EGG-HFRU-10309

Trip Report: Onsite Analysis of the Human Factors of an Event at LaSalle 2 April 20, 1992

(Reactor Water Cleanup System Isolation Bypass)

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Published June 1992

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Prepared for the
Office for Analysis and Evaluation of Operational Data
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
Under DOE Contract No. DE-AC07-76ID01570

EXECUTIVE SUMMARY

As part of the Office for Analysis and Evaluation of Operational Data (AEOD) of the U.S. Nuclear Regulatory Commission (NRC) program to study human performance during operating events, a team conducted an onsite investigation of an event that occurred at the LaSalle 2 nuclear generating station on April 20, 1992. The team focused on the factors that influenced the performance of operations staff and performed an analysis based on interviews with operations and technical staff personnel, plant logs and recordings, operations procedures and training material.

On April 20, 1992, the Unit 2 reactor was at 20% power, following a month-long outage. The reactor water cleanup system (RWCU) was shut down to verify the motor operator limit switch settings on the RWCU inboard and outboard containment isolation valves. The nuclear station operator (NSO) closed the RWCU system return valve prior to stopping the two RWCU pumps, in reverse order from that stated in the procedure.

About a minute later, an RWCU high differential flow alarm was received in the control room, indicating the start of a 45 second delay timer, which precedes an RWCU automatic isolation. Several weeks earlier, an RWCU isolation had occurred due to a spurious RWCU high differential flow signal and both motors had failed due to faulty limit switch settings resulting from thermal expansion. The NSO, wanting to preserve the valve test, asked the shift foreman (SF) for permission to bypass the automatic high differential flow isolation of these valves, an Engineered Safety Feature (ESF). The NSO removed the keys from other front control board switches and gave them to a second NSO, who inserted them in the RWCU bypass switches on the back panel to prevent the isolation within 35 seconds after the initial alarm. The second NSO reported a continuing RWCU differential flow of 95 gpm.

About three minutes later, the operators verified that the alarm was not spurious: an equipment attendant identified flow from a RWCU regenerative heat exchanger relief valve, a third NSO found increasing Reactor Building Equipment Drain Tank (RBEDT) level, and the 95 gpm RWCU differential flow continued. The NSO asked the shift control room engineer (SCRE) and the SF how they wanted to isolate the RWCU. Both agreed that the keys should be removed to allow the automatic RWCU isolation. The operators returned the RWCU bypass key switch to normal, allowing the RWCU to automatically isolate, which terminated the loss of inventory from the RWCU through the open relief valve.

The following is a summary of the results of the human factors analysis of this event:

Teamwork/Command and Control

Control room teamwork and coordination with personnel in the plant were major factors in determining the validity of the RWCU high differential flow alarm. However, the control room hierarchy structure has two paths for the chain of command, which has the potential to lead to an unclear direction.

The coordination of the special test engineer with the control room operations personnel was conducted on an individual basis, whereas a crew briefing on what to do if there was an isolation signal would have been helpful.

The keys used to bypass the ESF were readily available in the other switches in the control panel. The use of such keys for multiple purposes suggests a lack of key control.

Procedures

The control room operators performed all recovery actions without consulting applicable procedures. A decision was made to allow automatic isolation of the system when the special test procedure directed having thermal overload protection available for the motor-operated valves.

The operators lacked understanding of the required order of performance of procedural directions. Operators lacked confidence in the usefulness of the procedures because of their frequent revision and level of detail. It would have been helpful if the special test procedure addressed operator response to or recovery from an isolation signal and differential flow alarm conditions.

The alarm response procedures for the RWCU high differential flow alarm do not mention the use of the rear panel RWCU differential flow meter, RBEDT level indication, local area radiation monitors, area temperature, dispatching personnel to the area for determining alarm validity, or criteria for using ESF bypass keys.

After the event, the shift engineer verbally instructed his crew that ESF signals shall not be bypassed in the future. But, it is not clear if other crews have been similarly informed. It would be helpful to operators to have this policy statement included in operating and administrative procedures.

Decisionmaking

The decision made to bypass the RWCU high differential flow alarm isolation signal was based on knowledge-based reasoning from existing knowledge about systems, processes and plant conditions rather than specific procedural steps. Several factors contributed to this decision, including previous operator experience with spurious RWCU isolation signals, management's criticism for not bypassing a RWCU isolation signal several weeks earlier when the valve motors were damaged and the operators' opinion of the usefulness of procedures during an emergency.

The decision to remove the bypass and have the system isolate automatically was made about three minutes after the initial RWCU alarm. The operators had time to consider the most appropriate method of isolating the RWCU; they could have decided to shut the isolation valves manually to keep motor thermal overload protection available, but the senior reactor operators, without thinking of this concern, opted instead to remove the keys from the RWCU bypass switches and allow the automatic ESF actuation.

Knowledge-based Behavior

The control room actions were primarily knowledge-based and knowledge-based behavior lead them both into and out of the event. If knowledge-based reasoning had been used that included concerns for the MOVs, the operators would have bypassed the ESF signal to ensure that thermal overload protection was available to the motors, relied upon their RWCU differential flow meter, and immediately closed the RWCU containment isolation valves manually.

Each operator's knowledge base is different and if their knowledge base was the only support available, other operators may not have had the same response. When actions are dependent on knowledge-based reasoning, operators are more prone to make decisions and take actions without considering their consequences or alternatives, as occurred in this case.

Human-Machine Interface

The primary RWCU differential flow indication is located on the rear panel, the RBEDT level indicator is located on another control room front panel, and area radiation monitors on another panel. The operator has only knowledge-based reasoning to properly connect the various control room indications needed to determine the validity of an RWCU differential flow alarm. If the indicator were on the front panel, the operator could monitor RWCU differential flow for determining system operation and alarm validity.

There is no RWCU relief valve discharge line indication in the control room; control room personnel must rely on equipment attendants in the plant to locate and identify discharge line flow.

ACKNOWLEDGMENTS

We express appreciation to the LaSalle staff for their cooperation for freely providing information necessary to analyze the human factors of the operating event. We particularly thank the Unit 2 operators and technical staff who were on duty during the day shift of April 20 for their cooperation during the interviews.

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FIGURES

ACRONYMS

AEOD	Office for Analysis and Evaluation of Operational Data
DSP	Division of Safety Programs
ESF	engineered safety feature
HMI	human-machine interface
MOV	motor operated valve
NSO	nuclear station operator
RBEDT	reactor building equipment drain tank
RCS	reactor coolant system
RO	reactor operator
ROAB	Reactor Operations Analysis Branch
RWCU	reactor water cleanup system
SCRE	shift control room engineer
SE	shift engineer
SF	shift foreman
SRO	senior reactor operator

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1. INTRODUCTION

1.1 Purpose

The Office for Analysis and Evaluation of Operational Data (AEOD) of the U.S. Nuclear Regulatory Commission (NRC) has a program to study human performance during operating events. As part of this program, AEOD formed a team to conduct an onsite analysis of an event that occurred at the LaSalle nuclear generating station during the day shift on April 20, 1992. The Reactor Water Cleanup system (RWCU) was being shutdown to conduct a special test on the inboard and outboard, motor-operated, primary containment isolation valves. An RWCU high differential flow alarm was received in the control room. A decision was made by the operating crew to bypass the automatic high flow isolation of the RWCU, an Engineered Safety Feature (ESF), with a keyed switch. Approximately three minutes later, the operators determined that the alarm was not spurious by identifying flow from a regenerative heat exchanger relief valve, an increasing level in the Reactor Building Equipment Drain Tank (RBEDT), and a high flow indication on an indicator located near the keyed bypass switch in the control room. Subsequently, the bypass key switch was returned to normal allowing the RWCU to automatically isolate and terminate the loss of inventory from the RWCU through the open relief valve.

1.2 Scope

The human factors analysis focused on the factors that influenced the performance of operations staff and technical support personnel throughout this event. The analysis was based on data derived from interviews with operations and technical staff personnel, plant logs and recordings, and review of operations procedures and training material. The Idaho National Engineering Laboratory (INEL) provided assistance as part of the AEOD program to study human performance during operating events.

1.3 Onsite Analysis

The onsite analysis team was at the site April 22-23, 1992 and was composed of the following members:

John Kauffman, NRC/AEOD/DSP/ROAB (team leader)

Robert Spence, NRC/AEOD/DSP/ROAB

Susan G. Hill, INEL/EG&G Idaho, Inc.

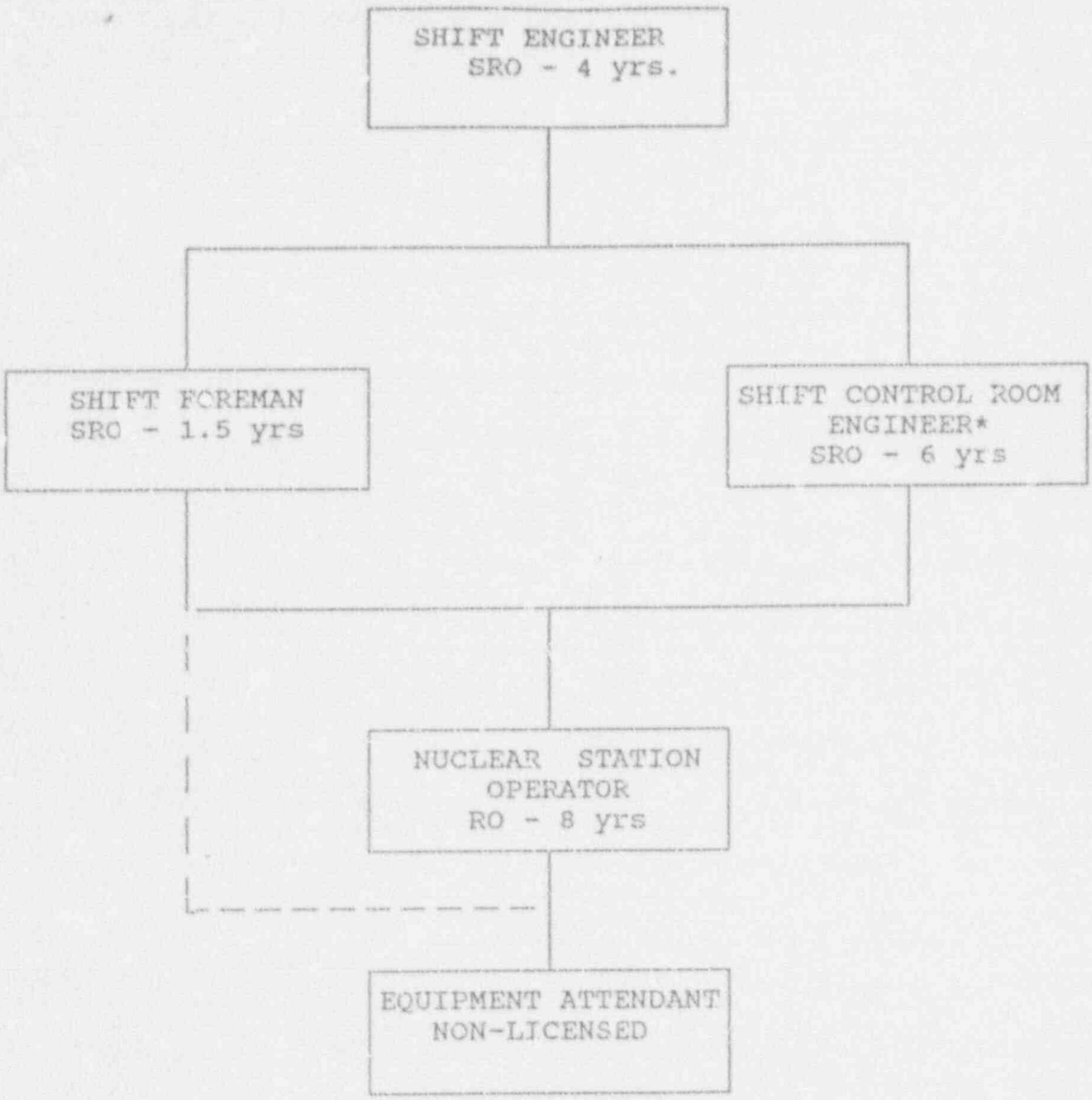
2. DESCRIPTION OF THE EVENT ANALYSIS

2.1 Background

The LaSalle County Nuclear Station, located in LaSalle County, Illinois, is owned and operated by Commonwealth Edison Company. The two, nearly identical, boiling water reactors are rated at 3293 megawatts-thermal. The units are operated from a common control room and have been in commercial operation since January and October, 1984, respectively.

On April 20, 1992, the Unit 2 reactor was at 20% power, following a month-long outage. The Unit 2 control room on-duty operating crew consisted of a shift engineer (SE), a shift control room engineer (SCRE), a shift foreman (SF), and several nuclear station operators (NSO) (see Figure 1). The regular crew was augmented by several extra NSOs to assist during startup activities. A special test procedure, LTP-100-2, "U-2 Reactor Water Cleanup MOV Cycle Test During Plant Startup," was scheduled to be performed. The purpose of the test was to stroke the inboard and outboard motor operated primary containment isolation valves #2G33-F001 and F004 of the Reactor Water Cleanup system (RWCU) in order to verify proper operation under normal operating conditions. The special test was approved by the Shift Engineer during the day shift, and, at approximately 8:40 a.m., preparation for the shutdown of the RWCU from the control room was started. RWCU shutdown was necessary prior to stroking the F001 and F004 valves closed for the test.

About two weeks prior to the event (on April 2, 1992), an RWCU isolation was received due to a high differential flow alarm. The F001 and F004 valves automatically isolated 45 seconds after receiving the alarm, as designed. However, subsequent investigation showed that the motor operators had failed on both valves due to a faulty limit switch setting. Thermal binding caused by heatup of the system had disabled the limit switch close position contact and had prevented the



* Assumes the role of Shift Technical advisor when position required.

NOTES:

1. SRO - Senior Operator license.
2. RO - Reactor Operator license.
3. All licensed personnel had more than 10 years with the company.
4. Shift crews are changed at first of the year if transfers are desired.
5. First day on dayshift following training week.

Figure 1. LaSalle operations shift staffing.

torque switch from deenergizing the motors. Consequently the motors were destroyed. The MOV assemblies were replaced and management startup directions were written stating "These isolations are expected during startup and it is not a red phone notification. We should try to prevent these isolations from occurring".

The RWCU has a history of spurious alarms from high differential flow during plant heatups and cooldowns when in the 200 - 300 degree F range. Flashing of water to steam results in pressure transients, flow oscillations and erratic indications during these transitions. Few problems have been experienced at normal operating temperatures. In the April 2nd failure of the RWCU motor operated isolation valves, it was reported in the Licensee Event Report that there was no actual high differential flow, although the alarm was received and the isolation occurred.

On the morning of April 20, the test engineer in charge of the special test procedure asked the SE if the test could be run that morning; he agreed. Next, the test engineer spoke to the SE, explained what would be done, and received the SE's permission and signature to proceed with the test. The test engineer then spoke with the SCRE, and then the NSO who would be shutting down the RWCU. The NSO asked for, and received, a copy of the special test procedure that would be used in this test.

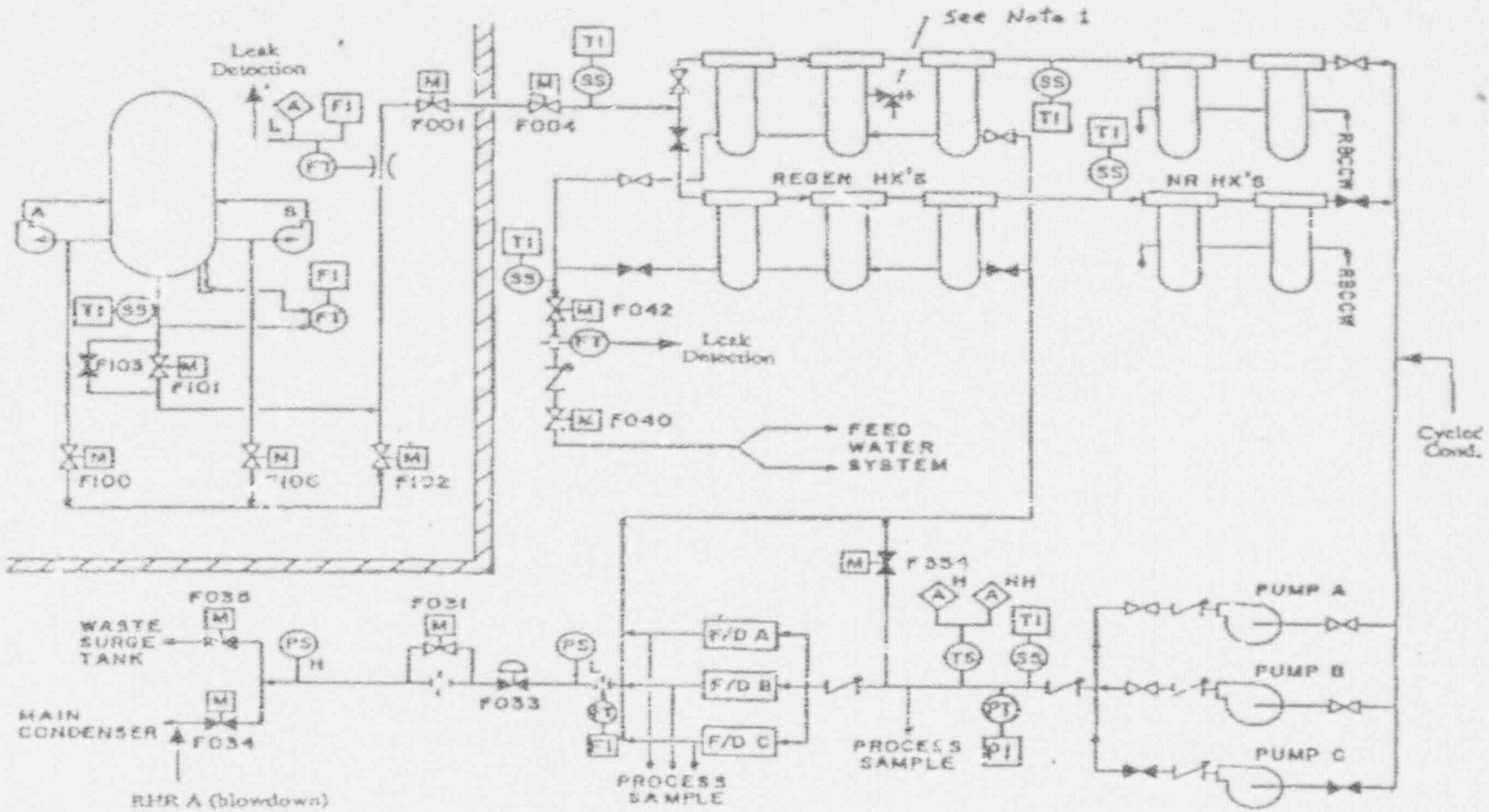
When the test engineer and his personnel were at the test location in the plant and all the test equipment had been readied for use, the test engineer contacted the NSO by telephone and notified him that the test personnel were ready whenever the NSO was ready to proceed. An equipment attendant was with the test team to assist them as needed.

The NSO proceeded to shutdown the RWCU, using the procedure LOP-RT-03, "Reactor Water Clean-Up System (RWCU) -- Shutdown". When he reached step 1e., he turned the switch to close valve MO-2G33-F040 (RWCU system return) and position switches to stop RWCU pumps A and B (see Figure 2). The switches for the F040 valve and the two pumps are on the same panel and in close proximity to each other. These actions were performed in the reverse order from that stated in the procedure. The sequence as performed left the pumps running momentarily applying full discharge pressure on the isolated section of the system. In addition, the regenerative heat exchanger tubes containing relatively hot reactor coolant were transferring energy to the isolated section increasing pressure due to thermal expansion. Shortly after these control actions, the high differential flow condition alarm was activated. The set point of the high differential flow is 70 gpm. The alarm initiated a 45 second clock timer after which the RWCU would automatically isolate, if the high flow condition was still present.

The NSO looked at the RWCU indications on the front panel to determine the validity of the alarm. All indications such as pressure, temperature, radiation monitors, and flow appeared normal. The NSO, wanting to preserve their testing, asked the SF for permission to use the key switches to bypass the automatic isolation system (the SCRE was on the telephone at this time.) The SF looked at the control board indications, determined there was nothing abnormal, and then directed the NSO to use the keys to bypass the RWCU automatic isolation.

Keys were removed from locations on the front control board panel and were handed to a second NSO who then went around to the back panel where the RCWU bypass key switches were located. The key switches were actuated about 30-35 seconds after receiving the flow alarms and before the 45 seconds expired, blocking the automatic isolation. The second NSO, while behind the panel, observed a RWCU differential flow meter which was located on the back panel near the key switches. He reported the differential flow was approximately 95 gpm.

The NSO who was conducting the RWCU shutdown called on the telephone to the local equipment attendant and asked him to check if there were any indications of relief valves lifting on the RWCU heat exchangers. The equipment attendant went up the stairs and checked first one



NOTE 1: Shell side of heat exchanger relief to RBEDT.

Figure 2. Reactor water cleanup system.

area, and then moved to a second area. He smelled hot paint, and observed water flowing through a relief valve discharge line sightglass (22MB). He called the NSO in the control room and reported the water flowing in the sightglass near one of the regenerative heat exchangers and reported the tag number.

A third NSO in the control room checked the display for the Reactor Building Equipment Drain Tank (RBEDT). He observed an increase in volume in the RBEDT, as indicated by a "right hand turn" on the chart recording and reported it to the NSO at the RWCU control panel.

The NSO asked the SCRE and SF how they wanted to isolate the RWCU. The SCRE and SF both agreed that the keys should be removed and to allow the isolation. The keys were removed and the automatic isolation occurred closing F001 and F004 valves. The NSO called the test engineer and told him that the valves were closing and to take electrical current readings.

Investigation of the tag number on the sightglass identified a relief valve on the B regenerative heat exchanger as having lifted when the RWCU system was shutdown and then reseated, after the RCWU isolation. The SCRE and SE determined that this event was not classified in the emergency plan, and the NRC was notified within four hours as per 10 CFR 50.72 (b)(2)(ii).

2.2 Time Line of the Event

The following event time line sequence was developed from interviews with the on-duty shift personnel, technical staff, copies of control room logs, and plant computer printouts.

Note: all times are Central Daylight Time

04/20/92

7:30 - 8:00 a.m.	•	Test engineer obtained permission from SE to perform the special test to cycle closed the F001 and F004 valves. Held individual discussions with SE, SCRE, and NSO regarding the special test.
8:40 a.m.	•	RWCU filters removed from service in preparation for special test.
8:46:34 a.m.	•	NSO at the RWCU control panel initiates closing valve F040.
8:46:48 a.m.	•	Valve F040 closed.
8:46:52 a.m.	•	NSO switched off RWCU pump B.
8:46:53 a.m.	•	NSO switched off RWCU pump A.
8:47:47 a.m.	•	High differential flow alarm sounded.
	•	NSO checked front panel instrumentation; it appeared normal.
	•	NSO asked SF (SRO) for permission to bypass RWCU isolation.
	•	SF (SRO) decided to bypass isolation by using key switches.
8:48 a.m.	•	Keys handed to second NSO and he went to back panel where key switches are located.
8:48:30 a.m. (approx.)	•	Keys were inserted into the isolation bypass key switch and were turned to the bypass position.
	•	NSO at the control panel requested equipment attendant to check if a relief valve had lifted on a RWCU regenerative heat exchangers.
	•	Second NSO at the rear panel observed RWCU differential flow meter at ~95 gpm and communicated this to first NSO at the RWCU control board.
	•	Third NSO saw RBEDT level increasing at the 13J panel and communicated this to first NSO.

- Equipment attendant saw flow through a regenerative heat exchanger relief valve discharge line sightglass and reported this to the control room.
- NSO at the RWCU control panel realized there were three indications that the RWCU high differential flow alarm was not spurious and there was a leak from the system.
- NSO asked SCRE and SF for direction on which way to isolate RWCU.
- SCRE and SF directed taking the keys back to the normal position and allowing the system to automatically isolate.

8:51:01 a.m.	• Removed keys to isolation bypass.
	• NSO called special test staff to take ammeter readings.
8:51:24 a.m.	• RWCU isolated.
9:00 a.m. (approx.)	• SF checked B regenerative heat exchanger relief valve and piping was still hot but cooling verified the relief valve lifted and then reseated.
10:37 a.m.	• SCRE notified NRC.

2.3 Analysis

There were a number of factors which contributed to human performance during the event. These are discussed in the following sections

2.3.1 Teamwork/Command and Control. The teamwork in the control room and coordination were major factors in the ability to obtain needed information and determine the validity of the RWCU high differential flow alarm. The NSO performing the RWCU shutdown quickly directed other NSOs to obtain needed information in the control room. The NSO directed the local equipment attendant to check if there were any lifted RWCU relief valves in the plant. The NSO also coordinated with the technical staff who were in the plant to conduct the special test, suggesting they take ammeter readings to test status of valves as they were closing and verify the motor operators shut off.

The command and control within the control room were carried out in accordance with expected practices. The NSO asked for direction from a supervisor (SRO) related to bypassing the isolation. The SF (SRO) made the decision to bypass the isolation. The operating crew continued investigation of the alarm. When additional information was obtained that suggested there was a leak from the RWCU and the high flow alarm was not spurious, the NSO asked for direction regarding isolating the RWCU. He received direction from the SCRE (SRO) and the SF (SRO) to remove the bypass and allow the automatic isolation.

However, the control room hierarchy structure is perceived by the operators to have two paths for the chain of command (see Figure 1). The operators perceive the SCRE and the SF to be equivalent supervisors. This perception has the potential to lead to unclear roles and chain of command.

The coordination of the special test engineer with the control room operations personnel was conducted on an individual basis, with the test engineer speaking individually to the SE, SCRE, SF, and the NSO responsible for RWCU shutdown. Shutdown of the RWCU had been accomplished many times before and was not considered a special or difficult task. However, automatic isolations of the RWCU due to spurious signals were not unexpected -- the daily orders (04/18 to 04/20, 1992) and RWCU operating procedure suggested that there may be spurious alarms. This is a case where prior planning of what to do if there was an isolation signal would have been helpful. There was a precaution in the special test procedure that indicated that the isolation valves should not close without thermal overload protection, implying that the valves should not be shut automatically, but should instead be shut manually by the control room operators. Prior planning, discussed with all relevant crew personnel as a group, would have taken into account the special test procedure precaution and determined what would be the most appropriate plan of action if an isolation signal was received.

Another aspect of command and control was the availability and control of the keys used to bypass the ESF. Keys were readily available in the control room as they were left in key switches on the front panel. Keys could also be used in multiple key switches; a single key was not dedicated to a single use. The availability and multiple use capability suggests a lack of control of the keys that can be used to bypass ESF actuations.

2.3.2 Procedures. This event occurred over a relatively short amount of time, spanning three to four minutes. The control room operators performed all recovery actions without consulting applicable procedures. This did not pose a problem during the initial bypassing of the isolation or the diagnostics leading to the discovery that inventory was being lost. However, a decision was made to allow automatic isolation of the system when procedures would have directed manual isolation providing additional protection in the circuitry for the motor-operated valves.

There were a number of issues that related to procedures during the event. The execution of the RWCU shutdown procedure, LOP-RT-03, included a step with two sub-steps which directed the operator to stop the pumps and close the valve. The operators understood that procedures were to be performed in the step sequence given unless specifically exempted in the procedure. However, they did not have a common understanding whether or not sub-steps were to be performed in order. There was ambiguity as to when the sub-steps could be performed in any order versus when sub-steps must be performed in the given sequence. In this case, the switch was turned to close the valve before the switches were turned to stop the pumps, the reverse order from what was stated in the procedure. This resulted in the pumps running with no flow and maximum discharge pressure. The higher pressure may have contributed to lifting the relief valve though no pressure spike was observed by the NSO because the pressure reading in the control room came from instrumentation which was downstream of the closed valve.

Operators reported that the procedures were constantly changing and were revised frequently. It was also reported that there was great detail in the procedures which upon occasion affected the operators' ability to identify and locate the needed procedural step. These reports suggest that operators question the usability of the procedures.

The special test procedure, LTP-100-2, "U-2 Reactor Water Cleanup MOV Cycle Test During Plant Startup," contained an erroneous precaution that a valve operation without thermal overload protection could damage the motor or the valve. This indicated that an automatic isolation may have created an un-isolable reactor coolant system (RCS) leak prior to torque and limit switch setpoint verification. Later, the test engineer stated in the interview that the valve would not have been damaged if automatic isolation occurred. However, the operators were not aware of that at the time of the event.

It would have been helpful if the special test procedure addressed operator response to or recovery from an isolation signal and differential flow alarm condition. There is no requirement for test procedures to have a "Recovery" section.

The alarm response procedures for both "LD RWCU FLOW HI" Div 1 and 2 do not mention the use of rear panel RWCU differential flow meter, the RBEDT indications, local area radiation monitors area temperatures, or dispatching personnel to the area for determining alarm validity. These are some of the indications that might be used to assist in determining alarm validity. The alarm response procedures do not provide criteria for use of the bypass keys, nor do they reference other procedures where criteria might be present.

The "Conduct of Operations" procedure, LAP-1600-2, addresses temporarily withdrawing systems from operation when it is apparent that continued operation would aggravate the plant condition. There is ambiguity in whether or not this statement includes engineered safety feature (ESF) equipment or actuation or under what conditions the statement applies.

After the event, the SE verbally instructed his crew that ESF signals shall not be bypassed in the future. Therefore, this one crew has been instructed not to bypass ESF, but it is unclear that other crews have been similarly informed. It would be helpful to operators for this statement of policy and its associated actions to be included in appropriate operating and administrative procedures, rather than as only a verbal instruction that may be forgotten or confused. It would also ensure that all operating personnel were informed.

2.3.3 Decisionmaking. The decision made to bypass the RWCU high differential flow alarm isolation signal was not based on specific procedural steps but was based on existing knowledge about systems, processes and plant conditions. The decision to bypass the isolation signal, then, was a knowledge-based decision (Rasmussen, 1983). Various factors were influential in making this decision. A major factor was the previous experience of the operators with spurious signals and alarms regarding the RWCU differential flow. Operators reported that the high differential flow alarm had activated before, and in many cases it cleared before the 45-second isolation timer had timed out. This previous experience with spurious alarms was written into the daily orders (04/18 to 04/20, 1992) where it was stated that differential flow alarms were expected during startup and "we should however try to prevent these isolations from occurring (it is a lot less hassle)." It was reported that operators were criticized for not preventing a RWCU isolation when the valves limit and torque switches malfunctioned and motor damaged resulted (on April 7).

The factors that contribute to making decisions, such as the decision to bypass the automatic RWCU isolation, can be complex. Some researchers have suggested that decisions are made by generating alternatives and weighing the advantages and disadvantages of each before deciding which alternative to carry out. Recent studies, however, indicate that experienced operators (such as firefighters and military commanders) rely more upon their recognition of similar situations than on a linear progression of decision making through a search for, and evaluation of, options (Klein, 1989). The decision to bypass RWCU isolation, given the previous spurious high differential flow alarms, may be an example of such a "recognition-primed decision." The operators appeared to rely on the ability to recognize and classify a situation, as "that" kind of situation, and then determined a way of reacting to the classified situation. In general, the response may be based on what the typical response is, what the most recent response was, what responses are available, or other factors. In this event, the high differential flow alarm, with normal indications, appeared to "fit" the situation of spurious alarm. The response may have been based on recent experience, that is, the knowledge that the isolation valve motors burned up when the system isolated two weeks previously, influencing the control room personnel to bypass the isolation rather than experience potentially burned valve motors or valve damage. The pattern looked familiar and the response was based on that identification and classification of the situation. The decisionmaking process can be aided by determining appropriate responses to possible (or even likely) events, such as holding a prebriefing with crew members to discuss what should be done under certain circumstances. If decisionmaking is actually based on recognizing patterns, then the decisionmaking process may also be aided by exposing operators to a number of different situations, via training and simulation, to enhance their abilities in identifying unusual situations and the most appropriate responses to them. It is also possible to require operators to look at different combinations of instruments that may allow them to assess the current pattern.

There was a second decision based on additional information, approximately three minutes later, to remove the bypass and have the system isolate automatically. The additional information of readings from the differential flow meter, from the RBEDT chart, and the equipment attendant report resulted in the knowledge-based decision to remove the bypass. The operators might have decided to shut the isolation valves manually, thereby ensuring thermal overload protection. However, having determined that the RWCU should be isolated, the control room operating personnel acted to recover from (i.e., "undo") the initial bypass decision by removing the bypass via the key switch.

2.3.4 Knowledge-based Behavior. The actions performed by the control room personnel were primarily knowledge-based actions. The knowledge-based actions included using the key to bypass the RWCU isolation signal; gathering additional information from control room instrumentation and outside the control room to determine the validity of the high differential flow alarm; directing the equipment attendant in the plant to check locally for relief valve lifting indications; directing the technical staff on hand locally [illegible] the special test to check the isolation valve motor controller to ensure the motor had stopped.

Knowledge-based behavior is characterized by cognitive processing of existing knowledge of systems and processes. The knowledge is a result of experience and training. An operator's knowledge base will support the use of procedures (i.e., rule-based behavior). It is acknowledged that error probabilities are higher for knowledge-based behavior than for rule-based behavior. Good procedures will identify what the appropriate situation is and what should be the response to that situation. If there is no procedure, a situational match is not specifically identified and will be left to the individual operator's ability to identify it as "that" kind of situation. In this event, knowledge-based behavior contributed to the decision to bypass the isolation. Knowledge-based behavior also contributed to gathering and processing of additional information to determine alarm validity. The NSO's knowledge base regarding the system, processes and plant conditions included knowledge that indications of a relief valve lifting might be present in the plant, and led to directing the equipment attendant to look for signs of a lifted or open relief valve. The knowledge base also led to suggesting to the test personnel that they take ammeter readings to assess the status of the MOVs.

In this event, knowledge-based behavior led to positive, quick thinking actions to determine alarm validity and appropriate responses. However, each operator's knowledge base is different and, if their knowledge base was the only support available, other operators' may not have had the same quick thinking response. When actions are dependent on knowledge-based reasoning, operators are more prone to making decisions and taking actions without considering all possible alternatives and their consequences.

2.3.5 Human-Machine Interface. There were several human-machine interface (HMI) issues which contributed to the event. The primary instrument for displaying RWCU differential flow is located on the rear panel. In order to see that indicator, an operator must walk behind the rear panel. It would have been helpful to have that indicator on the front panel to check during the high differential flow alarm response and might also be helpful for the operator to be able to monitor the RWCU differential flow during system operation.

The RWCU flow and pressure instrumentation that was used to initially determine if the high differential flow alarm was valid did not contain sufficient information to make a correct judgment. The instrumentation that was subsequently used in the control room to determine if the high differential flow alarm was valid included the differential flow indicator which is located on the rear panel and the reactor building equipment drain tank (RBEDT) indicator which is located approximately 15 feet from the RWCU controls area. Therefore, the available instrumentation needed to determine the validity of a RWCU differential flow alarm is located in various areas of the control room. In addition, as has been discussed, the operator needed to use knowledge-based reasoning in order to identify the instrumentation that would provide the indications needed. Currently, those indications are not discussed in the procedures. There is not direct relief valve discharge line temperature indication in the control room. Such an indication would assist the operators in identifying a lifted relief valve flow in the line while remaining in the control room rather than relying on coordinating with equipment attendants in the plant to locate and identify discharge line flow.

3. REFERENCES

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