TRIP REPORT

Jerry L. Harbour
Orville R. Meyer

On-Site Analysis of the Human Factors of an Event at Catawba Unit 1 on March 20, 1990

(Overpressurization of RHR System)

Investigative Team

Jerry Harbour, INEL/EG&G Idaho
*George Lanik, NRC/AEOD
Orville Meyer, INEL/EG&G Idaho
Ann Ramey-Smith, NRC/RES

*Team Leader

May 1990

INEL/EG&G Idaho, Inc.

ACKNOWLEDGMENTS

Appreciation is expressed for the cooperation of the Catawba Station staff, in particular the Unit 1 control room operators who were on duty during the day shift on March 20 and who freely provided information concerning their observations, thinking, and actions. The acquisition of on-site information was also greatly facilitated by Curtis Rapp, Reactor Engineer, Region II, William Orders, Senior Resident, Region II, and Mark Lesser, Resident Inspector, Region II. Thanks are also due to Steve Johnson, certified PWR Operator Examiner, for assistance in operations analysis and to Elaine Beardall for her efficient text processing.

EXECUTIVE SUMMARY

On March 20, 1990, at about 0930, Catawba Station Unit 1 experienced an overpressurization of the Residual Heat Removal System (RHR) and Reactor Coolant System (RCS) during the procedure to initially pressurize the RCS to 100 psig following a refueling outage. As part of the AEOD program to investigate the human factors aspects of operational events, a team was sent to the site. The team leader was George Lanik of AEOD; other team members were Ann Ramey-Smith from the Human Factors Branch, RES, and Orville Meyer and Dr. Jerry Harbour from the Idaho National Engineering Laboratory (INEL). The team spent the day of March 27 at the site and gathered data from discussions, plant logs, and interviews with control room operators and other station staff. The team also had access to the draft results of the then on-going investigation by NRC Region II personnel. This trip report provides a review of the details of the event, a preliminary analysis of the human factors issues that were relevant to the event, and a summary of the findings from the event analysis.

Catawba Unit 1 had completed an approximate seven week refueling outage and reinstalled the reactor vessel head. The control room night shift on March 20 completed the initial fill and vent and had vented water and gas (bubbly flow) from the reactor head vent for one to two hours hours longer than on previous fill and vent operations. At the time of the shift change (0700 hours), the pressurizer was 97% full, the RHR system was in operation with pump A operating and pump B in standby (suction valve open), and the Chemical and Volume Control System (CVCS) was in operation with approximately equal charging and letdown flow of 50 gpm. Figure 1, Solid Plant Operation, illustrates the RCS, RHR and CVCS configurations.

The on-coming day shift initiated the pressurization of the RCS at about 0705. The pressurizer fill was topped off until water exited the PORVs. The PORVs were then shut and their control placed in the Low Temperature Over-Pressure Protection Mode. The RCS makeup flow from centrifugal charging pump 1B was increased to 100 GPM and the letdown flow decreased to 30 GPM. The target RCS pressure was 100 psig.

Similar previous pressurizations had required four to six hours to reach 100 psig. Due to the gases trapped in the steam generator U tubes, the pressure rise is exponential and is not detectable over the early, longer part of the charging period. The operators had three indicators for monitoring RCS pressure (two wide range [WR], 0-3000 psig, and one low range [LR], 0-800 psig) which were being closely monitored for a detectable rise in RCS pressure. However, unknown to the control room operators on duty, all three RCS pressure instrument transmitters were still isolated after the welding of the tubing fittings during the refueling outage. The two WR RCS pressure instruments are the sensors for the Low Temperature Over-Pressure Protection Mode for the PORVs.

Possibly due to the more extended venting of the reactor head by the previous shift, the RCS pressure rose faster than anticipated. At 0938 the RHR pump suction relief valve lifted and limited RCS pressure to 455 psig maximum and the RHR pump discharge pressure to 625 psig maximum. These pressure rises were not observed by the operators although the RHR discharge pressure indicator was operable. The RHR suction relief valve remained open passing the RCS charging flow to the Pressurizer Relief Tank (PRT). The rising PRT level indication was observed by the operators who began a search for the leakage path from the RCS. The open RHR suction relief valve and abnormally high RHR pressure were discovered, leading to the realization that the RCS had pressurized. No annunciators alarmed during this sequence since the maximum RHR pressure that was reached was slightly below the actuation setpoint of the pressure switch.

The factors that affected personnel performance during this event are discussed below:

Planning and Scheduling

Activities during a refueling outage at Catawba were scheduled and tracked by an Integrated Scheduling organization. Integrated Scheduling had issued a Work Request to replace tubing fittings with socket welds on the RCS pressure instruments during the refueling outage and had scheduled a functional test with the RCS pressurized prior to Mode 4. The need for these pressure instruments to be operable after fill and vent and prior to initial pressurization of the RCS was overlooked by both Integrated Scheduling and the Instrumentation and Electronics (IAE) planners. No formal independent review of outstanding Work Requests was made prior to initial fill and vent.

Tagging of Out-of-Service Control Room Instruments

The operability of control room instruments was the responsibility of IAE. There is a tagging procedure at Catawba, but it was not the practice of IAE to always place a tag on an inoperable control room indicator. Since the three RCS pressure indicators in the control room were not tagged and since the three indicators provide apparent redundancy, the operators were led into a cognitive trap of relying exclusively on these three indicators to detect pressurization of the RCS.

Systems Monitoring

In addition to the RCS pressure indicators, there were other means available for detecting the rise in RCS pressure. Both the letdown (CVCS) pressure and the RHR pump discharge pressure rose in response to the rise in RCS pressure. Both of these pressure indicators were located near the RCS pressure indications since the RCS pressure indicators are grouped with the CVCS and RHR indicators and controls for a single operator. Initiation of a significant change in state of a system should prompt the operator to monitor the overall indicated status of the system. In this event, the survey should have included the pressures in the CVCS and RHR systems as well as the RCS. It is axiomatic that such operational surveys will reveal nothing abnormal most of the time. However, these surveys under normal conditions can provide the images of normal operation that permit the operator to detect the unexpected abnormality.

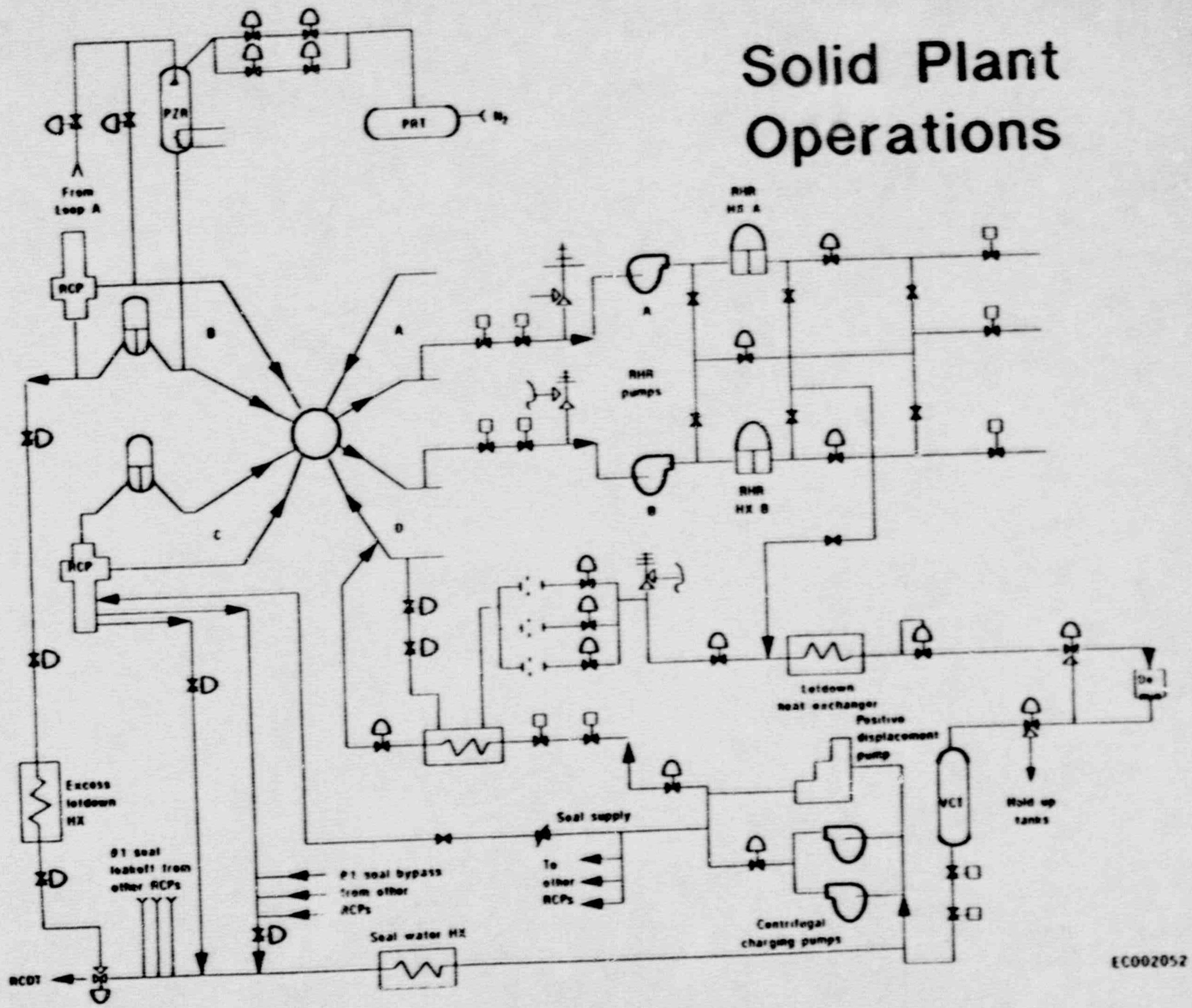
Operator's Initial Diagnosis

The increasing PRT level indication alerted the operators that the RCS response was abnormal. However, the fact that the operators were unaware that the three redundant, diverse RCS pressure instruments were isolated had created a cognitive trap for the operators and their initial diagnosis assumed that the RCS was not pressurized. The input of the previously uninvolved RCS system engineer may have helped break this trap.

Variation in the Performance of Procedures

The initial fill and vent of the RCS was performed in accordance with the applicable procedure. However, venting of gas from the reactor vessel head vent had continued for a longer time interval before the vent valve was closed than on previous RCS initial fill and vent evolutions. The greater volume of gas removed from the RCS <u>may</u> have contributed to an earlier rise of RCS pressure after charging was initiated. The principle of "change analysis" is that any change ' execution of a procedure can create unforeseen effects. In this event, application of the principle may have alerted the operators to the possibility of an earlier rise in RCS pressure.

Figure 1



Solid Plant Operations
From Loop A
PZR
PRT
RCP
RCP
A
B
C
D
RHR pumps
RHR HX A
RHR HX B
Letdown heat exchanger
Positive displacement pump
VCT
Hold up tanks
Seal supply
To other RCPs
Centrifugal charging pumps
Excess letdown HX
#1 seal leakoff from other RCPs
#1 seal bypass from other RCPs
Seal water HX
RCDT
EC002052

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Purpose

The purpose of this site visit on March 27 was to gather information regarding the overpressurization event at Catawba Unit 1 on March 20, 1990. This was the second of a planned series of studies to be conducted by NRC/AEOD for the purpose of analyzing the factors that affect human performance during operational events.

1.2 Scope

This study addresses the factors affecting human performance which resulted in inoperable RCS pressure instruments and the operators' reliance on them during the filling and initial pressurization of the RCS. The discussion also addresses the recognition of, and the recovery from, the overpressurization event.

1.3 Team Composition

The team leader was George Lanik from the Nuclear Regulatory Commission's (NRC) Office for the Analysis and Evaluation of Operational Data. The other team members were Ann Ramey Smith, NRC's Office of Nuclear Regulatory Research, Human Factors Branch, and Dr. Jerry Harbour and Orville Meyer, both from the Idaho National Engineering Laboratory/ EG&G Idaho Human Factors Research Unit.

2.0 DESCRIPTION OF INVESTIGATION

2.1 Background

The Catawba Station is located in South Carolina and consists of two Westinghouse 4-loop PWRs, each of 1129 MWe net capacity. Unit 1 entered commercial operation in 1985, Unit 2 in 1986.

Unit 1 and Unit 2 are operated from a common control room. The normal control room crew complement is shown in Table I. The non-licensed operators are not preassigned to individual units. Both the Unit 1 and the Unit 2 supervisors are qualified Shift Technical Advisors (STA). If an event occurs on one unit, the supervisor from the second unit becomes the STA for the unit in an emergency condition. Personnel interviewed by the event analysis team are listed in Table II.

On March 20, Unit 1 was ending a seven week refueling outage which had been entered on January 27, 1990. The event occurred about 2-1/2 hours into the day shift. The previous shift had completed the fill and vent of the RCS with the pressurizer level at 97% and the PORVs open. In order to permit the operation of pressurizing the RCS to 100 psig and jogging RC pumps to be initiated and completed by the same shift crew, the night shift had elected to use the remaining few hours of their shift to continue venting of the reactor vessel head. The plan was for the day shift to top off the fill of the RCS until water flowed through the open PORVs, close the PORVs, and continue charging the RCS until an RCS pressure of 100 psig was reached. The off-going shift briefed the day shift on the plant status and previous activities, but the possible significance of the continued venting of the reactor vessel head was not discussed.

The day shift crew expected that it would require 4-6 hours to attain 100 psig RCS pressure with the pressure rise undetectable until late in that time interval because of the exponential increase of RCS pressure with time. However, the crew was unaware that the RCS pressure instruments (Two WR, 0-3000 psig indication, and one LR, 0-800 psig indication) were inoperable because their root valves were inadvertently left closed. In addition to indication, the two WR instruments provide Low Temperature Over Pressure Protection (LTOP) for the RCS by automatic opening of the pressurizer PORVs and provide overpressure protection for the RHR system by auto-isolation of the suction valves. The LTOP protection mode of the PORVs was therefore not available, unknown to the crew. The A train of the RHR system was in operation. The suction valve for the B train of the RHR system was also open.

TABLE I

Normal Control Room Crew Complement

A. Control Room

Control Room Shift Supervisor (SS)
Control Room Senior Reactor Operator (CRSRO)
Nine (typically) Non-Licensed Operators (NLOs)

B. Unit 1

Unit Supervisor (US)
Operator at the Controls (OATC)
Balance of Plant Operator (BOP)

C. Unit 2

Unit Supervisor (US)
Operator at the Controls (OATC)
Balance of Plant Operator (BOP)

TABLE II

Catawba Personnel Interviewed

T. D. Williams, SS (on duty on Unit 1 during the event)
M. T. Lee, BOP (on duty on Unit 1 during the event)
R. B. Abernathy, Integrated Scheduling
R. N. Casler, Superintendent of Operations/NP
S. T. Rose, Nuclear Production
J. H. Knuti, Operations
W. W. McCollough, Mechanical Maintenance
R. T. Simril, Jr., Operations

.2.2 Event Description

The following event time line sequence was constructed based upon interviews with the control room operators and upon review of the initialled and dated control room copy of the Initial Fill Procedure and the plant process computer records. The results of the event analysis by the station staff and by the NRC Region II and Resident Inspectors personnel were also available and very informative.

1/27/90

o Unit 1 enters refueling shutdown.

2/7/90

o Root valves are closed by IAE technicians to isolate RCS Wide Range (WR) Pressure Instruments INCP5120 and INCP5140 and RCS Low Range (LR) Pressure Instrument INCP5142 per Work Request 5491 IAE-1. The instrument sensing line tubing fittings are to be replaced by socket weld fittings per Work Request 1493 MES-1.

o No permanent record or tag-out of the inoperability of these three pressure instruments is made in the control room, i.e., no out-of-service tag is hung on the indicators. The IAE group is considered to have operational responsibility for instruments in the application of Catawba Nuclear Station Directive 3.1.1 (OP), "Safety Tags and Delineation Tags."

[A sequence scheduling error had been made in the writing and issuance of the above Work Requests. Completion of the Work Requests was identified as being required prior to Mode 4. The scheduling error had a common mode effect on all three pressure instruments (2 WR and 1 LR).]

2/21/90

o Socket weld installations completed on all three pressure instruments. Root valves remain closed on the two WR and the LR NC pressure instruments.

3/12/90

1207

o reactor vessel head studs tensioned. Unit 1 enters Mode 5.

3/13/90

1300

o Entered the fill procedure for the RCS system.

3/20/90

0419

o reactor vessel head vents are closed. [The operators who were interviewed stated that venting from reactor vessel head vent was continued for approximately three hours vs approximately one hour on previous fills of the RCS system.]

0700

o Control room operators shift change. Plant conditions are:

o RCS fill is nearly complete as evidenced by pressurizer level instrument reading of 97%.

o PORVs are open.

o Train A of the RHR system in operation. Pump suction isolation valve for Train B is open.

o The CVCS system is in operation with centrifugal charging pump 1B running and charging and letdown flow balanced at approximately 50 gpm.

[Operators are unaware that both WR and the LR RCS pressure instruments are inoperable due to the root values being closed.]

o Charging flow increased to approximately 110 gpm to complete the fill of the RCS system.

0708 The following sequence takes place:

o The Pressurizer Relief Tank (PRT) level increases indicating to the operators that the pressurizer is over flowing through the PORVs.

o The PORVs are closed and the Low Temperature Over-Pressure Protection Mode for the PORVs is selected. [In this mode the PORVs controls are set to open the PORVs automatically upon receipt of actuation signals from the two WR RCS pressure instruments in the event of high RCS pressure. The two WR RCS pressure instruments also provide overpressure protection for the RHR system by initiating an auto-isolation at 600 psig. Since the two WR pressure instruments are inoperable, this protection is inoperable.]

o Charging flow is adjusted to approximately 100 gpm and letdown flow to approximately 30 gpm to begin pressurizing the RCS system to 100 psig. The operators are expecting this pressurization to require four to six hours, based on previous experience. Since the pressure rise is controlled by the pressurization of the gases trapped in the U-bends of the steam generator tubes, the operators expect that it will require two or more hours to detect a pressure increase in the NC system. [P = MRT/V relation creates an exponential rate of rise of NC pressure.]

o After this adjustment, the operators begin observing the two WR and the LR RCS pressure instruments in order to detect the first indication of increasing pressure in the NC system.

[There are three factors present at this time that could prompt operators to check the operability of the three pressure instruments, i.e., (1) the plant has been in a shutdown condition for nearly two months with work in progress in containment and no opportunity to observe the operability of the three RCS pressure instruments, (2) the two WR instruments are providing the NC low temperature overpressure protection, and (3) operability checks are marginally possible by checking for the static head pressure of approximately 28 psig in the RCS system (1% of 0-3000 range on WR, 3-1/2% of 0-800 range on LR) and, more positively, by also observing the RHR system pump discharge pressure which is a low range pressure instrument.]

o The licensed RO designated as the Unit 1 Operator at the Controls (OATC) is controlling the RCS pressurization. A licensed RO designated as the Unit 1 Balance of Plant (BOP) operator is on duty in the control room. The Unit 1 supervisor is in the plant directing a test of the main feed pump turbine 1A overspeed controls. The control room shift supervisor and control room senior reactor operator, who are licensed SROs, are in the control room. Other activities in the control room on Unit 1 are SSPS response time testing, which periodically activates the annunciator horn, and valve stroke testing of the Letdown Isolation Valves. [The operators indicated in the interviews that these were distractions but that they did not directly interfere with the monitoring and control of the RCS pressurization.]

0938

o The RCS and the connected RHR system have pressurized to the degree that suction relief valve on RHR train B has opened. This is 2-1/2 hours after initiation of charging vs the expected four to six hours. This reduces the RCS pressure to approximately 175 psig and the relief valve remains open passing the net charging flow from the CVCS system to the PRT. [The setpoint for this relief valve is 465 psig and it is large enough to relieve the combined flow of the charging pumps.]

o The RHR pump 1A High Discharge Pressure annunciator does <u>not</u> alarm (setpoint 579 psig) and operators do not observe the abnormally high RHR pressure instrument indications because of their concentration on the three inoperable RCS pressure indicators. [Later analysis concludes that the RHR discharge pressure reached a conservative maximum of of 625 psig, possibly less since the RHR high pressure annunciator did not alarm.]

0945

o Operators observe an increasing level in the PRT.

o Charging is reduced to 95 gpm. Unit supervisor is notified. PRT pump down lineup is checked since previous shift had reported problems with PRT pump down. PRT pump down is verified. PRT level continues to increase.

1000

o Operators suspect PORVs may be leaking into the PRT.

o PORVs isolated singly, but PRT level continues to increase.

1015

o System diagrams are pulled and examined. The RCS systems engineer, who was in the control room on unrelated matters, participates in the diagnostics and recalls an NRC Information Notice on interfacing systems loss of coolant. System diagrams are reviewed for possible leakage paths.

o Operators observe that the RHR pump discharge pressure is abnormally high at 375 psig. Since the RHR pump head is approximately 200 psig, this indicates that the RCS may be pressurized to approximately 175 psig.

o The OATC directs an equipment operator to check RHR system suction relief valves located in the containment.

o Increased letdown flow to 120 gpm and gradually reduced charging flow to depressurize RCS and RHR system to approximately 200 psig as indicated on the RHR pump discharge pressure instrument.

1020

o The equipment operator finds the relief valve on the suction of the B Train RHR system is discharging water as evidenced by sound and vibration.

- The B Train RHR system is isolated. The A Train RHR suction relief valve remains connected to the RCS.

[The control room notifies station management and an investigation is initiated. The WR and LR RCS pressure instruments are unisolated. It is estimated that the RCS pressure peaked at 455 psig. The RHR discharge piping reached a maximum of 625 psig which is above the 600 psig design pressure for operation but within ASME Code limits.]

2.3 Analysis

2.3.1 <u>Planning and Scheduling of Equipment Outages</u>

The direct cause of this event was the failure to unisolate and verify the operability of the three RCS pressure instruments after completion of the welding of the fittings and before entering the fill and vent procedure. The sequencing of the operations of isolating, welding, and unisolating were under the control of the Integrated Scheduling activity during the refueling outage. An Operations Outage Information Request Sheet had been filled in by the RCS systems engineer indicating that the work was required prior to entering Mode 5 (tensioning of reactor vessel head studs) and that a functional test was required prior to entering Mode 4 (hot operations).

The Work Request issued by Integrated Scheduling to install the socket welds on the three RCS pressure instruments was scheduled to be done during the refueling outage and was completed by Mechanical Maintenance prior to setting the reactor vessel head. A functional check of the pressure instruments was scheduled to be completed prior to entry into Mode 4 when RCS pressure was applied to the instrument sensors. The isolation and unisolation of the sensors to be performed by IAE were identified only as notes on the Work Request. The notes were reviewed by an IAE planner and documented on a Standing Work Request (SWR) 6114 which is used to assure that the RCS pressure instrumentation is aligned and operable prior to Mode 4. A formal review of outstanding work and of the maintenance data base was not performed prior to initiating fill and vent and initial pressurization of the RCS.

The station management's investigation of this event has determined that a change should be made to the scheduling mechanisms. This change will provide for a review of activities and work completion required for entry into each of Modes 1-6, inclusive, and for changing from the RCS filled to not filled conditions and vice versa. To be effective, this listing should not rely solely upon the required completion conditions on the work requests or an error on a work request will not be detected. These listings should receive a review that is independent of the release of the work requests.

The station management has indicated that they will also change the controlling procedure for unit shutdowns so that it will require a signoff from IAE that the RCS wide range pressure instruments are valved in and operable prior to setting the reactor vessel head. This action is specific to the oversight causing this event only.

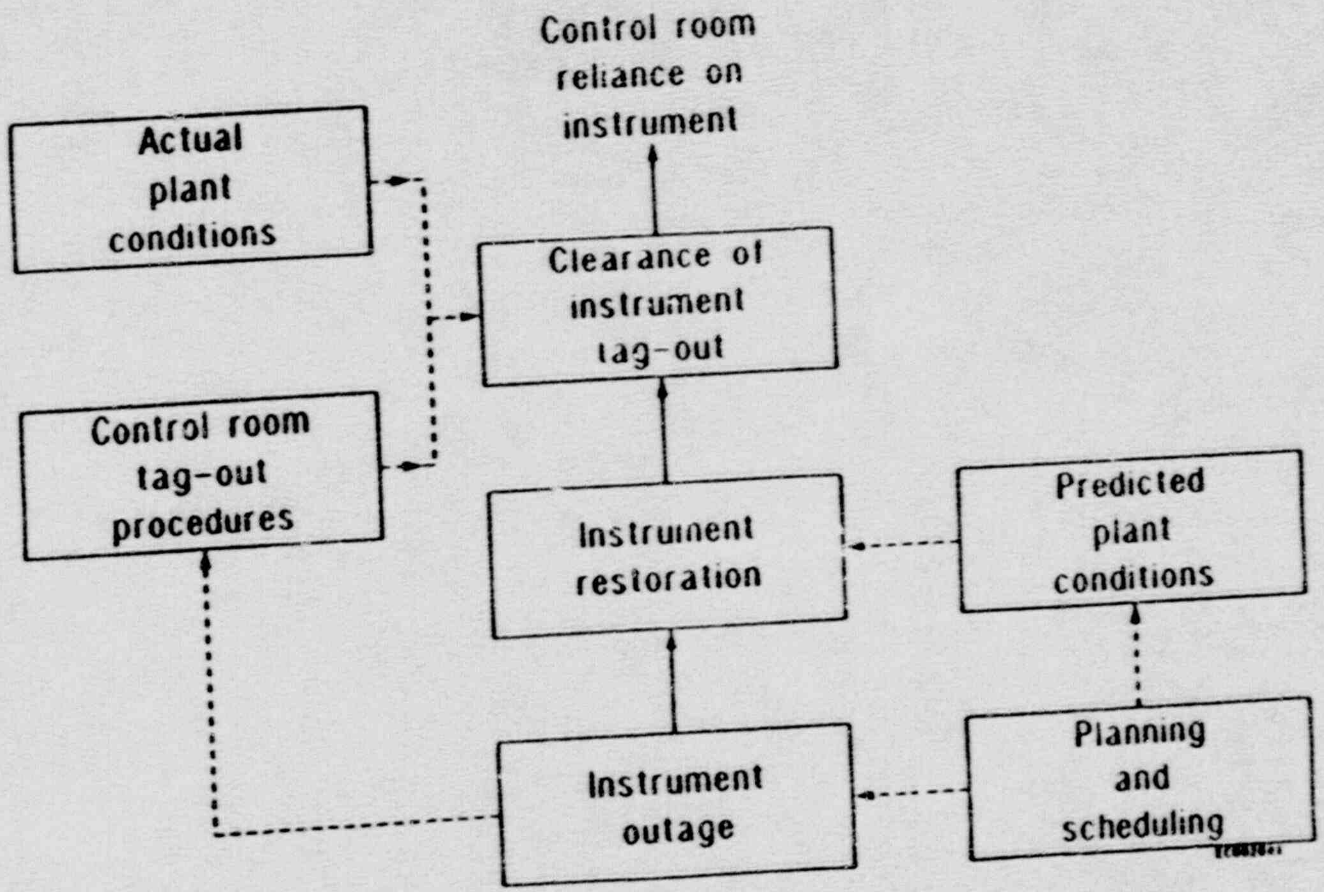
2.3.2 Procedures for Out-of-Service Instruments

Catawba Nuclear Station Directive 3.1.1, "Safety Tags and Delineation Tags," is applicable to the removal of control room instruments from service. However, IAE has operational responsibility for the control room instruments and it was not their practice to always hang a tag on the instrument indicator in the control room but to sometimes place the tag elsewhere. It was a normal practice for IAE to advise the control room of outages and restorations, but there was no formal procedure or permanent control room record. The operators had instructions to not place their own tags on out-of-service indicators.

Consequently, there was no out-of-service tag or record in the control room to alert the operators that the LR and both WR pressure instruments were inoperable. Such tags and records would have provided an independent safety barrier against entering a sensitive operation while relying on indicators that were inoperable because of the IAE work. Their value rests on the fact that they are additional, independent barriers and upon the fact they initiate a check for operability at the time when plant conditions as observed by the operators require operability of the instruments. An unplanned event could create a situation where the control room operators need or use an instrument at a time which cannot be foreseen by planners. In such a situation, an outage tag directs the operators to use an alternate operable instrument or restore the instrument. See Figure 2.

As illustrated in Figure 2, planning and scheduling is a predictive process where a sequence of activities is developed with key events pre-established, e.g., initial fill and vent of the RCS, where certain conditions must be satisfied before the sequence can continue. Planning and scheduling is absolutely essential during operations such as a refueling outage and has been developed by the nuclear industry into a reliable process. The value of a procedure where the control room operators place their own tag on an instrument which is to be taken out of service is that it is an independent reminder to the operators to check for operability before again relying on the instrument. In this event at Catawba it would have been a simple task for an operator to visually verify that the socket welds were in place and the root valves opened. It is not a substitute for planning and scheduling and for quality work by maintenance personnel. Most often before removing an out-of-service tag, the check that the control room operator performs consists of receiving assurance from maintenance that the instrument is ready for service.

Figure 2. Tagout Procedures for Control Room Instruments



2.3.3 Systems Monitoring

As noted in the Event Description, Section 2.2, the rise in RCS pressure was observable on the letdown pressure indicator and the RHR pump discharge pressure. The fact that this was not observed by the operators is understandable since they had two independent WR RCS pressure instruments and a separate NR RCS pressure instrument which provided some diversity. However, the use of the RHR pump discharge pressure after the rise in PRT level to deduce that the RCS pressure was approximately 175 psig and not zero illustrates a useful rule of "systems monitoring."

An accepted rule of systems monitoring is that when a significant change in operating conditions is occurring, then the available indications on all the affected systems should be surveyed. In this event, the initiation of pressurization of the RCS would not only affect the RCS but also the interfacing CVCS and RHR systems. On almost all occasions, such surveillance will reveal only the normal effect on the interfacing systems, but such observations provide a baseline reference for the operators. On the occasion such as during this event where there is an anomaly, the anomaly may be then more readily detectable. Even without previous experience in this RCS pressurization operation, this type of surveillance would probably have noted the RCS pump discharge pressure rise. This type of surveillance is sometimes described as attaining and maintaining a "process image" which means an overall view and understanding of the process.

2.3.4 Operator Recovery from the Event

The operators' confidence that they were receiving reliable, redundant, and diverse readings of RCS pressure not only permitted the RCS pressure rise to be undetected but also was the basis for their explanation of the rise in PRT level and the actions the operators selected to resolve the rise in PRT level.

Figure 3

INPUT - ACTION MODELS

Approximate Times	Input Signals	Explanation (Hypothesis)	Selected Action(s)
0706 - 0945	RCS pressure indicators @ 0	Normal charging of RCS	Monitor WR and LR RCS instrumentation
0945 - 1008	Rapid increase in PRT level AND RCS pressure indicators @ 0	Leak in RCS or connected system	(1)*Check PORVs for leakage (2) RCS makeup flow reduced and check for other RCS or RHR leaks (3) RHR suction relief valves checked for flow.
1008 - 1112	Passing flow rather than just leaking in RHR suction relief valve AND RHR pump discharge pressure @ 380 psig AND RCS pressure indicators @ 0	(1) RHR suction relief valve must have been lifted by high pressure, therefore, RCS pressure must also be high (2) RCS pressure indicators still isolated following maintenance	RCS pressure reduced

*Numbers indicate sequential actions/hypotheses.

Figure 3 illustrates selected actions of the operators' based on their understanding of detected input signals, as represented by various control room instrumentation readings. For example, from 0708 - 0945, the operators' observed the RCS system pressure indicators at 0 psi (an input signal). Their explanation or hypothesis for this detected input was that the RCS was charging normally. Their selected action (representing a decision), was to continue normal monitoring of the WR and LR RCS instrumentation. Although their explanation and selected action was to prove faulty, it was based on, or initiated by, a false signal (i.e., RCS pressure indicators at 0 psi). Only at 0945 when they detected a rapid increase in PRT level (representing a second, and conflicting input signal), did they change their initial hypothesis from RCS charging normally, to a leak was present in the RCS or connected system. Based on this second explanation, the operators' selected actions that would conform to this new (yet still incorrect) understanding of the system state. Finally, from 1108 - 1112, they detected other input signals (e.g., RHR discharge pressure at 380 psi) that forced yet another explanation of the system state (this time correct) which resulted in actions being selected that returned the plant condition to a normal configuration.

The information that the RHR suction relief valve was "passing flow" (operator's terminology) rather than merely leaking led to the explanation that the RHR pressure was high. Even then, according to the operators recollections, it was difficult to disbelieve the three separate instrument readings of 0 psig RCS pressure. It was only when someone provided an explanation, i.e., the recollection that all three pressure instruments had been valved out at one time during the refueling outage, was there acceptance of the conclusion that the 0 psig RCS pressure readings were false and that the RCS was pressurized.

3.0 SUMMARY OF FINDINGS

The findings from the analysis of this event can be classified as follows:

1. Planning and Scheduling

   A mistake in planning and scheduling of maintenance, repair or modification can lead to scenarios that would be considered nearly incredible, particularly if the mistake is carried forward from an outage into Mode 5 and beyond. There are defenses against the effects of a scheduling mistake which can be added to the scheduling activities; the independent listing of requirements that must be met before initiating a significant change in plant conditions (entering Mode 5, initiating filling of the RCS, etc.) which is being considered by the Catawba Station staff, is an effective defense.

2. Tagging of Out-of-Service Control Room Instruments

   Administrative procedures that require that information is available to the control room operators on current plant status provide an independent defense against scheduling mistakes. Reliable and immediate knowledge of current plant status is important if an unplanned event occurs that could not be foreseen by the scheduling activity. Knowledge of current status of control room instrumentation is particularly important because if the operator can be misled into the use of a false signal a progression of explanations and actions by the operator is initiated that may be difficult to interrupt. A false signal leads to a false hypothesis which leads to ineffective actions, or worse.

3. Systems Monitoring

   Maintenance by the operator of an overall surveillance of the systems under his control can provide a final defense against many types of problems, including in this event, the existence of false signals. It is not an infallible means of defense, but it is of value on its own merit in providing the operator with his own image of the normal response of the systems. Abnormal responses may, then, be more readily apparent.

4. Operators' Initial Diagnosis

The increasing PRT level indication alerted the operators that the RCS response was abnormal. However, the fact that the operators were unaware that the three redundant, diverse pressure instruments were isolated had created a cognitive trap for the operators and their initial diagnosis assumed that the RCS was not pressurized. The entry of the previously uninvolved, RCS system engineer may have helped break this trap.

5. Variation in the Performance of Procedures

The initial fill and vent of the RCS was done in compliance with the applicable procedure. However, venting of gas from the reactor vessel head vent had continued for a longer time interval before the vent valve was closed than on previous performances of the RCS initial fill and vent. The greater volume of gas removed from the RCS <u>may</u> have contributed to an earlier rise of RCS pressure after charging was initiated. The principle of "change analysis" is that any change in execution of a procedure can create unforeseen effects. In this event, application of the principle may have alerted the operators to the possibility of an earlier rise in RCS pressure.