0263 is a nonconformance, for which the decision for acceptability is being investigated in **PIR 96-0430** as opposed to a PM or surveillance problem.

What was the proximate cause to the event, and was the response appropriate?

The apparent cause to this event was the formation of ice on the CW traveling screens, and ESW trash racks. This caused CW screen trouble and CW bay emergency alarms to be received in the Control Room. Because of a decrease in SW pressure along with an increase in cooling load temperatures, Operators made the decision to start the ESW system. A continued downward trend in CW bay levels, caused Operators to secure the CW pumps, and trip the Reactor. Approximately five and one-half hours after the ESW pumps were started, ice formation on the "A" ESW fore bay trash rack reduced inlet flow to that pump, forcing Operators to secure it. This, together with the TDAFWP being out of service, placed the plant in T/S 3.7.1.2 b, which required a six hour Cooldown to <350°F. A misalignment during the initiation of the ESW system, and a failure to verify and correct this misalignment, may have contributed to the speed in which the ice reduced inlet flow to the "A" ESW fore bay.

Responses to problems in fluctuation of CW and SW bay levels included the following:

When CW screen trouble alarms were received by Operators, the Site Watch was dispatched to verify these. Shortly after receiving a report from the site watch, that traveling screens at CW were frozen, the Shift Supervisor (SS) notified the Manager Operations of the plant status. Throughout the progress of the event, timely and accurate reports were relayed to the Control Room, aiding Operators in evaluating the situation. SW pumps were started and secured as conditions warranted to maintain a continuous flow of SW to plant equipment. These actions were prudent although complicated by the "B" pump being out of service and unavailable.

As conditions deteriorated, "Do-Not-Operate" tags were removed from the "B" CW pump. The pump was subsequently placed in service with the traveling screens in fast in an attempt to prevent freezing. This was done when Operators were forced to secure the "A" pump because of ice blockage at the traveling screens, and a loss of fore bay level. The ESW system was started in response to a drop in SW pressure and an increase in load temperatures. ESW systems were started without the use of the a procedure due to the gravity of the situation.

Management expectations and standard operating practices dictate that if a continuous use procedure is not used during the manipulation of plant equipment, a verification of the manipulation will be performed in a reasonable amount of time. With the amount of activity going on in the Control Room, after this evolution took place, this verification was overlooked. Attempts to perform this verification were begun, but were never completed. This failure to verify is addressed in **PIR 96-0338**.

When the loss of CW was imminent, Operators manually tripped the plant off-line and secured all CW pumps. RCS temperatures were controlled by auxiliary feed to the S/Gs

and steam release through the atmospheric relief valves. This represented proper decision making.

Five control rods failed to completely insert after the reactor trip. Emergency boration was commenced by the RO's. The control rods subsequently dropped to the bottom, and adequate shutdown margin was confirmed by Reactor Engineering. The boration was secured prior to completing a shutdown margin calculation (STS RE-004) as required by OFN BG-009, however, the surveillance was later completed. This sequence was proper, noting the subsequent completion and verification of shutdown margin by the appropriate procedure.

A report was received by Operators at 0503 hours that the TDAFWP was spraying water across the room. Operators sent the turbine building watch to confirm this report, and requested assistance from MMA. MMA reports stated that part of the packing was blown out and the leak could not be stopped. Operators secured the pump and declared it inoperable. The pump was later secured locally to conserve condensate water. These were appropriate actions. The adequacy of maintenance performed on this pump is being pursued by another IIT.

At turnover on the morning of the January 30, 1996, the on-coming RO noticed that the line-up for the ESW system was not correct. This was communicated to the on-shift RO, but the issue was not pursued. A note was made in the on-coming RO's personal note book to discuss this with the oncoming SO after turnover, but again deteriorating plant conditions led to this being forgotten. This failure is addressed in **PIR 96-0338**.

Formation of ice on the "A" Train ESW trash racks caused fore bay levels to decrease and pump discharge pressures to drop. In order to avoid damage to the pump, Operators secured the pump and placed it in PTL. This placed the plant in T/S 3.7.1.2 b, requiring a six hour Cooldown to <350°F. An additional Licensed Operator in the Control Room, while

checking on various plant parameters, noticed that the ESW line-up was not in the correct position. This was brought to the attention of the SO, and the RO restored the line-up to the correct configuration. Operations issued **PIR 96-0281** to address this. These were prudent actions.

Additional Operators were assigned to various tasks in order to free the Control Room staff for plant stabilization. In addition, plant management assisted with some of the administrative emergency plan responsibilities assigned to the SS, to aid him in overall plant control. This was a good utilization of resources.

The plant Cooldown specified in T/S 3.7.1.2 b was not completed within the required 6 hours. Several factors that may have contributed to this include the following:

No past plant experience or training with six hour Cooldowns.

A relatively inexperienced SO, working with an SS who was not a normal member of that crew.

GEN procedures that may contain steps that are not absolutely necessary for a rapid Cooldown.

Operations expectations for procedure compliance may have contributed to sequential performance.

When it was realized that the six hour requirement would not be met, the decision was made to ensure the safety of the plant and not try to rush the Cooldown. The decision to continue in a safe manner, when it was realized that the T/S could not be met, is considered a safe and proper decision. Missing a required T/S Cooldown is not an acceptable practice, however, and is addressed in **PIR 96-0264**.

Were subsequent actions taken prudent with respect to protection of the UHS?

A common feeling among Operators was that the UHS was a tool designed to protect safety related systems at all times. This feeling was still predominant after the loss of CW. When the incorrect line-up of the ESW warming line was discovered by an extra Licensed Operator, it was promptly corrected to restore full flow. After the loss of the "A" ESW pump, initial actions included ensuring heat loads remained on the "B" Train, installation of temporary heaters in the ESW fore bays, and continuous watch on fore bay water levels. Additional actions that were taken as resources became available included the erection of tents with heaters blowing on the fore bays, injection of hot water and air to break-up and dissipate the ice at the trash racks, and adding additional heat loads to the "B" Train ESW.

Description of actions taken to protect the UHS:

The initial ESW train line-up, although not correct, was performed with the understanding that flow to the warming line would be maintained. Valves EF HV-37 and -38 when closed electrically are maintained in a throttled position. At this time the mind-set of Operators was that the UHS was designed to be the ultimate cooling source, and would not be susceptible to freezing. This is substantiated by letter OP 90-0235, stating that "Their (Engineering) position is that since traveling screens at ESW are inside and pump-house is heated that Frazil Ice is not a concern." This letter had been sent to all SS's in December of 1990.

An additional Licensed Operator in the Control room on the morning of January 30, 1996, noted that the line-up of the ESW system was not correct. This was brought to the attention of the on-shift SO and promptly corrected. However, this correction was not performed in time to provide full flow to the "A" Train ESW warming line prior to a loss of fore bay level, and the securing of the pump. Because the majority of heat loads were on the "B" Train, the correct line-up would not have prevented the restriction of flow from ice build-up, but could have delayed it.

After the loss of the "A" ESW pump, at 0747 hours on the January 30, 1996, immediate actions taken to protect the "B" pump included, ensuring heat loads remained on the "B" Train, and the installation of temporary heaters in the ESW fore bays. Heaters installed consisted of, one diesel fired heater per train tented and ducted to the fore bays, and two electric heaters per train ducted to the fore bays. This was accomplished through the approval of temporary modifications TMO 96-005-NG and TMO 96-004 NG, at 1013 hours. These heaters were operating by 1230 hours. ROs stated, during interviews, that they were concerned a majority of efforts were being concentrated on restoring the "A" pump and not on ensuring the "B" pump remained in service. When questioned about this Operations Management responded by saying that this was not the case. RO's were not informed of all activities because they wanted them to focus on stabilization and protection of the plant. The SS was kept current of all activities in progress and in the planning stage; however, feeding the RO's information, that was not really necessary, might have taken them away from their primary responsibility.

Efforts to clear the ice from the ESW fore bays, in addition to the portable heaters included, portable boilers and compressors brought in to dissipate and melt the ice from in front of the ESW fore bays. These efforts commenced at 1435 hours, on January 31, 1996. Continuous watches were placed on this equipment to ensure non-stop operation. By 2045 hours on January 31, 1996, the ice had cleared. Operability of the "A" ESW pump was declared at 1005 hours on February 2, 1996.

Included in, but not primarily related to protection of the UHS, were efforts to ensure that if the UHS were lost, plant safety would be maintained. This included repair of the TDAFWP. At 1411 hours on January 30, 1996, the TDAFWP was declared functional. An additional action taken in this area was the procurement of a make-up water system. This would ensure that an adequate water supply for plant cooling through the S/Gs was maintained.

At some time between 2002 hours and 2010 hours reports were received from the Site Watch that the "B" ESW fore bay levels were decreasing. In response to this Operators placed the "B" Train Residual Heat Removal (RHR) system in operation. This increased the amount of heat sent to the ESW warming line and the fore bay level begin to recover. This quick action definitely had a direct positive effect in preventing the loss of the "B" Train ESW pump.

Did plant equipment respond appropriately to and throughout the event, and were known exceptions adequately dealt with?

A review of the Post Trip report, plant logs, Operator interviews and NPIS revealed that equipment that failed to operate as expected were the CW system, the SW system, the Control Rods, the TDAFWP, the ESW system, and the Auxiliary Boiler.

The CW system experienced icing conditions on the traveling screens. This icing led to the eventual loss of the CW System and degraded SW System performance. The Crew attempted to alternate running CW and SW pumps while shutting down the Unit. These were prudent actions.

Five Control Rods failed to fully insert following the Manual Reactor Trip. The crew noted this immediately. Per the requirements of the emergency procedure network the crew correctly referenced the Off Normal procedures and commenced Emergency Boration.

The TDAFWP developed a leak on the inboard packing gland. The Crew removed the pump from service, tagged it out, and directed repairs. The "A" ESW pump was placed in PTL and declared inoperable at 0747 hours on the morning of January 30, 1996. Reports of low fore bay level, fluctuating discharge pressure, and strainer ΔP alarms led to this determination. This action placed the Unit in T/S 3.7.1.2, action b.

The operating crew initially determined one of the "D" Main Steam Line Safety Valves to be inoperable. This determination was made based on a report from outside the Control Room and a comparison of the operating parameters of all S/Gs.

Though initially declared inoperable, it was later determined by an Engineering Evaluation that the Safety Valve was operable throughout the event. The inoperable determination was conservative, and had no impact on the mitigation strategy.

The Auxiliary Boiler trips caused the crew to be concerned with the loss of outside tanks and other components that would be required to shutdown the plant. The boiler was tripping because the fuel oil was cold and the boiler was operating under low load. The Auxiliary Boiler has a history of trips when switching from the auxiliary to main gun. An Engineering Evaluation should be conducted to resolve reliability issues. **PIR 96-0417** was written for this condition.

Were procedures correct and were they adhered to?

To answer this question the Post Trip review was utilized. Both the Night Shift Crew and Day Shift Crew were interviewed.

Procedures were generally correct, with numerous On The Spot Changes (OTSC) required. During the course of this investigation several opportunities for procedure improvements were noted. They are addressed in the above discussed question (Is there a need for any additional operator training or any changes to operator procedures?). EMG ES-02 was not in its correct location. **PIR 96-0278**, was written to address this condition. Two instances of procedure non-compliance were identified.

Upon receipt of various CWSH alarms the crew referred to and carried out the actions of the ALR's. Included in this event sequence was placing traveling screens in fast, (ALR 00-006B, "CWSH Screen Block," and ALR 00-006C, "CWSH Fast Wash") and placing the ESW System in service (ALR 00-008B, "Service Water Pressure Hi/Lo"). The ESW system was placed into service without reference to SYS EF-200, "Operation Of The ESW System." **PIR 96-0281** was written to document this event. It is expected that in some cases, in-hand procedure use is not the most conservative action. It is also, however, clearly Management's expectation that all system manipulations be

verified by procedure in a timely manner. This action did not occur for approximately 6 hours. This was inappropriate. A root cause evaluation was conducted for this event. See **PIR 96-0338**. The evaluation identified the root cause to be a failure to verify the actions against procedural requirements in a timely manner. There are several contributing factors to this root cause that will be addressed through the PIR process. They are: **PIR 96-0373, 96-0374, 96-0375 and 96-0541. PIR 96-0362**, was generated as a result of this root cause evaluation to determine if written guidance and expectations from Reactor Engineering caused the Operators to place undue emphasis on control of Axial Flux Difference during plant maneuvers. A separate question was identified with regard to the reliability of Limitorque valves. At question was the confidence level of the RO when he went to the close position on the ESW returns to the UHS. Discussion with the MOV Engineer and review of all Limitorque failures at Wolf Creek Nuclear Operating Corporation (WCNOC) revealed that the confidence was justified. There is no Wolf Creek Generating Station (WCGS) history of Limitorque valves failing to stop at the set position due to limit switch failures.

The unit was not placed at an average RCS temperature of <350°F in the requisite 6 hours. While the decision making and control of the cooldown were prudent, events leading up to that situation warrant attention. **PIR 96-0264** was generated to document this event. A separate root cause analysis was conducted for this event and **PIR 96-0264** was amended to include the root cause evaluation. The root cause is identified as belief of the SO that GEN-005 Attachment "A" had to be complete prior to cooldown. Several actions in the controlling procedures could have been performed in parallel. Although the SS expressed his desire to commence the cooldown, thus complying with T/Ss, no method for achieving that end was presented or discussed. Other causal factors are identified in the root cause analysis and are addressed by **PIR's 96-0264, 96-0369, 96-0370, 96-0371**, & **96-0372**. WCNOC has never experienced the pace of operations required to achieve Hot

Shutdown (MODE 4) in the requisite 6 hours while operating within the procedure network designed for a normal controlled cooldown to 350°F. A review of the Outage Schedule with all equipment and personnel staged, shows a ten hour window allotted to maneuver the plant from MODE 3 to MODE 4.

Emergency Boration was terminated after all control rods were fully inserted. Procedure OFN BG-009 requires a Shutdown Margin be performed using STS RE-004 to terminate emergency boration flow. While a SDM calculation was not performed until later, the crew terminated emergency boration flow with the concurrence of the Reactor Engineer. Interviews with the crew and the Reactor Engineer were conducted. It is believed that the actions taken by the Crew were prudent and justified based on plant conditions. **PIR 96-0406** was written to address the computer problems encountered when attempting to perform SDM calculations.

Was the Emergency Response Plan Followed?

Prior to the declaration of the first NUE, the SS began calling out additional support beginning at 0200 hours on January 30, 1996. These personnel included the Manager Operations (notified at 0212 hours), Supervisor Facilities Maintenance (notified at 0238 hours), Supervisor Maintenance (notified at 0312 hours) and Supervisor Reactor Engineering (notified at 0326 hours). In turn, the Manager Operations notified the Vice President Plant Operations, Superintendent Operations, Superintendent Work Authority, and Manager Plant Support. During an interview, the SS stated that these individuals were crucial to his ability to handle the plant situation and that these particular personnel possessed the necessary expertise. Further, the assistance provided by these individuals allowed the SS to focus his full attention toward the changing plant conditions.

Two declarations of a NUE occurred. The first NUE was declared at 0846 hours on January 30, 1996, and the second NUE was declared at 1000 hours on January 31, 1996. The responsibilities identified on Form EP 01-1.0-1, "Shift Supervisor Task List" were completed as is evidenced by Control Room, Security, and

TSC/OCC logs and copies of Immediate and Follow-up Notification Forms. Control Room personnel completed notification to Security, Coffey County, and the State of Kansas within 15 minutes, as required. Plant personnel were notified through pager activation and over the plant's gaitronics public address system. However, required announcements were delayed 30-40 minutes in buildings accessed by another plant address system following the declaration of the first NUE (**PIR 96-0216** was initiated to address this issue). Building walk-through announcements were completed in buildings not serviced by any public address system. Several paged personnel expressed confusion at receiving the message "No Emergency Declared" when calling into the ADS to acknowledge having received the pager (**PIR 96-0260** was initiated to address this issue). As initial corrective action for this event, the ADS message has been changed to state that the "ADS has not been activated." Pagers are activated manually for emergency classifications declared during normal working hours. Other elements inclusive to the implementation of the Emergency Response Plan are as follows:

All Immediate Notifications associated with the termination of both NUEs were completed as required by Form EP 01-1.0-1, "Shift Supervisor Task List," for NUE. During interviews the SS stated that Form EP 01-3.1-1, "Immediate Notification Form," proved to be a cumbersome tool for event termination as much of the specified information on the form is not consistent with NUE termination conditions (**PIR 96-0296** was initiated to address this issue and to recommend further evaluation of event termination guidance).

As evidenced by Control Room logs and interviews of plant personnel, an open line of communication with the NRC was established over the ENS line. This line was manned by various Operations personnel, including the Manager Operations, thereby relieving the SS of this task so he could focus his full attention upon plant conditions. At 1745 hours on January 30, 1996, this line, at the request of the NRC, was maintained throughout the night after the NUE was terminated at 1758

hours. This line was later manned by the TSC ENS Communicator who informed the NRC of the second declaration of the NUE at 1000 hours on January 31, 1996. In addition, specific data was requested by the NRC to be communicated at either 30 minute intervals or upon occurrence, as appropriate. At the request of the NRC the transmittal of this information was later changed to hourly. Information requested at 30 minute intervals (later hourly) were Tavg, Pressurizer level/temperature/pressure, S/G pressure/level prior to RHR cooling, ambient temperature, wind speed/duration, CST level prior to RHR cooling; data requested upon occurrence included major equipment changes, updates on control rod issue, radical change in weather, major maintenance performed, and problems with temporary heating at ESW.

"Followup Notifications" to Coffey County and the State of Kansas were conducted in accordance with EPP 01-3.2, "Follow-up Notifications." Eighteen (18) Immediate and 95 Follow-up Notifications were made during the first and second NUE classifications, respectively. Minor inconsistencies, errors, and improvement items were identified on the completed forms. However, none of these errors resulted in adverse consequences, or reportability issues. **PIR 96-0346** was initiated to document minor inconsistencies, errors, and improvement items identified on the completed forms.

The Onsite Public Information Coordinator performed the duties assigned to his position following the declaration of the first NUE in accordance with EPP 01-1.6, "Public Information Organization." This position continued to be staffed throughout the second declaration of a NUE.

Following the declaration of an emergency classification, four responsibilities are assigned to the SS. These responsibilities are transferred to the Duty Emergency Director upon the activation of the TSC. These responsibilities may not be delegated. Two of these responsibilities, authorizing emergency exposures and making protective action recommendations, were not required

with these two NUE classifications. The third, authorizing offsite notifications was clearly satisfied. Because of the duration and nature of the plant conditions, and the pursuant involvement of non-control room personnel in these events, the responsibility of assumption of command-and-control requires specific explanation. Interviews with the two SSs who were on duty when the NUE's were declared, the Vice President Plant Operations, Manager Operations, and one of the Outage Shift Managers revealed the following results:

a) Both NUE's were declared by the on-duty SS who continued to have command-and-control of the emergency throughout the events. In addition to possessing command-and-control, the SSs possessed full authority with regard to the operation of the plant and associated licensee requirements.

b) The Outage Shift Managers supported the SSs by establishing the OCC within the TSC. This established a central point of contact for responding to the Control Room needs, to coordinate engineering and maintenance activities and to ensure that information regarding engineering and maintenance activities was communicated to the SS. In addition, the TSC/OCC was manned by additional personnel assigned to the TSC Emergency Response Organization, including the TSC ENS Communicator who provided an additional source to the NRC for emergency related information.

c) The Manager of Operations supported the SS by maintaining a continuous line of communication with the NRC, thereby allowing the SS to focus his attention upon the plant. The Manager of Operations and his direct report, the Superintendent Operations, also traveled between the TSC/OCC and Control Room to ensure that the needs of both facilities were satisfied.

d) The Vice President Plant Operations provided executive management support and ensured the provision of all WCNOC resources.

Are changes to the Emergency Action Levels, (EAL's), needed to better classify the event?

Event Classification:

Throughout the initial transient, shutdown, and cooldown of the plant, the SS evaluated the plant condition according to established plant procedures. The Emergency Classification procedure (EPP 01-2.1) indicated, at two separate times, that a NUE could be declared based upon the Administrative. These declarations were made by the SS. In addition to the SS classifying and declaring the two NUEs, the Shift Engineer also performed an independent review of the plant status and EAL classification as required by plant procedures.

The SS consulted at various times with other plant staff and management. These discussions were effective, and supportive of the decisions made by the SS. Interviews were conducted with the SSs, Executive Management, Manager Operations, Manager Emergency Planning, Outage Shift Manager (TSC), Shift Engineers, and Emergency Planners. From these interviews, it was determined that the SS did indeed have command and control of the plant throughout the event.

Emergency Action Level (EAL) Charts:

The WCGS EAL Charts (for event based and initiating condition based decision making -- Charts 1-12) led to a classification of 'No Action This Category' throughout the event. Potential paths to higher classifications were recognized by the SS, and discussed at various times with other plant staff and management.

The EAL charts most applicable to the classification (at various times) were the Administrative Chart (13-ADM), and the Safety System Failure or Malfunction Chart (8-SSFM). The Loss of Electrical Power/Assessment Capability Chart (6-LEP/AC) would have been important for classification if offsite power had been lost. The EAL Administrative Chart performed its function in raising the level of awareness and plant preparedness by

classifying an event that did not meet any of the criteria on the first twelve charts.

By following the Charts as they were written it was possible to proceed directly from no classification to a Site Area Emergency (e.g., 8-SSFM1,4,7). On January 31, 1996, a specific "B" ESW fore bay level was assigned and plans were made to enter an Alert based upon reaching an ESW fore bay level of 1083.' In addition, a Site Area Emergency would still be declared upon a fore bay level of 1070' (as listed in EPP 01-2.1-2, referenced from 8-SSFM7). By establishing ESW fore bay level guidance, the emergency response activities could be escalated in a step-wise manner. The action taken by management to strengthen the approved, written EALs was appropriate because it moved the decision to an objective point rather than a subjective point. Such guidance should be evaluated for incorporation into the EAL Charts (See **PIR 96-0432**).

Draft EAL Chart Changes:

After the event and during the IIT investigation, a draft set of EAL Chart changes was prepared by the Manager Emergency Planning. The initial draft changes: 1) Remove a page referred to from the Safety System Failure or Malfunction and place the criteria within the EAL logic flowchart, 2) Add additional basis regarding Safety System Failures and examples of Natural Phenomena. The draft changes do not alter the basic logic or intent of the currently approved EAL Charts. However, the draft EAL Chart changes, along with additional basis guidance, are expected to add significantly to the decision making process by minimizing subjective decision making.

Performance Improvement Requests:

Three PIRs were written during the evaluation of the Emergency Action Level classification process. **PIR 96-0287** was written to evaluate the declaration of a NUE based upon the EAL Administrative Chart. Based upon the review for IIT 96-002, it was determined that the use of the EAL Administrative Chart

was the appropriate means to classify the event. The IIT 96-002 recommended that **PIR 96-0287** be closed based upon the proper use of the procedures and evaluation of plant conditions.

The subject of the second PIR was EAL enhancements. **PIR 96-0432** was written to evaluate ESW fore bay level guidance for incorporation into the EAL Charts, and to document and track the proposed draft changes to the EAL Charts.

The third PIR was written against the UHS level indicator, physically located in the "B" ESW pump fore bay. **PIR 96-0365** was written to investigate the erratic readings of the ESW fore bay level indicator (EF LIT-0027).

Were Communications adequate with the NRC, State, County, Public and employees?

Communications with offsite agencies were conducted in accordance with emergency planning procedures. Interviews and logs of various plant personnel generally depict the communication to be thorough and appropriate. An interview conducted with officials from the State of Kansas and Coffey County concluded that both agencies were satisfied with communications.

As discussed elsewhere in this report, an open-line of communication was established with the NRC over the FTS-2000 ENS line. This open line was maintained throughout both emergency classifications and, at the NRC's request, through the period of time between classifications.

Immediate notifications were made to Coffey County and the State of Kansas within fifteen minutes as required. All followup notifications were conducted as required. Interviews with Control Room personnel did not reveal that personnel receiving these notifications at the offsite agencies had any concerns during the notification processes. Following the manning of the TSC, personnel had several phone conversations with various State and County officials for the purpose of updating them personally. Further, a teleconference discussion occurred on

January 31, 1996, between officials of the State of Kansas, Coffey County, NRC Headquarters, NRC Region IV, FEMA Region VII and the President and Chief Executive Officer, the Chief Administrative Officer, the Manager Community and Government Affairs and an Emergency Planning Engineering Specialist of WCNOC concerning the potential declaration of a Site Area Emergency in the event "B" ESW pump became inoperable. It was mutually agreed that the most appropriate action to take under these particular circumstances was to not evacuate JRR at the SAE (**PIR 96-0405** was initiated to address this issue). The agreement was to use Note "A" on the Protective Action Recommendation chart as the highest priority guidance based upon the current weather conditions and the fact that no one had been seen at John Redmond Reservoir by the Army Corps of Engineer. The County raised the issue of not activating the sirens at the SAE. FEMA strenuously objected. It was agreed that if an SAE was declared, the sirens would be activated and a news statement would be released that evening concerning what actions the public should take if the sirens sounded. An Emergency Alert System (EAS) statement would also be revised to identify the proper actions to be taken by the public. Everyone agreed these actions only applied to this particular situation. The teleconference ended with the regulators, licensee and offsite officials feeling very positive about the discussion. They felt it was noteworthy to have such communications prior to reaching the point where evacuations may have been implemented rather than waiting until the decision was upon us.

Eleven (11) news statements were released during the event. Numerous live interviews were granted to various media by official WCNOC Spokespersons. Executive Management considered the quality of information released to the media to have been very good.

Employees were kept informed of the plant situation through plant announcements of emergency classifications and distribution of news statements through electronic mail. In addition, a meeting was conducted at 0840 hours on January

31, 1996, to brief Team "B" Emergency Response Organization personnel on the requirements of second shift TSC/OCC and Public Information staffing. Personnel to staff the Emergency Offsite Facility (EOF) and augment the Public Information Organization to full staffing status also reported for second shift availability.

Are restart plans thorough, well understood and well communicated?

This question was included when the original intention was to bring the plant back on line prior to going into the RFVIII outage. Since the decision was subsequently made to start the outage early rather than bring the plant on line, this question is no longer valid in its original context.

Were the Emergency Response Facilities, which were manned, adequate and appropriately staffed?

In the early morning hours of January 31, 1996, the decision was made to staff the TSC/OCC in order to parallel the heightened response staffing at the NRC Region IV and Headquarters facilities. At 0103 hours, the Outage Shift Manager notified engineers already on site in response to the plant conditions to centrally locate in the TSC/OCC. At 0208 hours, a manual callout commenced of Emergency Response Organization (ERO) Team "A" personnel assigned to the TSC. Those personnel reported to the TSC/OCC during the next two hours. At no time was an emergency classification considered in order to activate the TSC, nor did the need arise. During interviews, the Outage Shift Manager revealed that additional Chemistry Technician, Health Physics Technician and Maintenance craft personnel were not called out to augment the existing back-shift staffing levels. Because of the non-radiological nature of the event, the Outage Shift Manager felt that he had adequate personnel to perform all necessary operational functions. However, he also stated that in order to activate the facility, additional personnel beyond those on back-shift (primarily Health Physics Technicians) would have been required. Further, plans were developed for second shift and subsequent shift staffing for a prolonged period of time not only for TSC

personnel but also EOF and Public Information Organization personnel. EOF manning was never required. Selected individuals in the Public Information Organization did perform the duties of their positions in support of the public information effort. In summary, the emergency response facilities were adequately staffed to respond to the needs of the given event. However, interviews with other personnel revealed that the procedural requirement which establishes the minimum staffing for activation of the TSC/OCC is not clear (**PIR 96-0424** was initiated to ensure the clarity and completeness of procedural guidance for the activation of the TSC/OSC).

Why did this icing situation occur now, but not during any past operations?

To answer this question, one first must consider the environmental conditions for frazil ice to form. These conditions are as follows:

1. Water temperature just above the freezing point

2. Rapidly dropping air temperature below 22°F.

3. Sufficient wind to preclude the formation of surface ice and allow supercooling of the surface layer of water (the neutral buoyancy of frazil ice crystals coupled with the turbulence created by the wave action allows the frazil ice to travel to great depths in the already near-uniformly cooled water column. This then promotes further cooling of the water at depth to the point where frazil ice formation is possible at depth).

These conditions existed the evening of January 29, 1996, and into the morning of January 30, 1996. Recorded lake temperatures indicated that the water may have reached a supercooled condition at approximately 0246 hours on the morning of January 30, 1996. This time is given as this is the point when the CW inlet water temperature sensor recorded its lowest value (32.2°F). The other sensor, which consistently recorded higher values than the first, recorded its lowest value (32.6°F) at

0201 hours. Obviously, the accuracy of the readings are suspect, and the actual lake water temperature may have gone below the freezing point prior to either one of these times, but this data gives a good reference point as to approximately what time frazil ice could have begun forming in the lake water immediately in front of the CWSH. Normally, frazil ice development will cease during the daylight hours due to sufficient solar radiation to prevent the decrease in temperature below 32°F necessary for frazil ice to form. Documentation does not exist to know exactly how much of the lake surface, in the vicinity of the intake structures, was frozen over by the evening of January 30, 1996. Apparently, sufficient open water existed in proximity to the ESW intake structure to allow for formation of frazil ice the night of January 30, 1996, and into the morning of January 31, 1996. Frazil ice has been documented to travel under surface ice for some distance. Continued high winds throughout the day and into the morning of January 31, 1996, coupled with decreasing air temperatures during that period would have been conducive to frazil ice formation again. Actual lake temperature data is not available after 0337 hours on the morning of January 30, 1996, until approximately 1700 hours on February 1, 1996, as the CW System was not operating, and the temperature sensors that provide the lake water temperature are located in the CW piping in the Turbine Building. Wind speeds decreased during the daylight hours of January 31, 1996, allowing surface ice to form in the vicinity of the intake structures. During the night of January 31, 1996, and the morning of February 1, 1996, with very light winds and temperatures, it is unlikely that frazil ice production could have continued. Based on recorded lake temperatures and the increased amount of surface ice, after 1700 hours on February 1, 1996, it is unlikely that any additional frazil ice could have been produced near enough to the intake structures for it to be drawn into the intake of either CW or ESW.

To summarize, based on the available data, conditions conducive to frazil ice formation in the vicinity of the intake structures existed during the early morning hours of January 30,

1996, and continued into the early morning hours of January 31, 1996.

Research into why frazil ice had not previously caused intake problems found that since the winter of 1992-1993, recorded lake temperature from the CWSH intake has been less than 32.4°F only once. This occurred during the early morning hours of January 30, 1996, (the time of the icing problems at CWSH and ESW) when the lake temperature was recorded at 32.2°F. This fact alone may account for the absence of any icing problems on trash racks or traveling screens from the winter of 1992-1993 up to January 30, 1996. Prior to the winter of 1992-1993 beginning with the winter of 1985-1986 (the first operational winter), nine time frames were identified when lake temperatures could have approached 32°F. For six of these nine time frames, sufficient surface ice cover was documented to preclude the occurrence of frazil ice in the area of the intake structures. During the remaining three time frames, a review of Control Room Operator Logs gave no indication of ESW pump operation on those dates.

Was the first operability determination of ESW Pump "A" adequate?

The team concluded that the Operability Review performed was inadequate due to inadequate engineering review of the actual plant conditions. ESW "A" Pumphouse fore bay level fluctuations, prior to securing the pump, should have made it obvious that flow blockage was occurring upstream of the pump suction. The cause of the blockage was not conclusively determined nor steps taken to ascertain that the blockage had cleared.

Based upon the knowledge base and information on icing utilized by the personnel at the time, the decision made by the Duty SS to declare the pump operable appeared to be valid. Procedural controls were correctly followed and the chain of command was well utilized in making the operability decision. The pump operation for the previous two hours was within normal parameters and met the performance criteria specified.

Supplemental heating to the ESW Pumphouse fore bays and continuous site watch surveillance appeared to provide adequate assurance to maintain the pump operable. The review and concurrence of the PSRC was obtained prior to declaring the pump operable.

However, the suction to ESW Pump "A" was being restricted by continuing frazil ice buildup on the trash rack from the lake. This phenomenon was not recognized by the personnel involved and was therefore not taken into consideration during the decision making process regarding ESW Pump "A" operability. A visual inspection of the ESW fore bay during the incident incorrectly concluded that the ice present existed only at the surface.

Although visual inspection into the ESW fore bay could determine the presence of surface ice, the depth or degree of coverage of ice on the trash racks could not be positively determined. Nor was it known or recognized that the quantity of warming line flow and temperature was less than the given design values. Previous correspondence from Engineering to Operations had established a basis of understanding that frazil ice blockage was not a credible event. This event demonstrates that a good questioning attitude is necessary to sometimes break a mindset prevalent at the time of the initial investigation. If the cause of the blockage is not thoroughly determined, then assurance of it not reoccurring again cannot be guaranteed. **PIR 96-0368** addresses the concern of not recognizing the potential of frazil ice accumulation. **PIR 96-0377** was initiated to find and remove documentation referring to frazil ice as not being a credible event. Furthermore, **PIR 96-0412** addresses the concern of not modeling the SW/ESW warming lines into the Wolf Creek Individual Plant Examination for the same reason.

How close did the "B" ESW Pump come to becoming inoperable during the event?

"B" ESW pump was operable throughout the entire period when frazil ice blockage was being experienced on "A" ESW,

delivering the required flow and pressure. However, due to design problems and operational valve lineup problems, the amount of warming line heat input to the "B" ESW pump intake appears to have been marginal. Ice was visible on the surface upstream of the trash racks, but the depth of this ice was not verified as divers did not inspect the "B" trash racks since the pump was running. Abnormal level variations were observed at times in the "B" ESW pump suction bay, and some "B" ESW pump discharge pressure variations occurred. These variations were not to the point of making the pump inoperable but indicated that some frazil ice blockage had occurred.

The closest to losing "B" ESW appears to have been at about the time that "A" ESW pump was secured for the second time, 1925 hours on Tuesday January 30, 1996. Reports from ESW indicate that "B" ESW pump suction level was trending downward. The site watch observed that the lowest level reached was below the lower platform (<1072'). Minimum pump submergence is 9' (about 1068'). From the site operator and control room logs additional RHR heat load was put on "B" CCW by the Operators in an attempt to reverse falling "B" ESW suction bay levels at about 2015 hours. This was effective in reversing dropping levels within about 15 minutes and suction levels were fully restored to normal by about 2130 hours. Recognition of the downward trend of "B" ESW Fore bay level and the timely response in increasing the heat load onto "B" ESW via the RHR System reflects a strength on the part of the Operating crew. The trend of decreasing fore bay level can also be detected in "B" ESW pump discharge pressure trend.

Had the Operating crew not increased the heat load onto the "B" ESW Train, the "B" ESW Pump fore bay would have likely continued to drop to the 1068' elevation further resulting in degraded or eventual loss of the "B" ESW Pump discharge pressure and flow.

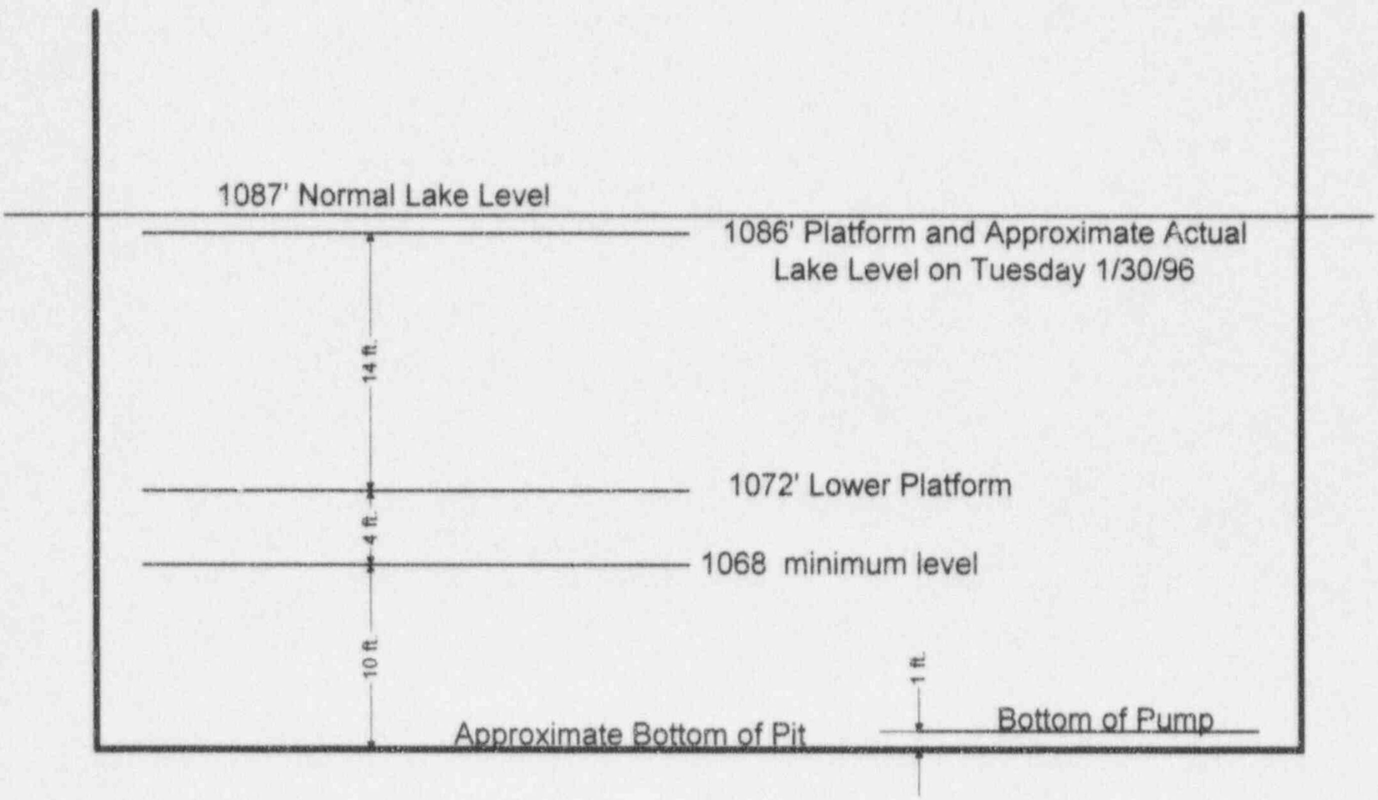
Personnel at ESW also reported level fluctuations of up to 9' below normal on ESW "B" during the day on Tuesday, January

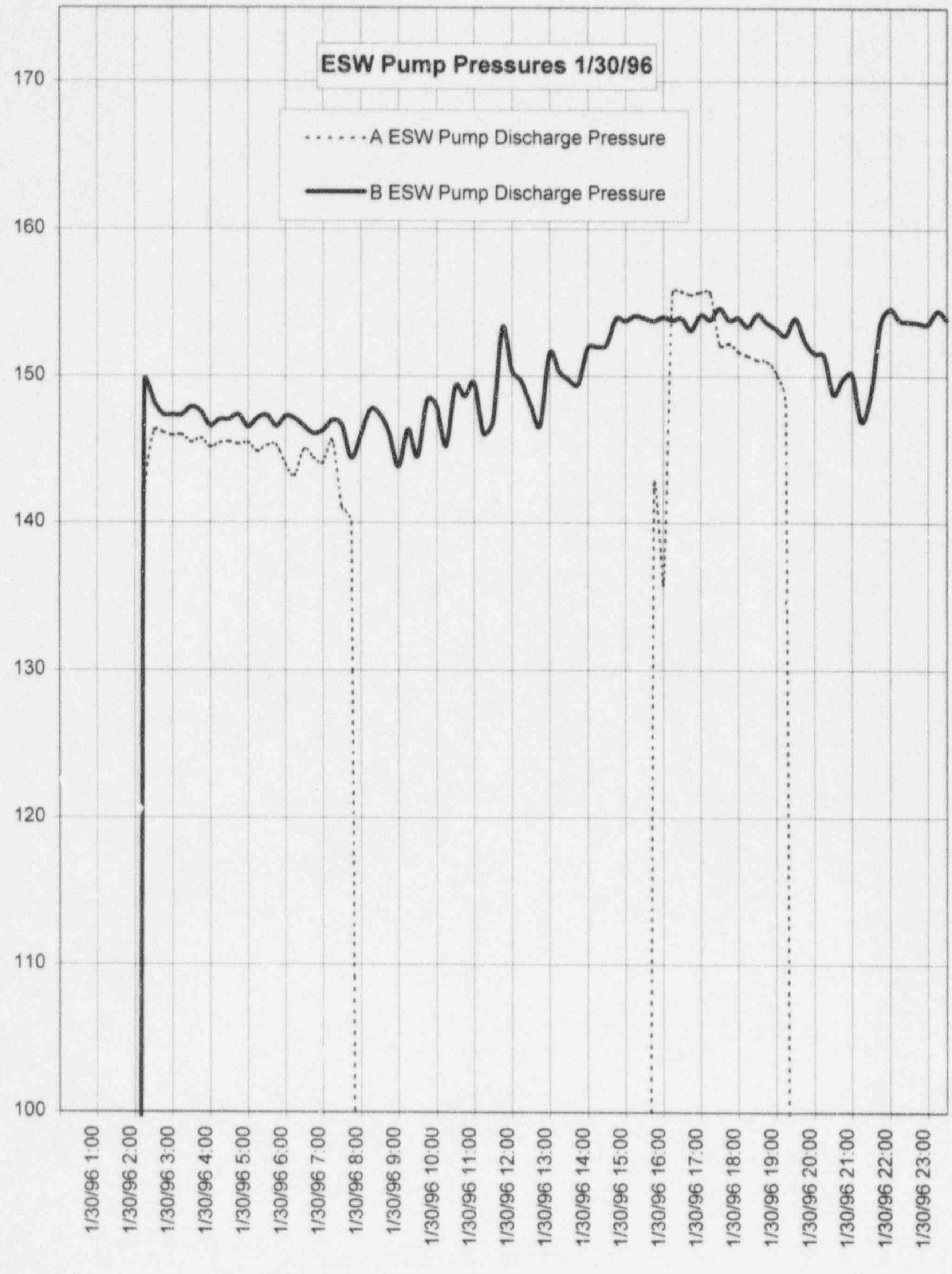
30, 1996. From the written reports it appears that the lowest level during the day would have been about elevation 1077.'

UHS ultrasonic level indicator was erratic much of the day, presumably due to oscillating levels. Communications between the TSC and ESW during the day indicate that this indicator was not tracking level very well. This indicator is normally steady even when ESW pumps are running. Its behavior seems to be representative of level in that its indication is erratic when actual level is erratic, but it can not track actual level when levels are erratic. It is noteworthy that in the evening, when level at the "B" ESW pump suction was reported to be decreasing, that LI-27 seems to track level fairly well.

"B" CCW dwarfs other ESW loads present on "B" Train ESW on Tuesday, January 30, 1996. A plot of "B" CCW Heat Exchanger Δ-temperature is attached. It remained steady throughout the day until late afternoon when it decreased slightly. From site operator and control room logs additional RHR load was put on "B" CCW by Operators in an attempt to reverse falling "B" ESW suction fore bay levels at about 2015 hours.

ESW Inlet Bay Elevations




ESW Pump Pressures 1/30/96
A ESW Pump Discharge Pressure
B ESW Pump Discharge Pressure
170
160
150
140
130
120
110
100
1/30/96 1:00
1/30/96 2:00
1/30/96 3:00
1/30/96 4:00
1/30/96 5:00
1/30/96 6:00
1/30/96 7:00
1/30/96 8:00
1/30/96 9:00
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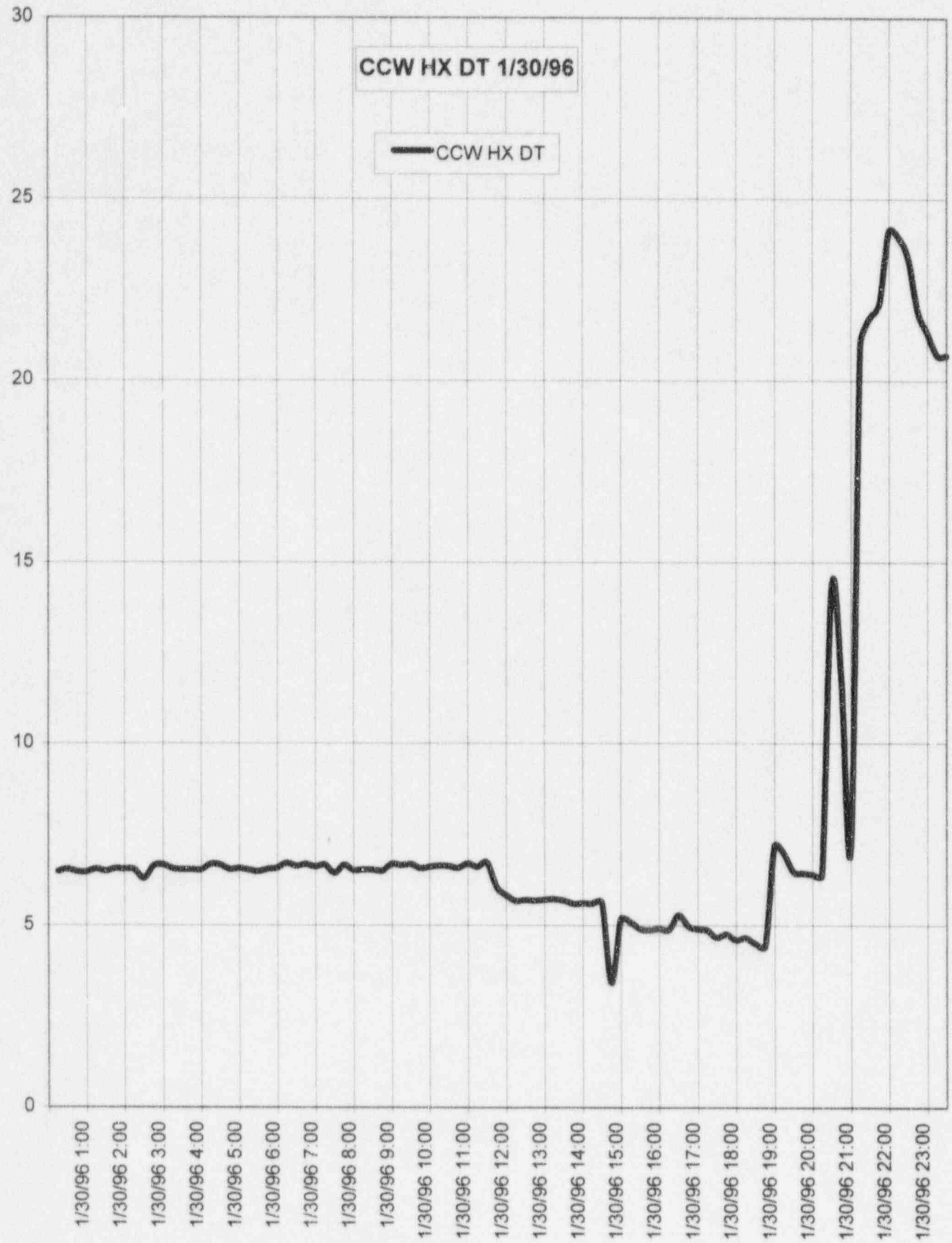
1/30/96 23:00


CCW HX DT 1/30/96
CCW HX DT
30
25
20
15
10
5
0
1/30/96 1:00
1/30/96 2:00
1/30/96 3:00
1/30/96 4:00
1/30/96 5:00
1/30/96 6:00
1/30/96 7:00
1/30/96 8:00
1/30/96 9:00
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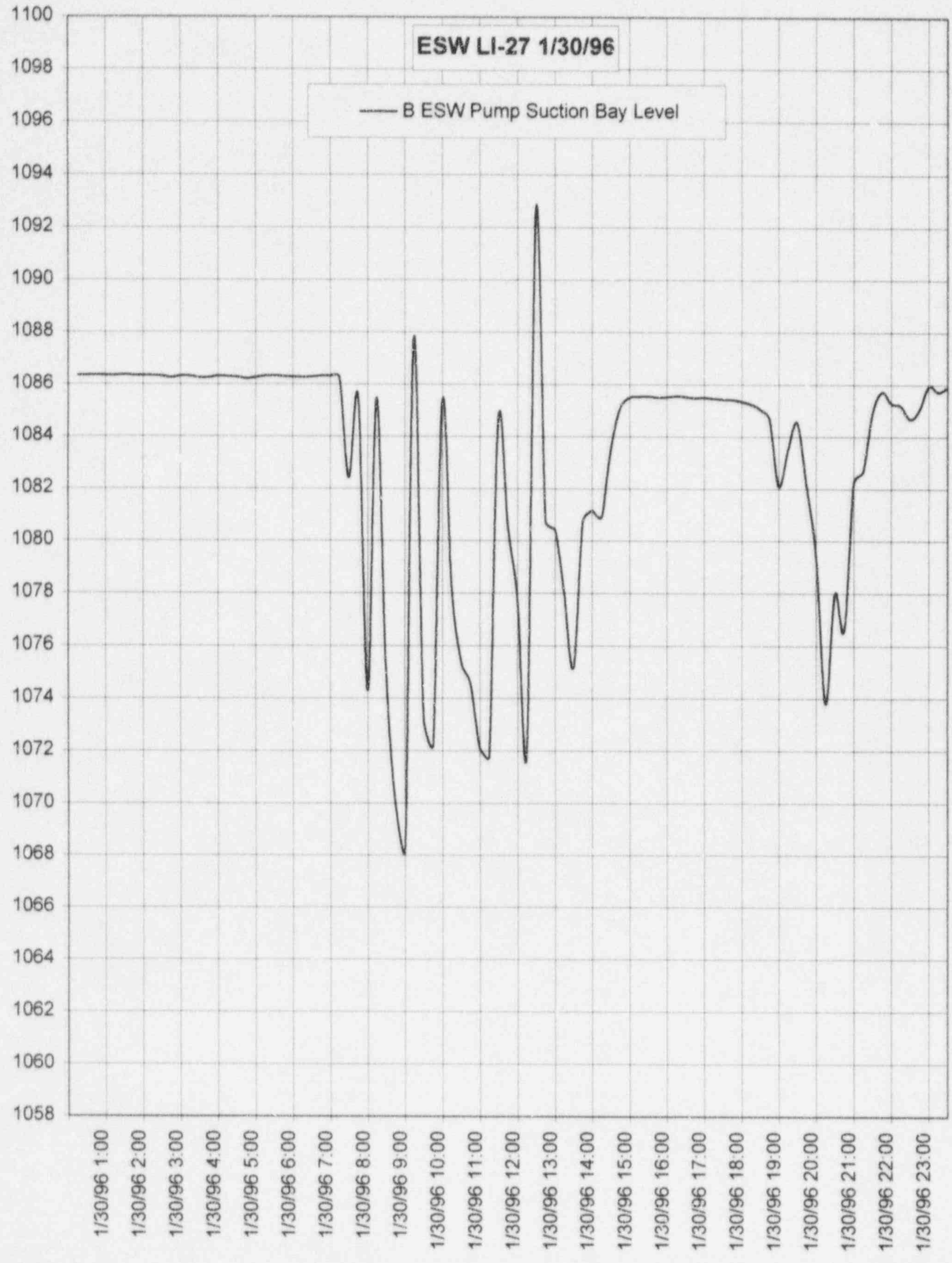
ESW LI-27 1/30/96
B ESW Pump Suction Bay Level
1100
1098
1096
1094
1092
1090
1088
1086
1084
1082
1080
1078
1076
1074
1072
1070
1068
1066
1064
1062
1060
1058
1/30/96 1:00
1/30/96 2:00
1/30/96 3:00
1/30/96 4:00
1/30/96 5:00
1/30/96 6:00
1/30/96 7:00
1/30/96 8:00
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V. **DETERMINATION OF ROOT CAUSES:**

Summary:

The root cause of both of the icing events is inadequate design. The CW system and the ESW system are expected to be able to operate under the environmental conditions experienced on the morning of January 30, 1996. Failure to verify design assumptions resulted in an inadequate design of these systems and their inability to operate satisfactorily during this event.

Process for Identifying Root Cause:

The identification of the root causes associated with this event were done with the processes outlined in procedures AI 28B-003, Rev. 4, "Incident Investigation Team," and AI 28B-004, Rev. 0, "Guidelines For Performing Root Cause Analysis." As with any in-depth root cause investigation, the process involved a large amount of data collection and formal industry-accepted methods for ensuring the event and its causes are thoroughly understood.

An initial Event and Causal Factor (E&CF) chart was the first step in understanding the sequence of events. This information was obtained from a review of the Shift Supervisor and Control Room Logs. At the same time, decisions were being made on who to interview and what questions to ask. Procedures, drawings, calculations and a wide variety of other documents were reviewed (as described below). As more information was obtained, important events or activities were added to the E&CF chart. For each event or activity, the question was asked: "Was this action appropriate for the given circumstances?" was formulated. Those identified as inappropriate are identified on the chart.

Once inappropriate actions were identified, efforts were made to understand why they occurred. This was done through additional interviews and document review along with Barrier Analysis, Change Analysis and STORM analysis. Broken barriers, conditions existing at the time of the inappropriate action and causes identified with these methods were then placed on the E&CF chart. Causes were

reviewed to identify any programmatic causes and corrective actions were proposed.

Sources of Information:

Appendix "C" provides a list of documents reviewed by the IIT, including procedures, WPs, lesson plans, NRC inspection reports, Quality Evaluation Surveillance Reports, Wolf Creek letters and inter-office correspondence, calculations, logs, drawings, temporary modifications, work histories and TSC/OCC documents.

Appendix "F" provides a list of personnel interviewed during the investigation. Efforts were made to interview all individuals involved in an event or activity and to verify statements against procedures, design documents or other interviews.

Event and Causal Factor Chart:

Appendix "E" provides a detailed sequence of activities and events leading up to or occurring between January 30, 1996, and February 2, 1996. The chart identifies those actions determined to be inappropriate for the given conditions. Inappropriate actions are shown separately on Appendix "E" along with related conditions, broken barriers and causes.

Barrier Analysis and Change Analysis:

Barrier analysis is the identification of barriers, physical or administrative in nature, that are intended to prevent an event from occurring. Often when an event occurs, one or more barriers have been broken. Appendix "E" identifies the barriers that should have been in place to prevent the inappropriate actions and why they were ineffective.

Change analysis is a review of activities that have been performed successfully in the past to determine what changes caused them to be performed unsuccessfully. Although many of the activities occurring during this event had either not been performed in the past or were infrequently performed, change analysis did provide some insights and verification of potential causes of this event. Appendix "E" provides the results of this review. The questions contained in

Appendix "E" are the standard set of questions for change analysis that are contained in AI 28B-004.

STORM Analysis:

Once conditions or potential causal factors that are likely contributors to the event have been identified, STORM analysis can be applied to identify areas that needed further investigation. STORM stands for Stimulus, Team, Operation, Response and Management and is a table of specific questions contained in AI 28B-004 that provides assistance in identifying a root cause category. STORM is only for analyzing human performance problems, and therefore, was not applied to design issues identified during this investigation. Appendix "E" provides a summary of the STORM analysis for the inappropriate actions involving human performance on the E&CF chart.

Root Causes:

The ice blockage of the CW traveling screens and the ESW trash racks are the primary events that were reviewed by this IIT. Several other events were also investigated, including the misalignment of the ESW valves and the plant cooldown not being completed in 6 hours as required by T/Ss. The following is a list of the main events, their root causes, primary contributing causes and proposed corrective actions to prevent recurrence. Additional actions related to these events (immediate and enhancements) are contained in Sections VI through IX of this report.

Event: Ice buildup on the CW traveling screens resulting in plant shutdown.

Root Cause:

Inadequate design. The design of the CW Intake Structure and associated Traveling Screens was not adequate for the harsh environmental conditions imposed on them during the events of January 30, 1996. The design is inadequate for the following reasons:

- When in "Auto" the traveling screens are susceptible to damage by surface ice build-up. Such damage occurred during the first several years of plant operation and was corrected in 1988 by

changing how the traveling screens were operated. They were placed in "Manual slow" during the winter to prevent the build-up of surface ice.

- When in "Manual slow" the traveling screens are susceptible to ice build-up near the spray wash area and on the traveling screens themselves. The metal traveling screens are exposed to cold air for approximately 7 minutes when they rotate out of the water during their 36-minute cycle. At one point during this 7 minutes, they are sprayed with SW that is at approximately lake temperature. During this event air temperature was approximately 7°F , winds were from the north at 10 - 25 mph and lake temperature was near 32.4°F. When the traveling screens leave the water under these conditions, they Cooldown rapidly from near 32°F. When sprayed with approximately 33°F water, icing conditions result. It is believed some inactive frazil ice may also have been present in the water, which could have contributed to the ice build-up on the traveling screens.

Contributing Cause:

The failure of actions taken in 1988 to correct the design problem of surface ice around the traveling screens allowed an additional icing event to occur. A revision to STN GP-001 resulted in placing the traveling screens in manual slow to compensate for the design problem. This operational change compensated for one failure mode (surface ice) but caused another failure mode to become more likely to impact operations.

Event: Ice build-up on the ESW trash racks.

Root Cause:

Inadequate design. There was insufficient warming line flow for the actual warming line temperature to prevent the formation of frazil ice. A design calculation performed in 1976 assumed an ESW warming line temperature of 35°F. With this assumption, the calculation determined a flow of 4000 gpm was required. Later, a design calculation determined that actual flow would be 4413 gpm with the additional assumption that the pipes would be full of

water. Both of the above assumptions were incorrect. The actual warming line temperature on the morning of January 30, 1996, was approximately 33°F. It was also discovered that the warming line and the ESW to UHS return line piping diameters and elevations are such that portions of these lines operate with partial pipe flows and with the dry portions not vented. This condition was apparently not foreseen by the piping designer, and makes the calculation methodology used for sizing the warming line invalid with resulting non-conservative errors. The warming line flow rate during an accident line-up for the piping as-built configuration cannot be readily calculated or measured with a high degree of certainty, but is estimated to have been about 2500 gpm.

<u>Contributing Causes:</u>

The incorrect ESW valve line-up was a contributing cause to the ice build-up at the ESW trash racks. During the approximately six hour period preceding the first time "A" ESW pump had to be secured due to the ice blockage, ESW return to SW return cross tie isolation valves were open and the ESW return to the UHS valve was throttled. This caused some of the ESW return flow to be diverted from UHS through the normal SW discharge line. It is estimated that this caused warming line flow to be reduced to about two thirds of what it would have been, or about 1700 gpm.

Event: Incorrect Line-up of ESW System Valves

<u>Root Cause:</u>

The root cause of this event was a failure to verify procedure requirements in a timely manner. Although the procedure was not used while doing the line-up, this was acceptable given the urgent conditions of the plant. Not using a procedure however, increases the risk a line-up will be done incorrectly. Because of this increased risk, effective communications become even more important. Additionally, it is important to verify actions taken by performing a timely review of the applicable procedure. The six hour delay is not timely and did not meet management expectations regarding implementation of urgent action and subsequent procedure verification reviews.

Contributing Causes:

There are three contributing causes to the incorrect valve line-up:

1. Contributing to the incorrect line-up were three examples of ineffective communication. When the Shift Supervisor instructed the RO to start the ESW Pumps, he did not fully communicate his expectations to isolate the ESW from the SW. When the RO's were walking the boards during shift turnover, the oncoming RO did not gain a full understanding from the on-shift RO as to why the abnormal ESW line-up existed. When the on-coming RO identified the abnormal line-up, he did not communicate it to his SO.

2. Some resources were not effectively used during the time period of this event. Rods were in manual and one RO was dedicated to monitoring ΔI to minimize any impact on the fuel during the power change. This left one RO to carryout the rest of the RO's responsibilities. During a transient such as this, placing the rods in automatic would have allowed the RO to focus on higher priority issues. The Shift Supervisor and the SO are responsible for effective use of resources.

3. The Alarm procedure for SW Pressure Hi/Low, ALR 00-008B, instructed the operator to start the ESW Pumps in accordance with SYS EF-200. This caused some delay in performing necessary immediate actions and, in this case, set the stage for immediate actions being performed without the aid of a procedure. Placing detailed actions in the alarm procedure (i.e., instructions to start the ESW Pumps and what valves to open and close), would have allowed the RO to perform the desired line-up in a timely manner.

Event: Failure to complete cooldown to MODE 4 in 6 hours as required by Technical Specification 3.7.1.2.

Root Cause:

The root cause of this event is the lack of procedure guidance for performing a rapid cooldown. The SO believed that he had to complete GEN 00-005, Appendix "A" prior to beginning a plant

cooldown. Several of the actions in the Appendix could have been completed in parallel with the performance of GEN 00-006. This would have expedited the start of plant cooldown.

Contributing Causes:

The SO had only been in his position for approximately 8 months, and had no prior experience or simulator training at completing the cooldown process within 6 hours. It should be noted that Wolf Creek as a plant has never experienced the pace of operations required to achieve Hot Shutdown in 6 hours.

Adherence to procedures is the expectation of Operations, which focused the SO on ensuring each step was completed prior to traveling on to the next.

The crew configuration had been changed that morning. The Shift Supervisor was assigned to this crew when the regular Shift Supervisor went home sick. This presented a condition where the crew was working in an environment where the individuals had not had the opportunity to form a solid working relationship.

Programmatic Causes (Generic):

Of those root and contributing causes identified, some are considered programmatic weaknesses. The following is a list of those causes deemed programmatic in nature.

- High level alarm procedures often reference other procedures as the immediate response requirements. This hinders timely implementation of these actions, at a time when prompt response is important.
- No formal administrative controls exist to ensure a procedure gets verified when conditions necessitate actions without the use of a procedure.

These programmatic issues are being investigated as part of the corrective actions identified above.

VI. IMMEDIATE ACTIONS TAKEN:

Although there were numerous actions taken in response to the icing event of January 30, 1996, the following is a brief summary of the key actions that were taken to mitigate the consequences of the event. A complete listing of all actions taken is contained at the end of this section of the report.

Essential Service Water (ESW) System:

Upon confirmation of a low "A" ESW pump fore bay level the operators immediately secured the "A" ESW pump. Personnel were dispatched to the ESW Pumphouse to determine the cause and implement actions to restore fore bay level.

These subsequent actions included the erection of a tent (temporary shelter) over the fore bays to minimize conductive heat losses. The procurement and installation, on an interim basis, of portable space heaters and heater blowers to warm the air in the ESW Pumphouse and fore bays. The procurement and installation of portable air compressors, an air bubbler system, and portable water boilers. These items were used to inject air and warm water into the fore bays of the ESW pumps to aid in the agitating/breakup and removal of the frazil ice. WCNOC established a 24 hour watch of the temporary equipment installed at the ESW Pumphouse and fore bays to assure continuos proper operation of the equipment and to inform the Control Room of any equipment degradation.

Circulating Water System (CW):

Upon receipt of the alarms associated with the CW pump traveling screens the Control Room immediately dispatched personnel to the CW Pumphouse to assess the alarms and to provide an equipment status report to the Control Room. Upon determination of severe icing of the CW traveling screens the Control Room immediately implemented actions to place the plant in a configuration which minimized its reliance on CW and SW. These actions included a power reduction and subsequent reactor trip. Further, the Control Room rotated the operating CW pumps and SW pumps and subsequently tripped all CW pumps and placed the ESW System in service.

Subsequent actions included the erection of a tent (temporary shelter) over the fore bay and traveling screens to minimize conductive heat losses. The procurement and installation, on an interim basis, of portable space heaters and heater blowers to warm the air in the fore bay. The procurement and installation of portable air compressors, an air bubbler system to inject air in front of the fore bays to the CWSH to aid in the agitating/breakup and removal of the ice.

Emergency Response Program:

In response to the above discussed events WCNOC entered and implemented its Emergency Response Program. This consisted of the classification and declaration of two NUEs and the twenty four hour augmentation of plant staffing to aid the Control Room in responding to the above discussed events.

Appendix "E" consists of a complete chronological listing of the actions taken following the icing event.

VII. ADDITIONAL ACTIONS TAKEN

Letter WM 96-0014, from [name deleted] to [name deleted] documents: The following contingency actions have been implemented and will be taken whenever lake temperature is 40°F or lower until long term actions are implemented:
1. Air bubblers will be maintained in each outer bay. As a minimum, two air compressors are located at the ESW Pumphouse. A minimum of one air compressor is aligned for bubbling the outer bays with an additional compressor as a backup.
2. Tents will be maintained over the grating of the outer bay to provide additional freeze protection.
3. A dedicated cognizant individual will be stationed at the ESW Pumphouse 24 hours a day. This individual will: 1) monitor the air compressors 2) monitor the tents and 3) watch for formation of ice in the outer bays. The Control Room will be notified immediately upon compressor failure, tent degradation or ice formation in the outer bays.

Letter WM 96-0014, from [name deleted] to [name deleted] documents: Wolf Creek Nuclear Operating Corporation is taking the following additional actions to assure continued operability of the ESW System:
1. Cold weather preparations and equipment lineups in place prior to and during this event will be reviewed and incorporated into the appropriate operational procedures and training.
2. The lessons learned from the icing problems encountered at the CW Screenhouse will be captured and incorporated into the appropriate operational procedures and training.
3. Design adequacy of the ESW System for cold weather operations will be reviewed and actions taken as appropriate.
4. Design adequacy of the SW and CW System for cold weather operations will be reviewed and actions taken as appropriate.
WCNOC formed IIT 96-002 to determine the cause of the icing event. **(PIR 96-0311)**
IIT 96-002 performed an evaluation of the initial engineering nonconformance evaluation on 2/2/96. The IIT issued **PIR 96-0367** recommending revision of the evaluation and the proposed immediate temporary actions.

VIII. RECOMMEND CORRECTIVE ACTION:

Essential Service Water Intake	
Recommended Action	**Purpose**
Design change to ensure adequate warming line flow. The hydraulics of the ESW discharge to the UHS and Warming Line to the ESW Pumphouse must be changed to establish full pipe flow and distribute the proper amount of flow to the ESW Pumphouse Warming Line. Due to the low amount of heat (3/4~1°F) available from the worst case safety train, a higher flow rate than the original design (4,000 gpm) may be required. The upper bound for this warming line flow will be dictated by the UHS cooling	To Correct Problem. The purpose is not to only correct the original design flow deficiency, but to establish the appropriate flow rate to prevent ice blockage of the ESW Pumphouse trash racks due to a lower than expected temperature rise (3/4~1°F) across the worst case ESW train. **(PIRs 96-0316 and 96-0334)**

characteristics and the temperature range chosen for this mode of operation. To achieve the proper flow and full pipe conditions, back pressure on the ESW discharge to the UHS must be raised downstream of the Warming Line tee. The back pressure orifices located upstream in the Powerblock ESW discharge lines will need to be re-evaluated as to not increase the overall back pressure on the ESW to an unacceptable level.	
All documents referring to frazil ice at ESW as not being a credible need to be revised or removed from records.	To eliminate incorrect information. **(PIR 96-0377)**
Recommended the deletion of T/S Clarification 003-88, Rev. 2.	To eliminate incorrect information provided to operators on frazil formation at the ESW Pumphouse. **(PIR 96-0366)**
Maintenance activities including repairs should be completed on valves EFV-0262, 0263, 0264 and 0265 prior to warm weather in order to accommodate the corrective actions being developed to alter the ESW System hydraulic characteristics for satisfactory warm and cold weather operation.	To Correct Problem. **(PIR 96-0483, WPs 102996, 103096, 106532, 100818, 104072, 100644; ARs 7587, 7681, 7823, 10031, 11774, 5718, 5544, 8228)**
Circulating Water Intake	
Recommended Action	**Purpose**
Enclose traveling screens with a structure that provides adequate heat and light. This effectively removes the CW Traveling Screens from the environment that promotes ice formation and also provides an environment that accommodates personnel to perform	To Correct the problem. **(PIR 96-0316)**

surveillance and maintenance activities on the Traveling Screens.	
Misalignment of ESW System	
Recommended Action	**Purpose**
A method for tracking urgent actions and subsequent verification of acceptability of these actions will be developed. This methodology should provide a simple tool to the operating crews to log, track, and resolve urgent actions.	This action is being implemented to provide the operating crews with the necessary tools to prevent recurrence of this type of an event. **(PIRs 96-0338 and 96-0373)**
Communication training will be enhanced for the operating crews. The training will add emphases to stressing use of clear concise instructions, and not taking the watch until the relieving individual has a full understanding of all abnormal conditions. The need to bring abnormal conditions to the attention of supervision will be reinforced.	This action is being implemented to assure all operating crew members have a clear understanding of management's expectations in this area. **(PIRs 96-0338 and 96-0374)**
The alarm procedure for the top-level alarms will be reviewed and revised, as needed. These revisions will incorporate all expected operator actions into the applicable alarm procedure.	This will eliminate the need to have operation personnel use a secondary procedure to implement immediate alarm procedure response requirements. **(PIRs 96-0338 and 96-0375)**
Delayed Cooldown	
Recommended Action	**Purpose**
Procedures GEN 00-005 and GEN 00-006 will be revised to provide guidance on which steps are mandatory and which steps may be delayed in an accelerated shutdown condition.	This action is being implemented to remove un-necessary programmatic obstacles for the performance of an accelerated cooldown. **(PIRs 96-0264, 96-0369, and 96-0480)**
Simulator Training will be developed to	This action is being

provide the operating crews with the opportunity to operate under conditions which require a forced cooldown in 6 hours.	implemented to provide the operators with an understanding of the actions and time frames to accomplish the action for a rapid forced cooldown. **(PIRs 96-0264 and 96-0370)**
Management's expectations will be reviewed regarding procedure adherence as they relate to rapid cooldown events.	This action will be implemented to assure adequate guidance has been provided to the operating crews. **(PIRs 96-0264 and 96-0372)**
The need for a method/strategy for addressing heightened awareness to communication techniques and command and control issues in the Control Room when an operating crew makes configuration changes will be evaluated.	This action is being implemented to assure the operating crews have been given the necessary tools to perform their assign duties in an effective manner under these conditions. **(PIRs 96-0264 and 96-0371)**

IX. RECOMMENDED ENHANCEMENTS:

Essential Service Water Intake	
Recommended Action	**Purpose**
Provide an accurate lake water temperature indication.	Monitoring for frazil conditions.
The potential for frazil ice is significant when bulk lake water temperature is at 33°F and decreasing. Very small changes in temperature when the water is in the 32°F range can trigger frazil production. Lake water temperature indication with a high degree of accuracy (+/-0.2°F) at the inlet to the ESW Pumphouse can provide the most reliable means to detect the conditions	Accurate temperature monitoring of the lake water conditions can be used to initiate additional measures to detect and mitigate frazil ice blockage. **(PIR 96-0316)**

conducive to produce frazil ice.	
Provide an air bubbler (broom) to sweep frazil ice off of the trash racks. Once the lake has reached the critical environmental conditions to produce frazil ice and the ESW Pumps suction begins pulling frazil ice-laden water into the Pumphouse inlet, Air bubblers can provide a brooming or sweeping effect upward across the trash rack to keep off or break off frazil ice accumulation. Air bubbling also creates a high circulation ratio of the bulk fluid, thus promoting mixing and heat transfer.	Compensatory Measure It is envisioned that air bubbler tube manifolds be used as a compensatory measure, with air compressors, hoses and manifolds being brought in and utilized in a temporary fashion. **(PIR 96-0316)**
Enclose and heat the ESW trash rack enclosure. Supplemental heating should be considered in the ESW Traveling Screen Bay area as well. Observations made during the ESW freezing incident indicated that limited amounts of ice washed off of the traveling screens and that this limited amount did not affect traveling screen operation.	Compensatory Measure As the lake is the prime source that produces frazil ice, enclosing the trash rack area does not prevent frazil ingress. It does, however, provide a suitable environment for personnel to monitor the trash rack fore bay and perform ice removal work activities, if necessary. **(PIR 96-0316)**
Surveillance on ESW warming lines to ensure appropriate warming line flow. Provisions for a flow metering device should be included in the design change development to determine the actual warming line flow. This would also assist in future ESW and EA system flow balance determinations and detection of flow degradation.	Monitoring for ESW Warming Line flow. **(PIR 96-0316)**
Local ESW Bay level indication for each of the traveling screen bays and trash rack bays.	Monitoring for trash rack/screen blockage. **(PIR 96-0316 and 96-0329)**

Local ESW Bay level indication would provide the means for site watch personnel to clearly determine existing bay levels and the margin in regard to the minimum expected lake level and ESW Pump net positive suction head. Level Indication could simply be an attached tape or painted elevations to the ESW Bays.	
Manual Rake Available Based upon the recommendation of the Army Corp of Engineers, the use of a "Rake" to manually remove frazil ice is successfully used by other power plants.	Compensatory Measure **(PIR 96-0316)**
Provide adequate lighting in the bay and trash rack area. This should be integrated with the design efforts.	Monitoring for frazil ice. **(PIR 96-0316)**
Discharge path for the ESW traveling screen and strainer backwash became restricted due to the buildup of ice.	Need to assess/ identify methodology of keeping path free of ice. To prevent flooding of the ESW Pumphouse. **(PIR 96-0396)**
Provide Computer based tools for modeling ESW System hydraulics.	Assist in correcting problem. **(PIR 96-0316)**
System Engineering will reevaluate the operability call associated with Work Request 5134-93 and Valve EFV-0263.	To assure that correct guidance is provided to the operating crews on warming line flow with the valve stuck in the 50% open position. **(PIR 96-0430)**
Determine and correct cause of erratic operation of EF LIT-0027.	To assure accurate ESW Bay Level indication is available. WP 109205 was generated and STN IC-265 will be performed. **(PIR 960-0365)**

Circulating Water Intake	
Recommended Action	**Purpose**
CW Traveling Screen Operation Procedure Change Procedure STN GP-001 will be revised to require controlotron setup and zero adjustment prior to opening the CW Warming Line valve. Procedure SYS SW-121 will be revised to provide guidance on the use of air bubblers to assist in breaking up surface ice.	To rnonitor for degradation. **(PIRs 96-0398, 96-0316, and 96-0482)**
Revise ALR 00-006C CWSH Fast Wash, should be revised to place the traveling screens wash local mode switch to OFF when icing conditions are apparent.	To prevent the buildup of ice on the traveling screens. **(PIR 96-0399)**
Provide an air bubbler (broom) for inactive bays (and all bays) during shutdown mode to mitigate effect of surface ice. The CW Warming Line was found to be adequate in providing heat to the CW Screenhouse, thus preventing frazil ice accumulation on the trash racks. However, when CW pumps are secured or Condenser vacuum is broken, CW warming either becomes unavailable or has a much lower heating content.	Compensatory measure. It is envisioned that air bubbler tube manifolds be used as a compensatory measure, with air compressors, hoses and manifolds being brought in and utilized in a temporary fashion. **(PIR 96-0316)**
Procedure SYS SW-121 will be revised to delete the requirement to operate the traveling screens continuously in slow manual during cold weather or unusual icing conditions.	To eliminate the spraying of cold (near or at freezing temperature) water on the screens. This will eliminate the ice buildup on the traveling screens which occurred during the January 30, 1996, icing event. **(PIR 96-0376 and 96-0482)**

Procedure SYS SW-121 will be revised to direct operators to use air sparging in situations, where icing can occur.	This actions will provide the operators with a tool for breaking up surface ice that may inhibit traveling screen operation. **(PIR 96-0316 and 96-0482)**
Emergency Plan	
Recommend Action	**Purpose**
PAR Charts require clarification to make allowances for not evacuating JRR for non-radiological events.	To align WCNOC's Emergency Plan Program with the State and County Programs / Desires. **(PIR 96-0405)**
On 2/8/96 the Manager Emergency Planing drafted several changes to the EALs. These changes were drafted based on the recent icing event. In addition the evaluation should include a review of the evacuation of the ESW Bay.	To provide better tools to the operating crews. **(PIRs 96-0418 and 96-0432)**
Need to revise EPP 01-4.1 to ensure that the minimum staffing requirements for the TSC/OSC activation are clear, concise, and consistent with the RERP.	To remove ambiguity from the procedure and to assure correct staffing prior to activation of the facility. **(PIR 96-0428)**
Need to evaluate a revision to the Emergency Program at WCNOC. This revision should provide a mechanism for accounting for personnel who are responding to a non-radiological event, the need to establish a assembly point outside of the exclusion area and the need for an assembly point inside the exclusion area.	To provide enhanced response to non-radiological emergencies which require the activation of the Emergency Program. **(PIRs 96-0424 and 96-0427)**
Need to develop a non-emergency callout method for the TSC/OSC/ERO Personnel.	To provide the operating crews with a simple and fast tool for obtaining the necessary assistance to

	respond to a non-radiological emergency **(PIR 96-0428)**
During the icing event pagers were activated but the ADS Machines indicated that an emergency was not declared. Need to change message on ADS Machine to eliminate confusion during an event where the TSC is being staffed but an emergency has not been declared.	To eliminate confusion and to assure personnel respond when needed. **(PIR 96-0260)**
During the icing event security failed to make the NUE announcement for the buildings not covered by Gatronics. Review announcement methodology to assure proper tools are made available to assure announcements are made in a timely manner.	To ensure all personnel are informed of an emergency **(PIR 96-0261)**
During the icing event two NUEs were declared. It has been determined that the procedure do not provide adequate guidance on how to terminate an event. Revise procedures to provide adequate event termination guidance.	To eliminate confusion which occurred during the icing event. **(PIR 96-0296)**
During the icing event WCNOC made several emergency notifications. A review of the notification revealed minor form completion inconsistencies. Perform a review to determine if action is warranted.	To provide greater assurance forms are completed correctly. **(PIR 96-0346)**
Misalignment of ESW System	
Recommended Action	**Purpose**
Management will reiterate expectations that plant personnel will obtain and utilize the applicable procedures when performing a task. Under special conditions the Shift Supervisor may	To assure procedure use and adherence in accordance with management expectations. **(PIR 96-0541)**

direct Control Room personnel to conduct activities without the aid of procedures provided that a verification of actions taken per the approved procedure is conducted in a timely manner.	
Delayed Cooldown	
Recommended Action	**Purpose**
Perform a review to determine if Reactor Engineering/Management has provide adequate guidance on when and how it is appropriate to implement actions to control ΔI.	To eliminate confusion and delays in performing a rapid cooldown. **(PIR 96-0362)**
Need to enhance Shutdown Margin Calculation Program to address plant coastdown practices.	The program did not encompass this operating aspect and as a result did not function correctly during the 1/30/96 reactor trip event. **(PIR 96-0406)**
Need to consider including Reactor Engineering personnel in selected simulator training scenarios.	To provide the operating crews and the reactor engineers with the opportunity to practice interface activities under stress conditions and to give the reactor engineer a perspective on maneuvering the plant and a sense of urgency with regard to operational concerns during these periods. **(PIR 96-0416)**
Probabilistic Safety Assessment	
Recommended Action	**Purpose**
PAS models for ESW and SW did not model warming lines in the fault tree. The models will need to be revised.	To correctly model all possible system faults. **(PIR 96-0412)**

Frazil Ice Training	
Recommended Action	**Purpose**
The IIT recommended that frazil ice formation and contingencies for its formation be included in applicable training material.	To provide the operating crews with enhanced knowledge of frazil ice and the methodologies of retraveling it. **(PIR 96-0415)**
Auxiliary Boiler	
Recommended Action	**Purpose**
During the recent icing event the boiler tripped several times. Perform an evaluation to determine the adequacy of this component's operation and the need for improved performance	To prevent un-need distraction to the operating crew and to prevent equipment damage. **(PIR 96-0417)**

X. APPENDICES: