TRIP REPORT

Jerry L. Harbour

On-Site Investigation and Analysis of
the Human Factors of an Event
at Braidwood Unit 1
on October 4, 1990

(Reactor Coolant System Loss)

Investigative Team

*Wayne Shafer, Region III, NRC
Sammy Diab, NRR/PRAB
Stevie Dupont, Region III, Dresden SRI
Wayne Kropp, Region III, Byron SRI
Stephen Sands, NRR/PD32
Eugene Trager, AEOD/ROAB
Dr. Jerry Harbour, INEL/EG&G, Idaho

*Team Leader

October, 1990
INEL/EG&G Idaho, Inc.

ACKNOWLEDGMENTS

Appreciation is expressed for the cooperation of the Braidwood Station staff, in particular the Unit 1 Control Room operators and technical staff engineering personnel who were on duty during Shift 3 on October 4 and who freely provided information concerning their observations, thinking, and actions. Thanks also to Orville Meyer, EG&G, Idaho, for his valuable input and editorial comments.

OUTLINE

EXECUTIVE SUMMARY

On October 4, 1990, at approximately 1:24 a.m., Braidwood Station Unit 1 experienced a loss of approximately 600 gallons of water from the Reactor Coolant System (RCS) while in cold shutdown. Later that day, NRC Region 3 formed an Augmented Inspection Team (ATI) to investigate the event. The AIT team leader was Wayne Shafer of Region III, NRC. Other team members included Sammy Diab, NRR/PRAB, Stevie Dupont, Region III, Dresden SRI, Wayne Kropp, Region III, Byron SRI, Stephen Sands, NRR/PD32, Eugene Trager, AEOD/ROAB, and Dr. Jerry Harbour, Idaho National Engineering Laboratory (INEL). INEL provided assistance as part of an AEOD program to study the human factors aspects of events. The team spent October 4 through 6 at the site and gathered data from discussions, plant logs, and extensive interviews with control room operators, technical staff engineering personnel, work planning personnel, and other station staff. This trip report provides a review of the details of the event, an analysis of the human factors that were relevant to the event, and a summary of the findings from the analysis.

At the time of the incident, Braidwood Unit 1 was in cold shutdown with the RCS at ≈ 180 degrees F and 360 psig. Two procedures were being executed in parallel by technical staff engineering, BwVS 4.6.2.2-1, Reactor Coolant System Pressure Isolation Valve Leakage Surveillance and BwVS 0.5-2.RH.2-1, Residual Heat Removal Valve Stroke Test. The two surveillances had begun on Shift 3 (3 to 11 p.m.) and were still ongoing at shift changeover from Shift 3 to Shift 1 (11 p.m. to 7 a.m.). At approximately 1:20 a.m., two Technical Staff Engineers (TSEs 1/2) stationed in the control room, instructed another technical staff engineer (TSE 3) stationed in the 364 Elevation of the Auxiliary Building Unit 1 penetration area, to have the Equipment Attendant (EA) close vent valve 1RH028B, which was being used to collect leakage from the closed valve 1RH8702B, per BwVS 4.6.2.2-1. At approximately 1:24 a.m. TSE 1, without receiving confirmation from TSE 3 that the 1RH028B valve had closed, instructed the Auxiliary Nuclear Station Operator (Auxiliary NSO) to open valve 1RH8702B per BwVS 0.5-2.RH.2-1.

Opening valve 1RH8702B aligned the RCS to the inlet of the still open vent valve 1RH028B. During the time that the 1RH8702B was open and the 1RH028B was being closed by the EA, flow through the vent suddenly surged and burst the tygon tubing attached to the valve, resulting in personnel in the Auxiliary Building being sprayed with hot water. Total indicated loss of pressurizer level was 5%, from 40 to 35%, which represents an approximate loss of 600 gallons.

TSE 3, another TSE present in training with TSE 3, and the EA, were all decontaminated following the incident. The EA received a second-degree-burn approximately 2 in. in diameter, on his left forearm when he shielded his face from the spraying water. After being decontaminated, he was taken to a local hospital for treatment of the burn.

The human factor issues were the controlling factors for this event and included:

<u>Task Characterization</u> - - TSEs 1/2's task of coordinating two procedures in parallel without any written guidance represents a fairly complex, dynamic task which requires knowledge-based behavior as opposed to rule-based behavior. The probability of making an error or mental slip (e.g., momentarily forgetting a step,) is quite high in such situations. This probability may be increased if the person involved in such activities is in a possible state of physical/mental fatigue, suggested by the fact that TSEs 1/2 had been working some 17 to 19 hours. In executing dynamic tasks, it is critical that system redundancies or checks be in place to catch and/or prevent such errors. No such redundancies, however, were in place at Braidwood Unit 1 immediately preceding the incident at 1:20 a.m. on March 4th.

<u>Task Involvement/Awareness</u> - - Three levels of task involvement and awareness by operational and technical staff engineering personnel were identified. The Shift Control Room Engineer (SCRE), Unit 1 NSO, Shift Engineer (SE), and Shift Adviser (SA) had a low level of task involvement/awareness and, in fact, were not cognizant that two procedures were being conducted. This lack of knowledge is

attributed to insufficient information being transferred during the shift turnover/briefing, and the SCRE and Unit 1 NSO not monitoring the types of activities being conducted in the Unit 1 control room. TSE 3 and the Auxiliary NSO had a moderate level of task involvement and awareness. Although they directly participated in executing some of the activities associated with the two procedures, both individuals appeared to lack an overall understanding of the system's configuration at all times. The Auxiliary NSO did not involve himself in monitoring the state of the system while executing the valve manipulations and, thus did not serve to provide redundancy to the activities of TSEs 1/2. TSEs 1/2 had a high state of task involvement/awareness and were directly involved in all aspects of conducting and coordinating the two procedures.

This task involvement/awareness configuration points out that overall task success was essentially a function of TSEs 1/2's performance. As noted earlier, however, their performance was affected by conducting a difficult coordination task under a possible state of physical/mental fatigue. Without any redundancies or checks on their performance by other operational personnel, which would be expected in a normal command, control, and communication structure, the likelihood of committing some type of error (e.g., slip) was quite high.

<u>Bypassing Normal Command, Control, and Communication Structure</u>

A normal command, control, and communication structure was not present during the execution of these two surveillances. The SE, SCRE, and Unit 1 NSO were not sufficiently in the command, control, and communication loop to offer oversight of the technical staff engineering activities, nor were they aware of changes in the RCS configuration.

1.0 INTRODUCTION

1.1 Purpose

NRC Region III formed an Augmented Inspection Team (AIT) to investigate the October 4, 1990 loss of approximately 600 gallons of water from the Reactor Coolant System (RCS) at Braidwood Unit 1 while in cold shutdown. The RCS loss resulted from the inadvertent opening at approximately 1:20 a.m. on October 4th of valve 1RH8702B per Procedure BwVS 0.5-2.RH.2-1, Residual Heat Removal Valve Stroke Test, prior to completing the closure of valve 1RH028B per Procedure BwVS 4.6.2.2-1, Reactor Coolant System Pressure Isolation Valve Leakage Surveillance.

1.2 Scope

INEL provided assistance to the AIT as part of the AEOD program to study the human factors aspects of events. This report describes the results of analyses of the human factors aspects of the October 4, 1990 Braidwood I loss of reactor coolant event. These analyses focused on operational staff configuration, operational staff shift changeover briefings concerning the two ongoing procedures, communication channels among key personnel, characterization of the tasks being performed, the degree of involvement/awareness of personnel pertaining to the execution of the two surveillance procedures, the adequacy of the procedures, the adequacy of the human-machine interface, administrative controls on overtime, and operator recovery from the event.

1.3 Team Composition

The inspection team was lead by Wayne Shafer, Region III, NRC. Other team members included Sammy Diab, NRR/PRAB, Stevie Dupont, Region III, Dresden SRI, Wayne Kropp, Region III, Byron SRI, Stephen Sands, NRR/PD32, Eugene Trager, AEOD/ROAB, and Dr. Jerry Harbour, Idaho National Engineering Laboratory.

2.0 DESCRIPTION OF INVESTIGATION

2.1 Background

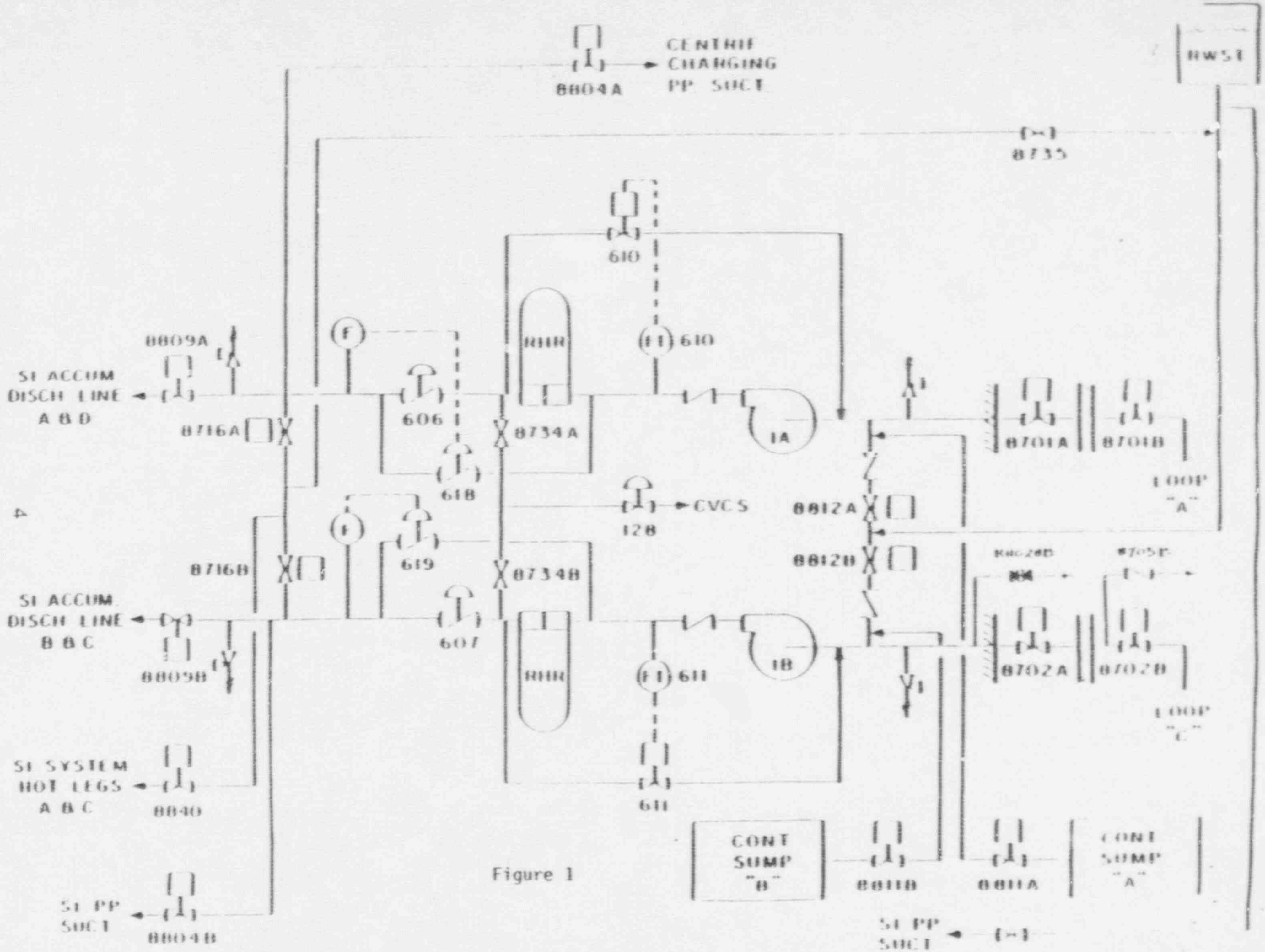
The Braidwood Nuclear Station is located in Illinois, approximately 60 miles southwest of Chicago, and consists of two Westinghouse, four-loop PWR's, each of 1120 MWe net capacity. The plant entered commercial operation in 1988. Both units are operated from a common control room. At the time of the incident, Unit 1 was in cold shutdown with the RCS at ≈ 180 degrees F and 360 psig.

Control room personnel are under the direction of the SE, with a SCRE responsible for oversight of both Units 1 and 2. A licensed NSO is directly charged with the operation of each unit. A SA is also present to assist personnel in the control room. At the time of the incident, another licensed NSO, termed the Auxiliary NSO, was working in the Unit 1 control room and was directly involved in conducting the two surveillances with technical staff engineering personnel. All operational personnel at the time of the incident, which occurred at approximately 1:20 a.m., had reported on shift at approximately 11:00 p.m., October 3. This shift is designated Shift 1, and runs from 11:00 p.m. to 7:00 a.m. The SCRE, Unit 1 NSO, Auxiliary NSO, SA, and SE were interviewed during the on-site investigation. The SCRE and SE are licensed SROs; the NSOs are licensed ROs.

Three technical staff engineers (TSEs 1, 2, and 3), a technical staff engineer in training who was with TSE 3 and one Equipment Attendant (EA) were directly involved in conducting the two procedures (BwVS 4.6.2.2-1, Reactor Coolant System Pressure Isolation Valve Leakage Surveillance and BwVS 0.5-2.RH.2-1, Residual Heat Removal Valve Stroke Test) at the time of the incident. TSE 3 and the EA were positioned in the 364 Elevation of the Auxiliary Building, Unit 1 penetration area. A second technical staff engineer was with TSE 3 in the Auxiliary Building and was observing the surveillances. This individual, however, appeared to play no role in the ongoing events. TSEs 1/2 were positioned in the Unit 1 control room, working directly with the Auxiliary NSO. TSE 2 served primarily as a communications interface between the control room and the Auxiliary Building. TSE 1 signed off on all procedural steps and primarily directed and coordinated all activities relating to the execution of the two procedures. This task division, however, was not rigid. TSE 1 for example, did communicate at times direcuy with TSE 3 in the Auxiliary Building. Technical staff engineering personnel had reported on shift the previous morning, October 3. TSE 1 had been working approximately 19 hours at the time of the incident, and TSE 2 approximately 17 hours. TSEs 1, 2, 3, the observer, and the EA were interviewed during the on-site investigation.

During performance of Procedure BwVS 4.6.2.2-1, Reactor Coolant System Pressure Isolation Valve Leakage Surveillance on March 4, valve 1RH0288, RH Hot Leg Suction Vent Valve, was opened to collect leakage past the RH Hot Leg Suction Valves, 1RH8702A and 1RH8702B, and past the RH Hot Leg Suction Line Pressure Relief Check Valve, 1RH8705B. Procedure BwVS 0.5-2.RH.2-1, Residual Heat Removal Valve Stroke Test, which times the opening stroke of the Hot Leg Suction Valves 1RH8702A&B, was also being performed in parallel with BwVS 4.6.2.2-1. The 1RH8720A valve had been timed when it was opened via BwVS 4.6.2.2-1 to change lineups to check leakage past the 1RH8702B and 1RH8705B valves. Figure 1 depicts schematically the various valve configurations and lineups.

After the leakage check on the valves was completed, the EA, via TSE 3 stationed in the Auxiliary Building, was directed by way of radio communication at approximately 1:20 a.m., to close vent valve 1RH028B, which was being used to collect leakage from the closed valve 1RH8702B per Procedure BwVS 4.6.2.2-1, Step F.2.21, by TSEs 1/2 in the Unit 1 control room. After approximately 4 minutes elapsed, TSE 1 directed the Auxiliary NSO to stroke open valve 1RH8702B per Procedure BwVS 0.5-2.RH.2-1, Step F.4.3. This directive by TSE 1 to the Auxiliary NSO was not heard by TSE 2, who was awaiting confirmation of the closure of valve 1RH028B from TSE 3. Further, TSE 1 had not received confirmation that valve 1RH028B had been closed before issuing the directive to open valve 1RH8702B.


CENTRIF
CHARGING
PP SUCT
8804A
RWST
8735
610
8809A
SI ACCUM
DISCH LINE
A B D
RHR
FT 610
606
8734A
1A
8716A
8701A
8701B
618
LOOP
"A"
128
CVCS
8812A
8716B
619
8734B
8812B
SI ACCUM.
DISCH LINE
B B C
607
8809B
RHR
FT 611
1B
8702A
8702B
LOOP
"C"
SI SYSTEM
HOT LEGS
A B C
8840
611
CONT
SUMP
"B"
8811B
8811A
CONT
SUMP
"A"
SI PP
SUCT
8804B
SI PP
SUCT
Figure 1

Opening valve 1RH8702B aligned the RCS to the inlet of the still open vent valve 1RH028B. During the time that the 1RH8702A valve was open and the 1RH028B valve was closing, leakage through the vent increased and burst the tygon tubing attached to the valve, resulting in personnel in the Auxiliary Building being sprayed with hot water. Total indicated loss of pressurizer level was 5%, from 40 to 35%, which r- -resents an approximate loss of 600 gallons.

TSE 3 in the Auxiliary Building upon being sprayed, immediately called the control room and reported the leak. The Unit 1 NSO noted a decrease in pressurizer level and immediately closed the 1RH8702B valve to stop the RCS inventory loss. He further closed the 1RH8702A valve to ensure the leak was isolated.

TSE 3, the TSE observing the procedure with TSE 3, and the EA, were all decontaminated following the incident. The EA received an second degree burn approximately 2 in. in diameter, on his left forearm when he shielded his face from the spraying water. After being decontaminated, he was taken to a local hospital for treatment of the burn.

2.2 Event Time Line

The following event-time-line sequence was constructed based upon interviews with the control room operators, technical staff engineering personnel, work planning personnel, and various log and briefing sheets:

<u>10/3/90</u>

- 0700 Operating engineer determined that BwVS 4.6.2.2-1, "Reactor Coolant System Pressure Isolation Valve Leakage Surveillance" would be conducted on A and B trains in a continuous manner.

• 0900 Technical staff engineering personnel decide to perform stroke surveillance test Procedure BwVS 0.5-2RH.2-1, "Residual Heat Removal Valve Stroke Test."

• 1500 Procedure 4.6.2.2-1 determined to be critical path and Technical Staff Engineering personnel instructed to provide 24-hour coverage.

• 1515 No records indicate that the two surveillances were discussed during Shift 2 to Shift 3 turnover.

• 1645 BwVS 4.6.2.2-1 and BwVS 0.5-2RH.2-1 surveillance testing started on Train A.

• 2100 Tech staff engineering personnel decide engineering personnel relief crew is not necessary, since surveillances will be completed in a few hours.

• 2200 Relief Tech Staff engineering crew notified not to come in.

• 2300 1A RH surveillances completed (partial).

• 2342 B-RH surveillance started

10/4/90 B-RH leak test surveillance in progress.

• 0120 TSE 2 in control room instructs TSE 3 in Auxiliary Building to close 1RH028B vent valve. TSE 1 further instructs TSE 3 to hang OOS tag.

TSE 3 in Auxiliary Building acknowledge instructions to TSE 2 in control room and begin task of closing valve.

• 0124 TSE 1 directs Auxiliary NSO to open valve 1RH8702B.

Auxiliary NSO opens valve 1RH8702B.

5% PZR level drop.

Tygon tube ruptures spraying personnel in Auxiliary Building. TSE 3 in Auxiliary Building calls the control room on telephone to report problem.

1RH8702B valve closed by Unit 1 NSO - - event terminated. All testing secured and measures initiated to decontaminate individuals in Auxiliary Building and provide medical treatment for EA.

(Possible precursor: Tech staff engineering determined they had failed to stroke-test one isolation valve in Train A during the leak test surveillance, and had to repeat step.)

2.3 Analysis

2.3.1 Crew Briefings

Following shift changeover from Shift 3 (3 to 11 p.m.) to Shift 1 (11 p.m. to 7 a.m.), the SCRE, the unit NSO, the SE, and the SA were advised that Procedure BwVS 4.6.2.2-1, Reactor Coolant System Pressure Isolation Valve Leakage Surveillance, was in progress and being conducted by Technical Staff Engineering. They were not informed, however, that Procedure BwVS 0.5-2RH.2-1, Residual Heat Removal Valve Stroke Test, was also being conducted in parallel with the leakage test. The only member of the control room operational staff who was aware that both procedures were being conducted was the Auxiliary NSO, who did not pass this information on to other operational staff personnel.

2.3.2 Communication Channels

As illustrated in Figure 2, communication patterns at the time of the incident included direct communication between TSEs 1/2 and TSE 3 in the Auxiliary Building, between TSE 3 and the EA in the Auxiliary Building, and between TSEs 1/2 and the Auxiliary NSO in the Unit 1 Control Room. The Auxiliary NSO was not in direct or continuous communication concerning the execution of the two surveillances with any other operating staff personnel (e.g., NSO, SCRE, SA, and SE). This observation is substantiated by the fact that the NSO, SCRE, SA, and SE were unaware that two surveillances were being conducted in parallel. Also, it is important to note that the Auxiliary NSO and TSE 3 were not in direct communication with each other, but rather interfaced through TSEs 1/2. Figure 2 further illustrates that the standard command, control, and communication structure was bypassed, with the NSO, SCRE, and SE completely out of the command/control loop. As will be noted, this absence resulted in a lack of system redundancy or checks on the activities being performed by technical staff engineering personnel.

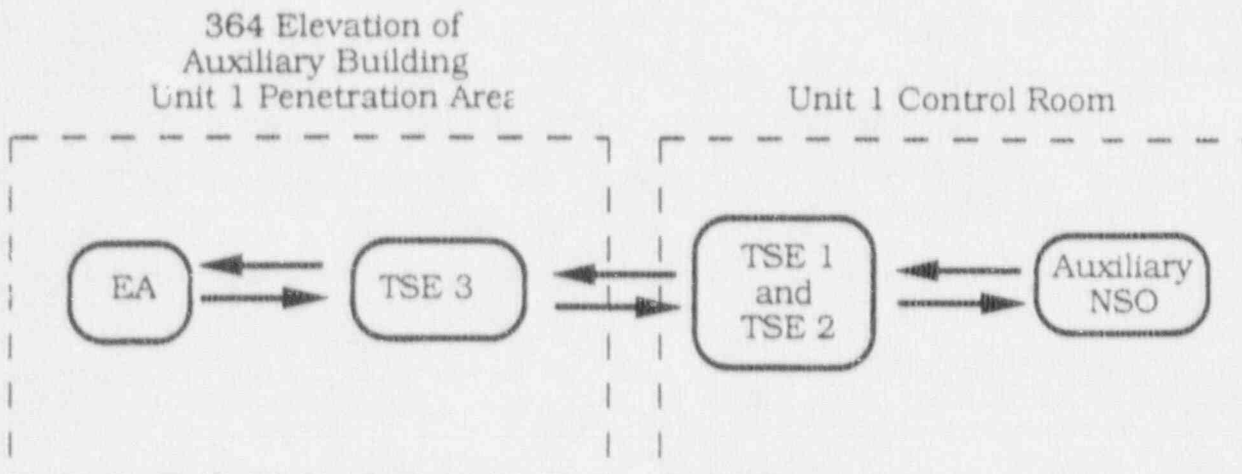


Figure 2. Communication patterns.

2.3.3 Task Characterization

At the time of the incident, two procedures, BwVS 4.6.2.2-1, Reactor Coolant System Pressure Isolation Valve Leakage Surveillance, and BwVS 0.5-2RH.2-1, Residual Heat Removal Valve Stroke Test, were being conducted in parallel by technical staff engineering personnel. It should be noted that the two procedures are compatible and can be executed in parallel. However, there are no written guidelines on how to coordinate the two separate surveillances. Further, when questioned, most personnel could not remember conducting the two surveillances in parallel prior to October 3 and 4, 1990. Although the execution of each procedure, separately, is fairly straightforward and falls under what is termed rule-based behavior (e.g., behavior in which a person follows written rules; a step-by-step task), the coordination and execution of both procedures in parallel is a knowledge-based behavior (e.g., a behavior that requires an individual to plan his actions based on an analysis of the functional and physical properties of a system), and is more difficult to execute successfully. This type of coordination effort is referred to as a dynamic task, which requires a higher degree of man-machine interaction than is required for routine, procedurally guided tasks. Dynamic tasks may involve decision making, keeping track of several functions simultaneously, controlling several functions simultaneously, or any combination of these.

The increased complexity of performing both procedures in parallel was substantiated by the Auxiliary NSO who noted that they had become "lost" in attempting to coordinate the two separate surveillances at various times during Shift 1. It should be further noted that while conducting the same two surveillances on the A train during Shift 3 (3 to 11 p.m.), a step involving the stroking of a valve was omitted. Also, at the time of the incident, TSE 1 had been on the job for approximately 19 hours, and TSE 2 for some 17 hours. Thus, the probability of committing an error on a dynamic task that is rarely performed in a potential state of high fatigue is quite high. For example, Swain and Guttman, 1983 (NUREG-1278, Table 20-16) place the probability of committing such an error at between 0.25 and 0.5.

2.3.4 Task Involvement/Awareness

A determination of task involvement/awareness among various operational personnel was also attempted. Task involvement refers to the degree in which an individual directly participated in executing the various steps of the two procedures. System awareness refers to the extent those same individuals were aware of changes in system configuration based on executing those steps (e.g., aware that by opening a valve, a change in the configuration of the system had occurred, and being able to mentally "picture" and understand that change). Three levels of involvement/awareness were identified: high, medium, and low. Based on this categorization, personnel were assigned to each level, as illustrated in Figure 3.

As depicted in the figure, the SCRE, Unit 1 NSO, SA, and SE had a low level of task involvement/awareness and in fact, were not even cognizant that both a leakage and a stroke surveillance were being conducted in parallel. This low task involvement/awareness appears to have been caused by an inadequate shift turnover, inadequate shift briefings, failure of the Auxiliary NSO to appraise the NSO of the extent of testing taking place, failure of the NSO to appraise himself of the exact nature of the tasks being conducted within the Unit 1 control room, and bypassing of the normal command, control, and communication structure.

TSE 3 and the Auxiliary NSO had a moderate level of task involvement/awareness. Although they were directly involved in executing some of the tasks required per the two procedures, they did not execute all of them. For example, the Auxiliary NSO was not always aware of instructions being given to TSE 3 by TSEs 1/2, nor was TSE 3 aware of instructions given to the Auxiliary NSO. As a result of this incomplete involvement and not communicating directly, neither individual was totally aware of the overall configuration of the system at all times - TSE 3, because he was not informed of all procedural steps being conducted by TSEs 1/2 in the Unit 1 control room, and the Auxiliary NSO, because he was not cognitively monitoring changes in system configuration as a result of executing the various procedural steps (e.g., he appeared to be only following instructions from TSEs 1/2). If a greater integration of TSE 3 and the Auxiliary NSO had occurred, the two individuals could have served as redundancies, serving as checks on the actions and directives of TSEs 1/2.

TSEs 1/2 had a high involvement/awareness of the two surveillances. They were involved in monitoring all facets of the two procedures, issuing all procedural directives, performing all required calculations, signing off all completed procedural steps, acting as the critical communications interface between themselves and TSE 3 and the Auxiliary NSO, and continuously monitoring all changes in system configuration.

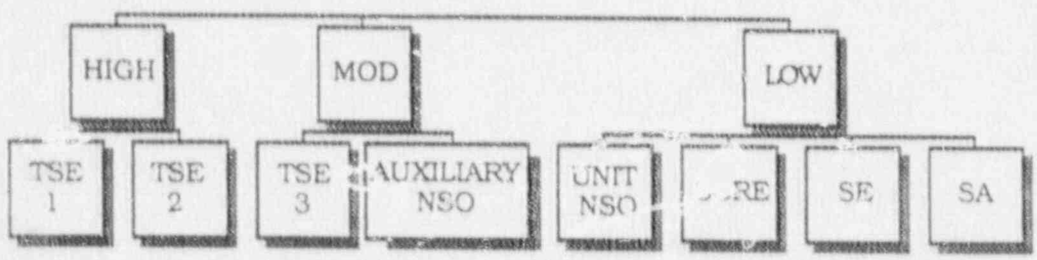


Figure 3. Personnel task awareness/involvement.

Based on this task involvement/awareness configuration, successful task performance was essentially dependent on the successful performance of TSEs 1/2. However, TSEs 1/2 performance was affected by attempting to coordinate a fairly complex dynamic task, as described in section 2.3.3, and in a possible state of physical and mental fatigue, suggested by the number of hours worked (approximately 19 and 17 hours, respectively). Also, this configuration highlights the lack of any redundancies or checks on TSEs 1/2's performance.

2.3.5 Administrative Controls on Overtime

Presently no administrative controls exist for limiting the amount of allowable overtime of technical staff engineering personnel.

2.3.6 Procedures

As previously described, two procedures, BwVS 4.6.2.2-1, Reactor Coolant System Pressure Isolation Valve Leakage Surveillance, and BwVS 0.5-2RH.2-1, Residual Heat Removal Valve Stroke Test, were used. Upon review, no discrepancies or irregularities in either procedure were noted. Further, no procedure was used, or even exists, for conducting the Leakage and Stroke surveillances in parallel.

2.3.7 Human-Machine Interface

No deficiencies were identified in the human-machine interface.

2.3.8 Operator Recovery from the Event

The event was quickly terminated by the actions of the Unit 1 NSO. He noted a decrease in pressurizer level and closed valve 1RH8702B to stop the RCS inventory loss. He further closed the 1RH8702A valve to ensure the leak was isolated. TSE 2, who received the call from TSE 3, did not immediately understand the source of the leakage. This lack of understanding is most likely attributed to his not knowing that the directive to open the 1RH8702B valve by TSE 1 had been given. Also, the Auxiliary NSO did not immediately diagnose the problem, presumably as a result of being under the impression that the

1RH028B valve had been closed. TSE 1 realized the source of the leakage, but by that time, the NSO had already taken steps to terminate the incident.

2.4 Synthesis

As previously stated, the initiating event that resulted in the incident at the Braidwood Unit 1 on March 4th, was the premature opening at approximately 1:20 a.m. of the 1RH8702B valve per Procedure BwVS 0.5-2RH.2-1, Step F.4.3, Residual Heat Removal Valve Stroke Test, before completing the closure of the 1RH028B valve per Procedure BwVS 4.6.2.2-1, Step F.2.21, Reactor Coolant System Pressure Isolation Valve Leakage Surveillance. According to the investigation and developed time line, the Auxiliary NSO was directed by TSE 1 in the Unit 1 control room to open the 1RH8702B valve before receiving confirmation from TSE #3 stationed in the Auxiliary Building that the 1RH028B valve had actually been closed. Both TSEs 1/2 stationed in the control room were aware that the EA had been directed to close valve 1RH028B. However, only TSE 1 was aware of the second directive given to the Auxiliary NSO to open valve 1RH8702B.

The primary cause of this incident is the failure ("forgetting") of TSE 1 to receive confirmation of the closure of valve 1RH028B before issuing the directive to open valve 1RH8702B. However, a number of factors contributed to this error of omission and the fact that checks built into the system to detect and avert such errors were not implemented.

As noted earlier, the performance of TSE 1 was adversely affected by performing a fairly complex "dynamic task" requiring knowledge-base behavior and involving the coordination of two separate procedures. Further, these procedures are not routinely conducted in this manner, thus experience level was also a factor. Also, task complexity may have been further compounded by the fact that TSE 1 had been working for approximately 19 hours at the time of the incident. Fatigue may have affected his mental capacities, which in turn would have made a complex task even more difficult. Given these circumstances, the probability of making an error in such situations by a single individual is quite high, as demonstrated Swain and Guttman, 1983 (NUREG-1278, Table 20-16), who placed a probability of committing such an error at between 0.25 and 0.5.

Given this high error potential, it is extremely important that redundancies or checks built into the system are utilized. This, however, was not the case in the Unit 1 control room. Because of an inadequate shift turnover/briefing, the SCRE, Unit 1 NSO, SE, and SA were unaware that both tests were being performed in parallel. It is possible that had they been aware of the extent of testing, they would have implemented some types of redundancies. It is also noteworthy that the Unit 1 NSO was unaware of the scope of testing being performed, even after some 2 hours on shift. These observations point out that the normal command, control, and communication structure that one would expect to find was not in place.

The Auxiliary NSO, who was assigned to assist the technical staff engineers in conducting the tests, was not cognizant of the configuration of the system he was operating. It appears that he was simply following instructions without thinking of the consequences/changes in the system's configuration. This lack of system awareness was partly a result of the way the test was being performed (e.g., directed only by TSEs 1/2), not communicating directly with TSE 3, not monitoring all instructions given to TSE 3 and TSE 3's responses, and overrelying on TSEs 1/2 to maintain a mental model of the system's state.

TSE 3, stationed in the 364 Auxiliary Building, only received instructions from TSEs 1/2 pertaining to actions required in the Auxiliary Building (e.g., to physically close a valve). Had he been informed of all procedural actions, as well as all directions given to the Auxiliary NSO, he may have been able to avert the situation that occurred. For example, if TSEs 1/2 had informed him to close valve 1RH028B as well as informing him that they were going to instruct the Auxiliary NSO to open valve 1RH8702B, he may have immediately replied that valve 1RH028B had not been closed yet. Also, if he would have communicated directly with the Auxiliary NSO, both he and the Auxiliary NSO would nave been more integrated into the overall task configuration and would have served as redundancies or checks on TSEs 1/2.

It is suggested that given the requirement of performing a dynamic task in a possible fatigued state, it is not unlikely that an error will be committed. This observation is reaffirmed by the fact that a step was omitted earlier while conducting the same two procedures on Train A. Given this high error probability, it is essential that the task be configured in such a way that redundancies or checks are present. These redundancies were lacking, however, at the time of the incident, and the expected command, control, and communication structure was not in place.

3.0 SUMMARY OF FINDINGS

The findings from the analysis of this event may be summarized under two topics.

1. Task Characterization

   The task of coordinating two procedures in parallel without any written guidance represents a fairly complex, dynamic task which requires knowledge-based behavior as opposed to rule-based behavior. The probability of making an error or mental slip (momentarily forgetting a step, etc.) is quite high in such situations. This probability can be increased if the person involved in such activities is in a possible state of physical/mental fatigue, suggested by the fact that the persons in question had been working some 17 to 19 hours. In executing dynamic tasks, it is critical that system redundancies or checks be in place to catch and/or prevent such errors. No such redundancies, however, were in place at Braidwood Unit 1 immediately preceding the incident at 1:20 a.m. on March 4th.

2. Task Involvement/Awareness

Three levels of task involvement/awareness by operational and technical staff engineering personnel were identified. The SCRE, Unit 1 NSO, SE, and SA had a low level of task involvement/awareness and, in fact, were not even cognizant that two procedures were being conducted. This ignorance is attributed to insufficient information being transferred during the shift turnover/briefing, and the SCRE and Unit 1 NSO not monitoring the types of activities being conducted in the Unit 1 control room. TSE 3 and the Auxiliary NSO had a moderate level of task involvement/awareness. Although they directly participated in executing some of the activities associated with the two procedures, both individuals appeared to lack an overall understanding of the system's configuration at all times. The licensed Auxiliary NSO did not involve himself in monitoring the state of the system while executing the valve manipulations and, thus did not serve to provide redundancy to the activities of TSEs 1/2. TSEs 1/2 had a high state of task involvement/awareness and were directly involved in all aspects of conducting and coordinating the two procedures.

This task involvement/awareness configuration points out that overall task success was essentially a function of TSEs 1/2's performance. As noted earlier, however, their performance was affected by conducting a difficult coordination task under a possible state of high physical/ mental fatigue. Without any redundancies or checks on their performance by other operational personnel, which would be expected in a normal command, control, and communication structure, the likelihood of committing some type of error (e.g., slip) was quite high.

3. Bypassing Normal Command, Control, and Communication Structure

A normal command, control, and communication structure was not present during the execution of these two surveillances. The SE, SCRE, and Unit 1 NSO were not sufficiently in the command, control, and communication loop to offer oversight of the technical staff engineering activities, nor be aware of changes in the RCS configuration.