UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, D.C. 20555

December 30, 1994

NRC INFORMATION NOTICE 94-90: TRANSIENT RESULTING IN A REACTOR TRIP AND MULTIPLE SAFETY INJECTION SYSTEM ACTUATIONS AT SALEM

Addressees

All holders of operating licenses or construction permits for nuclear power reactors.

Purpose

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice to alert addressees to the events associated with the loss of circulating water at Salem Nuclear Power Plant, Unit 1, on April 7, 1994, that led to a reactor trip followed by multiple automatic actuations of the safety injection system. It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. However, suggestions contained in this information notice are not NRC requirements; therefore, no specific action or written response is required.

Description of Circumstances

On April 7, 1994, at 10:00 a.m., Salem, Unit 1 was in Mode 1 at 73-percent power. Public Service Electric and Gas Company (the licensee) was operating the unit at reduced power because river detritus (marsh grass) had fouled the circulating water intake structure causing a reduction in condenser cooling efficiency. In response, the operators decreased the power level of Unit 1 to approximately 60 percent because of an increase in condenser back pressure caused by grass fouling of the traveling screens at the intake structure. In response to an impending loss of circulating water, the operators began reducing load by 1 percent per minute. However, in rapid succession, several of the Unit 1 traveling screens became clogged with grass, causing the associated pumps to trip, until only 1 circulating water pump remained running. As the pumps were lost from service, operators increased the rate of the load reduction to 8 percent per minute.

Operators attempted to reduce unit load as rapidly as reactor power was being decreased by insertion of control rods and addition of boron. The effort caused a power mismatch that resulted in a slight, but continuing, increase in reactor coolant temperature. In response, the nuclear shift supervisor directed the operator controlling reactor power to go to the electrical distribution control panel and shift plant electrical loads to offsite power sources. Although operators believed that the plant was stable, they failed

to recognize that reactor power was still decreasing because of the delayed effect of a previous addition of boron. This caused a reversal of the power mismatch and resulted in reactor coolant system (RCS) temperature decreasing to below the minimum temperature at which criticality is allowed. The operators attempted to restore RCS temperature by increasing reactor power from approximately 7 percent to 25 percent. However, since power had been below 10 percent, the power range "high neutron flux-low setpoint" trip had been automatically reinstated, establishing 25-percent reactor power as the trip setpoint. When power reached 25 percent, the reactor automatically tripped.

Almost immediately, train "A" of the safety injection (SI) logic actuated on a high steam flow signal coincident with low RCS temperature. (Later investigation revealed that the high steam flow signal was actually the result of a pressure wave created in the main steam lines when the turbine stop valves closed as a result of the turbine trip). In response to the reactor trip and safety injection, the operators entered the plant emergency operating procedures. The SI logic did not reposition all necessary components to the expected, post-actuation position because the initiating signal was so short. The operators manually repositioned the affected components to their proper positions. At 11:00 a.m., the licensee declared an unusual event based on a "manual or automatic emergency core cooling system actuation with a discharge to the vessel." When the operators took action to reset the SI logic, they discovered that train "B" of the SI logic had not actuated, indicating an apparent logic error.

As the operators were attempting to stabilize the plant, the RCS continued to heat up because of reactor decay heat combined with reactor coolant pump heat. Steam generator pressure increased but was not automatically relieved by the steam generator atmospheric relief valves because of a pre-existing condition that prevented the proper automatic operation of the valves. Concurrently, because of RCS heatup and the volume of water added by the safety injection, the pressurizer filled to a solid condition, and the pressurizer power-operated relief valves cycled several hundred times to control RCS pressure. A short time later, steam generator pressure increased in the "11" and "13" steam generators to the safety valve lift setpoint. The opening of a safety valve caused a rapid cooldown and depressurization of the RCS that was magnified by the solid condition of the system. RCS pressure rapidly reached the automatic SI setpoint of 1755 psig, and since train "B" of the SI logic had remained armed, a second automatic SI actuation occurred. At about the same time, operators manually initiated safety injection in response to the rapidly decreasing RCS pressure. After the second safety injection, operators remained in the emergency operating procedures, and continued their attempts to stabilize plant conditions. The pressurizer relief tank rupture disk actuated because of increasing tank pressure caused by the volume of RCS water relieved to the pressurizer relief tank from the pressurizer power-operated relief valves.

The operators controlled plant pressure using the charging and letdown provisions of the chemical and volume control system because normal RCS pressure control was not available due to the solid condition of the system. At 1:16 p.m., licensee management declared an alert to ensure activation of the Salem Technical Support Center to provide the Salem operators with additional technical assistance to support cooldown of the plant. Accordingly, the Technical Support Center was fully staffed.

At 3:11 p.m., the operators established a steam bubble in the pressurizer using pressurizer heaters. At 4:30 p.m., operators restored pressurizer level to the normal band and returned level control to automatic. They subsequently exited the emergency operating procedures and used the integrated operating procedures to cool the plant down to Mode 4 (Hot Shutdown), which was achieved at 1:06 a.m. on April 8, and then to Mode 5 (Cold Shutdown), which was achieved at 11:24 a.m. on the same day.

Discussion

On April 8, 1994, the NRC dispatched an Augmented Inspection Team to investigate the event. The results of that inspection were documented in NRC Inspection Report 50-272/94-80, dated June 24, 1994. Although several issues emerged from the NRC investigation of this event, three specific aspects are of particular concern. These aspects are discussed below.

Solid State Protection System Logic Mismatch: During the first SI actuation, the "A" and "B" logic trains of the solid state protection system were mismatched. Train "A" sensed and responded to conditions representative of a steam line break accident, namely a low RCS temperature coincident with a high steam line flow. Although these conditions were real indications, the RCS low temperature was due to operator error and the high steam flow was a transient signal induced by a pressure wave resulting from the closure of the turbine stop and control valves. This transient signal had a duration of about 30 milliseconds, which system response testing later showed was sufficient for certain portions of the "A" logic to respond, but of insufficient duration for the "B" logic to respond. The logic mismatch appears to be a result of the variations in response sensitivity to the steam flow input relays. The licensee modified the design to require a longer signal duration before the logic is actuated so that such transient signals would not result in an undesired safety injection.

Nuclear Instrument Rod Shadowing: Before the initial reactor trip, when the operators were raising reactor power to restore RCS temperature, the intermediate range and power range nuclear instruments were not in agreement with respect to indicated power. The intermediate range detectors were "trailing" the power range by about 5 to 10 percent. This led to a condition in which the reactor was tripped at the 25-percent power range setpoint before the rod block signal was received from the intermediate range detectors at 20-percent power. The discrepancy between the power and intermediate range nuclear instruments was apparently due to "rod shadowing."

The combination of the cool RCS and the rod pattern resulting from the down power maneuver shielded the intermediate range detectors, causing the instruments to indicate a lower power than the power range detectors. Although this bias was within an acceptable envelope for detector operability, the response of the instruments was not initially understood. This led to concern that the nuclear instruments were not properly operating.

Control Room Command and Control: Before the initial reactor trip, shift management directed staff to support actions necessary to restore circulating water. The Shift Technical Advisor, a senior reactor operator assigned to the work control station, was directed to assist in the restoration of affected equipment. The extra duty reactor operator was directed to assist at the intake structure. The senior shift supervisor was initially in the control room area, but subsequently left to go to the turbine building. This deployment of licensed operators led to minimal staffing of the control room at the onset of the transient.

During this time, the operators were preparing to take the unit turbine off line, and the reactor controls operator was directed by the shift supervisor to initiate actions to transfer plant electrical loads. This led to the reactor controls watch station not being staffed during a reactivity change. The RCS began to cool as a result of a slight power mismatch between the reactor and the turbine. When the shift supervisor first discovered this mismatch, he began to raise reactor power to restore temperature, which led to a momentary loss of the command oversight function. He subsequently recognized the need to maintain an overall command posture and stopped withdrawing control rods. However, he continued to allow the reactor controls operator to swap the electrical loads and the RCS temperature continued to decrease. When the reactor controls operator completed the electrical plant realignment, the shift supervisor then directed him to raise reactor power to restore RCS temperature. The shift supervisor did not discuss the fact that he had manipulated the control rods with the reactor controls operator, and his direction to the relatively inexperienced operator lacked specificity (how far or how fast to raise power). The operator subsequently raised reactor power until the 25-percent power trip was reached.

Related Generic Communications

- NRC Information Notice 94-55, "Problems with Copes-Vulcan Pressurizer Power-Operated Relief Valves," August 4, 1994.

  This information notice discusses cracking of plug material, severe wear of plugs and cages, and a problem with the misalignment and galling of a stem in the power-operated relief valves discovered as a result of valve inspection subsequent to the April 7, 1994, event.

- NRC Information Notice 94-36, "Undetected Accumulation of Gas in Reactor Coolant System," May 24, 1994.

  This information notice discusses lack of operator awareness of an accumulation of nitrogen in the reactor vessel head during cooldown and depressurization of the RCS subsequent to the April 7, 1994, event.

This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact the technical contact listed below or the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

Brian K. Grimes, Director
Division of Project Support
Office of Nuclear Reactor Regulation

Technical contacts: Robert J. Summers, RI
(609) 935-3850

Eric J. Benner, NRR
(301) 504-1171

Attachment:
List of Recently Issued NRC Information Notices

Attachments filed in Jackets

LIST OF RECENTLY ISSUED NRC INFORMATION NOTICES

Information Notice No.	Subject	Date of Issuance	Issued to
94-89	Equipment Failures at Irradiator Facilities	12/28/94	All U.S. Nuclear Regulatory Commission irradiator licensees.
94-88	Inservice Inspection Deficiencies Result in Severely Degraded Steam Generator Tubes	12/23/94	All holders of OLs or CPs for pressurized water reactors.
94-87	Unanticipated Crack in a Particular Heat of Alloy 600 Used for Westinghouse Mechanical Plugs for Steam Generator Tubes	12/22/94	All holders of OLs or CPs for nuclear power reactors.
94-86	Legal Actions Against Thermal Science, Inc., Manufacturer of Thermo-Lag	12/22/94	All holders of OLs or CPs for nuclear power reactors.
94-85	Problems with the Latching Mechanism in Potter and Brumfield R10-E3286-2 Relays	12/21/94	All holders of OLs or CPs for nuclear power reactors.
94-40, Supp. 1	Failure of a Rod Control Cluster Assembly to Fully Insert Following a Reactor Trip at Braidwood Unit 2	12/15/94	All holders of OLs or CPs for nuclear power reactors.
94-84	Air Entrainment in Terry Turbine Lubricating Oil System	12/02/94	All holders of OLs or CPs for nuclear power reactors.
89-25, Rev. 1	Unauthorized Transfer of Ownership or Control of Licensed Activities	12/07/94	All fuel cycle and material licensees.
94-83	Reactor Trip Followed by Unexpected Events	12/06/94	All holders of OLs or CPs for nuclear power reactors.

OL = Operating License
CP = Construction Permit

This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact the technical contact listed below or the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

Brian K. Grimes, Director
Division of Project Support
Office of Nuclear Reactor Regulation

Technical contacts: Robert J. Summers
(609) 935-3850

Eric J. Benner
(301) 504-1171

Attachment: List of Recently Issued NRC Information Notices

E-mailed to John White and Robert Summers of Region I for review on 10/21/94.

OFC	OECB:DOPS	PUB:ADM	SC/OECB:DOPS	BC/SRXB:DSSA
NAME	EBenner	Tech Ed*	EGoodwin*	RJones*
DATE	11/14/94	10/17/94	10/24/94	10/26/94

OFC	OECB:DOPS	BC/OECB:DOPS	D/DOPS
NAME	RKiessel*	AChaffee*	BGrimes
DATE	11/02/94	11/16/94	/ /94

[OFFICIAL RECORD COPY] DOCUMENT NAME: S:\DOPS_SEC\SALEM.IN

This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact the technical contact listed below or the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

Brian K. Grimes, Director
Division of Projects Support
Office of Nuclear Reactor Regulation

Technical contact: Robert J. Summers
(609) 935-3850

Eric J. Benner
(301) 504-1171

Attachment:
1. List of Recently Issued NRC Information Notices

E-mailed to John White and Robert Summers of Region I for review on 10/21/94.

OFC	OECB:DOPS	PUB:ADM	SC/OECB:DOPS	BC/SRXB:DSSA
NAME	EBenner EJB	Tech Ed*	EGoodwin*	RJones*
DATE	11/14/94	10/17/94	10/24/94	10/26/94

OFC	OECB:DOPS	BC/OECB:DOPS	D/DOPS
NAME	RKiessel*	ACheffee	BGrimes
DATE	11/02/94	11/16/94	/94

[OFFICIAL RECORD COPY] DOCUMENT NAME: G:\EJB1\SALEM.IN

This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact the technical contact listed below or the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

Brian K. Grimes, Director
Division of Projects Support
Office of Nuclear Reactor Regulation

Technical contact: Eric J. Benner
(301) 504-1171

Attachment:
1. List of Recently Issued NRC Information Notices

E-mailed to John White and Robert Summers of Region I for review on 10/21/94.

OFC	OECB:DOPS	PUB:ADM	SC/OECB:DOPS	BC/SRXB:DSSA
NAME	EBenner EJB	Tech Ed*	EGoodwin*	RJones*
DATE	11/2/94	10/17/94	10/24/94	10/26/94

OFC	OECB:DOPS	BC/OECB:DOPS	D/DOPS
NAME	RKiessel	AChaffee	BGrimes
DATE	11/2/94	/ /94	/ /94

[OFFICIAL RECORD COPY] DOCUMENT NAME: G:\EJB1\SALEM.IN

shift supervisor was initially in the control room area, but subsequently left to go to the turbine building. This deployment of licensed staffing led to minimal staffing of the control room at the onset of the transient. During this time, the operators were preparing to take the unit turbine off-line, and the reactor controls operator was directed by the shift supervisor to initiate actions to transfer plant electrical loads. This led to the reactor controls watch station not being manned during a reactivity change. The RCS began to cool as a result of a slight power mismatch between the reactor and the turbine. When first identified by the shift supervisor, he began to raise reactor power to restore temperature, which led to a momentary loss of the command function. The shift supervisor subsequently recognized the need to maintain an overall command posture and stopped withdrawing control rods. However, he continued to allow the reactor controls operator to swap the electrical loads and RCS temperature continued to degrade. When the reactor controls operator completed the electrical plant realignment, the shift supervisor then directed him to raise reactor power to restore RCS temperature. This direction was not specific as to how far to raise power, which, coupled with the operator's inexperience, led to the operator raising reactor power until reaching the 25 percent power trip.

Related Generic Communications

- NRC IN 94-55, "Problems with Copes-Vulcan Pressurizer Power-Operated Relief Valves," August 4, 1994.
- NRC IN 94-36, "Undetected Accumulation of Gas in Reactor Coolant System," May 24, 1994.

This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact the technical contact listed below or the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

Brian K. Grimes, Director
Division of Projects Support
Office of Nuclear Reactor Regulation

Technical contact: Eric J. Benner
(301) 504-1171

Attachment:
1. List of Recently Issued NRC Information Notices

E-mailed to John White and Robert Summers of Region I for review on 10/19/94.

OFC	OECB:DOPS	PUB:ADM	SC/OECB:DOPS	SRXB:DSSA
NAME	EBenner EJB	Tech Ed MMEJAC	EGoodwin	
DATE	10/14/94	10/17/94	10/22/94	/94

OFC	BC/SRXB:DSSA	BC/OECB:DOPS	D/DOPS
NAME	RJones RJ	AChaffee	BGrimes
DATE	10/26/94	/ /94	/ /94

[OFFICIAL RECORD COPY] DOCUMENT NAME: G:\EJB1\SALEM.IN

This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact the technical contact listed below or the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

Original signed by
Brian K. Grimes

Brian K. Grimes, Director
Division of Project Support
Office of Nuclear Reactor Regulation

Technical contacts: Robert J. Summers, RI
(609) 935-3850

Eric J. Benner, NRR
(301) 504-1171

Attachment:
List of Recently Issued NRC Information Notices

DOCUMENT NAME: 94-90.IN

*See previous concurrences

E-mailed to John White and Robert Summers of Region I for review on 10/21/94.

OFC	OECB:DOPS	PUB:ADM	SC/OECB:DOPS	BC/SRXB:DSSA
NAME	EBenner	Tech Ed*	EGoodwin*	RJones*
DATE	11/14/94	10/17/94	10/24/94	10/26/94

OFC	OECB:DOPS	BC/OECB:DOPS	D/DOPS
NAME	RKiessel*	AChaffee*	BGrimes
DATE	11/02/94	11/16/94	12/27/94

[OFFICIAL RECORD COPY]