U.S. NUCLEAR REGULATORY COMMISSION

REGION III

Report No. 50-254/91006(DRP)

Docket Nos. 50-254 Licenses No. DPR-29

Licensee: Commonwealth Edison Company
Opus West III
1400 Opus Place
Downers Grove, IL 60515

Facility Name: Quad Cities Nuclear Power Station, Unit 1

Inspection At: Quad Cities Site, Cordova, Illinois

Inspection Conducted: January 26 through February 5, 1991

Inspector: S. G. DuPont

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Date 2/14/91

Inspection Summary

Inspection from January 26 through February 5, 1991 (Report No. 50-254/91006(DRP)
Areas Inspected: Special, announced safety inspection of the licensee's activities associated with the January 24, 1991 loss of reactor vessel inventory event.
Results:

- The Team concluded that two loss of coolant inventory events occurred at Quad Cities Unit 1 on January 24, 1991. The first occurred when an electrician locally opened the shutdown cooling pump suction valve (1-1001-43D) while the shutdown cooling valve (1-1001-50) was open. This resulted in a loss of about five inches of water level from the reactor vessel. The second occurred when the control room operator opened the isolation valve (1-1001-50) refilling the drained shutdown cooling header.

The second event resulted in a loss of about nine inches of reactor vessel inventory. Both losses had a flow through open vent and drain valves on the idle loop of the resident heat removal system to the reactor building floor drain.

- A total of 4200 gallons of water was lost to the reactor building floor drain. (2800 gallons from the reactor vessel, 1400 gallons from the shutdown cooling header).

- Root causes included the lack of management and supervisory involvement and personnel errors.

- Several instances of failure to adhere to administrative, operations and maintenance procedures occurred.

- The governing procedure for temporary lifting of out-of-services was found to be inadequate by not providing adequate guidelines and overview of the process.

- A significant lack of questioning attitude was found as demonstrated by the actions of the Senior Journeyed Electrician, Station Control Room Engineer, Nuclear Station Operator and communications center staff.

- Overview of both the control room and in-plant activities was inadequate.

- The control room, electrical maintenance and communications center staffs demonstrated an inadequate awareness of plant status.

- Communications, both inside and outside of the control room, were inadequate.

Two apparent violations were identified. The first apparent violation is comprised of five instances where procedures were not adequately followed as described in paragraphs 7.b. and 8. The second apparent violation is for an inadequate procedure for temporary lifts as described in paragraph 7.b.

TABLE OF CONTENTS

DETAILS

1. Persons Contacted

a. Commonwealth Edison Company (CECo)

D. Galle, Vice President - BWR
*N. Kalivianakis, General Manager - BWR
*R. Bax, Station Manager
*G. Spedl, Production Superintendent
*R. Robey, Technical Superintendent
*K. Smith, Nuclear Quality Assurance
*J. Tietz, Superintendent of Station Programs
*J. Swales, Assistant Superintendent - Operations
*W. McGaffigan, Assistant Superintendent - Work Planning
*D. Craddick, Assistant Superintendent - Maintenance
*T. Tamlyn, Site Project Manager - ENC
*J. Sirovy, Services Director
*A. Lewis, Radiological Protection Supervisor
*D. Gibson, Regulatory Assurance Supervisor
*R. Walsh, Technical Staff Supervisor

b. Persons Interviewed

Brian Bitler, Electrical Maintenance, Senior Journeyed Electrician
Bob Decker, Electrical Maintenance, Journeyed Electrician
Jerry Snyder, Electrical Maintenance, Apprentice Electrician
Jack Huizenga, Electrical Maintenance Foreman
Robert Lundstrom, Nuclear Station Operator
Robert Dammann, Station Control Room Engineer
John Brassard, Shift Foreman
Michael Graham, Engineering Assistant
James Guest, Shift Engineer
Guillermo Rojas, Nuclear Station Operator
Gary Spedl, Production Superintendent
Mike Pacilic, Master Electrical Maintenance
Charles Norton, Station Control Room Engineer
David Cook, Master Instrument Maintenance
Mike Turbak, Superintendent of On-Site Safety Groups
Dan Gibson, Regulatory Assurance Supervisor
Gerry Teitz, Superintendent of Station Programs
Joseph Manemann, Shift Engineer
Daryl Clark, Shift Engineer
John Lange, Electrical Maintenance Foreman
Kevin McCabe, Nuclear Station Operator
Mark Kooi, Operating Engineer

c. Nuclear Regulatory Commission

*W. D. Shafer, Branch Chief, Division of Reactor Projects
*B. L. Burgess, Section Chief, Division of Reactor Projects
*S. G. Du Pont, Team Leader, Special Inspection Team

R. M. Lerch, Assistant Team Leader, Special Inspection Team
G. West, Team Member, Special Inspection Team
*R. Bocanegra, Team Member, Special Inspection Team
*J. Shine, Team Member, Special Inspection Team
*T. Taylor, Senior Resident Inspector - Quad Cities

Note: * Indicates those in attendance at the exit meeting on February 4, 1991.

2. Formation of the Special Inspection Team

On January 25, 1991, NRC Region III formed a special inspection team to evaluate the licensee's actions associated with the loss of reactor vessel inventory event at Quad Cities Nuclear Power Station Unit 1 on January 24, 1991. The Team consisted of the team leader, S. G. DuPont, Senior Resident-Braidwood, assistant team leader, R. Lerch, Project Engineer-Region III, R. Bocanegra and J. Shine, resident inspectors-Quad Cities, G. West, Nuclear Reactor Regulations (NRR)-Human Factors and J. DeBor, consultant on human factors from Science Applications International, Inc. The Team was assigned a charter on January 25, 1991 and arrived onsite on January 26, 1991.

3. Description of Event

The following description of the event was developed upon review of operating logs, strip charts, and interviews conducted during the inspection. Some of the times listed are approximate.

On January 23, 1991, in preparation for testing the shutdown cooling pump suction valves (1001-43C and 1001-43D) on the residual heat removal (RHR) system, a temporary lift (TL) was initiated to allow stroking of the valves as part of a post modification test. The temporary lift was requested by electrical maintenance through the operations Shift Engineer (SE). The SE included special instructions with the TL request to the engineering assistant indicating that shutdown cooling (SDC) was to be off, the shutdown cooling suction valve (1001-50) closed, and that caution cards be placed on the 1001-43 C and D valve control switches in the control room. The TL preparer and the TL verifier were tasked with incorporating the special instructions, reviewing the applicable out-of-service (OOS) cards, and determining adequate electrical and piping boundaries to perform the evolution. The TL was verified on January 23, 1991, and implemented prior to 7:00 a.m. on January 24, 1991. Operations personnel including the Unit 1 Nuclear Station Operator (NSO) were briefed by the off-going operating engineer at the 6:00 a.m. planning meeting on January 24, 1991, and also by the SE during the routine shift brief in the control room at 7:00 a.m. The need to ensure that the 1001-50 valve was closed prior to the stroking of the shutdown cooling pump suction valves was emphasized. The Electrical Maintenance (EM) Foreman independently briefed the electrical maintenance crew prior to starting work and also emphasized the need to receive permission from the control room prior to stroking the valves.

The Electrical Maintenance Foreman and the Shift Control Room Engineer (SCRE) discussed stroking the valves at approximately 12:30 p.m., concluding that SDC would be secured just prior to stroking the valves, initiated by a call from the electrical maintenance crew that their instrumentation was in place and requesting permission to stroke the valves. At 12:40 p.m. the EM Foreman explicitly briefed the Senior Journeyed Electrician (who was to supervise two other electricians during the evolution) to notify the control room prior to stroking the valves. Subsequently, the Senior Journeyed Electrician closed the breaker providing power to the 1001-43D valve prior to notifying the control room. At 1:18 p.m. the Journeyed Electrician, who had local control of the valve and was in direct communication with the Senior Journeyed Electrician at the breaker, assumed that the proper notifications were made and permission received, and stroked the valve without further verbal notification. The electrician at the valve heard water rushing through the valve, surmised that it was abnormal, closed the valve, and informed the Senior Journeyed Electrician. The Senior Journeyed Electrician then notified the Unit 1 NSO that a partial stroke of the 1001-43D valve had occurred but failed to mention that flow had been heard through the valve. The reactor vessel level decreased approximately five inches but was not noticed by the NSO. In this configuration, vessel water passed through the 1001-50 valve into the RHR "B" loop SDC piping and through the 43D valve. It then passed through three out-of-service open "B" loop vent and drain valves to the "B" reactor building floor drain sump, which overflowed, spilling water onto the basement floor. The NSO then closed the 1001-50 valve, the 1000-29A (LPCI inboard injection valve) and turned off the "A" RHR pump. At this point SDC was secured but the NSO observed higher than expected pressure in the "A" RHR pump discharge line. The NSO authorized the Senior Journeyed Electrician to continue stroking the 43 valves. The 43D valve was stroked consecutively on three occasions, once by the NSO. This resulted in partially draining the SDC header between the isolation and pump suction valves through the open vent and drain valves to the reactor building floor drains. The NSO did not inform the SCRE of any concerns or anomalies at this time.

At approximately 1:26 p.m., the Unit 1 NSO turned over the unit to the control room extra NSO, who was cognizant of plant status but also unaware of the coolant loss. The Unit 1 NSO returned to the control room several minutes later and was informed shortly thereafter (approximately 1:35 p.m.) that there was water on the floor of the Unit 1 reactor building basement. The Unit 1 NSO had recently been involved in an RHR heat exchanger relief valve lift event on the service water side and along with the previous concern for high pressure noted above, surmised that a relief valve on the RHR side of the heat exchanger had lifted. At 1:38 p.m. the Unit 1 NSO instructed the Senior Journeyed Electrician (via the paging and telephone system) to close the 43 valves. The NSO verified the 43 valves closed through panel light indication and then cycled the 1001-50 valve to relieve the high RHR pressure back to the vessel. Approximately 9 inches of vessel water passed through the 1001-50 valve and refilled the shutdown cooling header up to the closed 43 valves. The Unit 1 NSO was not aware of this and informed the Senior Journeyed Electrician that stroking of the valves could continue. The continued

stroking of the 43 valves allowed the SDC piping to drain again into the reactor building basement sump, culminating with a reduction in inventory of approximately 4200 gallons, with 2800 gallons originating from the vessel, and 1400 gallons from the shutdown cooling header.

At approximately 1:40 p.m., the EM Foreman (who had previously been informed by the Senior Journeyed Electrician of the 1:18 p.m. partial stroke of the 1001-43D valve with the 1001-50 valve open, and had just overheard the NSO paging the Senior Journeyed Electrician) called and informed the SCRE of the previous error by the electricians. The SCRE, with the EM Foreman on the line, stepped over to the panel, verified SDC was secured, the 1001-50 valve was closed, and vessel level was stable. The SCRE then informed the EM Foreman that the electricians were authorized to continue their work. Concurrently, the center desk NSO was informed by an equipment attendant (EA) (who was dispatched after the 1:35 p.m. notification of water) that there was water on the basement floor and the RHR pump vents and drains were open. The SCRE, who was on the phone with the EM Foreman, was not made aware of the EA report for several minutes.

At 2:11 p.m. the Shift Engineer entered the control room and had a discussion with the SCRE and Unit 1 NSO. The NSO was then instructed to inform the Senior Journeyed electrician to stop work. However, the electricians had previously completed their last stroke of the valves, verified by a strip chart recording, at approximately 2:10 p.m.

4. SEQUENCE OF EVENTS

1/23/91 Temporary lift of Out-of-Service on RHR valves 1001-43C, 43D, 7C and 7D to perform post modification installation testing was requested by Electrical Maintenance. The request was received by the Shift Engineer (SE) to determine the boundary of the system.

A communication center engineering assistant completed the temporary lift package. The package included breakers, handwheels and control switches only. The boundary was believed to be adequate by establishing the SE recommended caution tags on the shutdown cooling suction valve control switches. However, no vent and drain valves were included.

Temporary lift (TL) package was reviewed and verified by a Shift Foreman. However, including the vent and drain valves as part of the TL package was missed during the Shift Foreman's review.

NOTE: The boundary established by the caution tag, with the vent and drain valves open, still provided a path that would have resulted in draining the SDC header (about 1400 gallons) to the reactor building floor drains.

1/24/91 (Prior to 7:00 a.m.)

Temporary lifts were performed and caution tags were placed on control room valve control switches for 43C and 43D.

NOTE: Caution tags were not placed at either the MCC breaker or valve handwheels as recommended by administrative procedures.

6:00 a.m. The Operating Engineer briefed day shift operations management on scheduled activities, including the 43 valves.

7:00 a.m. The Shift Engineer briefed the operating crew including the Unit 1 NSO on scheduled activities, including the requirement to remove shutdown cooling from service and close the suction valve (1001-50) prior to stroking the 43C or 43D valves.

7:00 a.m. The Electrical Maintenance Foreman briefed the electricians on the scheduled work on the 43C and 43D valves. The Senior Journeyed Electrician was informed that shutdown cooling had to be off before stroking the 43C or 43D valves.

NOTE: Both briefings were independent and did not involve a job task briefing with the operations and maintenance cognizant individuals to discuss communications, limitations or actions to be taken if problems should arise.

7:30 a.m. The EM Foreman received permission from the SCRE to test the 7C and 7D valves. The SCRE also informed the EM Foreman that shutdown cooling must be off before stroking 43C or 43D.

8:00 a.m. The SCRE reviewed prints and verified that 3 drain valves were closed and out of service but failed to detect that 3 other vent and drain valves were open.

9:30 a.m. Started testing 7C and 7D valves; completing at about noon.

12:30 p.m. The SCRE notified the EM Foreman that operations would be able to stop shutdown cooling; but to call operations for permission and that the SCRE will give approval.

12:40 p.m. The Senior Journeyman Electrician called the Unit 1 NSO and asked if there was a problem with stroking the 43's. The NSO responded that it was O.K., but to call back so shutdown cooling could be removed from service first.

NOTE: The EM did not call the SCRE nor did the NSO inform the SCRE.

12:45 p.m. The EM Foreman again briefed the Senior Journeyed Electrician that shutdown cooling was to be removed and the 50 valve closed before stroking the 43 valves and instructed that they could hook up the test equipment but not to stroke the valves until the Senior Journeyed Electrician called operations.

Between 12:45 and 1:18 p.m.

The test equipment was hooked up.

The Journeyed Electrician at the valve (the Senior was three elevations above the valve at the MCC breaker and the phone) requested via radio that the Senior close the breaker.

Between 1:18 and 1:19 p.m.

The Journeyed Electrician stroked the 43D valve about 3/4 of full stroke open and heard a rush of water past the valve. The Journeyed Electrician started closing the valve.

The Journeyed Electrician at the valve notified the Senior Journeyed Electrician via radio that water was heard rushing past the valve.

The Senior Journeyed Electrician directed the Journeyed Electrician to close the 43D valve. The valve was closed.

1:18 p.m. The reactor vessel water level decreased about 5 inches, unnoticed by the control room staff.

1:19 p.m. The Senior Journeyed Electrician contacted the Unit 1 NSO and stated that the 43D valve had been partially open and closed and asked to have shutdown cooling removed.

NOTE: No information about the rush of water past the valve was passed on to the control room, nor did the NSO question the effect on the system of operating the 43D valve with shutdown cooling on and the 50 valve open.

The EM Foreman arrived at the MCC and was briefed by the Senior Journeyed Electrician on the out of sequence operation of the valve.

1:20 p.m. The NSO stopped shutdown cooling and closed the 50 valve. The NSO told the Senior Journeyed Electrician that the 50 valve was closed and to continue testing.

The RHR discharge pressure spiked off scale and appeared to settle at about 300 psig (due to "normal" response from securing shutdown cooling per the procedure). The NSO believed the spike was abnormal in that the pressure increased faster than expected.

NOTE: The NSO did not observe reactor vessel level.

Between 1:20 and 1:34 p.m.

The Electricians completed stroking the 43D valve two more times at 1:34 p.m., then the NSO stroked the valve from the control room.

The Senior Journeyed Electrician called and received permission from the NSO to test the 43C valve. The Electricians began testing the 43C valve.

NOTE: No loss of inventory occurred with the stroking of the 43C valve since the closed 50 valve bounded the system from the reactor vessel. However, since the shutdown cooling header remained partially full, the header partially drained each time the 43D or 43C valves were opened.

NOTE: Also, the SCRE was still unaware that the 43D and 43C valves were being stroked.

The center desk and unit NSOs received notification by the Operations Shift Foreman of water on the reactor building basement flood and dispatched an Equipment Attendant.

Reactor building sump alarms. (One of the sump alarms was previously up, and the second is believed to have alarmed at this time. However, the alarm printer did not indicate and the NSO was not aware of the time associated with the alarm.)

The NSO pages the Senior Journeyed Electrician. This page may have alerted the EM Foreman.

The Unit 1 NSO instructs the Senior Journeyed Electrician to close 43 valves.

The Equipment Attendant reports back to the control room that water is on the floor, that the EMs are in the area and that the pump vent and drain valves are open. (The SCRE failed to receive this information.)

The NSO believed the water is from a lifted RHR relief valve, due to the perceived high pump discharge pressure.

1:38 p.m. The NSO cycled the 50 valve open and closed to relieve back to the vessel the perceived high RHR discharge pressure. (This action set up the Second loss of inventory by refilling the shutdown cooling header.)

NOTE: Throughout these actions, the NSO did not communicate to the SCRE that any problems existed.

Reactor vessel level drops an additional 9 inches unobserved.

The NSO notified the Senior Journeyed Electrician to continue testing. The testing continues to drain the shutdown cooling header to the reactor building floor drains.

1:39 p.m. The NSO observed that the reactor vessel level was stable at 72 inches and is aware that level had decreased 14 inches. The extra and unit NSO ran a point history of vessel level which indicated that level decreased twice. This information was relayed to the SCRE.

NOTE: The NSO was not previously aware that level dropped over 14 inches because the NSO had not documented in the unit logs what the initial level was at the beginning of the shift or prior to the start of the valve stroking. The NSO's log only stated that level was about 18 inches below the main steam lines. Also, earlier in the shift, the 1B recirculation pump had been started and the NSO did not note the vessel level.

1:40 p.m. The SCRE was notified by the EM Foreman that an error had occurred during the testing of the 43D valve. The SCRE went to the unit control panels and verified that the 50, 43D and 43C valves were closed, that reactor level was stable, and that shutdown cooling was off. (The SCRE failed to inquire about any problems with the NSO.)

The center desk NSO informed the Shift Foreman and SCRE about the report on the vent and drain valves being open, but the SCRE didn't hear the report while on the phone with the EM Foreman. (Sometime later the SCRE talked directly with the Equipment Attendant and learned about the loss of water.)

2:11p.m. The Shift Engineer entered the control room and work was stopped.

NOTE: Sometime before the work stopped, valve testing was completed.

5. System Description

The design bas's of the shutdown cooling (SDC) mode of the Residual Heat Removal (RHR) system is to remove decay heat and sensible heat from the primary system so that the reactor can be shut down for a refueling and servicing operation. The SDC mode cools the vessel by taking suction from the recirculation system vessel outlet line and discharges to the recirculation system vessel inlet line. The system contains two redundant loops which have a common suction path from the recirculation system vessel outlet line through two motor operated isolation valves (1001-47 and 50). Each loop consists of two RHR pumps, one RHR heat exchanger and two RHR service water pumps. The SDC suction line of each RHR pump contains a motor operated isolation valve (1001-43A, B, C, D) from the SDC header downstream of 1001-47 and 50 valves. The 1001-47 and 50 valves are group 11 primary containment isolation valves and will automatically close should an isolation signal (+ 8 inches reactor vessel water level) occur. Contained in each loop are various manual vent and drain valves downstream of the 43 valves, including the 1001-27 and 1001-128 (RHR loop to reactor building floor drain sump drain) valves which provide a 3" path from the suction line of each RHR pump to the reactor building floor drain sumps. (Attachment 2 provides a single line diagram of the shutdown cooling system.)

6. Valve Testing Description

The test evolution being performed by the electrical maintenance crew was a construction test to verify that the electrical work had been done correctly on the motor operated valves. This included electrically actuating the valve to verify such things as proper valve movement and limit switch set points. To facilitate doing this, the electricians installed a test box at the valve which allowed them to manipulate it. The valves were out-of-service, therefore the operations department had aligned the system so this could be safely done. The installation of the test box disconnected the control leads to the control room or any other remote operation switch. The test box had spring loaded buttons which allowed the electrician to move the valve in either direction and observe the valve motion. When a button was released, valve motion stopped. After the box was installed, the power had to be restored to the valve operator. The Senior Journeyed Electrician was to obtain permission from the control room before closing the breaker restoring power. However, the Senior Journeyed Electrician failed to obtain this permission, closed the breaker, and the Journeyed Electrician locally opened the valve using the test box.

It is also important to note that the Senior Journeyed Electrician had been made aware of the requirement to obtain permission from the control room on three separate occasions, twice by the Electrical Maintenance Foreman and once each by the control room Nuclear Station Operator.

7. Operations Department and Communications Center Involvement

a. Narrative

The operations department and communications center involvement in the event was extensive, in that operations' objective was to establish a proper boundary to perform the evolution and protect the reactor vessel from uncontrolled inventory loss. The initial step to achieve the objective included processing the temporary lift (TL) request in accordance with administrative procedure QAP 300-55. The process included Shift Engineer (SE) authorization and determination of the impact on the plant, Engineering Assistant preparation of the isolation boundary checklist and independent Senior Reactor Operator (SRO) verification of the checklist. The Engineering Assistant and a Senior Reactor Operator (SRO), in this case, were required to scrutinize approximately nine existing out-of-service (OOS) cards on the idle "B" loop of the residual heat removal (RHR) system for applicability to the requested TL. Two drain valves (1001-27 and 1001-128) and a pump casing vent were inadvertently not included for closure in the TL which provided a path for draining the RHR suction header and possible reactor vessel draindown through the 1001-43D and 1001-43C valves. In addition, the boundary was established with caution cards requiring the closure of the 1001-50 valve and securing of shutdown cooling (SDC). These caution cards were placed in the control switches for the 1001-43C and D valves in the control room. Several briefings were held for operations management and control room staff. Emphasis was placed, at these briefings, on the need to ensure shutdown cooling (SDC) was off and the shutdown cooling isolation valve (1001-50) was closed prior to stroking the shutdown cooling pump suction valves (1001-43C and D). The Station Control Room Engineer (SCRE) and Electrical Maintenance Foreman responsible for the valve testing, also had a discussion at approximately 12:30 p.m., concluding that SDC would be taken off just prior to stroking the valves. The Senior Journeyed Electrician supervising the valve test was to inform the Nuclear Station Operator (NSO) when ready to stroke, to insure that SDC was secured, and the 1001-50 valve was closed.

The NSO received a call from the Senior Journeyed Electrician at approximately 1:18 p.m. informing him that a partial stroke of the shutdown cooling (SDC) pump suction (1001-43D) valve had occurred. The NSO, unaware that vessel level had decreased five inches, removed and isolated SDC, and told the Senior Journey Electrician that testing could continue. The NSO had previously failed to observe the light indication of the 1001-43D valve on the 901-3 control room panel indicating that the breaker had been closed, or the intermediate indication indicating the valve stroke was in progress. The NSO observed high pressure on the discharge side of the RHR "A" loop when taking SDC off, but failed to address this condition or inform the SCRE of any problems at that time. Reactor vessel level had decreased five inches utilizing a path through the 1001-50 valve, SDC piping, 1001-43D valve, RHR loop vents and drains

and overflowed the "B" reactor building floor drain sump (2200 gallon capacity), and ran onto the reactor building basement floor. Apparently the sump high level alarm was previously acknowledged, but not cleared.

About 20 minutes after stopping SDC, the NSO received a report of water on the reactor building basement floor. The NSO, reacting to high RHR pressure, water on the floor, and a recent event involving the lifting of a relief valve, surmised that a RHR heat exchanger relief valve had lifted. The NSO then paged the Senior Journeyed Electrician, instructed the closing of the 1001-43C and D valves, verified them closed by control room light indication, and cycled the 1001-50 valve, relieving the perceived high RHR discharge pressure back to the reactor vessel. Reactor level decreased nine inches through the open 1001-50 valve, but was not noticed by the NSO. The NSO then gave permission to the Senior Journeyed Electrician to continue testing. After these actions, the unit NSO and control room extra NSO became curious about reactor level and pulled up the computer point history, which indicated two step level drops had occurred. It appears that an attempt was made by the NSO to inform the SCRE at this time, but apparently the essence of the information was lost, as the SCRE remained unaware of the level drops. Concurrent with the cycling of 1001-50 valve, the SCRE received a call from the EM Foreman, who responded to the page by the NSO, to inform the SCRE of the previous inadvertent opening of the 1001-43D valve. The SCRE walked over to the Unit 1 panels, verified level was stable, the 1001-50 valve was closed, and SDC was secured. The SCRE then returned to the phone and informed the EM Foreman to continue stroking the valves. The SCRE was also unaware of the Reactor Vessel level drops or water on the basement floor, or communications between the center desk NSO and an Equipment Attendant which revealed that the RHR pump vent and drain valves were open. The SE entered the control room at 2:11 p.m., held discussions with the NSO and SCRE, and participated in a decision to stop the valve stroking.

b. Summary

The Team found that several of the root causes associated with the event related to operations and communications center personnel. The Nuclear Station Operator (NSO), communications center staff and Station Control Room Engineer demonstrated a lack of a questioning attitude during the event. The NSO failed to question the consequences of the out of sequence movement of the shutdown cooling pump suction valve (1001-43D) which could have prevented the second event. The SCRE failed to question the NSO when given indications of a possible problem by the EM Foreman. The communications center staff failed to question the system boundary established by the Shift Engineer or the use of caution tags only in the control room.

The lack of attentiveness to plant status was also a root cause of the event. The NSO failed to observe several control board indications that could have alerted the control room staff of the

first inventory loss and prevented the second. The NSO failed to observe the return of valve indications when the electrical supply breaker to valve 1001-43D was closed. The most significant was the failure of the control room staff to observe a five and nine inch vessel level drops, indicating the loss of inventory.

A lack of adequate overview by operating's supervision existed throughout the event. The inadequate evaluation of the temporary lift boundary, inadequate awareness of plant system status, and failure to ensure that the individuals involved with the evolution understood their required actions demonstrated the lack of involvement of management and supervision in daily operations.

The failure to adequately communicate vital plant status information during the event was a significant root cause. The electrical maintenance personnel failed to communicate important information pertaining to the existence of the first event to the control room staff. The NSO failed to communicate the valving error, that valve stroking was ongoing or the perceived high RHR discharge pressure to the SCRE. Subsequently, the NSO failed to communicate, to the SCRE, the actions taken to relieve the perceived discharge pressure.

Operations procedure OOP 1000-6, Shutdown Cooling Shutdown, Revision 7 (June 27, 1990), Section F.12, requires the Nuclear Station Operator (NSO) to verify that the residual heat removal (RHR) system discharge pressure is less than 90 psig after stopping the pump. The Unit 1 NSO noted that RHR discharge pressure had spiked off scale and returned to about 300 psig after stopping the pump. The NSO failed to take any action for about 18 minutes to ensure that RHR discharge pressure was less than 90 psig. This is an apparent violation (254/91006-01b) of Technical Specifications 6.2 which requires adherence to procedures.

Administrative procedure QAP 300-1, Operations Department Organization, Revision 19 (June 11, 1990), Section C.10.p, requires the NSO to be attentive to the control room board indications. During the event, several indications of the loss of inventory went unobserved by the NSO. The NSO failed to observe that the valve position indication lights for the shutdown cooling pump suction valve (1001-43D) when the Senior Journeyed Electrician closed the power feed breaker to the valve, indicating that the electricians had started testing of the valve without permission from the control room. This was a missed opportunity to prevent the first loss of inventory. In addition, the NSO failed to observe two vessel water level decreases of five and nine inches, and possibly a reactor building sump alarm. This is an apparent violation (254/91006-01c) of Technical Specifications 6.2 which requires adherence of procedures.

Administrative procedure QAP 300-2, Conduct of Shift Operations, Revision 29 (December 31, 1990), Section C.14.i requires in part, that evolutions involving many individuals, especially from two or more departments or disciplines, may require large formal briefings or preplanning sessions. If the evolution is complex and involves close coordination, the briefing session shall be coordinated by the Operating Engineer or designee and should include: examination of each individuals responsibility; discussion of expected results or performance; review of limitations, hold points, emergency action to be taken if contingencies arise; and assurance that everyone understands the interface and communications required. Although the actual stroking of the valves by electrical maintenance personnel was not complex nor required individuals between two departments, the evolution of stroking these valves required close coordination between several individuals from operations and maintenance department to remove shutdown cooling and provide isolation protection for the vessel. Since the evolution had the potential of draining the vessel, close coordination was required and this coordination of communications and operations resulted in valve stroking becoming a complex evolution. Since the licensee's briefings on January 24, 1991, did not include discussions of actions to be taken if contingencies arise, examination of each individuals responsibility, and assurance that everyone understood the interface and communications required, this is an apparent violation (254/91006-01d) of Technical Specifications 6.2, which requires adherence to procedures.

Administrative procedure QAP 300-2, Section C.28.c states that the Station Control Room Engineer (SCRE) shall have the responsibility of controlling control room activities to assure safe plant operation. The SCRE failed to maintain the responsibility of controlling activities within the control room and several occasions during the event. The actual evolution of stroking the valves occurred without the awareness of the SCRE. The Unit 1 Nuclear Station Operator (NSO) secured shutdown cooling without the SCRE's awareness. The NSO operated the shutdown cooling suction isolation valve (1001-50) to relieve perceived high residual heat removal system discharge pressure without the SCRE's awareness. This is an apparent violation (254/91006-01e) of Technical Specifications 6.2, which requires procedure adherence.

During the review of administrative procedure QAP 300-14, it was noted that QAP 300-14 did not provide appropriate guidance for preparation and overview of the temporary lift process. The procedure failed to assign responsibilities and to provide guidelines for establishing appropriate temporary lift system boundaries and performing a review for boundary adequacy. As a result, the operations communications center staff failed to establish and independently verify an adequate system boundary to test the shutdown cooling (SDC) pump suction valves on the idle loop of RHR and include the vent and drain valves. This resulted in three vent and drain valves being open, providing a leakage path when the shutdown cooling pump suction valve, 1001-43D, was opened with the isolation valve open. This is

an apparent violation (254/91006-02) of 10CFR50, Appendix B Criteria V, which requires that procedures are of a type appropriate to the circumstances. QAP 300-14 was not appropriate to the circumstances of controlling the temporary lift process.

8. Electrical Maintenance Involvement

Electrical Maintenance (EM) personnel had previously modified the motor operators on the 1001-43C and 1001-43D valves. These valves were previously taken out-of-service so this and other work on the system could be done. When the work was complete, a request for a temporary return to service, called a temporary lift (TL) was submitted to the operations department. This was to allow the verification of the work. When the temporary lift was ready, it was discussed in the shift briefing for operations and the daily planning meeting. The EM Foreman attended these meetings and discussed the testing with the SCRE. In each of these discussions, it was communicated that the control room would be notified and permission obtained prior to manipulating these valves so that isolation of the reactor vessel could be done using the 1001-50 valve. The EM Foreman also briefed the electricians on these requirements and that the work package contained a precaution to notify the control room prior to manipulating valves. The Senior Journeyed Electrician was tasked with notifying the control room and initially contacted the control room from the electrical shop and discussed the work with the Nuclear Station Operator (NSO) to make sure it was alright to proceed with the job. The NSO reiterated that the electricians could proceed to get ready but to call before stoking the valves. The plant physical arrangement required that the Senior Journeyed Electrician be at the electrical breaker panel several levels above the Journeyed Electrician at the valves and that headphones be used for communications. An electrical test box was already installed so the Journeyed Electrician at the valve asked the Senior Journeyed Electrician to close the power breaker. After the Senior Journeyed Electrician closed the breaker, the Journeyed Electrician proceeded to open the valve (1001-43D), immediately heard water rushing past the valve and closed it. The Journeyed Electrician informed the Senior Journeyed Electrician about the opening of the valve and the results. The Senior Journeyed Electrician realized that an error had been made and immediately informed the NSO that the 1001-43D valve had been opened and then closed. However, no mention of the sound of water was made. The NSO then closed the 50 valve and gave permission to resume testing. Electrical maintenance procedure QEMP 600-1, Electrical Maintenance of Safety Related and Non-Safety Related Motor Operated Valves, Revision 7 (December 29, 1990), Section D.1, requires that prior to moving a motor operated valve off of either the open or closed seat, permission will be obtained from the Operations Department. The electrical maintenance personnel moved the shutdown cooling pump suction motor operated valve (1001-43D) off of the open seat without obtaining permission from the Operations Department. This is an apparent violation (254/91006-01a) of Technical Specifications 6.2, which requires adherence to procedures.

9. Licensee's Corrective Actions

In response to the event the licensee implemented the following corrective actions.

a. Immediate Corrective Actions

When the event was recognized by station management, corrective actions were immediately put in place. This included actions taken by the Shift Engineer at the conclusion of the inadvertent draining and subsequent actions taken by management until such time the event could be further investigated. These actions are listed below:

(1) The Shift Engineer discontinued further valve testing until the situation could be better understood.

(2) The Shift Foreman and the Communications Center EA were removed from all activity related to out-of-service work.

(3) The NSO was removed from Control Room panel responsibilities until after the licensee's investigation and a determination of appropriate actions was made.

(4) The Senior Journeyed Electrician was removed from work responsibilities until after the licensee's investigation and a determination of appropriate action was made.

(5) All further valve manipulations by non-operating departments were disallowed until specific guidelines were established.

(6) All oncoming shift operators were briefed on information relative to the event. Specific emphasis was placed on the out-of-service program, communications between work groups, maintaining a questioning attitude towards your job, job briefings, and how these issues related to the event.

(7) The Operating Engineers were tasked with performing independent reviews to verify all out-of-services, temporary lifts, and return-to-services. This verification will continue until the licensee's outage organization is implemented.

(8) A control room overview function was implemented with a senior reactor operator (SRO) trained individual to specifically assess/correct communication problems within the control room. This was implemented on all shifts beginning January 28, 1991. This function will continue until the new outage organization is implemented.

(9) Specific valve stroking guidelines were written and approved which delineated the exact rules to follow for a non-operating department to manipulate a valve to maintain operating department control. A new procedure was written to implement the new guidelines before this related work began.

(10) The Outage Unit Operating Engineer will meet daily with the Assistant Superintendent of Operations and Production Superintendent to discuss upcoming important outage activities.

(11) The licensee's investigation team was assembled on January 24, 1991, to begin gathering the facts of the event. This team was supplemented by corporate personnel on January 25. Additionally, a team of corporate and personnel from an independent third party organization joined the licensee's investigation team on January 27, to add a broader perspective to the issues being addressed at CECo's request.

b. Licensee's Investigative Team Recommended Corrective Actions

Based on the information gathered by the licensee's investigation team, the following recommended corrective actions were presented to station management:

(1) Assurance that management's standards are being communicated to all station personnel by:

(a) Documenting management's standards to implement a safety culture.

(b) Conducting a station meeting to express management standards.

(c) An ongoing effort by senior management to convey its standards to the workers in the plant.

(d) A training session focused on determining what the workers perception of plant management's standards are,

(e) Specifically addressing the issue of workers exhibiting a questioning attitude.

(2) The station should revise the control room organization to place additional licensed supervisory personnel in the control room to allow greater involvement in plant activities.

(3) Establish a station policy that identifies critical tasks and specifies the precautions to be considered prior to performing these tasks. These precautions would include items such as holding a group briefing, as necessary.

(4) Develop a critical task list per the policy statement in item 3, above, using lessons learned from industry, CECo, and station experiences. The list should be proceduralized.

(5) Establish a station policy which requires a multi-disciplinary review of critical tasks to be coordinated by the planning department. This review would be a comprehensive look at all possible options including planning of the activity, scheduling the activity at the proper time and evaluating the potential risks involved.

(6) The station should implement a self-check program.

(7) The station should discontinue use of partial TLs.

(8) Revise the OOS procedure to limit a temporary lift to 8 hours.

(9) Rewrite the OOS procedure to accomplish the following:

(a) Establish required actions and criteria for all individuals implementing the procedure with emphasis placed on preparation and review. Produce a marked-up drawing of the identified boundaries in the OOS package.

(b) Establish specific training and qualification standards which are required to be fulfilled for the task of preparing OOS's.

(c) After the OOS procedure is revised, enhanced training should be given to personnel implementing the procedure. This enhanced training should include: review of individual's responsibilities, discussions of typical OOS problems, and appropriate lines of communications.

(d) Electrical outages which involve detailed print review should require face to face discussion of the Out-of-Service boundary between operating and electrical personnel to assure clear communications and understanding of what is needed.

(10) The quality assurance manual should be revised to eliminate the necessity for temporary lifts.

(11) Revise procedure QAP 300-13, Caution Cards, to give guidance on where the caution card should be hung to provide its expected benefit, and any elements of the CECo Production Instruction not already included in the procedure.

(12) Revise QEMP 600-1 to include a caution and/or sign-off to notify specific control room personnel immediately prior to valve manipulation. Additionally, provide this guidance to the periodic procedure review process and procedure rewrite project.

(13) The station should implement a policy requiring operators to perform breaker manipulations on installed equipment.

(14) The station should implement clear and concise rules on when non-operating departments can manipulate valves to assure Operating Department maintains complete control of plant equipment.

(15) Establish a policy for interdepartmental and intra-departmental communications at the station which includes:

(a) Formal communications training for necessary personnel.

(b) Establishment of clear formal lines of communication between departments.

(16) Methods should be established to assure all parties are aware of the work status for jobs requiring independent operations from separate locations. (e.g., duplicate checklists, clarifying and confirming communications, repeat backs, understanding of who is in charge, etc.)

(17) Personnel involved should be counseled on this event and action considered based on their performance.

(18) The following equipment changes should be submitted for review:

(a) Reactor building floor drain sump alarms

(b) Adjustable level alarms for computer points

(c) RHR Heat exchanger relief valve flow alarms.

10. Human Factors

The Team reviewed the January 24, 1991, event from the many human factors, training and human-system interfaces.

The Team found that the failure to recognize the loss of inventory reflected adversely on the training and qualification of both the Nuclear Station Operator (NSO) and Station Control Room Engineer (SCRE). The NSO was the weakest link in the operating chain. The NSO failed to recognize the first event and proceeded with the planned valve stroking, despite abnormal indications associated with reactor vessel water and reactor building sump levels. In addition, the NSO caused the second loss of inventory by opening the isolation valve (1001-50) without understanding the plant status.

The Communications Center Engineering Assistant, who reviewed the maintenance work request package and prepared the temporary lift package had not received formal training on systems and boundaries.

The Shift Foreman, who verified the temporary lifts, failed to recognize the system boundary problems. This reflected adversely on the quality of training.

The electrical and control room personnel demonstrated unacceptable skills with respect to communication and a team approach to performance of evolutions. This also reflected adversely on the quality of training associated with communications.

The Team also found that training on or knowledge of similar previous events at the Braidwood Station was not evident among most of the site personnel. Although plant management had implemented self reading of the Braidwood event, this effort was not completed prior to January 24, 1991. Additionally, corporate management had not implemented formal lessons learned prior to January 24, 1991.

The Team determined that the human-system aspects of the reactor building floor drain sump level alarms were a weakness. The sump alarms were known by the operators to annunciate spuriously. One of the alarms had annunciated continuously prior to the event and was considered to be spurious. This effectively removed an important indication to the control room staff. The Team indicated to the licensee that these alarms should be evaluated and to correct the spurious aspects of these annunciator alarms. The licensee agreed to include these alarms in their corrective actions.

11. Safety Significance

The safety consequence of the event was minimal due to the low probability of causing core damage by reducing the reactor vessel water inventory and the low residual decay heat existing in the core. The shutdown cooling isolation valve (1001-50) automatic closure on a group II isolation signal (+8 inches reactor vessel water level) is designed to provide more than adequate cooling of the core.

The potential for release was also considered to be low in that the secondary containment adequately prevented any release. Total amount of inventory, 4200 gallons, was also within the design of the waste treatment system and did not pose any potential threat to the safety of the public or plant.

However, the root causes of the event were considered significant in that they represented the failure of various administrative and operational barriers associated with safe operation.

12. Special Team Charter

The Special Inspection Team (SIT) was tasked with performing an inspection to accomplish the Charter. The following summarizes the team's accomplishment of the Charter (the Charter is provided as attachment 1):

a. Develop and validate the sequence of events associated with the loss of reactor coolant inventory that occurred on Unit 1 on January 24, 1991.

   The validated sequence of events is provided in the details of this report.

b. Evaluate the adequacy of licensee preparation for the evolution with respect to personnel briefings, tag outs, procedures, and overall coordination.

The team concluded that the application of caution tags only at the valve control switches, lack of communication requirements and discussion of actions required for contingencies during the briefings were major contributors to the events. The team also concluded that the failure to adhere to procedures and the lack of management overview were root causes of the events.

c. Determine the adequacy of the licensee's response to this event and whether the immediate actions taken and subsequent investigation was appropriate. In this regard, evaluate the apparent lack of a questioning attitude by the people involved, as evidenced by the decision to continue the evolution without a thorough understanding of what had earlier occurred.

The team concluded that the operator's immediate response to the events was inadequate in that the operator's actions taken were to address incorrect evaluations of the event indicators. The operator evaluated the event as a system relief valve lifting and failed to assess all of the event indicators, such as reactor vessel level. The immediate response by the operating shift supervisor was correct in terminating the problem evolution; however, the event had terminated itself by the completion of the evolution prior to supervisor's involvement.

The team found the licensee's subsequent investigation to be adequate in determining the root causes and contributors.

The team also found that the lack of a questioning attitude existed on the part of the operator, senior electrician, operating shift supervisor and the communications center coordinator. The team concluded that the lack of a questioning attitude was one of the root causes of the event.

d. Independently determine the root causes for the initial opening of the shutdown cooling suction valve, 1-1001-43D.

The Team concluded that the root causes of both the initial opening of valve 1-1001-43D and subsequently opening valve 1-1001-50 were summarized as the lack of management involvement and personnel errors. The licensee's subsequent investigation was in agreement with the Team's conclusion.

e. Determine and validate the volume of water discharged from the reactor vessel and shutdown cooling system to the reactor building.

The Team determined that a total of 4200 gallons were displaced to the reactor building floor drains; 2800 gallons of the total was directly displaced from the reactor vessel and an additional 1400 gallons were displaced from the shutdown cooling system header.

f. Review communications between the Control Room and the Communications Center with regard to activities by maintenance and other non-operations personnel.

The Team concluded that one of the root causes of the event was the inadequate overview of activities performed by non-operations personnel and the temporary lifting of out-of-services on the shutdown cooling system. The Team also concluded that communications between the in-plant activity and the control room and between the control room staff members were also root causes of the event.

g. Review supervisory overview and control by the operating shift of in-plant activities by non-operating department personnel.

The Team concluded that the operating staff had inadequate overview and control of the in-plant activities being performed by electrical maintenance personnel associated with valve stroking. The Team also concluded that the established overview inplace during and prior to the event was a normal practice. The inadequate overview of in-plant activities was determined to be one of the root causes.

h. Review the administrative controls over in-plant activities by non-operating department personnel.

The Team's efforts to review the administrative controls were limited to the processes and programs affecting the event. The Team concluded that the failure to adhere to administrative procedures and the lack of management overview were root causes.

i. Review the implementation of lessons learned from the Braidwood Unit 1 event of October 4, 1990.

The lessons learned from the Braidwood October 4, 1990 event were not fully implemented by the licensee's corporate staff prior to the Quad Cities January 24, 1991 event. Some efforts, directed at assigned self-reading of the Braidwood event, had been partially implemented at Quad Cities. However, those efforts had not included the operators involved with the event. The lack of fully implemented lessons learned were considered to be a major contributor to the events.

13. Conclusions

The Team concluded that the January 24, 1991 Quad Cities Unit 1 loss of reactor vessel inventory event consisted of two separate events with similar root causes. The first loss of inventory occurred when the electrical maintenance personnel stroked the 1-1001-43D valve without permission while the 1-1001-50 valve and the vent and drain valves on the idle loop of the residual heat removal (RHR) system were open. This event continued after the 1-1001-50 valve was closed by the draining of the shutdown cooling header between the 1-1001-50 and 1-1001-43 C and D valves with the continued stroking of the 1-1001-43 valves by both the electrical maintenance and control room personnel. The second event occurred shortly afterwards when the control room operator inadequately evaluated indications of high RHR discharge pressure, erroneously assumed the water on the reactor building basement floor was from a RHR system relief valve lifting and subsequently opened the 1-1001-50 valve to relieve pressure back to reactor vessel. This resulted in refilling the

drained shutdown cooling header from the vessel to be subsequently drained by the continuing stroking of the 1-1001-43 valves. The first loss of inventory event resulted in a loss of about 5 inches and the second resulted in a loss of about 9 inches for a total loss of 14 inches from the reactor vessel.

The Team identified the following root causes of this event.

Lack of management involvement was determined to be a significant root cause of the loss of inventory event. This was evident in the inadequate overview of the temporary lift process and oversight of control room and in-plant activities. Management expectations should include the monitoring of individual performance for professionalism, in addition to adherence to procedures and instructions. This event indicated that management and supervision's expectations were not met as evidenced by the ineffective communications between the electrical maintenance crew and the control room; ineffective communications between the control room staff members; the inadequate awareness of plant conditions by both the control room and the communications center; the inadequate procedure for the preparation and review of the temporary lift; and the procedure adherence failures by the electrical and control room personnel.

In addition to the above root causes, several personnel errors existed. The Shift Engineer, Shift Foreman, Station Control Room Engineer and communication center staff performed inadequate reviews of the requested temporary lift and failed to establish adequate boundaries by closing the vent and drain valves on the idle loop of RHR. These are also considered to be root causes. The Senior Journeyed Electrician had been reminded on four occasions, through communications with the control room and briefings by electrical maintenance supervision, to obtain permission from the control room prior to stroking the shutdown cooling pump suction valves (1-1001-43 C and D). However, the Senior Journeyed Electrician closed the electrical supply breaker to valve 1-1001-43D, when requested by the Journeyed Electrician at the valve location, allowing the Journeyed Electrician to stroke the valve without obtaining permission. The control room Nuclear Station Operator inadequately evaluated indications of high residual heat removal (RHR) system discharge pressure and reports of water on the reactor building basement floor as a system relief valve lifting and relieved the discharge pressure back to the reactor vessel via the shutdown cooling suction isolation valve 1-1001-50. This evaluation and resulting action was performed without observing reactor vessel water level changes, a primary indicator of the vessel inventory.

All of these root causes demonstrated the failure of many of the establish barriers to prevent the occurrence of events: procedures, communications, supervision and management overview, plant status indication and finally personnel judgement and response.

The lack of management and supervisory involvement was also evident in many of the contributors to the event. The most predominant contributor was the lack of awareness of the drained and vented status of the RHR loop which resulted in a general lack of understanding of the potential for draining the reactor vessel during the evolution. Although the Shift

Engineer was aware of the potential, emphasis of the potential was not established with either the control room or electrical maintenance staffs as evident by the failure to provide information of water passing through the valve 1-1001-43D to the control room during communications about the inadvertent stroking of the valve and the control room allowing continuation of testing without verifying the effect of the inadvertent stroking of the valve.

Other contributors also included the lack of documenting actual vessel levels in the operator's log at the start of the shift and prior to evolutions with the potential to change the reactor vessel water level, such as starting recirculation pumps and evolutions with a potential of draining the vessel; the incomplete implementation of lessons learned by corporate and plant management for the Braidwood Unit 1 event on October 4, 1990, and the Quad Cities Unit 2 reactivity transient on October 27, 1990; ineffective briefings that did not include discussions of actions required if contingencies should arise and the communications required to perform the evolution; the placing of caution tags only on the control room control switches for the purpose of establishing system boundaries and preconditions of the evolution; and the establishing of a work practice between the Operations and Maintenance Departments allowing manipulation of breakers and valves by electrical maintenance personnel through a memorandum of understanding without formalizing the practice with policy or procedures.

14. Recommendations

The inspectors have made the following recommendations for the licensee's and the NRC management's review.

- An inspection of the licensee's overview of various processes, such as out-of-services, should be conducted. Emphasis is recommended on operations in the area of relief, briefings and application of lessons learned.

- Particular attention should be given to the licensee's general lack of a questioning attitude and weakness demonstrated by the lack of plant status awareness on the part of the operations staff.

15. Exit Interview

The inspectors met with the licensee representatives denoted in Paragraph 1 during the inspection period and at the conclusion of the inspection on February 4, 1991. The inspectors summarized the scope and results of the inspection and discussed the likely content of this inspection report. The licensee acknowledged the information and did not indicate that any of the information disclosed during the inspection could be considered proprietary in nature.