NRC Form 366 (9-83)

U.S. NUCLEAR REGULATORY COMMISSION
APPROVED OMB NO. 3150-0104
EXPIRES: 8/31/85

LICENSEE EVENT REPORT (LER)

FACILITY NAME (1): Sequoyah, Unit 1

DOCKET NUMBER (2): 0 5 0 0 0 3 2 7

PAGE (3): 1 OF 0 7

TITLE (4): Thimble Tube Ejection, Revision 1

EVENT DATE (5)			LER NUMBER (6)			REPORT DATE (7)			OTHER FACILITIES INVOLVED (8)	
MONTH	DAY	YEAR	YEAR	SEQUENTIAL NUMBER	REVISION NUMBER	MONTH	DAY	YEAR	FACILITY NAMES	DOCKET NUMBER(S)
0 4	1 9	8 4	8 4	0 3 0	0 1	1 0	1 1	8 4		0 5 0 0 0
										0 5 0 0 0

OPERATING MODE (9): 1

POWER LEVEL (10): 0 3 0

THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR §: (Check one or more of the following) (11)

	20.402(b)		20.405(c)	X	50.73(a)(2)(iv)		73.71(b)
	20.405(a)(1)(i)		50.36(c)(1)		50.73(a)(2)(v)		73.71(c)
	20.405(a)(1)(ii)		50.36(c)(2)		50.73(a)(2)(vii)		OTHER (Specify in Abstract below and in Text, NRC Form 366A)
	20.405(a)(1)(iii)	X	50.73(a)(2)(i)		50.73(a)(2)(viii)(A)		
	20.405(a)(1)(iv)		50.73(a)(2)(ii)		50.73(a)(2)(viii)(B)		
	20.405(a)(1)(v)		50.73(a)(2)(iii)		50.73(a)(2)(x)		

LICENSEE CONTACT FOR THIS LER (12)

NAME	AREA CODE	TELEPHONE NUMBER
Glenn B. Kirk, Compliance Section Engineer	6 1 5	8 7 0 - 6 1 4 6

COMPLETE ONE LINE FOR EACH COMPONENT FAILURE DESCRIBED IN THIS REPORT (13)

CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO NPRDS	CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO NPRDS

SUPPLEMENTAL REPORT EXPECTED (14)

		EXPECTED SUBMISSION DATE (15)	MONTH	DAY	YEAR
YES (If yes, complete EXPECTED SUBMISSION DATE)	X NO				

ABSTRACT (Limit to 1400 spaces, i.e., approximately fifteen single-space typewritten lines) (16)

On 04/19/84, unit 1 was in mode 1 (2235 psig, 558 degrees F) at 30 percent reactor power with maintenance personnel cleaning incore detector thimble tubes. A high pressure connection on the thimble tube at the seal table failed resulting in a reactor coolant system pressure boundary leak of approximately 25-35 gpm and ejection of one incore detector thimble tube at 2100 CST.

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TEXT (If more space is required, use additional NRC Form 366A's) (17)

Background Information Leading to Event

The Reactor Engineering Unit (REU) had submitted various maintenance requests (MR) during late 1983 whenever a plugged incore detector thimble tube was encountered. In December 1983, REU submitted an MR requesting all unit 1 thimble tubes be cleaned (MR A098022). Due to manpower, time restrictions, and low priority, only nine thimble tubes were cleaned during the unit 1 refueling outage. Prior to startup following the outage, REU functionally tested the incore detector system (April 11-13) and identified 23 thimble tubes which were blocked. Research was done by REU to obtain information on the possibility of cleaning the tubes at temperature and pressure. It was determined that both Trojan Nuclear Plant and Beaver Valley Nuclear Plant had cleaned thimble tubes at reactor power operation with no problems being encountered. Westinghouse representatives were consulted, and they raised no objection to cleaning the tubes at pressure. Following management discussions, a decision was made to proceed with startup operations while cleaning the tubes in a similar technique as Trojan had used. This method would require removal of the 10 path selector and directly attaching a hand crank assembly which inserts a brush into the tube. Unit 1 entered mode 1 on 04/18/84 at 1118 CST and reached 30 percent reactor power on 04/18/84 at 1700 CST with thimble tube cleaning in progress.

The Event

On 04/19/84 after cleaning five thimble tubes, the job foreman was unsure if the brush was being inserted completely to the end of the tubes. A decision was made to insert the brush into an unblocked tube to obtain information on brush travel in a clean tube. The cleaning assembly was installed at tube D-12 and was inserted to approximately 15 feet prior to shift change. The second shift cleaning crew took over and began inserting the brush. Each turn of the cleaning tool crank resulted in inserting the brush 10 inches further into the tube. Personnel stopped at the fiftieth (50th) crank to ensure the number of turns had been properly counted. At the seventy-eighth (78th) turn, the tool handler noted that more pressure was being required to turn the crank. At approximately 2100 CST during the seventy-ninth (79th) turn (brush would be approximately 80.8 feet into the tube), water was noticed on the seal table. The work crew immediately evacuated the area. After exiting from the personnel containment airlock, the foreman requested the public safety officer stationed outside the airlock to notify the shift engineer (SE) of the situation. Since the public safety officer was unable to reach the SE by phone, the foreman proceeded directly to the control room following removal of his anti-C clothing.

At 2110 CST, the pressurizer level was decreasing and the charging flow was increased by 45 gpm (from 85 gpm to 130 gpm). At 2116 CST, the pressurizer level decrease stopped and began to increase, indicating the reactor coolant system (RCS) leakage was less than 45 gpm. Later estimates showed the leakage was approximately 30 gpm. At 2117 CST, power reduction at one percent per minute was initiated. At 2120 CST, Radiological Emergency Plan Procedure IP-2, "RCS Leakage Greater Than 10 gpm Identified" was initiated, and the Operations Supervisor and Assistant Plant Superintendent-Operations and Engineering were notified. At 2125 CST with reactor power at 18 percent (525 degrees F and 2235 psig), the TVA duty specialist was notified.

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At 2133 CST with steam generator level controls in manual at 12 percent reactor power, unit 1 tripped on low-low level in the number 1 steam generator. At 2152 CST, the NRC was notified of the event pursuant to 10 CFR 50.72.a.1.i (initiation of REP) and 10 CFR 50.72.b.1.i.A (plant shutdown). At 2205 CST, RCS pressure and temperature were at 1900 psig and 500 degrees F respectively, and a controlled shutdown to mode 5 was in progress.

During investigation following the event it was discovered that several instruments located in the incore instrument room were found out of calibration. This was probably due to the high temperature and humidity environment produced by the event itself. The class 1E qualified instruments which experienced a calibration shift were two pressurizer pressure transmitters and two pressurizer level transmitters. There were nine nonqualified instruments affected (six of which experienced a similar calibration shift). The remaining three nonqualified instruments were (1) an ice bed temperature recorder which required some input cards to be replaced, (2) an area radiation monitor that had to be replaced, and (3) a particulate radiation analyzer which had to be replaced. One containment sump level transmitter was also found to be out of calibration; however, this was determined to be coincidental and not due to the environment produced by the event.

All class 1E instrument calibration shifts were in the conservative direction and were within the technical specification allowable valves except for one pressurizer pressure transmitter (1-PT-68-340, a Barton transmitter, Model No. 763, Lot 2). This instrument was outside allowable valves for LCO 2.2.1 item 9 and LCO 3.3.2.1 item 1.d. A comparison was made between the calibration shift experienced and the allowable shift due to harsh environments for this model of Barton transmitter. The shifts experienced were found to be well within the environmental qualification limits. Under accident conditions the class 1E instrument's input to any needed reactor protection system or engineered safety feature would have occurred prior to any adverse calibration shifts.

Information and Events Leading to Recovery

At 0932 CST on 04/20/84, unit 1 entered mode 5 and depressurization of the RCS was initiated. At 1114 CST with RCS pressure at 250 psig, the leakage rate was estimated at 18 gpm. At 1400 CST with RCS pressure at 40 psig, the leakage rate was estimated at 5.4 gpm.

At approximately 0715 CST on 04/21/84, the vessel water level had been lowered to about 701 feet. Since the top of the seal table is at 702 feet, the only leakage would be due to the pressure of the nitrogen cover blanket in the pressurizer. Later calculations indicated approximately 16000 gallons of water were lost from the RCS during the event.

At approximately 0900 CST, four personnel entered the seal table area to observe the general condition of the area. Personnel reported the thimble tube to be completely ejected from the guide tube and twisted throughout the room. A small, steady stream of water was flowing from the guide tube at the seal table as a result of the pressure from the nitrogen blanket in the pressurizer. Radiation surveys indicated levels of 2-3 rem at the entrance to the seal table area, 200-300 rem at the end of the tube closest to the seal table, and greater than 1000 rem in the center of the ejected tube.

The radiation reading of a smear taken from the floor was 60 millirem per hour. Personnel reported the temperature and humidity in the area was very high, making working conditions difficult. The team took several pictures of the area, but only remained in the area for approximately two minutes. All four individuals received a total combined dose of 3.036 rem with a maximum individual exposure of 1.219 rem.

At approximately 1800 CST on 04/21/84, two individuals made a second entry into the seal table area to take additional, detailed photographs of the area. The two individuals were in the seal table area approximately seven minutes and received doses of 1.966 rem and 1.939 rem. The photographs that were taken during this entry became an extremely valuable asset. They were used to identify the best removal process which included a configuration mock-up to practice the removal techniques.

On 04/21/84, and again on 04/22/84, the following eight alternatives for removal of the ejected tube were discussed:

1. The thimble tube could be fed into the incore detector storage location inside the polar crane wall. This method would reduce radiation exposures due to the close accessibility of the storage location. But disadvantages such as possible interference with incore probes in storage, unknown interferences while inserting the tube into the storage location, future disposal of the tube, and whether the polar crane wall would provide adequate shielding were also pointed out.

2. The thimble tube could be reinserted into the guide tube. This would allow disposing of the tube by normal means during the next refueling outage (removal via the vessel), but would also cause loss of one incore detector location for the next cycle. Other disadvantages included unknown difficulties in starting the tube in the guide tube and problems caused by kinks and sharp bends in the ejected tube.

3. The tube could be moved into the keyway by inserting the tube through the seal table drain or spares. A shielded pipe could be installed in the keyway to store the tube, but additional radiation exposure would be obtained to fabricate the storage piping in the keyway. Additional difficulties included unknown hanger interference during transfer and problems with later access to keyway.

4. The thimble tube could be cut into pieces and stored in a pig. Using video monitors, long-handled tools would be operated from behind shielding to cut the tube and drop the pieces into a funnel-pipe arrangement which would transfer the pieces into a shielded pig in the raceway. This method would reduce personnel exposure and simplify disposal since disposal could be planned at a later date. This method could also be easily mocked-up at Watts Bar Nuclear Plant for simulated practice. Disadvantages such as the required weight of the pig, unforeseen problems with the funnel-pipe transfer assembly, and unforeseen problems with cutting tools were pointed out.

5. The thimble tube could be wound onto a spool in a water cask. This method could also be easily mocked-up at Watts Bar, but difficulty of connecting the tube to the spool, keeping the tube untangled as it was turned onto the spool, and the size and weight of the cask were pointed out as disadvantages.

6. The thimble tube could be pulled through a PVC pipe from the seal table to the refuel floor. This method was mentioned and immediately withdrawn as impractical.

7. Use of a mechanical robot to perform the work. This would greatly reduce personnel exposure and could be used in conjunction with one of the other methods. Disadvantages pointed out were the size and weight of the robot and unknown difficulties in setup.

8. An outside contractor could be hired to remove the tube. This method would reduce exposure to plant personnel, but the reduction in plant management control of the work would not be acceptable.

Following discussion of these eight items, management concluded to use option 4 above. On 04/23/84, the condition of the tubing in the seal table area was mocked-up at Watts Bar using the detailed pictures obtained during the second entry of 04/21/84. A work team then simulated the actions they would take during the actual work at Sequoyah. In conjunction with the practice sessions at Watts Bar, shielding was being installed at Sequoyah.

Following difficulties encountered during the practice sessions and exposure levels being received from shielding installation, management reevaluated the options on 04/24/84 and concluded to use a combination of options 4 and 7 above. The portion of the tube with the highest radiation level (approximately 20 feet) would be cut free and dragged into the raceway. Once in the raceway, the work of cutting this section into smaller pieces and placing the pieces in the pig could be performed by the robot. The lower radiation levels of the remainder of the tube would allow personnel to cut it up and dispose of it. A work team then simulated these actions on the Watts Bar mock-up. Following the practice session, additional meetings were held to finalize the plans of the operation. The plan was as follows:

1. On the first entry, one individual would enter and cut the tube near a designated point and immediately exit.

2. On the second entry, two individuals would then enter and coordinate attaching a cable to the section of tubing using a special clamp.

3. Another individual stationed in the raceway would then pull the section of the tube into the raceway using the cable attached in step 2 above.

Using this plan, the 20-foot section of the tube with the highest radiation levels was successfully transferred into the raceway on 04/25/84 with no problems being encountered and only 700 mr exposure. Personnel then entered the seal table area and cut the remaining portion of the tube into smaller pieces. The tube was completely removed from the seal table area by 1900 CST on 04/25/84 and actions to decontaminate the seal table area were initiated. During the activity of decontamination and removing the remaining section from the seal table area, one man-rem of total exposure occurred.

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The low radiation level section of the tube was delivered to the waste package area and prepared for shipment to an offsite burial facility. A new thimble tube was installed in the D-12 guide tube on 04/28/84 with no problems encountered. Cleaning of the remaining thimble tubes was contracted to NUS, who started the cleaning operation on 04/26/84 and completed on 04/30/84 with no problems encountered. Instrumentation in the incore instrument room was repaired, replaced, and recalibrated as needed.

An evaluation of all Class 1E equipment in the incore instrument room was made to determine if the environmental conditions experienced during this event could be detrimental to their present qualified life. The evaluation determined that no deterioration of qualified life was experienced based on temperature and radiation readings during and after the event.

On 04/26/84, the robot was lowered into the raceway for a mock-up test of the actual cutting operation. The robot would lift the tube and carry it to a table with two hydraulic cutters. Using video cameras, personnel would remotely operate the cutter when the robot had the tube in place. The robot would then carry the smaller (cut-off) piece and place it in the storage cask. When all of the tube had been cut and placed in the cask, the robot would fill the remainder of the cask with lead shot and close the cask. The actual operation was started on 04/27/84 and completed on 04/28/84. An approximate six-foot section of the tube was found to have a low radiation level and sent to waste packaging to be added to the other low-level tubing for shipping.

Evaluation of the Cause of Failure

Five possible modes of failure of the fitting were identified and evaluated. Evaluation of each possible failure was accomplished by inspection of the failed part and tests performed on a mock-up of the cleaning tool and seal table assembly. The possible failures and their dispositions are as follows:

1. Improper assembly of fitting (such as ferrule upside down or in wrong order).

   The ferrule and tubing were inspected and assembly found correct.

2. Improper expansion of the end of the tube.

   Inspection and comparison of the mock-up specimens to the ejected tube indicate the tube end was properly expanded prior to ejection of the tube.

3. Cracking of Ferrule

   Although the ferrule was found cracked circumferentially approximately 180 degrees on the inside diameter, the relative motion by the ejected tube and fitting would have caused the crack to close if it existed prior to the event.

4. Nut not tightened or had become loosened from other operations.

   The nut was found tight following the event. Destructive tensile tests performed on similar fittings confirmed that the nut remained tight.

5. The fitting being a combination of Gyrolok and Swagelok parts.

   Subsequent evaluation and discussions with vendors has determined that this configuration would not have caused the failure.

6. Cleaning fixture imposed unusual forces on the assembly. This appears to be the most probable cause of the failure from the tests performed on the mock-up. Three fittings were failed by a person pushing on the handle of the cleaning fixture mock-up. The failed mock-up tubes were similar in appearance to the actual failed tube and fitting. Strain gauges were installed on the mock-up tube and a measured force was applied to the mock-up handle. A plot was made using applied force versus strain. Tube strains of approximately 1000 strain units were noted just due to installation of the cleaning tool. Evaluation of the plot showed some slippage at 30 lbs. applied force. Some leakage appeared at 140 lbs. force and separation occurred at 250 lbs. force.

   The original Teleflex tool was modified (a base added) for use in cleaning the thimble tubes but was scrapped after becoming contaminated. The tool in use at the time of this event used a new and differently designed tool base. This newly designed base produced forces on the high pressure fitting but approximately 50 percent less resultant force multiplication to the fitting when compared with the original-designed base. Therefore, the initial error occurred in that the original tool supplied by Teleflex was modified by the addition of a base and not by the fabrication of a new base.

Corrective Actions

All short-term corrective action taken has been described in the above text. Per vendor recommendations, the seal table and associated fittings were inspected. This inspection determined that no additional corrective action was required. Two long-term corrective actions have been identified: (1) Management has made the decision that future thimble tube cleaning will not be performed using the same dry brush cleaning technique as was used during the thimble tube ejection with the reactor at temperature and pressure. Future at temperature and/or pressure thimble tube cleaning using alternative techniques will not be conducted until a careful and thorough evaluation has been completed. (2) The other corrective action being pursued is the identification of "special tools" as reflected in our response to NSRS conclusion I-84-12-SQN-10 (see reference below). The philosophy of "special tool" control has already taken root at the plant with respect to the refueling cavity seal evaluation required by NRC. It will take some time to identify all special tools and to implement a system of controls, but this corrective action is being undertaken.

We have attached our response to the recent Nuclear Safety Review Staff Report, Sequoyah Nuclear Plant (SQN) - Nuclear Safety Review Staff (NSRS) Investigation Of Unit 1 Incore Instrumentation Thimble Tube Ejection Accident On April 19, 1984 - NSRS Report No. I-84-12-SQN (a copy of which is also attached). Our response outlines those in-house corrective actions associated with this event. Attaching the NSRS report itself and our response will also make both a matter of public record.

TVA 64 (OS-9-68)

Prw rf

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UNITED STATES GOVERNMENT

Memorandum

TENNESSEE VALLEY AUTHORITY

TO : H. N. Culver, Director of Nuclear Safety Review Staff, 249A HBB-K

FROM : James P. Darling, Manager of Nuclear Power, 1750 CST2-C

DATE : SEP 18 1984

SUBJECT: SEQUOYAH NUCLEAR PLANT - NUCLEAR SAFETY REVIEW STAFF (NSRS) INVESTIGATION OF UNIT 1 INCORE INSTRUMENTATION THIMBLE TUBE EJECTION ACCIDENT ON APRIL 19, 1984 - NSRS REPORT NO. I-84-12-SQN

Reference: Your memorandum to me dated August 1, 1984 on this subject (L00 840803 516).

The Office of Nuclear Power has completed its review of the subject report and provides the attached response to the conclusions and recommendations stated in the report. In several instances, we have addressed more than one conclusion with a single response where the multiple conclusions involved, in our opinion, a common issue.

Our nuclear plant management supports, promotes, and practices a safety first policy. Program controls are in place to ensure that all operational and maintenance activities are conducted in accordance with that policy. Aggressive management attention is being given to key areas of these programs, as reflected in our response, to ensure that these programs are fully adequate and to provide strengthening of various program elements where weaknesses have been identified.

Our review of your staff's report, together with our first-hand knowledge of the various factors associated with this event, leads us to conclude that the event was not the result of significant programmatic deficiencies in the maintenance program at Sequoyah. Rather the direct causal factor of the event was the failure to recognize that utilization of a specific tool for the thimble tube cleaning activity could generate unacceptable stresses on the mechanical seal at the seal table. Other deficiencies in the conduct of this maintenance activity identified in your report are acknowledged but are not considered true causal factors in precipitating the event.

We acknowledge your conclusions regarding the planning and execution of the recovery efforts subsequent to this event. Other outside groups that either directly observed or subsequently reviewed these recovery efforts commented on the professionalism with which a difficult and complex activity was accomplished.

If you need further information or clarification of our response, please let me know.

TGC:PRW:REA:SFH
Attachment
cc (Attachment):
- NUC PR ARMS, 1520 CST2-C
- H. L. Abercrombie, 1760 CST2-C
- T. G. Campbell, NUC PR, Sequoyah
- H. G. Parris, 500A CST2-C
- G. F. Stone, 101 FIPB-M
- F. A. Szczepanski, 220 401B-C
- W. F. Willis, E12B16 C-K

I-84-12-SQN-1, Inadequate Corrective Measures to Alleviate the Degraded Condition of Thimble Tubes

Conclusion

The degraded condition of the thimble tubes had existed for a period of four years prior to the accident. Effective cleaning efforts had not been accomplished nor changes made in the methods prescribed by documented instructions to correct the problem despite the importance of the system. Responsibilities for the different aspects affecting system operability (operation and maintenance) were dispersed among several organizations with no one central figure responsible or accountable for overall system operability allowing the degraded condition of the system to remain uncorrected.

Response

While thimble tube blockage had existed and had been corrected several times during the life of Sequoyah Nuclear Plant (SQNP) unit 1, it had never reached the post unit 1 cycle 2 blockage level.

A review of past unit 1 maintenance history shows the following;

All thimble tubes cleaned in March 1980.
All thimble tubes cleaned in April 1980.
Nine (9) thimble tubes cleaned in September 1981.
Three (3) thimble tubes cleaned in December 1982.
Nine (9) thimble tubes cleaned in January 1983.

Although the unit 1 thimble tubes may have required a significant amount of cleaning to maintain them in an operable condition and capable of passing the detector-cable assembly, the degraded condition did not go unchecked for four years. During each cleaning activity, an attempt was made to clean each tube identified as having blockage and these efforts were reasonably effective. It must be emphasized that SQNP has always attempted to maintain all tubes operable and not just the minimum number necessary to satisfy plant technical specifications.

The reactor engineering section has overall system responsibility for the moveable detector system. This responsibility is recognized at the site. The reactor engineering section is aware of and actively following the proposed Westinghouse Owners' Group program to address the thimble tube blockage problem. Present assignments of "System Responsibility" are being reexamined as a consequence of the recent reorganization of the plant staff and site organization. This reexamination will be an on-going process.

I-84-12-SQN-2, Inadequate Industry Survey and Feedback to Field Services Group (FSG) Personnel

Conclusion

The industry survey performed by the Engineering Section was limited in scope and appeared to attempt to determine if the thimble tubes could be cleaned at power rather than how they could be cleaned safely. The engineer performing the survey did not use available information sources (INPO), had not read the cleaning instruction, had not cleaned thimble tubes, and did not interface with FSG personnel after the survey.

I-84-12-SQN-3, Inadequate Decisionmaking Process

Conclusion

The decisionmaking process for the conduct of the cleaning of the thimble tubes while at power was less than adequate. The process used to acquire information was inadequate, readily available information sources and input resources were not used, no independent hazard analysis was performed, and the magnitude of the hazards was not realized or identified (see section IV.B.3 for details).

Response (For Items I-84-12-SQN-2 and I-84-12-SQN-3)

Sequoyah reactor engineering personnel contacted five nuclear plants questioning if they had cleaned thimble tubes at power and any problems they had experienced. The results of this survey were molded into the overall plant decisionmaking process. The extent to which a survey of this nature should be carried out in order to constitute an adequate survey is subjective in nature. A survey is conducted only to establish an adequate information base to facilitate management decisions. In this case plant management felt that they had adequate information to proceed with at-power cleaning.

SQNP believes the assignment of the survey to the reactor engineering section is consistent with their overall moveable detector system responsibility. While no survey can be all encompassing, the additional information resources identified in the NSRS report have been noted for future surveys.

SQNP acknowledges that the personnel performing the survey were not familiar with the cleaning instruction and had no experience with the actual cleaning operation. Again, the objective was to provide management with part of the information necessary to make a decision regarding at-power cleaning. There was no need for the survey personnel to interface directly with FSG personnel since FSG management participated in the discussions leading to the ultimate decision to conduct at-power cleaning and were fully cognizant of survey results when making subsequent work assignments.

In retrospect SQNP does not take issue with the fact that the process used for cleaning the thimble tubes should not have been performed at power. SQNP believes the decisionmaking process itself was sound even though weaknesses were evident in the implementation process.

Management meetings were held to discuss this activity and the potential hazards associated with it. Discussions included the facts that (1) the work was to be performed on a pressurized system, (2) any leakage from a thimble tube could not be isolated, and (3) there were radiological hazards associated with the work. The only weakness with this process may have been the lack of management involvement in the details of the work associated with the accomplishment of this maintenance activity. SQNP management is committed to ensuring future maintenance activities comply with normal plant practices. This includes procedure adherence, hazards and analysis planning (see our response to I-84-12-SQN-6), and encouraging input from those responsible and accountable for the maintenance activity.

I-84-12-SQN-4, Assignment of Work Function to the FSG as an Ordinary Work Activity

Conclusion

The supervision, coordination, and execution of the cleaning operation were assigned as if the activity were an ordinary maintenance activity when in reality it was a unique activity with unique hazards identified. The coordinators and workers were unaccustomed to working on the system when the reactor was operating at rated temperature and pressure and with the dose rates that would likely be encountered and had little if any feedback from the industry survey and management discussion process. A sense of urgency was established as the supervisors, coordinators, and workers knew that the work would have to be done or the unit would be brought off the line.

Response

Meetings were held between the Assistant Plant Manager, Engineering Section Supervisor, Electrical Maintenance Section Supervisor, Assistant Field Services Group Supervisor, and Field Services Group Maintenance Specialist to determine if at-power thimble tube cleaning would be attempted. Therefore, FSG management was involved in the decisionmaking process. Further, FSG craft personnel had experience working on systems at temperature and pressure, had the greatest amount of experience in thimble tube cleaning, and was the logical choice for performance of this work.

The upper management involvement, full-time health physics and engineer coverage, industry survey, and work prebriefings conducted by personnel directly involved in the work showed neither management nor the personnel directly involved considered this a routine work activity. Conversation with the "evening shift coordinator" indicates he and the "day shift coordinator" recognized the uniqueness of the work involved both from a radiological and industrial safety standpoint.

There was no intent by management to create a sense of urgency associated with completing this job, but rather a responsible management decision was made that provided time to demonstrate the success of the at-power cleaning technique. Concurrent with this activity, the unit was operating with a leaking pressurizer safety valve. Plant management had previously concluded that the unit would be shut down after completion of the flux mapping at 30 percent power for safety valve replacement if the leakage persisted. Thus, there was no impending or required unit shutdown which was dependent solely on successful cleaning of the blocked thimble tubes. SQNP's only objective in attempting to complete the 30 percent power flux mapping prior to shut down was to avoid, upon returning to power, a prolonged hold point at 30 percent power in excess of 48 hours duration that would be required to complete the flux mapping. The fact that a job normally performed with the unit shutdown was being performed at power may have produced an unncessary sense of urgency with the workers. In the future, the potential for this type of mistaken worker perception will be eliminated by better communication between management and workers regarding operational schedules.

I-84-12-SQN-5, <u>Selection of an Inappropriate Instruction for the Control of the Work Activity</u>

<u>Conclusion</u>

Special Maintenance Instruction SMI-0-94-1 was a poor quality instruction and inappropriate for the activity to be controlled. However, the instruction was selected during the planning process as the primary procedural control for the cleaning activity apparently because those performing the planning and coordination function were not aware of what quality elements an instruction should contain, the change process for inadequate instructions, or had a careless attitude toward procedural compliance.

I-84-12-SQN-7, <u>Inadequate Field Quality Engineering (FQE) Review of Maintenance Request (MR) and Referenced Work Instruction</u>

<u>Conclusion</u>

SMI-0-94-1 was referenced and attached to the MR when sent to FQE for review. The poor quality of the instruction was not identified nor was the fact that the instruction could not be used to perform the cleaning activity with the reactor at power. The FQE review process had not been effective in initiating quality improvement of the instruction since its original issuance in July 1981.

I-84-12-SQN-11, <u>Violation of Work Instruction</u>

<u>Conclusion</u>

SMI-0-94-1 clearly stated that the Teleflex-supplied equipment and the instruction were not to be used at power. Using the equipment and instruction for that operation was a violation of work instruction and the unit 1 SQNP Technical Specifications. If the responsible engineers had written an adequate procedure appropriate for the activity and that procedure had been Plant Operation Review Committee (PORC) reviewed, the result of the cleaning operation <u>may</u> have been different (see section IV.D.2a for details).

I-84-12-SQN-17, <u>Poor Quality Cleaning Procedures and Inadequate PORC Review</u>

<u>Conclusion</u>

As noted in section III.C.2, SMI-0-94-1 was not adequate for its intended use. SMI-0-94-2 was written after the accident to clean the tubes via the NUS method. It too was a poor quality instruction and could promote accidents of a similar nature in the future. This conclusion is based upon the facts that SMI-0-94-2 had no cautions or warnings to prevent damage to the mechanical seals, no administrative barriers to prevent cleaning the tubes at pressure, no instructions for disassembly and reassembly of the detector drive system, no postmaintenance inspections after cleaning and before pressurizing the reactor, and postmaintenance testing to ensure operability was optional.

I-84-12-SQN-17, (Continued)

Despite the poor quality of the instructions, both were recommended for approval by PORC. In these instances, PORC failed to adequately fulfill its responsibilities to the Plant Manager on these matters relating to nuclear safety.

I-84-12-SQN-22, <u>Significant Breakdown in the SQN Procedure Process for Maintenance Activities</u>

<u>Conclusion</u>

There is an apparent breakdown in the procedure process at SQN for maintenance activities as PORC reviewed and recommended approval of two poor quality instructions used for cleaning thimble tubes (one after the accident); the biennial review did not correct poor quality in one instruction; instructions being used were inappropriate for the activities being performed; an instruction was violated; and some engineers and managers interviewed did not seem to understand what quality elements should be in a maintenance instruction, were not aware of the procedure change process, or expressed a careless attitude toward procedure compliance.

<u>Response</u> (For Items I-84-12-SQN-5, I-84-12-SQN-7, I-84-12-SQN-11, I-84-12-SQN-17, and I-84-12-SQN-22)

To adequately respond to the referenced findings one must consider the sequence of events leading up to and including initiation of this maintenance activity.

(1) Prior to the unit 1 cycle 2 outage, the Reactor Engineering Unit identified the need for thimble tube cleaning and prepared maintenance requests (MRs) to accomplish the cleaning. The MRs were included in the unit 1 cycle 2 refueling outage activity schedule and work was started to accomplish the cleaning but was terminated without adequate feedback to the Reactor Engineering Unit.

(2) During subsequent low power physics testing, it became apparent there was an inadequate number of unblocked thimble tubes to accomplish a full flux map.

(3) Management evaluated the performance of this maintenance activity by requiring a survey of other utilities, vendors, and Westinghouse to ascertain the acceptability of at-power performance.

(4) Management recognized the unique aspects of the job and provided for full-time health physics and engineer coverage.

(5) Management made the decision to clean the blocked thimbles tubes while at the 30 percent power level and specified adequate guidelines and precautions to conduct this work activity. However, the work package (MR and Special Maintenance Instruction SMI-0-94-1) were not revised to reflect these directions.

(6) The MR was reviewed by FQE as part of their responsibility to ensure an adequate procedure exists for the performance of the work.

(7) A job safety analysis was performed by the maintenance foreman as required by the MR process. Discussions were held between the cognizant engineer and foreman concerning the high pressure connections and their proximity to the 10-path breakdown connections. No work was to be done nor was it done without the lead engineers at the seal table.

(8) Hold orders and Radiation Work Permits (RWPs) were obtained for this maintenance activity.

(9) The 10-path transfer devices were disconnected and rolled back prior to beginning the cleaning process without a MR or procedural guidance, but the engineers involved were aware of the unit conditions at the time of the work, the system design, mechanical makeup of the components, and potential hazards. Employee awareness of the unit conditions and absolute requirements was demonstrated by informal planning and cursory attempts at satisfying requirements.

(10) The at-power cleaning process began using the MR and SMI-0-94-1 as procedural guidance.

After thoroughly analyzing this event and the NSRS conclusions, SQNP acknowledges the following: (1) The work package (SMI-0-94-1 and MR) provided poor quality instructions in that they were not revised to reflect at-power cleaning and did not meet technical specification requirements for this maintenance activity. This procedure has been cancelled. (2) SMI-0-94-2 did not contain all the quality elements necessary for this maintenance activity and it is being revised to reference Maintenance Instruction MI-1.9 "Bottom Mounted Instrument Thimble Tube Retraction and Reinsertion" for the disassembly and assembly of the 10-path transfer devices. Appropriate cautions and warnings are being added to prevent damage to the mechanical seals. Postmaintenance inspections and testing requirements will be added to SMI-0-94-2; however, it should be noted that this procedure previously contained a double signoff that precluded its use at power. (3) The MR and FQE's review of the MR did not meet the requirements of Sequoyah's Standard Practice Maintenance Instruction, SQM-2. SQNP will review the MR system and QA review process by October 31, 1984, to ensure no programmatic deficiencies exist. (4) Adequate feedback did not exist to the Reactor Engineering Unit regarding the failure to satisfactorily clean blocked thimble tubes during the outage. In the future, a detailed scheduling process for incore thimble tube maintenance will be incorporated into the outage schedule and any deviations from scheduled work will be justified to plant management. (5) A problem existed in the coordination of the hold order and RWP associated with this maintenance activity. To alleviate this problem, Administrative Instruction AI-8 will be revised to clarify what moveable detector system maintenance requires a hold order and hold order requirements for RWPs will be modified to indicate AI-8 will be followed.

SQNP does not believe generic program weaknesses have been indicated by this event. However, SQNP management understands their detailed involvement in how the job was to be implemented during the evaluation to determine its feasibility may have unintentionally sent a message to key implementing employees creating the impression they had authority to proceed without adherence to normal plant practices.

I-84-12-SQN-6, Inadequate Job Safety Analysis and Hazards Assessment

Conclusion

The job safety analysis and hazards assessment program associated with maintenance activities at SQNP is inadequate for identifying, evaluation, preventing, and mitigating accidents of this nature. Similar findings had been identified to SQNP as causal factors of an inadvertent radiation exposure at SQNP in December 1982, but recommendations in that report (I-82-21-SQN) have not been implemented.

Response

Both a job safety analysis and a work place hazard assessment methodology are in place for evaluating, preventing, and or mitigating accidents at SQNP. The relative attention given these tools is based upon the identification of the potential hazard in the initial review. Additional management emphasis will be placed on the initial evaluation of the degree of hazard. Those work activities identified as presenting hazards not normally associated with work generally performed by the assigned crafts or work groups will receive more detailed analysis and planning. Routine or frequently performed jobs involving extraordinary injury potential will also require specific job safety analysis and planning.

Office of Nuclear Power will continue to examine the existing workplace hazard assessment methodology to determine its applicability as a tool in job safety analysis. This should be complete by October 31, 1984.

SQNP acknowledges that recommendation I-82-21-SQN-1 of the December 1, 1982 NSRS report (I-82-21-SQN) was not implemented at the time of the thimble tube ejection. All the other recommendations of the report were implemented. Recommendation I-82-21-SQN-1 suggested that a procedure be implemented at the plant addressing specific as low as reasonably achievable (ALARA) preplanning criteria. Additional ALARA preplanning criteria has now been incorporated into RCI-10. The implementation of the procedure was delayed as part of a conscientious decision by senior plant and nuclear central office management to eliminate the root cause (determined to be excessive administrative burdens on plant management) of an increasing trend of NRC violations at SQNP.

I-84-12-SQN-8, Noncompliance With Requirements of RWP No. 01-1-00102

Conclusion

RWP No. 01-1-00102 specified the following requirement: "Verify hold order is in effect on incore probes prior to entering Reactor Building lower compartments and the Annulus." On April 18 and 19, FSC evening and day shift employees and an HP technician entered the reactor building lower compartment while the hold order was not in effect.

Response

For this particular job at least two (2) PORC-approved procedures were being followed, Radiological Control Instruction RCI-14 and Administrative Instruction AI-8. The intent of special instruction 11 of RWP 02-1-00102; "Verify hold order is in effect on incore probes prior to entering reactor building lower compartments and the annulus," is a reminder to comply with AI-8. AI-8 section 2.4 contains the following statement: "The removal of the hold order clearance for maintenance purposes may be accomplished after proper coordination with the following; operations, health physics, applicable maintenance sections." This coordination is allowed to provide for troubleshooting of the incore detector system. In order to troubleshoot the system, it must be operable while personnel are in the seal table area and, therefore, the hold order cannot remain in place. Due to the confusing nature of this allowance, some nontroubleshooting work was performed without verification of the hold order, but the work was performed with the coordination required by AI-8. For additional clarification, special instructions for hold order requirements for RWPs will be modified to indicate AI-8 requirements will be followed and AI-8 will be revised by October 31, 1984, to clarify that the conditional allowance is for troubleshooting only.

I-84-12-SQN-9, <u>Noncompliance With Requirements of Section 5.1.4 of AI-3, "Clearance Procedures"</u>

Conclusion

Hold Order No. 1 was issued only to the Assistant Shift Engineer (ASE) and not as required by AI-3 to the persons responsible for work being performed in the instrument room between 0220 on April 17 and 0400 on May 1. This is contrary to the requirements of section 5.1.4 of AI-3.

Response

The maintenance personnel responsible for performing the work were not included in the clearance while the work was being performed. The ASE was aware of the work being performed and was on the hold order on the incore probes. Additional emphasis will be placed on making all personnel aware of the requirement for the person responsible for work to be on the clearance. This will be accomplished in preoutage briefings, existing clearance procedure training classes, and the periodic management safety meetings which are attended by managers, foremen, and engineering personnel.

I-84-12-SQN-10, Modification of Cleaning Tool Base Supports Without Performing a Technical Evaluation or Testing

Conclusion

The cleaning tool base support was modified and a temporary base was constructed and used without a technical evaluation of the effect on the mechanical seals. No testing was performed before use. Use of the tool and its support was determined during post-accident testing to impose forces of considerable magnitude on the mechanical seals and those forces were found to cause strain sufficient that the thimble tube separated from the mechanical seal.

Response

A review of the final support fixture in use at the time of the event indicates that resultant forces were applied to the fitting by the fixture, but would apply approximately 50 percent less resultant force multiplication to the fitting than the originally fabricated support base which had been scrapped. These forces were not fully considered in any preevent analysis and, therefore, the NSRS conclusion is substantially correct. However, the actual error occurred in that the original tool supplied by Teleflex was modified by the addition of a base and not by fabricating a new base.

SQNP will review "special tools" and evaluate the need for modification controls for these types of tools.

I-84-12-SQN-12, Lack of Control of Egress Capability from Containment

Conclusion

For approximately 30 minutes during the morning of April 19, the inner door of the personnel airlock was made inoperable without the knowledge of some of the workers cleaning the thimble tubes. This would have hindered egress from the room if the mechanical seal had failed at this time. The FSG workers were unaware of the Technical Specification requirements for maintaining containment integrity and that leaving the inner door of the airlock open would enter the unit into a limiting condition for operation. Leaving the inner door open would have hampered rescue efforts if needed.

Response

It is evident from the supporting details of the NSRS report that the shift engineer made an evaluation of the work in progress and in his judgement the time necessary to clear the airlock provided adequate protection for the employees inside. It is important to note that the workers involved knew alternate egress routes from the incore instrument room. In particular the submarine hatch was nearby and available as an unhindered egress route.

SQNP certainly agrees that reactor building egress should not be impaired when maintenance or other activities within containment are necessary while the unit is at-power conditions. The establishment of good communications is essential particularly in situations where one maintenance activity has the potential for affecting egress routes associated with another maintenance activity. Present policies regarding such communication are being reviewed to ensure their effectiveness. However, it must be noted that plant policies must retain the flexibility for the shift engineer to evaluate such situations on an individual basis and determine the extent of notification required.

SQNP acknowledges the FSG personnel were not adequately aware of the technical specification requirements associated with the containment airlocks. Future emphasis will be placed on ensuring responsible maintenance personnel are made aware of the technical specifications associated with the airlocks on a job-by-job basis.

I-84-12-SQN-13, Breakdown in the ALARA Preplanning Program

Conclusion

The responsible supervisor is required to initiate and complete an ALARA preplanning report prior to job commencement. Even though the cleaning job was expected to involve unusually high dose rates, ALARA preplanning was not conducted until the cleaning operation was well underway on the day shift on April 19, and some recommendations made in the Trojan report to reduce the radiation dose to workers were not incorporated in the cleaning instruction or the work process. The responsible supervisor was not involved in the preplanning effort.

Response

SQNP supports and practices ALARA preplanning based on expected doses with consideration given to potential doses. In concert with corporate policy, it is the plant's goal to maintain radiation doses ALARA in all our work activities. In agreement with that philosophy and consistent with RCI-10, ALARA preplanning was conducted when a contact dose rate of 2 rem/hr was detected.

Prior to the initiation of this maintenance activity, Health Physics personnel evaluated a report from Trojan Nuclear Power Plant for similar maintenance and continuous Health Physics coverage was established but ALARA preplanning was not required per RCI-10, as it existed at the time of the event. When the 2 rem/hr dose was found, responsible supervisors were involved in the ALARA preplanning effort.

Since the time of the thimble tube ejection incident, RCI-10 has been revised to include specific ALARA preplanning criteria.

I-84-12-SQN-14, Need for Formal Documentation for Upper Plant Management Approval to Work in Radiation Dose Rate Fields Greater than 50 Rem/Hour

Conclusion

There are no requirements for formal documentation for authorization to work in dose rate fields greater than 50 rem/hour.

Response

At the time of the event, Radiological Control Instruction RCI-14 Radiation Work Permit (RWP) Program Section IV.B.6 specified that the Plant Manager review the RWP when dose rates exceed 50 rem/hour. The appropriate management personnel were notified and verbal authorization given to continue the job. RCI-14 has been revised requiring formal documentation of this review and authorization. The appropriate RWP signature sheets are being revised to include a signature slot for the Plant Manager if required and this revision is currently in reproduction. As an interim measure, the current RWP cover sheet has unspecified signature slots that may be signed by the Plant Manager until the new revised form is in place.

I-84-12-SQN-15, Availability of Communications Following the Accident

Conclusion

When the workers entered the airlock after the accident, they discovered that the telephone in the airlock was inoperable.

Response

SQNP acknowledges that the airlock telephone was inoperable. Additional emphasis will be placed on timely response for maintenance requests on these phones.

I-84-12-SQN-16, Effective Cleaning of the Thimble Tubes by Nuclear Utilities Services (NUS) Corporation

Conclusion

The method used by NUS as prescribed in SMI-0-94-2 to clean the thimble tubes after the accident was effective in eliminating the material causing the blockage in the thimble tubes. This effectiveness is primarily due to the pressure of the new backflush process (200 psi) versus that of the old method (40 psi) and the controlled application of NEOLUBE as prescribed in SMI-0-94-2.

Response

SQNP agrees that the NUS thimble tube cleaning method appears to be effective and will advise Watts Bar Nuclear Plant of the NUS technique. Ultimate effectiveness can only be judged after considerable more operating time has been accrued on the unit 1 thimble tubes cleaned utilizing this technique.

I-84-12-SQN-18, Noncompliance with Serious Accident Reporting and Accident Scene Preservation Requirements

Conclusion

Corporate and SQN procedures require that serious accidents be reported immediately and that the accident scene be preserved until released by the chairman of an appointed Accident Investigation Team (AIT). The accident was not reported as a serious accident until approximately three weeks after the accident occurred, nor was the accident scene preserved as restoration of equipment was essentially complete before the accident was reported.

I-84-12-SQN-19, Limited NUC PR Accident Investigation

Conclusion

The appointment of the SQN FSG supervisor to the NUR PR investigation team was inappropriate for this investigation as it created a potential conflict of interest. The NUC PR investigation did not address any breakdown of program controls such as job planning, job safety analysis, inadequate procedures, or the nuclear safety and radiological aspects of the accident. Overall the accident investigation performed by NUC PR is considered limited in scope, somewhat misleading, and did not address what NSRS determined to be the nature of the causes of the accident.

Response (For Items I-48-12-SQN-18 and I-84-12-SQN-19)

This event was initially considered in terms of its radiological impact with recovery to reduce exposure as its optimum concern. Industrial and radiological safety were both considered during this recovery. Approximately 12 days after the event a team from NUC PR was designated to review the industrial safety aspects of the accident to determine if it fell under the TVA Serious Accident Investigation Procedure and, if not, to proceed with a report highlighting lessons learned. The Designated Agency Health & Safety Offical (DASHO) and the Manager, Office of Power, were notified at this time. The investigation team was named to perform a specific function as stated in finding I-84-12-SQN-19. If it had determined that a serious potential did exist, the agency level team (AIT) would have been named by the DASHO and office manager. The division level teams would at that time have been disolved. In all probability the SQNP FSG supervisor would not have been designated to serve on the AIT. However, SQNP sees no conflict in his serving on the division level team. In fact, it is TVA's philosophy that safety is line management responsibility. Consistent with that philosophy, since the FSG was involved in this incident, the FSG supervisor should be involved in the investigation. The division level accident report did provide basic conclusions and recommendations in the area of industrial safety.

The team concluded that this event did not meet the requirements of the agency's procedure and made that recommendation to NUC PR management.

The Office of Nuclear Power acknowledges the need to review existing TVA reporting and investigation requirements for industrial safety incidents and, where needed, will provide clarification on when these requirements are applicable. This review will also focus on defining requirements related to the nuclear safety and radiological aspects of an incident and should be complete by January 1, 1985.

With regard to the NSRS concern on preservation of the accident scene, the accident scene immediately after the event was extensively recorded by photographs. In any event, it would not have been possible for either a division-level or agency-level team to actively investigate the scene of the accident due to the high postevent radiation fields present in the incore instrument room.

I-84-12-SQN-20, Needed Reemphasis on the TVA and SQN Employee Expression of Concerns for Safety and Safety-First Policies

Conclusion

The employees should have but did not relate their increasing concerns for the safety of the job to upper plant management, and an expression of concern for the adequacy of the design of the new tool support base was not followed up. The workers felt that they had to accomplish the job to prevent shutdown of the unit. It is probable that the workers are not acutely aware of TVA's and SQNP's policies and their related responsibilities for expression of concerns for safety and safety first before schedule.

Response

SQNP has numerous mechanisms available to the employee to express their concerns. TVA policy, posted on the plant safety bulletin boards, makes available all levels of management, including the DASHO, for expression of safety concerns. It is apparent that during the course of this activity concerns were expressed and actions taken to mitigate employee expressed concerns.

SQNP will however, through normal safety communications, reemphasize this right and responsibility of employees as described in SQNP Standard Practice SQS-7 and General Employee Traning GET 1.2.

I-84-12-SQN-21, Ineffective SQN Independent Safety Engineering Group (ISEG) Activities

Conclusion

The SQNP ISEG organization had been ineffective in performing the function that was originally intended for the organization. This is due in part to the dual responsibilities for compliance/ISEG activities and lack of true independence from line responsibilities and pressures.

Response

SQNP does not agree that such a broadly-stated conclusion can be justified based on the evaluation of this single event.

The SQNP ISEG organization has been described to NRC in correspondance and the site NRC residents are very aware of the ISEG organization. The present organization is an effective means of meeting the intent of NUREG and technical specifications requirements. The line duties of the compliance staff (coordinating the plant's response to all inspection/audit findings, investigation of potential reportable occurrences (PROs), preparation of Licensee Event Reports (LERs), tracking of corrective actions, and trending of PROs, LERs, and NRC violations - in short the maintenance of a broad overview of all activities potentially impacting plant safety) serve to enhance not detract from the ISEG function. SQNP acknowledges that the ISEG was not directly involved in the discussions and preplanning associated with this specific maintenance activity. The size of the ISEG staff necessarily precludes its detailed involvement in the conduct of every maintenance and operational activity occurring at the plant. The focus of the ISEG review activities in fulfilling its nuclear safety engineering function is directed toward determining the overall effectiveness of plant programs and systems which affect nuclear safety. To accomplish this objective, the ISEG monitors trends and looks for possible generic deficiencies in plant programs and systems.

The Office of Nuclear Power has not identified any programmatic problems associated with the SQNP ISEG function. This finding is supported by previous NRC, TVA Nuclear Safety Review Board, and TVA Quality Assurance evaluations in this area.

I-84-12-SQN-23, Inadequate Reporting of the Event to NRC

Conclusion

The subject LER was misleading in that the true nature of the leak was not described, there was no mention of an inadequate procedure or violation of procedures as causal factors, and the long-term corrective actions are not adequate to correct the true causal factors of the event.

Response

Following further review of the subject Licensee Event Report (LER) filed with NRC on May 18, 1984, SQNP has concluded that the LER was not misleading. The LER complies with 10 CFR 50.73.

The true nature of the leak (rate, amount, duration, its effect on instrumentation, as well as the ferrule failure and thimble ejection) was adequately described.

The LER did not mention inadequate procedures or failure to adhere to procedures in conduct of the maintenance activity because the plant did not and does not consider these to be causal factors of the event.

The LER will be revised by submittal of supplemental information to the NRC to indicate the cleaning technique in use at the time of the event will not be performed with the reactor coolant system at temperature and/or pressure but that other available techniques will be carefully and thoroughly evaluated prior to any future decision to clean thimble tubes with the reactor coolant system at temperature and/or pressure. In addition, the Office of Nuclear Power response to this NSRS report will be included in the supplemental LER submittal to NRC so that the full scope of short-term and long-term corrective actions associated with all aspects of this event are brought to the attention of NRC.

TVA 64 (OS-9-65)
UNITED STATES GOVERNMENT

L00 840803516

Memorandum

TENNESSEE VALLEY AUTHORITY

GNS '840801 050

TO : W. P. Darling, Manager of Nuclear Power, 1750 CST2-C

FROM : H. N. Culver, Director of Nuclear Safety Review Staff, 249A HBB-K

DATE : August 1, 1984

SUBJECT: SEQUOYAH NUCLEAR PLANT (SQN) - NUCLEAR SAFETY REVIEW STAFF (NSRS) INVESTIGATION OF UNIT 1 INCORE INSTRUMENTATION THIMBLE TUBE EJECTION ACCIDENT ON APRIL 19, 1984 - NSRS REPORT NO. I-84-12-SQN

On April 19, 1984 a unit 1 incore instrumentation system thimble tube was ejected at SQN into an instrument room adjacent to the reactor. The ejection caused a reactor coolant system leak of approximately 35 gpm at 545°F, and eight workers that were involved in a maintenance activity on the thimble tube had to evacuate the instrument room because of the hazards resulting from steam and high radiation. Because of the potentially serious nature of the event, NSRS investigated the accident to determine causes and to identify appropriate corrective actions.

The attached report indicates that there were some very positive actions that occurred before the accident, immediately after the accident, and during the recovery period. These positive actions include the efforts by the plant health physics staff prior to the accident in expressing concerns for the radiological safety aspects of the job which ultimately resulted in slowing the job down and an increased worker awareness of some of the hazards involved in the activity. The efforts of eight employees involved in the accident while exiting the work area and reporting the accident to the plant operations staff under stressful conditions, the prompt actions taken by the plant operations staff to mitigate the accident, and the planning and implementing actions taken by those involved with the recovery effort were all good examples of positive actions associated with the accident.

The report does, however, identify numerous breakdowns in the programs established to prevent an accident of this nature. The report indicates that the plant staff was aware of the root cause problem over an extended time period but had failed to correct that problem. When the root cause problem threatened the continued operation of the unit, actions were taken without adequate consideration for safety. Numerous program deficiencies allowed the maintenance activity to proceed without proper prejob planning and job safety analysis, with an inappropriate procedure, and using equipment that had been modified but not tested for adequacy prior to use. These numerous breakdowns precipitated the accident.

Although the event did not lead to serious physical injury, high radiation exposure, or loss of life, management should not be complacent since the ingredients actually existed to have resulted in any one or all three.

Please provide us within 30 days of the date of this memorandum your plans for taking action on the recommendations included in the report.

If there are any questions regarding the report or if NSRS can be of assistance in clarifying any part of the report, please contact me at 6180-K or M. S. Kidd at extension 7637-K.

H N Culver
H. N. Culver

GGB:BJN
Attachment
cc (Attachment):
MEDS, W5B63 C-K
H. G. Parris, 500A CST2C
G. F. Stone, 101 FIPB-M
W. F. Willis, E12B16 C-K

GNS '840801 051

TENNESSEE VALLEY AUTHORITY

NUCLEAR SAFETY REVIEW STAFF

INVESTIGATION

NSRS REPORT NO. I-84-12-SQN

SUBJECT: SEQUOYAH NUCLEAR PLANT - INVESTIGATION OF UNIT 1 INCORE INSTRUMENTATION THIMBLE TUBE EJECTION ACCIDENT ON APRIL 19, 1984

DATES OF INVESTIGATION: APRIL 25 THROUGH MAY 18, 1984

INVESTIGATORS: Gerald G. Brantley — GERALD G. BRANTLEY — DATE August 1, 1984

M D Wingo — MICHAEL D. WINGO — DATE 8/1/84

APPROVED BY: M A Harris for MSK — MICHAEL S. KIDD — DATE 8/1/84

MEDS, W5B63 C-K

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1. Trojan Nuclear Plant Flux Thimble Tube Cleanout at Full Power

2. INPO Entry

I. SCOPE

This investigation was conducted to identify the causal and event factors that precipitated the ejection of a highly radioactive thimble tube from its respective guide tube and the unit 1 reactor core into an adjacent instrument room containing eight employees. Additionally, an assessment was made of the actions taken to recover the ejected thimble tube, the Office of Nuclear Power (NUC PR) investigation and reporting of the accident, the efforts to determine the operational readiness of the unit for restart and return to service, and long-term planned corrective actions. During the investigation established accident investigation techniques were utilized in obtaining information from personnel interviews, document and record reviews, and accident scene observation.

II. MANAGEMENT SUMMARY

The thimble tube ejection accident subjected eight Sequoyah Nuclear Plant (SQN) employees to hazardous energy sources of water/steam at 545° F and high radiation levels but caused no injuries, and caused no danger to the general public or the environment. Approximately 16.5 man-rem of radiation exposure and 21 days were required to return the unit to its state prior to the accident (30 percent power).

After the accident the SQN operators took appropriate immediate and subsequent actions in accordance with established procedures to classify, mitigate the consequences of the accident, place the affected unit in a safe shutdown condition, and report the events as they occurred. The operator actions and the design of the plant systems prevented uncovering the reactor core and endangering the health and safety of the general public. The operator efforts were enhanced by prompt notification by the workers of the nature of the reactor coolant leak and conditions in the work area.

No physical injuries were reported as a result of the accident. This is attributed to coincidence, luck, and the prompt egress from the work area which was promoted by the increased awareness of some of the radiological hazards of the job. The increased awareness of the workers can be attributed to the actions by the plant health physics staff to question and slow the job down as the radiological hazards increased and the response of the workers to heed the warnings and stop and discuss the safety aspects of the job.

The causal factors that precipitated the accident were determined by NSRS to be associated with allowing the degraded conditions of the thimble tubes to progressively worsen without taking decisive and effective actions to restore the tubes to their fully operational status, an inadequate decisionmaking process to clean the tubes at power, and assignment of the work activity to a plant organization that was normally accustomed to working on the system while shut down, cooled down, and depressurized without providing sufficient information and management involvement. The assignment of a timeframe of less than 48 hours in which to plan and accomplish the job created an atmosphere of urgency as opposed to safety.

The workers were aware that if the job was not accomplished in that timeframe the reactor was going to be shut down and they were working hard to prevent that from happening.

Those factors discussed above promoted the subsequent breakdown in program controls that were established to regulate maintenance activities of this nature. These breakdowns resulted in the direct causal factors of the accident and include the following:

- Inadequate control of the maintenance activity in that planning, job safety analysis, and review phases were not adequate.

- Breakdown in the procedure process in that inappropriate work instructions were proposed, reviewed, approved, used, and violated.

- Inadequate controls over modification of tools used on the system in that tools were modified without performing adequate evaluations and testing to determine the effects on the system.

Indirect causal factors for the accident include the following:

- The ineffectiveness of the Independent Safety Engineering Group (ISEG) in executing their responsibilities for maintaining surveillance of plant maintenance activities to verify that known system deficiencies are identified and corrected.

- Failure to use all available resources for input into the decisionmaking process to do the job with the reactor at power.

There were other observed program weaknesses that were not causal factors for the accident but could have made the consequences of the accident worse or indicate possible program weaknesses. These include the following:

- Noncompliance with the requirements of a Radiation Work Permit (RWP).

- Improper issuance of hold orders.

- Lack of control of egress routes from the work area.

- Inoperative communication equipment.

On a more positive note the recovery effort was well planned and executed using available industry, TVA, and plant resources, approved instructions, and well-informed personnel. Those involved with the planning and execution of the recovery effort made themselves acutely aware of the hazards they were up against and exercised ingenuity in devising special tooling and simulated exercises to keep radiation exposures as low as reasonably achievable.

It should be emphasized that the TVA health physics organization performed well prior to and after the accident and their efforts can be credited with minimizing the possible serious consequences of this accident.

The actions taken to assure that unit 1 was safe for restart involved inspections, repair, and restoration of affected equipment along with special testing and evaluations. These actions were considered appropriate to ensure that the plant was safe for restart when the decision was made to proceed with returning the unit to operation.

TVA accident reporting and investigation requirements were not adhered to after the accident, and an accident investigation performed by NUC PR did not address important causal factors and respective corrective actions. The report submitted to the NRC describing the nature of the accident, causes, and needed corrective actions was misleading and revisions of that report have been recommended.

TVA's and SQN's policies for safety first before schedule and providing a safe work environment for our employees was not properly executed primarily because the plant staff did not take the time to carefully identify and evaluate the hazards of the job. This led to the subsequent breakdown of established program controls intended to prevent an accident of this nature from occurring. Realizing the hazards associated with the recovery, that effort was carefully evaluated, planned, and executed, and made good use of available resources and established program controls.

Management attention should be focused on evaluating and improving the execution of TVA policy and correcting direct and indirect causal factors and other identified program weaknesses of this accident. This was the second undesirable event involving radiation hazards that has occurred at SQN in less than two years, the last more serious than the first, that were precipitated by similar causal factors.

III. CONCLUSIONS AND RECOMMENDATIONS

A. Background

1. I-84-12-SQN-1, Inadequate Corrective Measures to Alleviate the Degraded Condition of the Thimble Tubes

Conclusion

The degraded condition of the thimble tubes had existed for a period of four years prior to the accident. Effective cleaning efforts had not been accomplished nor changes made in the methods prescribed by documented instructions to correct the problem despite the importance of the system.

Responsibilities for the different aspects affecting system operability (operation and maintenance) were dispersed among several organizations with no one central figure responsible or accountable for overall system operability allowing the degraded condition of the system to remain uncorrected (see sections IV.A.4 through IV.A.11 for details).

Recommendation

Responsibility for overall systems operability should be formally assigned to plant engineers and those engineers held accountable for periodically assessing the adequacy of the performance of the systems, the adequacy of instructions affecting the operation, maintenance or testing of the systems and for assuring that problems are promptly identified and corrected in a quality manner. The responsible engineers should be required to keep informed of industry and TVA information relating to the different aspects of the systems and to periodically formally update plant management on the status of the system.

B. The Decisionmaking Process to Clean the Thimble Tubes at Power

1. I-84-12-SQN-2, Inadequate Industry Survey and Feedback to Field Services Group (FSG) Personnel

The industry survey performed by the Engineering Section was limited in scope and appeared to attempt to determine if the thimble tubes could be cleaned at power rather than how they could be cleaned safely. The engineer performing the survey did not use available information sources (INPO), had not read the cleaning instruction, had not cleaned thimble tubes, and did not interface with FSG personnel after the survey (see section IV.B.1 for details).

Recommendation

In the future, work assignments of this nature should be given to those who are knowledgeable of and will be responsible and accountable for the success and safety of the operation to be accomplished. All available information should be identified and used.

2. I-84-12-SQN-3, Inadequate Decisionmaking Process

Conclusion

The decisionmaking process for the conduct of the cleaning of the thimble tubes while at power was less than adequate. The process used to acquire information was inadequate, readily available information sources and input resources were not used, no independent hazard analysis was performed, and the magnitude of the hazards was not realized or identified (see section IV.B.3 for details).

Recommendation

For unique activities plant management should take the time necessary to identify and thoroughly evaluate hazards associated with the activities using readily available inputs and obtaining information from knowledgeable personnel who will be responsible and accountable for the activity to be performed. Techniques such as a systematic hazard analysis methodology to identify and derive an independent assessment of the hazards involved should be used.

C. Assignment of Work Functions and Job Planning Prior to Beginning the Cleaning Operation

1. I-84-12-SQN-4, Assignment of Work Function to the FSG as an Ordinary Work Activity

Conclusion

The supervision, coordination, and execution of the cleaning operation were assigned as if the activity was an ordinary maintenance activity when in reality it was a unique activity with unique hazards identified. The coordinators and workers were unaccustomed to working on the system when the reactor was operating at rated temperature and pressure and with the dose rates that would likely be encountered and had little if any feedback from the industry survey and management discussion process. A sense of urgency was established as the supervisors, coordinators, and workers knew that the work would have to be done or the unit would be brought off the line (see sections IV.C.1 and IV.L for details).

Recommendation

Emphasize to plant management that it is a fundamental responsibility of management to assure that the knowledge and background of workers assigned to work functions is adequate and that sufficient time and information are provided to properly plan and execute the work activity.

2. I-84-12-SQN-5, Selection of an Inappropriate Instruction for the Control of the Work Activity

Conclusion

Special Maintenance Instruction SMI-0-94-1 was a poor quality instruction and inappropriate for the activity to be controlled. However, the instruction was selected during the planning process as the primary procedural control for the cleaning activity apparently because those performing the planning and coordination function were not aware of what quality elements an instruction should contain, the change process for inadequate instructions, or had a careless attitude toward procedural compliance (see section IV.C.2.b.(1) for details).

Recommendation

Conduct an awareness program to reaffirm supervisor, engineer, and worker knowledge of the importance of procedure controls, compliance with procedural requirements, and the proper change process for inadequate procedures. Emphasize the SQN policy as stated in SQA129, which states that following instructions and taking the time to correct those which are inadequate are methods to achieve nuclear safety.

3. I-84-12-SQN-6, Inadequate Job Safety Analysis and Hazards Assessment

Conclusion

The job safety analysis and hazards assessment program associated with maintenance activities at SQN is inadequate for identifying, evaluating, preventing, and mitigating accidents of this nature. Similar findings had been identified to SQN as causal factors of an inadvertent radiation exposure at SQN in December 1982, but recommendations in that report (I-82-21-SQN) had not been implemented (see sections IV.C.b.2 and IV.O for details).

Recommendation

The job safety analysis program should be upgraded. An effective hazards assessment methodology should be established as a tool to be used to analyze the identified radiological and industrial aspects of the job, the probability of an accident, and the impact on the workers, plant, and the public. Additionally, implement the recommendations of NSRS Report No. I-82-21-SQN.

4. I-84-12-SQN-7, Inadequate Field Quality Engineering (FQE) Review of Maintenance Request (MR) and Referenced Work Instruction

Conclusion

SMI-0-94-1 was referenced and attached to the MR when sent to FQE for review. The poor quality of the instruction was not identified nor was the fact that the instruction could not be used to perform the cleaning activity with the reactor at power. The FQE review process had not been effective in initiating quality improvement of the instruction since its original issuance in July 1981 (see section IV.C.2.c for details).

Recommendation

Improve the quality of the FQE review process of MRs to assure the quality of the referenced work instructions, the proper program controls are identified, and the instructions are appropriate for the activity being performed.

5. I-84-12-SQN-8, Noncompliance With Requirements of RWP No. 01-1-00102

Conclusion

RWP No. 01-1-00102 specified the following requirement: "Verify hold order is in effect on incore probes prior to entering Reactor Building lower compartments and the Annulus." On April 18 and 19 FSG evening and day shift employees and a HP technician entered the reactor building lower compartment while the hold order was not in effect (see sections IV.C.3.a-c for details).

Recommendation

Emphasize to plant employees that compliance with the requirements of RWPs is essential for their own protection.

6. I-84-12-SQN-9, Noncompliance With Requirements of Section 5.1.4 of AI-3, "Clearance Procedures"

Conclusion

Hold Order No. 1 was issued only to the Assistant Shift Engineer (ASE) and not as required by AI-3 to the persons responsible for work being performed in the instrument room between 0220 on April 17 and 0400 on May 1. This is contrary to the requirements of section 5.1.4 of AI-3 (see section IV.C.3.d for details).

Recommendation

As the hold order system is the method used at SQN for the protection of workers, the public, and equipment, strict compliance with the requirements of AI-3 should be emphasized and enforced.

D. Work Activities Related to the Thimble Tube Cleaning Prior to the Incident

1. I-84-12-SQN-10, Modification of Cleaning Tool Base Supports Without Performing a Technical Evaluation or Testing

Conclusion

The cleaning tool base support was modified and a temporary base was constructed and used without a technical evaluation of the effect on the mechanical seals. No testing was performed before use. Use of the tool and its support was determined during postaccident testing to impose forces of considerable magnitude on the mechanical seals and those forces were found to cause strain sufficient that the thimble tube separated from the mechanical seal (see section IV.D.1.a. and b for details).

Recommendation

Emphasize to the plant staff that changes to tools and equipment affecting work on critical structures, systems, and components (CSSC) can be made only after a thorough technical evaluation has been made on the effect it will have on the system and used only after the modified tool or equipment has tested satisfactorily.

2. I-84-12-SQ''-11, Violation of Work Instruction

Conclusion

SMI-0-94-1 clearly stated that the Teleflex-supplied equipment and the instruction were not to be used at power. Using the equipment and instruction for that operation was a violation of work instruction and the unit 1 SQN Technical Specifications. If the responsible engineers had written an adequate procedure appropriate for the activity and that procedure had been Plant Operation Review Committee (PORC) reviewed the result of the cleaning operation may have been different (see section IV.D.2.a for details).

Recommendation

Emphasize to the plant staff that adherence to PORC-reviewed, plant manager-approved plant instructions is mandatory and a requirement of the Technical Specifications and that instructions are controls established to assure nuclear and industrial safety. Periodic assessments of compliance with instructions should be initiated and corrective actions taken to correct weaknesses observed.

3. Health Physics (HP) Technicians Expression of Concern for Radiation Safety of the Job

Conclusion

The health physics technicians providing coverage for the job expressed concern for safety when they realized the potential for high dose rates. They made recommendations that as low as reasonably achievable (ALARA) preplanning should be performed and that further discussions should be conducted with management about the hazards. These recommendations were heeded by the workers and as a result the workers had an increased awareness of the hazards for the job before entering the containment to commence work on the evening of April 19 (see sections IV.D.2.a and d and IV.D.3 for details).

4. I-84-12-SQN-12, Lack of Control of Egress Capability from Containment

Conclusion

For approximately 30 minutes during the morning of April 19, the inner door of the personnel airlock was made inoperable without the knowledge of some of the workers cleaning the thimble tubes. This would have hindered egress from the room if the mechanical seal had failed at this time. The FSG workers were unaware of the Technical Specification requirements for maintaining containment integrity and that leaving the inner door of the airlock open would enter the unit into a limiting condition for operation. Leaving the inner door open would have hampered rescue efforts if needed (see sections IV.D.2.b. and IV.D.3 for details).

Recommendation

Establish a policy and methodology requiring an evaluation of the effect on work in progress and notification of affected workers as necessary before granting permission to incapacitate egress routes from the reactor building containment. Emphasize to plant managers and workers that working in the reactor building containment involves some risks and controls for containment integrity are established. Identify the risks involved and established controls to the employees.

5. I-84-12-SQN-13, Breakdown in the ALARA Preplanning Program

Conclusion

The responsible supervisor is required to initiate and complete an ALARA preplanning report prior to job commencement. Even though the cleaning job was expected to involve unusually high dose rates, ALARA preplanning was not conducted until the cleaning operation was well underway on the day shift on April 19, and some recommendations made in the Trojan report to reduce the radiation dose to workers were not incorporated in the cleaning instruction or the work process. The responsible supervisor was not involved in the preplanning effort (see section IV.D.2.c for details).

Recommendation

Emphasize to the plant staff that compliance with ALARA preplanning requirements as specified in RCI-10 must be accomplished.

6. I-84-12-SQN-14, Need for Formal Documentation for Upper Plant Management Approval to Work in Radiation Dose Rate Fields Greater than 50 Rem/Hour

Conclusion

There are no requirements for formal documentation for authorization to work in dose rate fields greater than 50 rem/hour (see section IV.D.3 for details).

Recommendation

Establish formal requirements and a method to document authorization to work in dose rate fields greater than 50 rem/hour.

E. The Accident

1. Failure Mode of the Mechanical Seal

Conclusion

Based upon observations of the workers immediately prior to the accident, a kink in the cleaning cable entered the cleaning tool and resulted in more force being exerted by the worker turning the handle. Additional force was transmitted to the mechanical seal resulting in strain of the seal metal allowing separation of the seal and the thimble. When separation occurred, the thimble tube started out of the guide tube immediately. SMI-0-94-1 had no restrictions or warnings on the use of the cleaning tool or the cable to alert the workers to the potential for causing a failed seal (see section IV.E.3 and IV.K for details).

2. Nature of the Leak

Conclusion

The leak occurred as a sudden spray of relatively cool water in the immediate vicinity of the workers (slightly wetting two of the workers) and rapidly developed into a "gusher" type leak flashing to steam above the workers constituting a life threatening hazard (see section IV.E.3 for details).

3. Egress From the Work Area After the Accident

Conclusion

The egress was rapid and orderly with the exception that one HP technician fell over the handrail a distance of approximately seven feet, there was some crowding and pushing at the door, and one worker was late getting into the airlock. The rapid egress can be attributed to the fact that by the time the workers entered the work area on the evening of April 19 they were acutely aware and alert to some of the hazards associated with the cleaning operation (see sections IV.E.2 and 4 for details). However, had welding in the airlock been in progress, or if the HP technician had been hurt in his fall and required assistance, the potential for catastrophic consequences is evident. NSRS attributes the fact that severe personal injury was not sustained during the accident to coincidence and luck as well as to the heightened sensitivity of the group to the hazardous conditions.

4. Head Counts of Employees

The FSG day shift coordinator had the presence of mind to conduct a head count in the airlock and again immediately after exiting the airlock. Had someone been injured and left behind in the instrument room it is probable that the head count would have initiated immediate rescue efforts and improved the chances for a successful rescue (see section IV.E.4 for details).

5. I-84-12-SQN-15, Availability of Communications Following the Accident

Conclusion

When the workers entered the airlock after the accident, they discovered that the telephone in the airlock was inoperable (see section IV.E.4 for details).

Recommendations

Anytime the telephone is out of service in the airlock, alternate communications methods should be considered and employed. Additionally, availability of communications should be considered during the performance of the job safety analysis and job planning.

6. Reporting of Accident Conditions to the Control Room

Conclusion

Immediately after exiting the airlock the FSG day shift coordinator told the Public Safety Officer controlling access to reactor building containment to notify the control room of what was happening. The officer was unsuccessful in getting through to the control room (reason not determined by NSRS). The coordinator exited the contamination zone immediately and notified the control room operators of the accident and the nature of the leak. This early notification was helpful to the operations staff in properly classifying the degree of the problem (see sections IV.E.4 and IV.F.1 for details).

F. Operator Actions to Mitigate the Accident

1. Immediate and Subsequent Operator Actions

Conclusion

Using the information provided by the FSG coordinator and properly analyzing the system responses, the operations staff classified the nature of the leak and took proper action in accordance with established procedures to shut the unit down, report the accident, and mitigate the leak. Reactor coolant charging capacity compensated for the leak rate. The core was never uncovered even though the leak was nonisolable and no core damage was sustained. Public health and safety were not jeopardized (see section IV.F for details).

G. Initial Actions Taken to Evaluate Conditions in the Instrument Room

1. Establishment of Upper Plant Management Direction and Control of the Recovery Effort

Conclusion

Realizing after the accident that the radiation levels in the instrument room were unusually high, one RWP (RWP No. 02-1-0005) was established to track total radiation dose acquired by the workers during the recovery effort and to establish plant manager control of all activities relating to the recovery effort. Considering the magnitude of the hazards in the room this was an appropriate decision (see section IV.G.2 for details).

H. The Recovery of the Thimble Tube and Actions Taken to Ensure Unit 1 Was Safe to Return to Power

1. Prior NUC PR Planning for Emergency Project Management

Conclusion

NUC PR had issued in November 1983 a procedure to delineate a program for emergency project management that enhances the ability of normal plant forces to ensure that nuclear safety and remaining plant capactity and availability are not affected. The plant manager elected to use the established concept for the recovery effort at SQN. The prior establishment of this concept and its use proved useful and effective during the recovery effort (see sections IV.H.1 and IV.H.2.a and b for details).

2. Effective Use of TVA and Industry Resources

Conclusion

Personnel were brought in from other industry, TVA, and NUC PR organizations to assist in obtaining ideas, planning, oversight, and execution of the recovery effort to ensure that the recovery was conducted in a safe manner and that the radiation doses to the workers involved were kept ALARA. This action proved useful to a successful recovery effort (see section IV.H for details).

3. Use of Ingenuity in the Planning and Execution of the Recovery Effort

Conclusion

The recovery effort of the highly radioactive thimble tube was carefully thought out, evaluated, planned, simulated, practiced, and executed using available resources, appropriate procedures for the activities, and remote handling tools. The radiation dose to individuals involved in the effort was closely monitored, controlled, and was very close to the projected man-rem dose for the job. Personnel involved in the effort demonstrated excellent ingenuity during the recovery effort (see sections IV.H.2.c and d for details).

4. I-84-12-SQN-16, Effective Cleaning of the Thimble Tubes by Nuclear Utilities Services (NUS) Corporation

Conclusion

The method used by NUS as prescribed in SMI-0-94-2 to clean the thimble tubes after the accident was effective in eliminating the material causing the blockage in the thimble tubes. This effectiveness is primarily due to the pressure of the new backflush process (200 psi) versus that of the old method (40 psi) and the controlled application of NEOLUBE as prescribed in SMI-0-94-2 (see sections IV.H.4 and IV.I for details).

Recommendation

Advise Watts Bar Nuclear Plant (WBN) of the effectiveness of the NUS cleaning method over the Teleflex method.

5. I-84-12-SQN-17, Poor Quality Cleaning Procedures and Inadequate PORC Review

Conclusion

As noted in section III.C.2, SMI-0-94-1 was not adequate for its intended use. SMI-0-94-2 was written after the accident to clean the tubes via the NUS method. It too was a poor quality instruction and could promote accidents of a similar nature in the future. This conclusion is based upon the facts that SMI-0-94-2 had no cautions or warnings to prevent damage to the mechanical seals, no administrative barriers to prevent cleaning the tubes at pressure, no instructions for disassembly and reassembly of the detector drive system, no postmaintenance inspections after cleaning and before pressurizing the reactor, and postmaintenance testing to ensure operability was optional.

Despite the poor quality of the instructions both were recommended for approval by PORC. In these instances, PORC failed to adequately fulfill its responsibilities to the plant manager on these matters relating to nuclear safety (see sections IV.H and IV.N.2 for details).

Recommendation

Evaluate the PORC procedure review process and consider supplementing the review process with expert subcommittees to properly evaluate procedures and advise the plant manager on their adequacy before he approves or disapproves.

Additionally, cancel SMI-0-94-1 and do not use SMI-0-94-2 again until it has been revised to include at least the quality elements listed above. Perform a generic review of all maintenance and special maintenance instructions to ensure adequacy.

6. Inspection, Testing, and Repair of Affected Equipment Before Returning the Unit to Power

Conclusion

The actions taken by SQN to inspect and repair the thimble tubes high pressure seals, evaluate various combinations of SWAGELOK/GYROLOK fitting hardware, and other equipment possibly affected by the accident were appropriate to ensure the unit was safe to return to power (see sections IV.H.6 through IV.H.9 for details).

I. Accident Investigations (Other than NSRS)

1. I-84-12-SQN-18, Noncompliance with Serious Accident Reporting and Accident Scene Preservation Requirements

Conclusion

Corporate and SQN procedures require that serious accidents be reported immediately and that the accident scene be preserved until released by the chairman of an appointed Accident Investigation Team (AIT). The accident was not reported as a serious accident until approximately three weeks after the accident occurred, nor was the accident scene preserved as restoration of equipment was essentially complete before the accident was reported (see section IV.J.2 for details).

Recommendation

Determine the cause of the noncompliance and take corrective actions as necessary to ensure future compliance with established requirements.

2. I-84-12-SQN-19, Limited NUC PR Accident Investigation

Conclusion

The appointment of the SQN FCG supervisor to the NUC PR investigation team was inappropriate for this investigation as it created a potential conflict of interest. The NUC PR investigation did not address any breakdown of program controls such as job planning, job safety analysis, inadequate procedures, or the nuclear safety and radiological aspects of the accident. Overall the accident investigation performed by NUC PR is considered limited in scope, somewhat misleading, and did not address what NSRS determined to be the nature of the causes of the accident (see section IV.J.2.a for details).

Recommendation

During future accident investigations appropriate personnel should be appointed to eliminate any potential conflict of interest; the investigation should be initiated as soon as possible after the accident as prescribed by established procedures; sufficient time should be allowed for conduct of the investigation; and it should encompass all aspects of the accident including programmatic weaknesses or breakdowns, and nuclear and radiological safety.

Recommendation No. 5 of the NUC PR report should be revised to delete the recommendation that consideration should be given to leaving the inner door open during such activities.

J. Employee Expression of Concerns for Safety

1. I-84-12-SQN-20, Needed Reemphasis on the TVA and SQN Employee Expression of Concerns for Safety and Safety-First Policies

Conclusion

The employees should have but did not relate their increasing concerns for the safety of the job to upper plant management, and an expression of concern for the adequacy of the design of the new tool support base was not followed up. The workers felt that they had to accomplish the job to prevent shutdown of the unit. It is probable that the workers are not acutely aware of TVA's and SQN's policies and their related responsibilities for expression of concerns for safety and safety first before schedule (see section IV.M for details).

Recommendation

Emphasize to all SQN employees that they are actually responsible for voicing their views concerning safety, that these views are valuable management tools to prevent accidents of this nature from happening, and that management is responsible for addressing the views in a satisfactory manner. Emphasize to all supervisors, engineers, and foremen that responsible concerns expressed to them by their employees must be evaluated regardless of how insignificant they may seem. The TVA and SQN safety-first policy should be emphasized to all SQN employees that nuclear safety is the number one SQN objective and that safety first means before schedule and before production.

K. Program Controls Established by SQN Unit 1 Technical Specifications

1. I-84-12-SQN-21, Ineffective SQN ISEG Activities

Conclusion

The SQN ISEG organization had been ineffective in performing the function that was originally intended for the organization. This is due in part to the dual responsibilities for compliance/ISEG activities and lack of true independence from line responsibilities and pressures (see sections IV.N.1 and IV.Q for details).

Recommendation

Reorganize or reassign functions as necessary to provide ISEG personnel adequate independence from line responsibilities and pressures. Additionally, functions should be limited to ISEG-type duties as required by Technical Specifications.

2. I-84-12-SQN-22, Significant Breakdown in the SQN Procedure Process for Maintenance Activities

Conclusion

There is an apparent breakdown in the procedure process at SQN for maintenance activities as PORC reviewed and recommended approval of two poor quality instructions used for cleaning thimble tubes (one after the accident); the biennial review did not correct poor quality in one instruction; instructions being used were inappropriate for the activities being performed; an instruction was violated; and some engineers and managers interviewed did not seem to understand what quality elements should be in a maintenance instruction, were not aware of the procedure change process, or expressed a careless attitude toward procedure compliance (see section IV.N.2 and 3 for details.)

Recommendation

The procedural process for maintenance activities at SQN should be thoroughly evaluated. Corrective actions including procedure verification should be initiated as necessary to improve the (1) knowledge of those personnel preparing and using procedures of what constitutes an appropriate procedure, the quality elements that should be incorporated into a procedure, and the change process for existing procedures; (2) quality of the PORC and biennial reviews; and (3) compliance with procedures.

L. SQN Licensee Event Report (LER) No. SQRO-50-327/84030

1. I-84-12-SQN-23, Inadequate Reporting of the Event to NRC

Conclusion

The subject LER was misleading in that the true nature of the leak was not described, there was no mention of an inadequate procedure or violation of procedures as causal factors, and the long-term corrective actions are not adequate to correct the true causal factors of the event (see section IV.P for details).

Recommendation

Revise the LER to reflect the true nature of the leak, the adequacy and violation of SMI-0-94-1, and effective long-term corrective action.

IV. DETAILS

A. Background

This accident occurred during the performance of maintenance activities on the unit 1 incore instrumentation system. The following is a description of that system along with a discussion of background information considered pertinent to the accident itself.

1. Incore Instrumentation System Description

This system was designed to measure temperatures and neutron densities at 58 different locations in the reactor core. The process of measuring the neutron density at different locations in the core is referred to as flux mapping. The flux mapping data is used to confirm nuclear design parameters and ascertain that the nuclear fuel is properly loaded and oriented.

a. Neutron Detectors and Drive System (Refer to figure 1 for the basic system schematic)

The neutron instrumentation portion of the system consists of six movable miniature fission chamber detectors (0.188 inches in diameter and 2.1 inches long). Each detector is welded to the end of a 0.188-inch-diameter helical (spiral wound) drive cable. Each detector and cable is inserted into the reactor core by an electric drive unit through interconnecting tubing via path transfer units which direct the detectors to the desired core location through an isolation valve and one of 58 stainless steel tubes known as "thimble tubes." The thimble tubes are terminated at a common header-type device known as the "seal table" (see figure 2) and are physically held stationary against reactor pressure by mechanical seals (SWAGELOK/GYROLOK fittings).

b. Thimble Tubes (Refer to figures 1, 3, and 4)

There are 58 stainless steel thimble tubes each having an outside diameter (od) of 0.300 inch and an inside diameter (id) of 0.201 inch. The last 1.5 inches of each thimble tube at the seal table is expanded from 0.300 inch od to 0.314 inch od to facilitate installation of the mechanical seal. The thimble tubes vary in length between 103 and 117 feet depending upon the distance between their respective position at the seal table and the route to their respective position in the reactor core. The clearances between the detectors and the inside of the thimble tubes is 0.013 inch. The ends of the thimble tubes in the reactor are sealed, the tubes are dry on the inside, and they serve as a reactor coolant system pressure boundary and thus are a "critical system, structure, or component" (CSSC). The tubes are designed for service at 2500 psig. Each thimble tube is individually routed from the seal table to the reactor vessel through its respective guide tube. The configuration of the thimble tubes as designed and installed creates a loop at the lowest portion of the system which is a natural collection or concentration point for any loose substances in the tube.

Approximately 12 to 14 feet of each thimble tube is in place in the reactor core region during normal plant operation. This portion of the tube is normally exposed to an intense neutron flux causing activation of the stainless steel tubing into long-lived radioactive nuclides.

The radiation from these long-lived nuclides caused high dose rates in the instrument room after the thimble tube was ejected during the accident, complicating recovery of the tube.

c. Guide Tubes

The guide tubes are 1 inch od stainless steel and are essentially extensions of the reactor vessel with no isolation valves. The thimble tubes are routed through the guide tubes which extend from the bottom of the reactor vessel through the concrete shielded area to the seal table (see figure 1). The space between the thimble tube and the guide tube contains approximately four gallons of reactor water at reactor pressure. The water in this space is relatively cool rather than at reactor water temperature (~545° F) as it is normally stagnant and there is approximately 100 feet of thimble and guide tube between the seal table and the reactor pressure vessel.

d. Mechanical Seals (Refer to figures 5 and 6)

The thimble tube is held in place at the seal table against reactor pressure (~2250 psig normal operating pressure) by two mechanical seals connected to the guide tube and thimble tube by a SWAGELOK union, ferrules, and nuts. The guide tube is reduced in size from 1 inch od to 0.625 inch od at the seal table and is welded in place at the seal table surface. The end of the thimble tube passes through the end of the guide tube at the seal table.

The high pressure fitting on the thimble tube involved in this accident contained a two-piece GYROLOK ferrule assembly in a SWAGELOK fitting. Figure 6 shows a photograph of a piece of thimble tube and a typical SWAGELOK fitting. Once tightened, the unit compresses the two-piece ferrule assembly against the thimble tube forming a reactor pressure boundary seal and holding the thimble tube in place against reactor pressure within the guide tube. The lower and larger portion of the fitting forms a reactor pressure boundary seal between the guide tube and the SWAGELOK union in a similar fashion.

2. Physical Arrangement of the Incore Instrument System Equipment

This accident occurred inside the lower compartment of the unit 1 reactor containment building in a room called the instrument room. Figure 7A is a top view of the lower compartment of reactor containment showing the instrument room, the relative position of the seal table, personnel airlock, a submarine hatch allowing access into the containment raceway, and a door allowing access to inside the polar crane wall (a wall supporting the polar crane and providing a radiation shield from the radiation produced by the reactor during operation). Figure 7B is a view of the WBN personnel airlock door as viewed from inside the reactor building containment. Figure 8 is an elevation drawing of the reactor building and illustrates the relative position of the seal table to the top of the reactor core. The drawing depicts the location of the raceway below the instrument room.

Figure 9 is an elevation drawing that illustrates the location of the incore instrumentation system equipment in the instrument room. The portion of the system directly over the seal table is on rollers and can be disconnected and rolled back out of the way allowing overhead access to the seal table.

Figure 10 is a top view of the location of the incore instrumentation equipment in the instrumentation room. The neutron detectors can be stored in cavities in the polar crane wall for radiation shielding while personnel are working in the area.

3. Access to the Instrument Room in the Reactor Building Through the Personnel Airlock at Elevation 690 (See figures 7A and 7B)

The personnel airlock is the primary means of entrance and egress to and from the instrument room where the seal table is located. This airlock is normally locked to prevent uncontrolled entry into the containment. Access is administratively controlled by Administrative Instruction AI-8, "Access to Containment." AI-8 establishes requirements that entry into containment will be controlled by the shift engineer with lock and key and strict personnel accountability by a public safety officer who formally tracks personnel entering and leaving containment on a "Containment Entry Checklist."

The personnel airlock is equipped with two doors that close to form a gastight seal. These two doors are interlocked with one another so that during unit operation both doors cannot be opened at the same time thus breeching containment integrity. Although infrequent, problems have been encountered with these interlocks and personnel have been prevented from exiting containment through that route because one or both doors would not open. On at least one occasion personnel have been caught in the airlock and could not get out without assistance. A telephone is provided in the airlock for communication.

4. Lubrication of the Incore Detectors, Cables, and Thimble Tubes

The lubricant selected for use in the portions of the system involved in this accident was a colloidal graphite alcohol mixture with a product name of "NEOLUBE." This lubricant was approved for use for this application and was selected because of its compatibility with the component constituents, its lubrication properties (described by those interviewed as not being the very best), its resistance to damage from radiation and temperature, and its low neutron activation properties. The lubricant works properly for this application only when used sparingly and properly applied. If used in excess in this environment (high radiation and temperatures), corrosion products from the system (thimble tubes and detector drive cables) mix with the lubricant and cause it to harden and lump resulting in thimble tube blockage.

5. Initial Installation, Cleaning, and Lubrication of Unit 1 Thimble Tubes

The thimble tubes for unit 1 were installed by TVA construction forces using Westinghouse specifications. After the thimble tubes were installed it was observed that they were significantly blocked. The reason for the blockage was not determined by the plant staff but was thought possibly to be caused by improper storage of the thimbles prior to installation causing the buildup of corrosion products or dirt on the inside of the tubes. Teleflex Corporation was contracted to clean the tubes prior to operation. Resistance was met during initial attempts to insert a cleaning cable into the thimble tubes. Copious amounts of NEOLUBE were added to the tubes by Teleflex personnel to facilitate insertion of the cleaning cable. The tubes were then brushed, backflushed, and dried using methods similar to those prescribed in Special Maintenance Instruction SMI-0-94-1 discussed in section IV.A.8 of this report.

During the performance of the "Incore Movable Detectors Preoperational Test W-11.4, Unit 1," in April 1980, blockage was encountered while attempting to insert test cables. Further cleaning efforts by the FSG was conducted along with attempts to "polish" the tubes by driving the test cables in and out of the tubes at a fast speed. When the unit 2 thimble tubes were installed they, were not blocked and no NEOLUBE was added to the tubes. Problems with thimble tube blockage on that unit have been minimal.

6. Maintenance History of the Incore Instrumentation System Thimble Tubes Prior to the Accident

The detailed history of prior cleaning activities was not determined by NSRS other than it was related to NSRS by plant management that they were not very successful since blockage problems continued to worsen. Prior to the shutdown for the cycle 2 outage, a maintenance request was written in December 1983 to clean all 58 thimble tubes during the outage. However, due to manpower limitations, time restrictions, and low priority only nine thimble tubes were cleaned. The personnel performing the cleaning reported that they had difficulties getting the brush and the backflush tubing to the ends of the thimble tubes due to the severe blockage and restrictions on the use of NEOLUBE in the thimble tubes.

7. NUC PR Requirements Applicable for the Control of Plant Maintenance

NUC PR requirements applicable for providing control over maintenance activities on CSSC equipment were delineated in Part II, Section 2.1, "Plant Maintenance," of the NUC PR Operational Quality Assurance Manual (N-OQAM). This section of the N-OQAM contained the following requirements:

- Paragraph 1.3 - Specified that maintenance on CSSC shall be properly preplanned and performed in accordance with written procedures or documented instructions appropriate to the circumstances.

- Paragraph 3.3.1.3 - Specified that the instructions shall contain requirements for verifying the quality of maintenance or repair and shall include appropriate quantitative or qualitative acceptance criteria.

- Paragraph 3.3.1.4 - Specified that upon completion of maintenance on any item of the CSSC list and before release for service, appropriate testing shall be performed to verify operational acceptability.

- Paragraph 4.4.2 - Specified that if generic problems are suspected, equipment maintenance history files should be consulted to determine the frequency, cause, and mode of previous failures. If evidence indicates that equipment of the same type has performed unsatisfactorily, corrective measures shall be planned and carried out.

8. Special Maintenance Instruction SMI-0-94-1, "RPV Bottom Mounted Instrument Thimble Tubes Cleaning," Issued July 10, 1981

The thimble tube cleaning process consisted of five steps, only three of which were discussed in SMI-0-94-1. SMI-0-94-1 established the primary administrative controls that had been used on past thimble tube cleaning operations at SQN. These steps and controls are discussed below.

a. Thimble Tube Cleaning Steps.

(1) Disconnecting the Overhead Drive Assembly (Not Discussed in SMI-0-94-1). The thimble tubes and interconnecting tubing were disconnected at the SWAGELOK union flare fittings between the high pressure fittings and the isolation valves (see figures 1 and 5). The overhead assembly was then rolled out of the way allowing access to the top of the seal table and the thimble tubes.

(2) Dry Brushing (Refer to figures 11A, 11B, 12A, and 12B). The dry brushing step involved the use of a brush assembly which consisted of a 0.200 inch od brass wire brush welded to a 0.187 inch od carbon steel helical (spiral wound) cable driven by a handcranked drivebox. The brush assembly was provided by the same vendor (Teleflex) that provided the detector drive system. The upper and lower supports for the handcrank device were fabricated by TVA. The lower support was equipped with a 90° base support that fit over a boss on a seal table providing additional stability to the support assembly as the handcrank was turned. The fit of the base support over the bosses for all the thimble tubes was not always secure. The brush assembly was used to "dry" brush each of the thimble tubes to dislodge particles and dried lubricant attached to the thimble tube wall by the scrubbing action of the brush. The brush was driven into the thimble 10 inches for each revolution of the handcrank. The brushing motion was strictly linear without any rotation of the brush.

(3) Demineralized Water Backflush. After the thimble tubes were dry brushed, pressurized water from the plant demineralized water supply system at approximately 40 psi was injected into each of the thimble tubes via a nylon fluid injection tubing (0.156 inch od) inserted into each thimble tube. It was intended that the turbulent waterflow backflushing out through the void between the inside of the thimble tube (0.201 inch id) and the

outside of the injection tubing would carry the particles dislodged by the scrubbing action of the dry brushing step out of the thimble tubes to waste. Backflushing was to continue until water leaving the tube was visually clear. The clearance between the backflush tube and the inside of the thimble tube is 0.045 inch. Note: The NUS system used to backflush the thimbles after the accident used demineralized water at approximately 200 psi.

(4) Drying of the Thimble Tubes. After the demineralized water backflush, the remaining water in each thimble tube was removed by injecting nitrogen or control air through the nylon injection tubing until there was no evidence of moisture in the nitrogen or air backflushing from the tubing.

(5) Reconnecting the Overhead Drive Assembly (Not Discussed in SMI-0-94-1). After the cleaning operation was complete, the interconnecting tubing and the thimble tubes were reconnected at the SWAGELOK union flare fitting.

b. Administrative Controls. The administrative controls for the thimble tube cleaning process as prescribed by SMI-0-94-1 are discussed below.

(1) Precautions and Warnings. SMI-0-94-1 contained cautions and warnings indicating that the cleaning equipment and the instructions were not to be used at power (reactor operating). These limitations were placed in the instruction because of contamination hazards created from the neutron activation of foreign matter in the thimble tubes. The materials removed from the thimble tubes would be extremely radioactive thus subjecting the workers to additional radioactive contamination.

With the reactor shutdown the normal radiation dose rate level in the work area (seal table) was approximately 10 millirem/hour. Since the special maintenance instruction was not to be used during power operations, no warning or cautions were included in the instruction addressing any unique radiation dose rate hazards that would be encountered due to activation of the cleaning equipment (cable and brush). The instruction did not address any special precautions or unique actions that should be taken if the thimble tubes were being cleaned at elevated reactor pressure regardless of the operating status of the reactor. The instruction did not address any special precautions that should be taken to prevent damage to the mechanical seals when disconnecting the drive system from the thimble tubes at the seal table, during the cleaning operation, or when connecting the drive system back up to the thimble tubes.

(2) Disconnection/Connection Instructions. There were no instructions provided for the disassembly and reassembly of the drive system from and to the thimble tubes at the seal table.

(3) Acceptance Criteria. The instruction contained no acceptance criteria other than section 5.2.E which stated "when all 20 thimbles are clean, as evidenced by continued clear fluid passing through the discharge base assembly, clean the remainder of the thimbles in the same manner." Note: If the backflush was ineffective in removing the loose materials in the tube the water backflushing would appear clean while the loose materials remained in the tubes.

(4) Postmaintenance Inspections. The instruction contained no postmaintenance inspections to verify that the mechanical seals had not been degraded during the cleaning activity.

(5) Postmaintenance Testing. The instruction contained no postmaintenance testing requirements of the thimble tubes to ensure operability after cleaning was performed.

In summary, the methods employed in the past cleaning operations including those during the outage had been ineffective in removing solid matter from the thimbles. This is due in part to the design of the system (minimal clearances between thimble tubes and guide tubes and low point collection of solid matter) and to the backflush method using demineralized water at 40 psig rather than at 200 psig as with the NUS method that was eventually used to adequately clean the system after the accident. The primary controlling document for the activity (SMI-0-94-1) did not promote thoroughness or prevent damage to the system as it contained only a marginally effective acceptance criteria to establish when the thimble tubes were clean, no postmaintenance testing requirements to ensure the thimble tubes were functional before reassembly and use, and no postmaintenance inspections to assure that the mechanical seals could perform their functions against full reactor pressure. The instruction contained no restrictions on the use of cleaning tools or cleaning cable other than those prohibiting the use of the tools and methods established in the instruction during power operations. Despite the historical ineffectiveness of the cleaning methods no changes had been made to the instruction (and thus the cleaning methods) since its original issuance in July 1981.

9. Plant Restart Testing Program

After a refueling outage the plant restart testing program as defined in Restart Test Instruction RTI-1, "Restart Sequence," revised April 13, 1984, required that a reactor core neutron flux map be performed prior to exceeding 30 percent reactor power. Section 3.3.3.2 of the SQN Technical Specifications required that 75 percent (44 of 58) of the detector thimble tubes must be operable (i.e., capable of passing the detector into the core) in order to perform the flux mapping.

10. Plant Responsibilities for Different Aspects Relating to the Operability of the Incore Instrumentation System

At SQN the incore detector system was operated by operators, nuclear engineers, and shift technical advisors (STAs). The system drive units were maintained by the Electrical Maintenance Section and thimble tube cleaning was performed by the FSG.

The operators of the system were aware that it would be required for the startup testing program but were not involved with the cleaning activities. Those involved with the cleaning activities were not involved with the startup program and were possibly not aware of the importance of the system to that program. There was no apparent central figure who seemed to be cognizant of the system as a whole to recognize and coordinate resolution of problems affecting the system. Efforts to clean the thimble tubes were not effectively accomplished until after the accident when it was recognized that the tubes must be cleaned and cleaned properly to continue the restart of the unit.

11. Unit 1 Operational History After the Startup From the Cycle 2 Refueling Outage

After the 56-day Cycle 2 refueling outage, initial criticality occurred on April 15, 1984. Low power physics testing commenced on April 15 in accordance with RTI-1. With the first attempts to insert the incore detectors into the reactor core for testing purposes, it was noted that the detectors could not be inserted through the required minimum number of thimbles (less than 75 percent of the thimble tubes were operable). Five of the nine thimbles cleaned during the refueling outage were still inoperable. Engineers and craft personnel from the FSG, the Reactor Engineering Unit (REU), and the Electrical Maintenance Section (EMS) performed testing and maintenance to try to determine if the blockages were unique to certain detector cables and drive units thus indicating problems with the cables and drive units, or if indeed the thimble tubes were blocked. From these testing and maintenance activities it was determined that 23 out of the 58 thimble tubes were blocked, leaving only 60 percent of the tubes operable. By 1700 April 18, the unit had reached 30 percent power and could proceed no further because of the blocked thimbles and the requirements of the restart testing program. Also, problems were being encountered with secondary water chemistry and a leaking power-operated pressurizer relief valve (PORV).

In summary, the unit 1 incore instrumentation system had been in a degraded condition since initial installation, preoperational testing, and subsequent power operations (approximately four years). The cleaning methods employed by the plant personnel as described by SMI-0-94-1 were ineffective in removing the material causing the blockage from the tubes. The cleaning instruction was of poor quality and did not meet the requirements as specified by the N-OQAM. The inadequate instruction was PORC reviewed and plant manager approved but had not been revised since the original issuance in 1981. Despite the importance of the system for the restart testing program to confirm nuclear design parameters and ascertain that the nuclear fuel was properly loaded and oriented and periodic verification of calculated parameters, cleaning of the tubes was given a low priority during the outage. Attempts were made to clean only 9 out of 58, and only 4 of these 9 were successfully cleaned. It is apparent that assigned cognizance responsibility for the overall system operability is less than adequate or improperly executed in that no decisive action was taken to correct the program inadequacies until the degraded condition of the thimble tubes prevented the plant restart process after the refueling outage and the occurrence of the accident. The less than adequate cognizance of system operability was determined by NSRS to be due in part to the dispersion of the assigned responsibilities for operation and maintenance of the system.

For conclusions and recommendations relating to this section, refer to section III.A.1.

B. The Decisionmaking Process to Clean Thimble Tubes at Power

During the restart from the refueling outage, plant management had recognized that if a neutron flux map could not be successfully obtained, the normal restart testing and power escalation of the unit could not proceed. The Engineering Section Supervisor had discussed cleaning thimble tubes at power with a representative from the Trojan Nuclear Plant during a reactor engineers conference he had attended in the past. Thimble tubes had been cleaned (dry brushed only) at the Trojan Nuclear Plant while operating at 100 percent power. The SQN plant management had a copy of a report of that particular cleaning activity (see attachment 1). This report was a brief outline of the Trojan cleaning operation, contained some recommendations, and related the problem encountered with the high dose rates at the seal table (170 rem/hour maximum and 60 rem/hour average) when the cleaning cable and brush were withdrawn. As a cleaning operation of this nature had been performed at Trojan, SQN upper management directed the Engineering Section Supervisor to perform an industry survey to obtain further knowledge of industry experience in cleaning thimble tubes at power. Additionally, they directed him to inquire about the possibility of acquiring the services of a contractor experienced in thimble tube cleaning to come to the plant and perform the cleaning operation at power. The Engineering Section Supervisor assigned these jobs to the Reactor Engineering Unit (REU) Supervisor who in turn assigned them to two nuclear engineers in his unit. The following are the results of the surveys and inquiries:

1. <u>Industry Survey of Operating Nuclear Plants to Determine Their Experience in Cleaning Thimble Tubes at Power</u>

   During the course of the survey the following nuclear plants were contacted by a SQN nuclear engineer:

   a. <u>Trojan Nuclear Plant</u>. Thimble tubes had been cleaned (dry brushed) at 100 percent power at Trojan in 1979. The major problem encountered during the cleaning operation was the high radiation dose rates (170 rem/hour maximum; 60 rem/hour average) at the seal table when the brush and cable were being withdrawn after they had been inserted into the reactor core. Teleflex, the vendor of the incore instrumentation drive system, assisted Trojan in the brushing operation.

   b. <u>Beaver Valley Nuclear Plant</u>. Beaver Valley had cleaned (dry brushed) thimble tubes at power and did not have any problems. However the cleaning operation was not effective since only one out of six tubes that were blocked was made operable by the dry brushing operation.

   c. <u>Kewaunee Nuclear Plant</u>. Kewaunee did not clean thimbles at power because their technical specifications were not as restrictive as the SQN technical specifications on the use of the incore instrumentation system. They had never had the need arise to clean the thimble tubes at power.

d. North Anna Nuclear Plant. North Anna did not clean thimbles at power because they have a subatmospheric containment of 10 psia which restricted access to containment during power operations.

e. Ginna Nuclear Plant. Ginna had contracted Nuclear Utilities Services (NUS) to clean their thimble tubes in 1978 using a water backflush method while they were shutdown. They hadn't experienced any problems with their thimble tubes since that time.

None of the people contacted at these plants indicated any problems with thimble tube ejections.

The nuclear engineer performing this survey was told which plants to call, had not read the special maintenance instruction (SMI-0-94-1) prior to making the survey, had no experience cleaning thimble tubes, and did not interface with the FSG personnel doing the cleaning after the survey. The information received from this survey was passed on to the Engineering Section Supervisor.

NSRS consulted the INPO "Nuclear Network" for industry experience with thimble tubes. The Network contained an entry made May 3, 1983 concerning incore thimble tube blockage (see attachment 2). The entry indicated that Salem Nuclear Plant had experienced problems with thimble tube blockage over the years at the point where the thimble tubes enter the reactor vessel. To discover the source of the blockage two tubes were removed and a contract awarded to Battelle Columbus Laboratories. The entry stated that the blockages had been successfully removed at Salem with the unit at full power by probing the thimble tubes with a test cable. Salem removed the input tube from a 10-path transfer device and attached a Teleflex hand drive with a cable loaded into it. They then drove the cable to the area of the blockage and pushed it out of the way. They had found it unnecessary to drive the cable into the core region. In fact they took precautions to prevent that from happening so as not to activate the cable to $\sim$ 100 rem/hour. They counted the revolutions of the handcrank and drove the cable to within 6 feet of the core. They then retracted the cable, rotated the 10-path to the next path and repeated the process. The method used by Salem did not subject their workers to high dose rates and did not subject the mechanical seals to any forces greater than those encountered during normal operation. The name and number for a contact at Salem for further information was given. SQN did not consult the INPO Network or talk to Salem during the survey.

The industry survey performed by the Engineering Section was limited in scope in that it did not identify any significant hazards or better methods to perform the cleaning operation and did not result in any changes to the cleaning instruction to improve the safety and efficiency of the operation. The engineer was told exactly who to call and did not use readily available information sources, had no experience in cleaning the thimble tubes, had not read the cleaning instruction prior to performing the survey, and was not responsible for performing the cleaning operation. The survey appeared to attempt to determi.e if the thimble tubes could be cleaned at power rather than how they could be cleaned safely.

For conclusions and recommendations relating to this section, refer to section III.B.1.

2. Inquiries of Contractors for Acquiring Services to Clean the Thimble Tubes at Power

During the course of the inquiries the following contractors were contacted by another SQN nuclear engineer:

a. Nuclear Utilities Services (NUS). NUS indicated that their method of cleaning thimble tubes (water flush) was not acceptable for cleaning at power because of temperature considerations (water would flash to steam and injection tubing would melt at 545° F). The NUS procedure did not include dry brushing thimble tubes.

b. Teleflex Corporation. Teleflex indicated that they would not dry brush the thimble tubes at power. They did indicate that they would send a representative from their company to SQN to advise and assist the plant staff during the cleaning operation if they did elect to clean at power. Plant management decided that they had people with sufficient experience in cleaning thimble tubes and thus elected not to acquire the services of the Teleflex adviser. NSRS was informed on May 7 by a representative of Teleflex that they had assisted Trojan with a dry brushing cleaning operation of thimble tubes at power and had decided after that operation not to do it at power again because of the radiation exposure received by their personnel during that operation.

3. Assessment of the Results of the Survey and Inquiries and Risks of the Job

The survey and inquiry information was relayed to the Assistant Plant Manager and on April 18 meetings were conducted to evaluate the results of the survey and to decide whether to clean the tubes or not. Those in attendance and providing input included the following:

- Assistant Plant Manager
- Engineering Section Supervisor
- Electrical Maintenance Supervisor
- Field Services Group Supervisor
- Field Services Group Maintenance Specialist

There were no health physics, safety section, or Independent Safety Engineering Group (ISEG) members present during these meetings. The ISEG organization was aware that the decisionmaking was in progress but that group was not involved.

The following is a summary listing of the pertinent information available to management at that time to support the decision to clean thimble tubes at power:

- The objective of a nuclear power plant is to produce maximum electrical power at the lowest practical cost consistent with maintaining a high degree of nuclear safety.

- The plant could not proceed past 30 percent power because 23 thimble tubes were blocked (9 out of 23 had to be cleared to meet 75 percent required by Technical Specifications).

- Trojan Nuclear Plant had cleaned thimble tubes at 100 percent power reportedly with no problems other than high radiation dose rates (170 rem/hour maximum; 60 rem/hour average).

- SQN had qualified and experienced health physics personnel along with approved radiation control procedures to assist during the cleaning operation and control radiation exposures to ALARA and below any plant limits.

- Plant management had a report from Trojan giving a brief outline of the cleaning method, the results, and containing some recommendations.

- Beaver Valley Nuclear Plant had cleaned thimble tubes at power. Even though 5 out of the 6 tubes cleaned were still blocked after the operation, they reported no problems during the cleaning itself.

- SQN had an established system of procedures that had been reviewed by PORC.

- SQN had an established method (Standard Practice SQM2) for the control of the planning, work instruction preparation, FQE review for quality assurance criteria, performance of job safety analyses, and work authorization to ensure no Technical Specification criteria were violated (MR process).

- SQN had an established plant operational review committee (PORC) to review any required work instruction to ensure it would not endanger the health and safety of plant personnel, the general public, and safe operation of the plant. PORC would recommend approval or disapproval of the instruction to the plant manager.

- SQN had an ISEG group that routinely reviewed maintenance activities to ensure that unsafe conditions were minimized.

- The plant had a trained and experienced operations crew with approved instructions to handle off-normal situations with plant operations.

- The nature of operating reactor and associated power conversion systems creates the necessity to perform maintenance on systems and components at elevated pressures and temperatures. Maintenance on pressurized systems at temperature can be and had been performed safely with proper planning, good procedures, and trained personnel.

- The probability that a thimble tube would rupture was minimal because of the material and metal thickness.

- SQN had previously performed cleaning operations on the tubes without creating leaks or problems.

- While cleaning the tubes the steam generator water chemistry problems could be stabilized and minimized.

- They had people on the staff who had experience cleaning thimble tubes while the plant was shutdown.

The following is a summary listing of the pertinent information available to management at that time to counter the decision to clean thimble tubes at power:

- SQN cleaning operations including both dry brushing and water backflushing had been only temporarily successful in the past in alleviating the blocked tube problem. Dry brushing was not a permanent fix to the problem.

- Five out of nine tubes cleaned (dry brushed and backflushed) during the outage were still blocked.

- Beaver Valley Nuclear Plant had cleaned (dry brushed) 6 thimble tubes at power and were unsuccessful as 5 out of 6 tubes were still blocked after the operation. Details of their operation were not known.

- Dose rates during the Trojan cleaning operation were 170 rem/hour maximum and 60 rem/hour average. They could expect the same at SQN. These dose rate levels are not encountered during normal plant maintenance activities and could result in higher than normal exposures.

- The Trojan report was brief and did not provide the details of how the cleaning operation at that plant was conducted. There was no real basis to compare the SQN and Trojan operation from a safety review standpoint.

- SQN had no appropriate procedure for performing the work at power.

- Ginna Nuclear Plant had contracted NUS to clean their thimble tubes in 1978 using a water backflush method while they were shutdown and they had not experienced any problems since. This represented a permanent fix.

- NUS indicated that they would not clean thimble tubes at power as their method involved a water backflush method (would flash to steam at reactor operating temperatures of 545° F and the injection pressure of their system 200 psig).

- Teleflex Corporation indicated they would not perform the dry brushing operation at power for TVA but would send an engineer in to advise TVA personnel. Teleflex had assisted Trojan with their cleaning operation at power.

- If a leak occurred in the thimble tube during the dry brushing operation, the leak could not be isolated.

- A thimble tube had been ejected at SQN during the initial cold hydro or hot functional testing probably due to a missing ferrule in a mechanical seal.

- They did not have anyone onsite who had experience cleaning thimble tubes at power operations.

- The job involved some risks to personnel both from the radiological aspects (high dose rates from brush and cable) and from the industrial hazards (working in containment during operation on systems pressurized and at temperature in contamination zone clothing including full face mask for respiratory protection).

- The commitment to maintain the safest work environment practical for employees is inherent in all TVA plant operating philosophy.

- The job involved some risk to the safety of the plant in the event a thimble tube leak occurred.

- Unit 1 had a PORV leaking and it would eventually have to be repaired.

- Unit 1 had problems with steam generator chemistry and they could clean up the water while shutdown.

During the meetings, the results of the industry survey and contractor inquiries and the potential hazards were discussed. The discussion included the increased radiation hazards, the inability to isolate the system should a leak develop through a ruptured thimble tube, and the fact that the work would involve working on a pressurized system (2250 psig) at temperature (545° F). The probability associated with rupturing a thimble tube was considered minimal because of the material of construction (304 stainless steel) and the wall thickness of the tube. The probability that the mechanical seal would leak was not considered because the tubes had been dry brushed before without creating leaks. No one in attendance recognized or discussed the probability that a thimble tube could be ejected in the event something happened to the mechanical seal. Note: A thimble tube had been ejected at SQN during initial hydro testing or hot functional testing of unit 1. Most of the managers interviewed were aware of this event but were unsure of the causes (some thought it was due to a missing ferrule in one of the fittings of the seal table.)

The dry brushing cleaning method was recognized by plant management as only a temporary fix but the goal at this point was not to provide a permanent fix to the problem but only to clear a sufficient number of tubes to facilitate continuing the restart program.

It was considered acceptable to work on a pressurized system at temperature because there are frequent maintenance requirements to do so and it had been done safely before. The primary hazard was considered to be due to the high radiation dose rates that would be encountered at the seal table during the cleaning activity, but it was felt that the dose rates and worker doses could be controlled by assigning constant health physics coverage during the cleaning activity. Management at this point did not recognize that the procedure was inadequate to perform the work and any potential hazard associated with use of the cleaning tool in promoting failure of the mechanical seal. Management did not recognize that a failed seal could cause a thimble tube to eject. The opinion of those in the meetings was that dry brushing the thimble tubes at power was an accepted industry practice as it had been performed at power at Trojan and Beaver Valley and there were no unusual risks involved in the process other than the high radiation dose rates. With this in mind the decision to clean the thimble tubes was made by the Assistant Plant Manager and the decision was approved by the Plant Manager in the afternoon of April 18. The Plant Manager established that if the thimble tubes were not cleaned by noon on Friday, April 20 that he was going to shut the unit down over the weekend to clean the tubes and resolve the other problems they were encountering (steam generator chemistry and a leaking PORV) during the restart. The weekend was considered a desirable time for the shutdown because of the lighter system load.

In summary, plant management made the decision to clean the tubes with a false sense of security and without the realization or knowledge of the magnitude of the hazards involved. Even though the radiation dose rates were unusually high, the operation involved working on a system pressurized at 2250 psig at 545° F, and the operation was to be conducted inside the reactor containment, the health physics supervision and the plant safety section were not consulted to provide an independent hazard analysis and to get a head start on job planning.

For conclusions and recommendations relating to this section, refer to section III.B.2.

C. Assignment of Work Functions and Job Planning Prior to Beginning the Cleaning Operation

The cleaning operation was assigned and planned as follows:

1. Assignment of Work Functions

The task of dry brushing the thimble tubes was assigned to the FSG as this group had cleaned or coordinated the cleaning of the thimble tubes in the past while the units were shutdown. The assignment was made in the afternoon of April 18 after normal working hours. The FSG mechanical supervisor was notified to make assignments for the cleaning operation. This supervisor had not been involved in the decisionmaking process nor had he interfaced directly with the REU for feedback from the utility survey and contractors inquiries. He in turn assigned a mechanical engineer on the evening shift the task of planning the preparation for the cleaning operation. (For purposes of this report this individual will be referred to as the "evening shift coordinator.") The evening shift coordinator had never cleaned thimble tubes prior to this assignment. He had been involved in the maintenance and testing activities associated with the incore instrumentation system since the startup on April 15 and had interfaced with the Shift Technical Advisors (STAs) and the nuclear engineers during these activities.

The FSG mechanical supervisor notified a mechanical engineer (for purposes of this report this individual will be referred to as the "day shift coordinator") assigned to the day shift to come in to work at 0315 on April 19 to relieve the evening shift and continue the work of dry brushing the tubes. The day shift coordinator was experienced in thimble tube cleaning as he had been involved in cleaning activities during prior outages. However, his experience was limited to cleaning while the units were shutdown, cooled down, and depressurized.

Management recognized that this was a unique activity as they had identified that the operation involved working on a system at pressure and temperature in the reactor building containment with the reactor operating, if a leak developed it could not be isolated, and the job would involve unusually high dose rates. Management had taken the trouble to have an industry survey performed and had tried to get the activity performed by a contractor. Neither contractor would do the job at power. Discussions concerning the activity had been held involving engineers and plant managers. However, the job assignment was made to the FSG as if the activity was an ordinary maintenance activity in that the supervision and coordination were assigned to a supervisor and engineers who had not participated in the surveys, inquiries, and management discussions, were not aware of the unique hazards, and were normally accustomed to working on systems while the unit was shutdown, cooled down, and depressurized. The routine process to plan and execute the activity was to be used when in reality this was not a routine job. Upper plant management involvement from that time on was minimal. Additionally, a sense of urgency was established as the work was to be planned and performed in less than 48 hours. Planning and work commenced almost immediately on the evening shift, one crew was called in at 0315 for around-the-clock efforts and coordination, and workers knew that the job had to be accomplished or the unit would be shut down.

For conclusions and recommendations relating to this section, refer to section III.C.1.

2. <u>The Maintenace Request Form (MR) for Initiating, Planning, and Controlling the Work Activity</u>

The methodology for managing the initiation, planning, scheduling, and execution of maintenance activities at SQN is depicted in Standard Practice SQM2, "Maintenance Management System," revised April 18, 1984. The primary mechanism for control of these functions is form TVA 6436, "Maintenance Request Form," commonly referred to as the MR.

a. <u>MR Origination</u>. MR A-238084 was initiated by a STA on April 18 and described the work requested as "dry brush blocked thimbles listed below: See attached.** Use <u>no</u> water or NEOLUBE.**" The attachment had 23 thimble tubes listed. The MR was assigned to FSG for planning, scheduling, and execution of the activity. The MR was initialed by the STA's supervisor signifying that the request was needed and that sufficient information had been given to allow FSG to plan the work to be done. The STA supervisor had been involved with the recent maintenance and testing activities of the incore instrumentation system and the industry survey and contractor inquiries.

The priority of the MR was classified as requiring immediate attention indicating that the maintenance activity was to be started expediently. The "Equipment Category" was classified as CSSC by the evening shift coordinator which ensured that the MR would be directed to the plant FQE for a quality assurance (QA) review to ascertain that required QA controls were in place. (QA controls are necessary when working on CSSC to assure that the quality of the system is not degraded by the operation being performed. QA controls include proper work instructions appropriate to the work being performed, qualification of workers, acceptance criteria, postmaintenance inspections, and postmaintenance testing to ensure the system is suitable to return to service.) The MR was forwarded to the FSG evening shift coordinator.

b. <u>MR Planning</u>

(1) <u>Work Instruction</u>. The evening shift coordinator referenced SMI-0-94-1 as the work instruction to be used in the performance of this work activity because that procedure had been used in the past for cleaning activities. He recognized that the instruction stated that the cleaning equipment and the instruction was not to be used at power but thought that the restriction was placed in the instruction to prevent the use of water for backflushing because of the high temperature water

flashing problem. For this reason he added the additional instructions to the MR "dry brush only following applicable sections of SMI-0-94-1." The applicable sections of SMI-0-94-1 were not specified on the MR. A copy of SMI-0-94-1 was attached to the MR. The selection of this instruction was inappropriate as it was a poor quality instruction for the activity to be performed and contained administrative barriers stating that the instruction and the equipment (including dry brushing equipment) were not to be used during power operations (see section IV.A.8 of this report).

The QA or postmaintenance test requirements were specified as "per SMI-0-94-1." SMI-0-94-1 did not contain any postmaintenance test requirements.

When asked how SMI-0-94-1 should have been changed to make it appropriate for the dry brushing cleaning operation at power, managers and engineers interviewed responded that a temporary change to the instruction should have been issued to delete the words concerning not using the instruction or equipment at power. NSRS determined that a temporary change would not be in order as a change of that nature would be an "intent" change and would thus be disallowed by section 6.8.3 of the SQN Technical Specifications. It was apparent that those managers and engineers interviewed were not aware of what quality elements procedures should contain and the procedural change process, or were expressing a careless attitude about procedure compliance. This lack of awareness or careless attitude toward procedural compliance allowed the unique activity to be initiated with inadequate procedural controls.

For conclusions and recommendations relating to this section, refer to section III.C.2.

(2) Job Safety Analysis. The MR was routed to an FSG second shift steamfitter foreman for performance of a job safety analysis. Section B.4 of SQM2 indicated that the responsible first line foreman (or engineer) will review each job for the safety aspects. The review was to include the need for transient fire load considerations, special work permits (replaced by the radiation work permit at SQN), and the need for a hold order. Section B.4 states "The MR supplement form should be used when one or more of the MR supplement (Form 6436D, Figure 2) safety/work control considerations are

required. If any 6436D item is required, Form 6436D should be filled out, signed by the planner, and attached to the MR."

Safety/work safety control considerations on the supplement that were applicable for this work activity included the following:

- Operations Authorization
- Hold Order Clearance
- Special Work Permit (SWP)
- Health Physics Assistance
- Respiratory Protection
- Special Processes

The supplement was not filled out and attached to the MR. Supervisors, engineers, and foremen in the FSG interviewed indicated that these forms were seldom used and attached to MRs. On the MR the foreman wrote the words "perform work safely." This was the statement normally used by the foremen unless there was some special precaution that should be observed.

Guidance provided in Standard Practice SQM2 for performing a job safety analysis addresses only transient fire load considerations, RWPs, hold orders, and special processes. There was little or no guidance for identifying and evaluating the safety hazards (radiological, industrial, and potential impact on safe plant operation) and prescribing unique accident preventive and mitigation measures for the following:

- Working on a system at primary or secondary temperatures and pressures that cannot be isolated, cooled down, and depressurized.

- Identifying unique safety hazards (such as use of improper tools and instructions) that might promote system failures.

- Performing an evaluation of how the job may promote failures of the system or components that might endanger the safety of workers, plant, and the public.

- Work performed in a harsh environment.

- Work in containment while the reactor is at power.

- Designation and control of primary and alternate egress routes during hazardous activities.

- Communications for emergencies.

- Evaluation of work instructions versus system/component hardware to ensure that they are compatible and the instructions contain adequate precautions to prevent degrading the system or component to the point of failure.

- Prejob meetings and briefings with supervisors, engineers, foremen, and crafts to seek out ideas for unique hazard identification, expressing safety concerns, and if concerns are identified, ideas for performing the work safely.

- Involvement of the plant safety engineering group for workplace hazard identification and assessment.

- Involvement of a plant cognizant authority for related industry and plant experience pertaining to the job and the system.

- Guidance on how to openly express any responsible concerns relating to the safety aspects of the job.

- Methodology for a hazards assessment of the identified industrial and radiological aspects of the job for their impact on the workers, the plant, and the public.

In summary, the unique hazards associated with this job were not recognized or adequately addressed in the preplanning phase for the job at the plant management, engineer, first line supervisor, FQE, operator, or craft level. The thought process that went into the safety analysis was not documented on the attachment to the MR as suggested. Interviews with managers and engineers indicated that the attachments were seldom used. The foreman that performed the safety analysis had never cleaned the thimble tubes, had not read the work instruction, and his experience was primarily construction and outage working on systems when the reactor is shutdown and systems are cooled down and depressurized.

In general the job safety analysis and hazards assessment program at SQN is inadequate for identifying and evaluating an operation of this nature. Similar findings had been previously identified to SQN as causal factors of an inadvertent 10-rem extremity exposure in December 1982 (see section IV.0 of this report).

Note: SQN Hazard Control Instruction (HCI) G29, "Workplace Hazard Assessment," establishes a methodology that can be used to evaluate and establish priorities to correct identified hazards. The methodology evaluates such items as proximity to hazardous condition/operation, number of employees exposed to the hazardous conditions, and the length of exposure and uses a point system (1-10) to establish a basis for determining the accident probability (highly likely, predictable, remote) and the hazard severity (catastrophic, serious, minor, negligible).

For conclusions and recommendations relating to this section, refer to section III.C.3.

c. MR Review. The MR was routed to the FQE unit for a QA review to assure the format and controls were in compliance with quality assurance requirements and that the preparation and initial planning guidelines for MRs had been consulted. Guidelines for review of MRs were specified in Appendix C of Standard Practice SQM2 and Quality Engineering Section Instruction Letter No. 5.3, "Maintenance Requests - FQE Section Review," revised January 20, 1984. SQM2, Appendix C guidelines included the following:

- Include appropriate clearance and permits [e.g., hold orders, temporary alterations, SWP (RWP), drilling and chipping permit, etc.]. Note: Hold Order 1 was normally required for any work on the detector drive system of thimble tubes to prevent exposing workers to the highly radioactive incore detectors. RWP No. 92-1-00102 was posted at the entrance to the personnel airlock. Therefore an RWP Timesheet was required to enter the lower compartment of the reactor building.

- Include appropriate controls for special processes (e.g., welding, NDE, hydro, cleaning, protective coating, etc.). Note: Appropriate controls include work instructions appropriate to the special process.

- Determine whether the work is within the skills of qualified maintenance personnel or if detailed instructions need to be included or referenced.

The MR and the attached work instruction had none of the following:

- No indication that a hold order was needed.
- No indication that a SWP (RWP) was required.
- No applicable acceptance criteria.
- No postmaintenance inspections.
- No postmaintenance testing.

Although not followed, the attached work instruction did contain cautions and warnings not to use the Teleflex supplied equipment and SMI-0-94-1 at power.

The MR was reviewed by an FQE engineering associate assigned to the evening shift, signed, and routed to the Operations Section for work authorization. The FQE review failed to identify that the MR and referenced work instruction SMI-0-94-1 (which was attached to the MR) had no indication that a hold order was required, no indication that an RWP was required, no acceptance criteria, no postmaintenance inspection and testing requirements were specified, and the equipment was not to be used at power. During an NSRS interview the FQE unit supervisor indicated that the MR and attached work instruction would probably have been approved even if reviewed by an engineer on day shift.

For conclusions and recommendations relating to this section, refer to section III.C.4.

d. Work Authorization. An assistant shift engineer on the second shift authorized the work in the evening of April 18. This authorization signified that the work would not violate technical specifications.

3. Radiation Work Permit (RWP) and Clearances (Hold Orders)

a. RWP and RWP Timesheets. The RWP is an administrative control used for radiation protection of workers and establishes requirements for entry or work in an area of known or potential radiological hazards. The RWP Timesheet is a subset to the RWP and is used to set protective clothing requirements, list specific instructions, and document personnel entry and exit date, time, and radiation exposure received for specific jobs. The work supervisor initiates the RWP Timesheet after discussion of the work to be performed with the HP representative.

b. Clearance Procedures. The clearance procedure process is the method used at SQN for the protection of workers, the public, and equipment. The shift engineer or designated assistant shift engineer (ASE) are the only persons authorized to issue a clearance. A clearance is established by the use of protective tags placed so as to indicate the main point of control and the boundary of isolation.

The hold order is a subset of the clearance procedure and is a red tag normally used as a master tag for the clearance. It is usually installed on the main control point to isolate equipment from all sources of energy and to permit work to be safely performed.

Hold Order No. 1, "Unit 1 Incore Probes," is the clearance used to assure that the highly radioactive incore detectors are stored in their storage cavities for radiation protection of personnel working in the reactor building lower compartments and the annulus (which includes the instrument room).

RWP No. C1-1-00102 was issued on January 1, 1984, for the seal table location for the job of "Inspection and Maintenance." The requirements established for entry were included in the RWP. One of the requirements stated "Verify hold order is in effect on incore probes prior to entering reactor building lower compartments and the annulus."

The FSG evening shift coordinator initiated an RWP Timesheet at 2000 on April 18 to "break loose thimble connections @ seal table, remove selector path from seal table, and dry brush blocked thimbles." The protective clothing requirements were specified on the RWP Timesheet.

The RWP Timesheets specified the following "Special Instructions:"

- Obey all instructions on the RWP

- Do not exceed 700 mrem per day

- Sign in and dress out to enter containment

- Do not enter high RAD areas (A high RAD area is an area where the radiation dose rate exceeds 100 mrem/hour.) Note: This special instruction was deleted on April 19 after high dose rates were encountered.

- HP to be present during job

- Protective requirements subject to change at the discretion of HP covering the job

- HP to instruct workers on proper placement of dosimeter, multibadging, and extremities.

c. <u>Hold Order No. 1 Issue and Release Versus Entry and Exit to and From the Instrument Room Before the Accident</u>. A comparison of the issue and release of Hold Order No. 1 versus entry and exit to and from the instrument room is depicted below. All times are Eastern Standard Time (EST).

- At 1910 on April 18 Hold Order No. 1 was released.

- At 2300 on April 18 five FSG evening shift personnel and an HP technician entered the instrument room.

- At 2330 on April 18 Hold Order 1 was issued to the ASE.

- At 0006 on April 19 Hold Order 1 was released.

- At 0020 on April 19 Hold Order 1 was issued to the ASE.

- At 0030 on April 19 Hold Order 1 was released.

- At 0330 on April 19 two FSG day shift employees entered the instrument room.

- At 0430 on April 19 two FSG day shift employees entered the instrument room.

- Between 0435 and 0525 on April 19 all employees exited the instrument room.

- At 0530 on April 19 Hold Order 1 was issued to the ASE.

The hold order was released while workers were in the instrument room to accomodate work being performed by FSG to free two detectors that were stuck in thimble tubes and could not be retracted using the drive units. At 2300 on April 18 and 0330 and 0430 on April 19, FSG and HP personnel entered the instrument room while Hold Order No. 1 was released and not in effect. This represents noncompliance with requirements of RWP 01-1-00102 and the respective RWP Timesheet.

For conclusions and recommendations relating to this section, refer to section III.C.5.

d. Issue of Hold Order to Person Responsible for the Work

Section 5.1.4 of AI-3, "Clearance Procedures," states that "no actual work shall begin on the equipment to be included in the clearance until the clearance has been issued to the person responsible for the work." Between 0220 on April 17 and 0400 on May 1 Hold Order No. 1 was issued only to the ASE while work was in progress in the instrument room before and after the accident. The ASE was not the person responsible for the work. This represents noncompliance with the requirements of section 5.1.4 of AI-3.

For conclusions and recommendations relating to this section, refer to section III.C.6.

D. Work Activities Related to the Thimble Tube Cleaning Prior to the Accident

The following is a discussion of the work activities conducted after the planning process to the time the accident occurred:

1. Work Activities During the Evening of April 18 to Approximately 0830 on April 19

a. Fabrication of New Support for the Cleaning Tool

The dry brushing tool (handcrank) and its support mechanism that had been used in past thimble tube dry brushing operations had been inadvertently discarded in radwaste. A handcrank device had been acquired from WBN. The support for the handcrank was not supplied from the vendor that supplied the dry brushing tool. The FSG second shift coordinator consulted with an FSG maintenance specialist who had been involved with prior thimble tube cleaning activities to determine what type of base support was needed for the new dry brushing tool. It was suggested that a new support device be fabricated somewhat differently than the one that had been used on previous cleanings. The change involved removing the right angle support on the base support (see figures 11A and 11B) to allow the base support to make better contact with the surface of the seal table. The problem with the old tool was that the support did not always fit up well with some of the "bosses" on the seal table and allowed the tool to move around during the turning of the handcrank. Figures 12A and 12B depict the tool and the base support in use when the accident occurred (part of the ejected thimble tube D12 is still attached to the upper portion in figure 12B).

The evening shift coordinator requested the FSG machine shop to fabricate the new base support pieces for the cleaning tool. Note: The new base support pieces were not finished and used until approximately 1500 on April 19. The day shift coordinator and his crew used the tool with the new base supports and he felt it offered much better support for the tool than the supports that had been used in the past. The steamfitter on the evening shift that was using the tool and support when the accident occurred and had experience with the old support was of the opinion that the new base support was not as good as the old ones used in past cleaning operations. He had expressed some concern about the design of the new support to the evening shift coordinator (see section IV.M.2 of this report).

The change to the tool base support was made without any technical evaluation of its effect on the mechanical seals. The new base support was not tested before use on the thimble tubes.

b. <u>Disassembly of the Incore Instrumentation System Drive Paths and Initial Assembly of Dry Brushing Cleaning Equipment</u>. The evening shift coordinator, one steamfitter foreman, three steamfitters, and an HP technician entered the instrument room through the personnel airlock at 2300 on April 18 (without verifying that Hold Order No. 1 was in effect) and worked until approximately 0430 on April 19 freeing two detectors stuck in their thimble tubing, disassembling the overhead drive paths at the SWAGELOK union flare fitting, and rolling the path transfer units and associated tubing back out of the way allowing access to the seal table. The high pressure fittings were reportedly not disturbed during this process. During this 5.5 hours activity in the instrument room, the maximum whole body radiation dose received (based on pocket dosimeters) was 15 millirem.

At approximately 0315 on April 19 the day shift coordinator, three steamfitters, and a steamfitter foreman reported to work. The day shift coordinator and a steamfitter entered the instrument room at approximately 0330 (without verifying that Hold Order No. 1 was in effect) and worked with the evening shift coordinator and his crew until the evening shift exited the instrument room through the personnel airlock. At approximately 0430 two steamfitters entered the instrument room (without verifying that Hold Order No. 1 was in effect) and the composite day shift crew removed deck grating from above the seal table and assembled the dry brushing equipment. It was noted at this time that there was no base support for the Teleflex-supplied dry brushing tool. The day shift coordinator and the three pipefitters exited the instrument room at approximately

0530 on April 19 to fabricate a temporary base support to be used until the new base support device being fabricated by the machine shop was finished and ready to use. During this two-hour activity in the instrument room, the maximum whole body radiation dose received (based on pocket dosimeters) was 3 millirem.

A temporary base support for the cleaning tool was fabricated out of angle iron. No technical evaluation was performed on this temporary support to assess the effect it would place on the mechanical seals. The temporary base support was not tested before use on the thimble tubes.

At approximately 0800 on April 19 it was announced at the morning meeting normally attended by most plant managers that the decision had been made to clean the thimble tubes at power. No objections were offered or concerns expressed.

For conclusions and recommendations relating to this section, refer to section III.D.1.

2. Work Activities from 0830 on April 19 until Approximately 1700 on April 19

a. Initial Cleaning of Five Thimble Tubes - 0830-1115 April 19. At approximately 0830 the day shift coordinator, a steamfitter, and an HP technician entered the instrument room and began to assemble the cleaning tool with the temporary base support. (At 0945 another steamfitter joined the group.) When the cleaning tool was assembled they connected the tool to the SWAGELOK union flare fitting on one of the tubes identified as blocked on the MR. The cleaning tool was assembled as depicted in figure 12A with the exception that the tool support base was at that time constructed of angle iron. As they had not previously had success with getting the cable and brush through the thimble tubes the workers decided to try a cable without a brush. They ran the cable without the brush into the first tube approximately 85 turns ($\sim$ 70 feet) and encountered severe resistance. They repeated this technique with the other four thimble tubes with the same approximate results. The day shift coordinator at this point thought that probably something was wrong with the cleaning cable. The dose rate on the cable when it came out of the thimble tube was approximately 10-15 mrem/hour at contact.

Note: The cleaning operation at this point had been initiated using SMI-0-94-1 as the primary procedural control for the activity. Section 1.1 of SMI-0-94-1 states "this system is not to be used at power." "This system" is in reference to the thimble cleaner, Teleflex part number 43679 which includes the brushing assembly. Section 4.3.A of SMI-0-94-1 states "This procedure is not to be used while the plant is at power. If cleaning at power is necessary contact Teleflex, Inc." Teleflex was contacted by the plant but they would not clean the tubes at power. Using the Teleflex-supplied equipment and SMI-0-94-1 to perform the cleaning operation at power was a violation of procedure and section 6.8.1.a of the SQN Unit 1 Technical Specifications (see section IV.N.3.a of this report).

The workers stopped the cleaning operation and exited the instrument room via the personnel airlock at 1115 on April 19.

During this 2½-hour activity in the instrument room, the maximum whole body radiation dose received (based on pocket dosimeters) was 22 millirem. The HP technician suggested that before resuming the cleaning operation that ALARA preplanning should be performed. After leaving the instrument room the HP technician covering the job went to the ALARA engineer and discussed the job and recommended that ALARA preplanning be performed. This action by the HP technician initiated the concern for the radiation safety of the job and resulted in an increased awareness of the hazards of the job. It should be noted that the workers and HP technicians did not have an awareness of the hazards to this point in the work process.

For conclusions and recommendations relating to this section, refer to sections III.D.2 and III.D.3.

b. <u>Welding Operation in Personnel Airlock During Work Being Performed in the Instrument Room</u>. Section 3.6.1.3.a of the SQN unit 1 Technical Specifications states that each containment airlock shall be operable with both doors closed except when the airlock is being used for normal transit entry and exit through the containment, then at least one airlock door shall be closed with one containment door inoperable. The operable airlock door is to be maintained closed. At 1050 on April 19 the shift engineer entered unit 1 into a Limiting Condition for Operation (LCO) for section 3.6.1.3 of the Technical Specifications because FSG personnel were welding in the personnel airlock with a welding lead running through the outer door rendering it inoperable because the door could not be shut. The door was made operable at 1121, and unit 1 went out of the LCO. While the outer door was open the inner door could not have been opened in an emergency because of the interlock which will not allow both doors to be open at the same time. The workers were cleaning thimble tubes at that time and the day shift coordinator was not aware that the outer airlock door was open thus hindering their egress from the area in the event of an emergency.

When the FSG welders requested permission from the shift engineer (SE) to do the work in the airlock, he informed them that people were working in containment and asked them how long it would take them to get their equipment out of the door. They told him that it would take approximately 15 seconds. Some workers did enter and exit while the welders were working. The workers would shake the handle or tap on the door when they wanted out.

For conclusions and recommendations relating to this section, refer to section III.D.4.

c. ALARA Preplanning 1115-1520 on April 19

(1) SQN ALARA Policy. Radiation Control Instruction RCI-10, "Minimizing Occupational Radiation Exposure," revised June 7, 1983, provides policy guidance to management and supervisory staff involved in the operating and maintenance of SQN so that occupational radiation exposures may be kept as low as reasonably achievable. The RCI states that maintaining occupational radiation exposures at the lowest level reasonably achievable requires as a minimum the following:

- Management commitment and support
- Careful design of the facility and equipment
- Good radiation protection practices, including good planning and proper use of appropriate equipment by qualified, well-trained people.

Section VI.C of RCI-10 states that jobs with potentially greater than 5 man-rem exposure (total radiation exposure accumulated by all persons involved in the job) shall require an ALARA preplanning report to be completed by the responsible supervisor. The report is to be submitted to the designated ALARA coordinator for review and approval prior to job commencement.

(2) <u>Processing of Attachment I to RCI-10</u>

At approximately 1130 on April 19 an ALARA HP technician along with a maintenance specialist (not the responsible supervisor) who was knowledgeable of the cleaning process with the reactor shutdown and who had been involved in the decision-making process initiated an Attachment I to RCI-10, "ALARA Preplanning." They calculated that there would be a total of 154 RWP man-hours at a radiation exposure rate of 20 millirem/hour and that the estimated man-rem for the job would be 3.08 rem (whole body dose). The feasible considerations for reducing exposure were as follows:

- Temporary shielding - "Take shielding in - might can be used during job."
- Special tools - "Use of improved drive box mounting device."
- Remote operations - "Use of teletector for survey" <u>Note</u>: A "teletector" is a radiation (X-ray, gamma, high energy beta) dose rate measuring instrument with an extendable detector which provides for increasing the distance between the person making the radiation dose rate measurement and radiation source thus reducing the dose rate to the person.
- Decontamination - "Use of vacuum cleaner with HEPA unit during job to minimize contamination." <u>Note</u>: A HEPA filter is a high efficiency filter for particulate activity (99.97 percent efficient for a 0.3 micron size particle.)
- Remove source - "Special precaution will be used when removing vacuum cleaner from area."
- Improve work instructions - "Reviewed Trojan Nuclear Plant's suggestions from when they did job at 100 percent power."

  <u>Note</u>: The Trojan method used a 10-foot conduit and funnel on the end of the cleaning tool so as to enable the worker turning the handcrank to be positioned above the seal table and away from the high dose rates when the cable and brush came out of the thimble tube and to ease transfer to the other tubes. The Trojan report suggested the use of a

12-foot rigid conduit, a motorized helical drive, and a support platform above the seal table for the helical drive operator. SMI-0-94-1 was not revised to incorporate these revisions nor was the Trojan technique used.

- Additional supervision - "HP and engineer at all times."

- Shift turnover discussion - "Turnover is scheduled."

- Proper Ventilation - "Use of vacuum cleaner with HEPA unit to reduce contamination."

- Reduce reactor power level - "Unit at 30 percent - trying to prevent reactor shutdown."

- Others:

  - "ALARA zone - when not performing work stay in ALARA area - per HP on job."

  - "Hold order - Insure hold order on incore probes." Note: Hold Order No. 1 is the applicable hold order.

Attachment I of RCI-10 was completed sometime after 1200 on April 19. The Trojan report was attached to the completed attachment, and the ALARA preplanning was discussed with the day shift coordinator and the recommendations implemented.

With the expected high dose rates the potential exposure would have been greater than 5 man-rem. However, the ALARA preplanning was only conducted after the job was in progress and after the HP technician expressed concern for the job. The lack of awareness of the potential high dose rates on the part of the FSG coordinators promoted this oversight. The lack of awareness was due to poor transfer of information to the coordinators from those making the decision to do the job at power. The responsible supervisor was not involved in the planning and the suggestions made in the Trojan report were not incorporated. However, even though the total man-rem whole body dose calculated out to be less than 5.0 man-rem (3.08 man-rem) the ALARA preplanning was implemented and the ALARA technician covered the job in addition to the HP technician assigned to the job.

(3) Preparations for Resuming Work in the Instrument Room

After lunch the day shift coordinator and his crew collected the additional equipment needed for implementing the ALARA plan. In addition, he acquired the new base support for the handcrank from the machine shop.

For conclusions and recommendations relating to this section, refer to section III.D.5.

d. Resumption of Work in the Instrument Room 1520-1705, April 19. At 1520 the FSG day shift coordinator, two HP technicians (one was the ALARA technician who had assisted in the ALARA preplanning), and two FSG steamfitters entered the instrument room to resume the cleaning operation. They changed to the new base support for the dry brushing tool. They continued to insert the cable into the blocked thimble tubes with the same lack of success as they had encountered in the morning. On the fourth thimble tube the cable inserted approximately six feet into the reactor core. As they were withdrawing the cable the HP technicians were measuring the dose rate from the cable as it came out. The dose rate started increasing rapidly and at 15 rem/hour the HP technician stopped the withdrawal process. The cable was reinserted into the thimble tube until background dose rates ($\sim$10 millirem/hour) were achieved at the seal table. The workers clipped the cable and tied it off so it could be retrieved later after the radiation levels decreased due to the decay of the activation products.

At this point the HP technicians prescribed the use of multidosimeters to ensure that the whole body and extremity radiation dose profile was properly measured. The workers were equipped with the dosimeters at various positions on the whole body (head, trunk, groin, upper legs, etc.) and extremities (forearms, hands, feet, and ankles).

The cable with the brass brush was connected to the dry brushing tool and the tool was connected to another thimble. The brush and cable were inserted into the thimble tube but met resistance during the insertion. The brush and cable entered the core but did not go to the end of the thimble tube. As it was being withdrawn a dose rate of 40 rem/hour was measured. The tool base support was shielded with some lead blankets that had been carried in for that purpose and the cable and brush were withdrawn and inserted into thimble tube

D-12. Note: Subsequent processing of the extremity dosimeters revealed that one steamfitter involved in the transfer of the tool from one thimble tube to the other accrued an extremity dose of 5 rem in the process.

The decision to try thimble tube D-12 was made by the day shift coordinator as he knew D-12 was a thimble tube that had not been identified as blocked and he wanted to determine if the resistance being encountered during insertion of the brush and cable was due to blocked tubes or kinks in the cleaning cable.

The cable brush and cable were inserted into thimble tube D-12 but again not to the end of the tube. As it was being withdrawn the HP technicians stopped the withdrawal when the dose rate increased to 40 rem/hour and instructed the workers to reinsert the brush and cable until the dose rate at the table was approximately background (approximately 15 feet). At this point the HP technicians, the day shift coordinator, and the workers were very concerned with the high dose rates being encountered. The day shift coordinator had not expected and had never worked with dose rates of this magnitude. He and the HP technicians decided that the work should be stopped and discussed with management before continuing. The workers exited the instrument room via the personnel airlock at 1705. The highest radiation whole body dose encountered during this portion of the cleaning operation was 145 millirem as measured by pocket dosimeters.

3. Work Activities from 1700 April 19 to 2120 on April 19

After the workers exited the instrument room, the day shift coordinator and his crew reported the problems they had encountered with the high radiation dose rates to their supervisor (the FSG mechanical supervisor). The HP technician reported the events to the HP shift supervisor. As a result a meeting was scheduled in the FSG office to discuss the progress of the cleaning activity, and the problems being encountered, and to do some further planning to better handle the high radiation dose rates. Those in attendance were the following:

- FSG assistant supervisor
- FSG mechanical supervisor
- FSG day shift coordinator
- FSG evening shift coordinator
- FSG mechanical maintenance specialist
- FSG evening shift mechanical general foreman
- FSG evening shift steamfitter foreman
- HP shift supervisor
- HP ALARA technician

During the meeting safety factors were discussed concerning performing the cleaning operation at full reactor pressure and temperature and the fact that if a leak developed the unit would have to come off the line to stop it. The problems being encountered with the radiation dose rates were addressed at length. Note: The HP group during the meeting reported that one of the steamfitters involved in the cleaning activity during the day had received an extremity dose of 5 rem (quarterly dose limited to the extremities is 18.75 rem as specified in SQN RCI-1, "Radiological Hygiene Program"). The supervisors and personnel in the meeting became very concerned with the safety aspects of the job. The primary concern was the radiation dose rates that were being encountered. The following additional decisions were made to improve the safety aspect of the job:

- After insertion the cables would be withdrawn until the dose rate began to increase, cut and tied off, and kept in the thimble tubes to be removed later after the dose rate had decreased.

- The decision was made to only clean all 10 blocked thimble tubes in C path as they were running short of time. After cleaning these tubes the path transfer units would be hooked back up and the detectors inserted. If all 10 tubes were clear, the flux map could be run as 83 percent of the tubes would be operable.

- The evening shift coordinator was very close to his legally allowable quarterly whole body radiation dose limit (3 rem). The majority of the dose had been received during the Cycle 2 refueling outage. The coordinator was equipped with a radiation dose rate meter to alarm if the dose rate increased. The coordinator was instructed to remain out of the high radiation dose rate areas.

- The inner door on the personnel airlock would be left open to allow for quicker egress in the event a leak developed. Note: The personnel involved were not aware that this would enter the unit into a limiting condition for operation (LCO). Additionally, leaving the door open would have hampered entry into the instrument room because of the interlocks in the event rescue efforts were required.

The ALARA HP technician questioned the advisability of using so many people from FSG (six) for the cleaning activity. He was informed that the additional personnel were necessary to provide additional management oversight for the activity and to provide additional training for this activity to some of the FSG craftsmen.

Section IV.B.6 of RCI-14 requires that the plant superintendent (Plant Manager) review the RWP when the dose rate exceeds 50 rem/hour. The HP shift supervisor notified the Assistant Plant Manager by phone (the Plant Manager had been absent from the plant April 19), the shift engineer, and the plant Assistant HP Supervisor temporarily in charge of unit 1 activities (the plant HP Supervisor was on annual leave) of the dose rate conditions and that it may be necessary to work in a dose rate field of over 50 rem/hour during the cleaning operation. Authorization to continue work was given. The six FSG workers then proceeded to the HP laboratory to pick up the protective equipment to be used during the work activity.

During the course of the work to this point the HP technicians covering the job and the FSG personnel took actions commensurate with the increasing hazards that they had identified. These actions were as follows:

- HP technician suggested work stoppage and ALARA preplanning - FSG responded.
- ALARA implementation even though the calculated total man-rem exposure was less than 5 man-rem.
- Additional ALARA technician coverage during the job (two HP technicians covering the job).
- Health Physics prescribed multidosimeters for measuring whole body radiation dose profile.
- Health Physics suggested work stoppage and further discussions with management about hazards of job - FSG responded.
- ALARA technician questioned the use of so many workers for the job.
- Health Physics shift supervisor responded to concerns when identified and participated in discussion with FSG workers and supervision.
- Health Physics notified upper plant management and shift engineer of increasing dose rates as prescribed by RCI-14 and was given permission to continue the cleaning process. Note: There are no requirements in RCI-14 that formal documentation be made for authorization for working in dose rate fields greater than 50 rem/hour. Legal actions being brought against corporations for radiological matters are increasing. Authorization to work in dose rate fields greater than 50 rem/hour should be formally documented.

The actions of the Health Physics staff and the FSG personnel involved in the cleaning activity to address increasing concerns for the radiological safety aspects of the job stimulated discussions about other safety aspects increasing the worker awareness of some of the hazards involved. When the accident occurred the workers in the instrument room were primed for exit.

For conclusions and recommendations relating to this section, refer to sections III.D.4 and 6.

E. The Accident

The following is a discussion of the worker activities immediately prior to the accident, work area and worker conditions, the accident, and the worker actions immediately after the accident:

1. Worker Activities Immediately Prior to the Accident

Between 2120 and 2145, FSG and HP personnel donned their contamination protective clothing (including face masks for respiratory protection) and radiation dosimeters and entered the instrument room in a staggered fashion (not all at once). An FSG craftsman was stationed outside the airlock to assist the workers inside if needed. A public safety officer was stationed at the outer airlock to control access to the reactor building containment as per AI-3.

The evening shift coordinator was one of the first workers to enter. He marked the thimble tubes that were to be cleaned (C group) with duct tape. At this time he noticed that the cleaning tool was on tube D-12 and that there was a small gap ($\sim$1/2 inch) between the upper and lower portions of the cleaning tool base support. Being aware that the base support had been modified to provide solid support from the cleaning tool to the seal table, he acquired two shims from the FSG worker stationed outside the airlock and shimmed the lower portion of the base support to make contact with the upper portion. As the last of the FSG employees entered the instrument room they shut the inner airlock door out of force of habit. This action was contrary to their contingency planning. At this time there were eight workers in the instrument room. Refer to figures 13A and 13B for their assigned functions and respective positions for the cleaning operation.

2. The Work Area and Worker Alertness

When work was initiated at 2120 on April 19 the work area was well lighted and reasonably uncluttered. The temperature of the work area was reasonably cool. The radiation dose rate in the area around the seal table was approximately 10 millirem/hour. The workers were in contamination zone clothing with respiratory equipment (coveralls, rubber gloves, plastic booties, shoe covers, surgeon caps, canvas hoods, and full face masks). The workers were reportedly fairly well rested and very alert because of the increased concerns for the safety of the job. When they entered the instrument room, the workers involved were acutely aware of the hazards from the high radiation dose rates being emitted from the cleaning cable and the possibility that in the event of a leak the water would be coming straight from the reactor. The workers cleaning the tubes on the day shift did not have the same level of alertness as they had not had benefit of the same level of concerns and discussions prior to beginning work.

3. The Accident

The workers assembled around and above the seal table as depicted in figures 13A and 13B for performing their assigned tasks. The evening shift coordinator noted that the cleaning tool was on thimble tube D-12 which was not included on the list to be cleaned. The cable was inserted approximately 15 feet into the thimble tube. The coordinator decided that as long as they were connected to thimble tube D-12 they would go ahead and clean it one more time to make sure it was clean. Steamfitter (D) on the cleaning tool turned the handcrank one complete revolution. Coordinator (A) measured the length of insertion to verify that the insertion was 10 inches per one complete revolution. Steamfitter (D) continued to turn the crank and stopped at 50 revolutions and called out the number of revolutions. The number of cranks was verified by steamfitter foreman (C). Steamfitter (D) continued to crank the tool inserting the cable into tube D-12. At approximately 70 cranks a kink was noted in the cleaning cable coming out of the cable container. The workers stopped and examined the kink and decided to proceed. After a total of approximately 79 cranks the cleaning tool offered some resistance to being turned. As the crank started its upward stroke it was noted that additional effort was being required to turn the handcrank. Some movement of the cleaning tool was observed. At this moment the leak occurred spraying water at ambient temperature and slightly wet two of the workers. The cleaning tool pulled loose from the the grasp of steamfitter (D). He reached up, grabbed the tool and pitched it out of his way to the left so he could get out. The water by this time was blowing straight up at a significant rate and was described as hanging up in the overhead. Someone yelled "Let's go."

One of the eight workers (the one farthest from thimble tube D-12) described the first indication of the leak as a bubbling action from around the tool support base. The remaining seven workers assembled around and above D-12 described the leak first as spraying of water from between the upper and lower tool support pieces followed by the leak rapidly developing into a "gusher" blowing straight up and hanging up in the overhead. As there is approximately four gallons of relatively cool water in the guide tube it is apparent that initially the spraying water would not burn the workers. However, after it started blo' ing straight up at 545° F/2250 psi, it was flashing to steam above the workers and constituted a life threatening hazard.

The seal failed and the leak occurred suddenly with little warning and the tool was pulled away from the worker turning the handcrank. This indicates that the thimble tube started out of the guide tube almost simultaneously with development of the leak.

It is evident that kinks were not uncommon in the cleaning cables as workers looking for kinks were stationed at the point where the cable left its container and that kinks caused problems with the cleaning process in that they were difficult to get through the cleaning tool or insert properly into the thimble tubes. Some of the workers interviewed felt that the extra effort required to turn the handcrank immediately prior to the development of the leak was caused by the kink entering the cleaning tool. SMI-0-94-1 had no restrictions addressing kinks in the cable.

For conclusions relating to this section, refer to sections III.E.1 and III.E.2.

4. Worker Actions Immediately After the Accident (see figures 13A and 13B for exit routes)

Workers (A), (C), (D), (E), (F) and (G) moved hurriedly onto the platform and started down the stairs. HP technician (G) noted HP technician (H) falling backwards towards the handrail. HP technician (H) dropped the teletector he was using to measure dose rates and fell over the handrail, hitting a toolbox on elevation 693. He started running toward the airlock.

When the seven workers reached the airlock, several tried to open the door together. One worker was pushed away by another worker. The door was opened and seven workers entered the airlock. HP technician (G) remembered seeing HP technician (H) falling backwards toward the handrail and became concerned that they had left him behind. He started asking if anyone had seen him. [HP technician (H) was in the airlock.] A head count was conducted by the coordinator (A) and the workers realized they were one worker short. The airlock door was being pulled shut when general foreman (B) stuck his arm in and stopped the door from closing. The door was opened, general foreman (B) entered the airlock, and the door was closed. The HP technician (G) noted that the dose rate inside the airlock was approximately 200 millirem/hour. The coordinator (A) went to the telephone in the airlock with the intention of calling the control room but noted that the telephone had a MR tag on it indicating it was out of sevice. The time elapsed from the incident until everyone was in the airlock was estimated by the workers to be approximately 20 seconds.

A few seconds prior to the incident the coordinator (A) looked at his dose rate meter and noted that the dose rate was approximately 2 millirem/hour. As he entered the airlock the alarm on the dose rate meter activated and he noted that it indicated 25 millirem/hour.

The outer door of the airlock was opened and the workers exited the airlock. The coordinator (A) yelled instructions to the public safety officer to call the control room and notify them that a leak had developed at the seal table. All workers started surveying themselves for radioactive contamination. The coordinator (A) conducted another head count to ensure that everyone was out of the airlock. The public safety officer was unsuccessful in contacting the control room (reason not determined by NSRS). The coordinator (A) exited the contamination zone, called the control room, and contacted the ASE for unit 1. He informed him that a leak had occurred at the seal table and that it could not be isolated.

The workers removed their protective clothing, surveyed for radioactive contamination (none was detected), and dressed in their personal clothing. The coordinator and the mechanical general foreman proceeded to the control room to inform the operators and the STA of the conditions inside the instrument room. The time was 2215.

The highest radiation dose recorded on the RWP Timesheet was 200 millirem (determined from pocket dosimeters). This dose was received by general foreman (B) who was the last one to enter the personnel airlock.

All workers were subsequently analyzed by whole body count to determine if they had ingested any radioactive materials during the incident. The whole body counts for all eight indicated that no detectable radioactive materials were ingested.

At approximately 0100 on April 20 the FSG evening shift coordinator and the mechanical general foreman submitted written statements of what they had observed before, during, and immediately after the accident.

In summary, the egress from the work area was rapid (20 seconds from when the leak occurred until everyone was in the airlock) and orderly with the exception that the HP ALARA technician was startled to the point that he fell over the handrail by the seal table and there was some crowding and pushing at the door. The general foreman who was located above the seal table was the last to enter the airlock. The day shift coordinator conducted a head count in the airlock and had identified that they were one short. He instructed the public safety officer outside the airlock to count heads again immediately after exiting the airlock. It is probable that the general foreman would not have been left behind because of the head count. As the workers entered the airlock they noted that dose rates were substantially higher than usual. After exiting the airlock the workers recorded their radiation dose received on the RWP Timesheet. The last person out, the general foreman, had received a radiation dose of 200 millirem which is amost twice the dose received by any of the other workers (50-125 millirem). The only action with the cleaning tool and thimble tube immediately prior to the accident was driving the cable and brush into the thimble which reduced the background radiation. The normal background was described as being approximately 10 millirem/hour and the general foreman was in the area for approximately one hour. His radiation dose received prior to the incident should have been 10-20 millirem. The general foreman therefore received approximately 180 millirem in 20 seconds. It is apparent that the thimble tube was out of the guide tube within 20 seconds of the break and before the workers were out of the instrument room.

For conclusions and recommendations relating to this section, refer to sections III.E.3, 4, 5, and 6.

F. Operator Actions to Mitigate the Accident

1. Immediate Operator Action

At 2200 the ASE/SRO on unit 1 was notified by the FSG coordinator that the seal on thimble tube guide D-14 (actually was D-12) at the seal table was severed and a high energy steam blow existed. Concurrently the "Pressurizer Pressure Low - Backup Heaters On" alarm on the unit 1 alarm panel activated. The unit operator noted a decreasing pressurizer water level and increased charging water flow to 130 gallons per minute (gpm) per section III.A. (Immediate Operator Action) of Abnormal Operating Instruction AOI-6, "Small Reactor Coolant System Leak." (A small leak is defined as one for which pressurizer level can be maintained by the charging system and a reactor trip or safety injection does not occur.) Prior to the leak the charging waterflow had been 85 gpm. At 2215 the pressurizer water level began to increase. The additional charging waterflow required to maintain pressurizer level was approximately 40 gpm.

2. Subsequent Operator Action

At 2217 the SE informed the ASE and unit operator to begin a shutdown of the unit at 1 percent per minute. At 2220 the SE noted in his journal that the leak was a pressure boundary leak and classified the event as an "Unusual Event" in accordance with SQN Radiological Emergency Plan - Implementing Procedure IP-1, "Emergency Plan Classification Logic," because the primary system leak rate was greater than 10 gpm and the source of the leak was identified. The Unusual Event is the emergency classification used by TVA to provide early and prompt notification of minor events which could develop into or be indicative of more serious conditions which are not yet fully realized. The purposes of Notification of Unusual Event are to (1) assure that the first steps in activating emergency organizations have been carried out and (2) provide current information on the event.

At 2220, IP-2, "Notification of Unusual Event" was initiated. IP-2 provides a method for timely notification of appropriate individuals when the SE has determined by IP-1 that an incident has occurred which is classified as an Unusual Event and provides a method for periodic reanalysis of the current situation by the Site Emergency Director to determine whether the Notification of Unusual Event action should be cancelled, continued, or upgraded to a more serious classification.

At 2233 with steam generator level controls in manual and the reactor at 12 percent power, the reactor tripped on low-low level in steam generator No. 1. At 2305 the reactor coolant system was at 500° F and 1900 psig (Hot Standby-Mode 3).

At 0110 on April 20 a surveillance instruction (SI 137.1) was completed and indicated 33.25 gpm leakage from unit 1.

3. Cooldown, Depressurization, and Draining of the Reactor Coolant System (RCS)

Cooldown and depressurization of the RCS continued and at 0508 on April 20 the temperature of the RCS was 350° F (Hot Shutdown-Mode 4).

At 0755 the residual heat removal (RHR) system was initiated and at 1032 the temperature of the RCS was ~200° F (Cold Shutdown-Mode 5). At 1214 the leak rate from unit 1 was approximately 18 gpm at 250 psig. At 1505 on April 20 the Unusual Event was cancelled as the identified leak rate had decreased below 10 gpm (estimated to be approximately 5.4 gpm at 40 psig).

At 0235 on April 21 the operators started draining the reactor coolant system and at 0815 the water in the reactor vessel was at elevation 701 (one foot below the top of the seal table) and the leakage was essentially stopped.

4. Technical Specification Requirements for Reactor Coolant System Operational Leakage

Section 3.4.6.2 of the SQN unit 1 Technical Specifications states that RCS leakage shall be limited to "no pressure boundary leakage." If a pressure boundary leak develops while the reactor is in Mode 1 (power operation) the reactor is required to be in at least Hot Standby (Mode 3) within six hours and in Cold Shutdown (Mode 5) within the following 30 hours. These actions are considered necessary as pressure boundary leakage of any magnitude is considered unacceptable since it may be an indication of an impending gross failure of the pressure boundary. Therefore, the presence of any pressure boundary leakage requires the unit to be placed in Cold Shutdown.

5. Operator Actions Specified by Abnormal Operating Instruction AOI-6, "Small Reactor Coolant Leak"

AOI-6 is an instruction that provides guidelines for RCS leakage where pressurizer level can be maintained with the charging system and does not increase containment pressure to the point of safety injection (SI) activation. Section IV.B.9, "Subsequent Operator Action" of AOI-6 states that if the pressurizer level stabilizes by additional charging pumps the operator is to determine the leakage source; and if the leak is not identified and isolated, and it is apparent the leak rate is greater than Technical Specification 3.4.6.2 (without running SI-137.1), and a trip will not be generated, the operator is to trip the reactor and proceed to cold shutdown. The source of the leak was identified to the operators by the FSG personnel, therefore a controlled shutdown was initiated.

Using the information provided by the day shift coordinator and properly analyzing the system responses the operations staff classified the nature of the leak and took immediate and subsequent action in accordance with established procedures to shut the unit down, declare an Unusual Event, cool down, depressurize, and drain the water level in the reactor below the seal table elevation thus stopping the leak.

For conclusions relating to this section, refer to section III.F.1.

G. Initial Actions Taken to Evaluate Conditions in the Instrument Room

1. Plant Management Decision to Enter the Instrument Room After the Accident

After the leak was stopped, plant management considered their priorities at that point were the following:

- To find out how much water was in the room.
- To find out the extent of the damage from the water, steam, and radioactive contamination.
- To determine the radiation levels in the room.

They knew that they had the following conditions that would prevent them from returning the unit to operation:

- An ice-bed temperature monitoring system was inoperable.
- A containment sump level transmitter was inoperable.
- A leak at the seal table that had to be repaired.

Plant management at this point did not know that a thimble tube had been ejected. They had reviewed the written statement submitted by the FSG Mechanical General Foreman which stated that before he left the work area immediately after the accident he observed the cleaning cable starting to lay back on the grating at the head of the stairs where he was located. He estimated that approximately 30 feet was laid out when he turned to exit. They assumed that the cleaning cable had been ejected from the thimble tube during the incident and the unusual radiation readings were from the cable.

A radiation survey and some pictures of the area were considered to be the first step necessary to determine the extent of the damage and the radiation levels in the room.

2. Radiation Work Permit (RWP) 02-1-00005

RWP 02-1-0005 was issued April 20, 1984, for the lower containment and seal table to provide radiological controls for all activities related to recovery from the seal table accident and to track total radiation dose acquired by the workers during the recovery effort. The RWP contained an instruction that no entry would be made into the seal table (instrument) room without prior knowledge and approval of the Plant Manager and/or the project supervisor that would be assigned from the Nuclear Central Office (NCO) to direct the recovery effort. The Plant Manager signed the RWP. This action established upper plant management direction and control of the recovery effort.

For conclusions relating to this section, refer to section III.G.1.

3. Initial Entry After the Accident into the Instrument Room

At 0935 on April 21, four members of the plant health physics staff made the initial entry into the instrument room for the purpose of assessing the damage to the room and to determine the radiation levels.

They found the thimble tube completely ejected from the guide tube and twisted throughout the room. A small amount of water was observed to still be flowing from the fitting for thimble D-12. This water was determined to be flowing from the system because of the pressure exerted by the nitrogen blanket in the pressurizer. The temperature and humidity in the room was very high making conditions difficult for the workers. The radiation dose rates at various locations and a contamination survey taken at one location while the workers were in the room is depicted in figure 14. The initial radiation surveys indicated dose rates of 1-2 rem/hour at the airlock, 300 rem/hr at approximate elevation 708 above and to the right of the seal table and 1000 rem/hour measured 8 inches away from a bend in the ejected thimble tube located at the surface of the seal table. Several pictures were taken of the area. The four individuals were in the area approximately two minutes. The total collective radiation dose received by the four individuals was approximately 3 rem. The highest dose received by one individual was approximately 1.2 rem.

4. Management Assessment of the Conditions Found in the Instrument Room During the Initial Entry

When plant management looked at the pictures taken during the initial entry and evaluated the radiation dose rates measured, they realized that they had a problem of greater magnitude than they had previously thought. They decided that they needed to make another entry and make more detailed pictures using a telephoto lens (to reduce the radiation dose to the photographer) to get as much detail as they could of the ejected tube and a more detailed idea of the condition of the room. They decided that they needed an experienced photographer to take the pictures because of the unusual conditions.

5. The Second Entry into the Instrument Room

Plant management located a photographer at the Power Operations Training Center. When he arrived onsite, he was briefed by the plant management and Health Physics Staff concerning the conditions in the room and radiological aspects of the work. At approximately 1830 on April 21 the photographer and a HP shift supervisor entered the instrument room and took photographs of the seal table area. They were in the instrument room for approximately seven minutes and received radiation doses of 1.97 rem and 1.94 rem.

6. Preparation of Drawing Depicting the Configuration of the Ejected Thimble Tube

The film was developed and the photographs returned to the plant. From the photographs the plant staff composed a drawing of the thimble tube configuration (see figure 15). An entry into the instrument room was made on April 23 at 1300 by the plant HP section supervisor, an HP shift supervisor, and an HP technician to confirm that the actual configuration was as depicted in the drawing. In addition, contact dose rates were taken at various locations on the ejected thimble tube with a radiation measuring instrument with an extendable radiation detector (see figure 16 for contact dose rates.) They determined that the actual configuration of the thimble tube was in agreement with that depicted in the drawing. The highest radiation dose received (based on high-range dosimeters) during the entry was 0.4 rem.

H. The Recovery of the Thimble Tube and Actions Taken to Ensure Unit 1 was Safe to Return to Power

The following actions were taken by NUC PR to recover the ejected thimble tube and to ensure unit 1 was safe to return to power operation:

1. Assignment of Responsibilities

The Nuclear Production Manager and the SQN Plant Manager assigned a project manager from the NCO to direct the overall effort of recovering and disposing of the ejected thimble tube. This assignment was made in accordance with NUC PR Area Plan Procedure No. 1200A12, "Emergency Project Management."

The Plant Manager made the following additional assignments to the members or organizations of his staff:

- Mechanical Maintenance - Coordinate the preparation and installation of the new thimble tube, examine the affected guide tube for damage, and examine the remaining thimble tube mechanical seals at the seal table for proper installation.

- Electrical Maintenance - Examine and evaluate the electrical equipment in the instrument room and affected areas to determine if any damage occurred and to repair any damage to that equipment.

- Instrument Maintenance - Examine and evaluate the instrumentation in the instrument room and affected areas to determine if any damage occurred and to repair any damage to that equipment.

- Plant Compliance Section - Collect and maintain any information and documents pertaining to the accident to preserve the historical account of the accident.

- Engineering Section - Coordinate the acquisition of NUS Corporation services to clean the thimble tubes.

- Maintenance Superintendent - Coordinate the decontamination efforts of the instrument room.

Additionally, the Plant Manager requested that the NCO Mechanical Branch assist in the examination of the fitting involved in the accident and an assessment of the other fittings on the seal table.

2. Recovery of the Ejected Thimble Tube

a. NUC PR Area Plan Procedure No. 1200A12, "Emergency Project Management". The current revision of the emergency project management procedure was issued in November 1983. The stated purpose of the procedure was to ensure that major components or other emergency maintenance projects receive proper expediting, coordination, procedural compliance, and documentation with the result being maximum efficiency in the use of resources and minimum errors in implementation. The procedure ensures that normal plant forces remain available to perform normal maintenance and ensure that remaining plant capacity and availability are not affected. The procedure is applicable to any major component project of a critical nature with respect to plant availability or nuclear safety.

   The activities to be performed by the project manager were to be within the scope of the emergency project management procedure.

b. Project Manager's Initial Interface with Plant Management. At approximately 1200 on April 21, the Manager of Nuclear Production contacted an NCO senior engineer and assigned him as the project manager for the ejected thimble tube recovery from the instrument room at SQN. He was to report directly to the Plant Manager during the execution of his duties. The assigned project manager immediately proceeded to SQN and at approximately 1400 on April 21 met with the Plant Manager and was briefed on the incident, the activities in progress, and the scope of his assignment.

For conclusions relating to this section, refer to section III.H.1.

c. <u>Planning and Preparation for the Recovery Effort</u>

On April 22, after the configuration of the thimble tube was determined, a meeting was held for the purpose of obtaining ideas for the recovery process. The participation of those at the meeting was reportedly very good. Ideas were discussed and evaluated; and during the afternoon of April 22, the general actions that would be taken to recover the tube were established.

<u>Note</u>: Personnel from NUC PR (Emergency Preparedness and Protection and Mechanical Branches), Office of Power (Radiological Hygiene Staff), and EN DES along with the project manager and the plant staff participated in planning and preparation for the recovery effort. The NRC (site resident and Region II inspectors) observed the planning and preparations.

On the morning of April 23, the project manager began directing the planning and preparation for the recovery effort. These activities were conducted with the goal of developing the safest method of recovering the ejected tube while maintaining the radiation dose to those involved in the process as low as possible. The planning and preparation activities involved the following:

- Made arrangements with WBN to use their unit 1 instrument room to simulate the existing conditions in the SQN instrument room.
- Designed and fabricated special tooling necessary to cut and move the tubing to shielded containers.
- Conducted recovery team trial runs at WBN with simulated conditions and mocked up thimble tubing using the special fabricated tooling.
- Health physics personnel projected the radiation dose for the first phase of the operation (cutting and removing the highly radioactive portion of the thimble tube from the instrument room). The projected dose for this portion of the recovery was 0.6 man-rem.

- Installed temporary shielding at SQN.

- Obtained a remotely operated robot from the Department of Energy (Y-12) to assist in the recovery effort.

- Prepared the following Special Maintenance Instructions incorporating the experiences gained during the WBN exercise and while installing temporary shielding at SQN:

  SMI-1-94-3, "Retrieval of Approximately 25 Feet of Unit 1 D-12 Incore Thimble to Acceptable Work Location," PORC reviewed and Plant Manager approved April 24.

  SMI-1-94-4, "Retrieval of Approximately 100 Feet of Unit 1 D-12 Incore Thimble From U-1 Containment to a Barrel Shield in U-1 El 690 Penetration Room," PORC reviewed and Plant Manager approved on April 25.

- Established maximum stay times for personnel in the instrument room.

- Established emergency personnel response teams in the event of injury or unforeseen circumstances during the tube recovery.

- Established alternate escape routes.

- Established that recovery team members would immediately exit the area if conditions were encountered that were different than those at the simulated WBN exercise.

- Established a communication link between the control point and the Plant Manager's office to allow the Plant Manager to monitor the recovery effort. Provided the link with a tape recorder to record the dialogue of the recovery effort.

- Members of POWER's Radiological Health Staff were onsite and reviewed the procedures and plans to ensure radiation doses to personnel would be ALARA during the recovery.

d. Recovery of the Ejected Thimble Tube and Cleaning Cable

(1) Recovery of the 25-Foot Section With the Highest Radioactive Levels

This portion of the recovery was conducted in accordance with SMI-1-94-3.

Dry runs on the final plans for the operation were conducted at WBN for practice. The recovery team members were briefed on the morning of April 25.

The recovery team leader (an NCO health physicist) entered the personnel airlock on elevation 690 and inspected the instrument room for obstructions with a mirror. (The airlock was shielded.) He noted an air sampler on the stairs by the seal table. The location of the air sampler was made known to the recovery team members that were going to enter the instrument room. The team leader stayed in the airlock to observe the operations with a mirror.

(a) First Entry to Cut the Thimble Tube

The team member designated to cut the thimble (an SQN HP shift supervisor) entered the instrument room through the airlock equipped with a pair of cutters. He proceeded to the stairs leading to the seal table and noted a portion of the tube laying across the railing on the stairs. He immediately exited the instrument room through the airlock as instructed since the tube in that position was unexpected and he was only wearing a surgeon's cap as specified on the applicable RWP Timesheet. He donned a canvas hood which affords better protection of the head and neck against radioactive contamination and reentered the instrument room. He proceeded to the stairs, ducked under the tube, and climbed the access steps to the 10-path trolley elevation and cut off approximately 25 feet of the most radioactive portion of the tube with the cutters. The 25-foot portion of the tube fell exactly as had the mocked-up portion during the practice sessions at WBN. He exited the instrument room through the airlock. During this process he received a radiation dose of approximately 100 millirem.

(b) Second Entry to Attach a Clamping Mechanism to the Thimble Tube and to Pull the Tube Into the Raceway Below the Instrument Room. Team members had been stationed in the raceway to pull the cut portion of the thimble tube into the raceway. One team member placed the clamping mechanism with the cable attached through the submarine hatch on the instrument room floor. Two team members (plant HP shift supervisors) entered the instrument room through the airlocks, picked up the clamp and cable, attached the clamp and cable to the 25-foot portion of the tube, and immediately left the instrument room through the airlock.

During this process one team member attaching the cable received a radiation dose of approximately 170 millirem and the other member approximately 10 millirem.

All personnel exited the airlock, both airlock doors were closed, and the team members in the raceway pulled the cut portion of the thimble tube from the seal table across the instrument room through the submarine hatch into the raceway. The thimble tube was then pulled to a predetermined location that had been marked on the floor with tape. The team members in the raceway exited the raceway and reactor building containment.

The accumulated radiation dose for all team members involved in this portion of the recovery was 0.7 man-rem.

(2) Recovery of the Remaining Portion of the Thimble Tube and Cleaning Cable from the Instrument Room. This portion of the recovery was conducted in accordance with SMI-1-94-4.

After the most radioactive portion of the thimble tube was in the raceway, the radiation dose rates in the instrument room were lowered substantially. A team leader for this portion of the recovery had been appointed and the team members briefed. On April 25 HP personnel entered the instrument room and located the portion of the remaining thimble tube and cleaning cable with the highest radiation levels. Team member personnel entered the instrument room, cut the most radioactive portions of the remaining thimble tube into 18- to 24-inch sections, placed these cut sections in specially fabricated buckets, and transported the buckets to the airlock. Team members outside the airlock retrieved the buckets and placed them in a barrel shield outside the airlock. These sections of the thimble tube and cleaning cable were transported to radwaste and prepared for shipment to an off-site burial site. This portion of the recovery was completed by 2000 on April 25.

(3) Cutting and Storage of the 25-Foot Section of Thimble Tube in the Raceway. From April 25 to the afternoon of April 26 the following actions were taken to prepare for cutting and storage of the thimble tube in the raceway:

- Erected scaffolding and special shielding and installed lifting devices in the raceway.

- Placed and secured a shielded cask to receive and store the cut sections of tubing in the raceway.

- Moved the robot to the raceway.

- Installed video equipment in the raceway to aid in the cutting and storage operation.

- Designed and fabricated special tools to be used in the cutting operation.

In the afternoon of April 26 a simulation of the cutting and storage operation was conducted, the process finalized and adjustments of tools and equipment were made.

On the morning of April 27, SMI-1-94-6, "Relocation, Cutting, and Storage of 25 to 40 Feet (approximately) of Unit 1 D-12 Incore Thimble," was prepared, PORC reviewed and approved by the maintenance superintendent for the Plant Manager. In the afternoon of April 27 in accordance with SMI-1-94-6 equipment placement and operability were verified, a practice run was completed, and a final briefing was conducted for all team members. The section of thimble was pulled using the cable previously attached around the raceway to a predetermined position for the cutting and storage operation.

With the aid of installed video equipment the team members controlled the robot and the hydraulically operated cutter from a remote location. The robot picked up the thimble tube and transported it to a cutting table. The robot then positioned the thimble tube, and the hydraulic cutter severed approximately 6 feet of the tube believed to have a low radiation level. This section of tubing was then put aside for survey and disposal as low level waste at a later time. The robot then picked up the remaining tubing, positioned the tubing on the cutting table, and the hydraulic cutter severed an approximate 18-inch section. The severed portion of the tubing was then transferred by the robot to the shielded storage cask. The robot then returned to the cutting table and picked up the remaining portion of the thimble tube and repeated the process until all of the tubing had been cut and placed in the cask (19 cuts were required). The cask was topped off with lead shot for additional shielding and sealed.

The cask containing the highly radioactive portion of the ejected thimble tubing will remain stored in the raceway until removal and disposal at a later date (probably the next refueling outage). The dose rate at the surface of the cask is approximately 6 millirem/hour.

For conclusions relating to this section, refer to sections III.H.2 and 3.

3. Decontamination of the Instrument Room

After the ejected thimble tube and cleaning cables had been removed from the instrument room, preparations were made for decontaminating the surfaces and equipment in the room. An instruction (SMI-1-317-22, "Decontamination of Seal Table and Other Components and Structures Located Inside Incore Instrument Room") was prepared, reviewed by PORC, and approved on April 25. The instruction prescribed the cleaning methods to be used in reducing the radioactive contamination in the room to acceptable levels, disposal methods for cleaning fluids and equipment, and analytical methods and final acceptance criteria for chlorides and boron concentrations on the surfaces of equipment.

Personnel from the FSG and HP groups began removing temporary shielding and commenced the decontamination effort at approximately 2200 on April 25 and completed the effort at approximately 2200 on April 26.

4. NUS Cleaning of Unit 1 Thimble Tubes

SQN contracted NUS Corporation to perform the cleaning operation of the thimble tubes. On April 26 an instruction (SMI-0-94-2, "Incore Flux Thimble Cleaning and Lubrication") was reviewed by PORC and approved for the Plant Manager. This procedure was essentially the NUS-supplied procedure applicable to their method for cleaning and their equipment used in the process. The NUS procedure was changed to the SQN format for special maintenance instructions and changes incorporated to adopt the procedure to specific SQN circumstances and requirements.

The primary steps of the instruction were as follows:

- Flush foreign material from the thimble tube with demineralized water at approximately 200 psig through a flexible tube assembly which is inserted the full length of the thimble.

- Remove the majority of the flush water from the thimble by applying instrument air or nitrogen through the flexible tube assembly.

- Perform a vacuum drying of the thimble tubes to remove all residual moisture.

- Application of a thin film of NEOLUBE lubricant to the thimble bore along the entire thimble length. Note: The lubrication method utilizes a metered fine spray lubricator nozzle which is withdrawn from the thimble at a controlled rate while spraying the lubricant.

- Performance of a final air drying operation to remove the alcohol vehicle from the lubricant and produce a thin uniform film of lubricant for the entire base length.

- Optional performance of a "dummy" test cable insertion of all thimbles to the "dead end" of the thimble to verify no obstructions or problems.

Using the instruction and the NUS equipment, the thimbles were all cleaned by NUS personnel during the timeframe of April 26-April 30. The cost of NUS cleaning operation was approximately $40,000, of which approximately $12,000 was for the purchase of the NUS cleaning system and training TVA personnel or its use.

SMI-0-94-2 was a better quality instruction for the activity to be performed and it is apparent that the method of back-flushing at 200 psi and lubrication with NEOLUBE was effective because after the startup of the unit the blockage in the tubes was removed. However, the instruction still had no cautions or warnings to prevent damage to the mechanical seals, no administrative barrier to prevent cleaning the thimble tubes at pressure, no instructions for disassembly and reassembly of the detector drive system, no postmaintenance inspections after cleaning and before pressurizing the reactor, and optional postmaintenance testing to assure operability is acceptable. For these reasons the new instruction for cleaning the thimble tubes with the NUS equipment is considered a poor quality procedure and should not be used again until it is upgraded.

For conclusions and recommendations relating to this section, refer to sections III.H.4 and 5.

5. Installation of a New Thimble Tube Into Guide Tube D-12
On April 26 an instruction (SMI-1-94-5, "Thimble Tube Instalation") was PORC reviewed and approved. Using this instruction a new thimble tube was prepared and inserted into guide tube D-12 on April 28.

6. Inspection of the Seal Table High Pressure Seals

a. Inspection and Results. All of the high pressure seals (fittings) on the seal table were examined for apparent damage or were gauged for proper tightness. During the course of the inspection, 174 high pressure fittings were examined. One fitting was found loose when gauged and 48 fittings were discovered made up with a combination of SWAGELOK and GYROLOK components (SWAGELOK and GYROLOK fitting components are designed for similar applications but manufactured by different companies). The cause of the loose fitting is not known.

b. Testing and Examination of Various Combinations of SWAGELOK and GYROLOK Brands of Fitting Hardware. Various combinations of SWAGELOK and GYROLOK brands of fitting hardware were cross-sectioned and examined by the NCO Mechanical Branch to determine if any combinations would render the assembled fittings unfit for service. The results of the study stated that the various combinations of fittings tested appeared to be satisfactory for the intended service (see reference IV.F.1 for details).

c. Repair of Loose Fitting. SMI-1-94-7, "Seal Table High Pressure Seal Repair," was reviewed by PORC and approved for the Plant Manager on April 30. The loose fitting was repaired in accordance with this instruction.

d. Inspection of Guide Tube D-12 at the Seal Table. The portion of guide tube D-12 at the seal table was visually examined and dye penetrant checked for damage. No damage was discovered.

7. Inspection of the Containment Ice Condenser

Inspection of the containment ice condenser indicated that the ice condenser doors never opened during the accident and steam did not enter the ice beds. Additionally, drain papers inspected were intact which indicated that no ice melted.

8. Inspection of Electrical, Mechanical, and Instrumentation Equipment

All electrical, mechanical, and instrumentation possibly affected by the event were inspected, cleaned, repaired, and recalibrated if necessary.

Note: A telephone located on the polar crane wall and approximately five feet to the right of the seal table was discovered melted and deformed by the heat generated from the leak from guide tubes.

SQN reported in Reportable Occurrence Report SQRO-50-327/8430. an evaluation of all class IE equipment was made to determine if the environmental conditions experienced during this event could be detrimental to their qualified life. The evaluation determined that no deterioration of qualified life was experienced. NSRS did not evaluate this area.

9. <u>NSSS Vendor (Westinghouse) Assessment of Acceptability of the Seal Table for Startup</u>

The plant management requested that Westinghouse perform an assessment of the seal table with the various combinations of SWAGELOK and GYROLOK fittings to determine if the configurations at the seal table were safe to restart the reactor and resume normal operations.

Westinghouse recommended that the reactor could be safely restarted and operated with the existing configuration of the fittings at the seal table for the following reasons:

- The thimble ejection accident occurred during a cleaning operation of the thimble and not during normal operation.
- There was no indication that the thimble ejection was due to mixed fitting components.
- Westinghouse conducted tests at 4250 psi on various fitting combinations with no leakage.
- SQN fitting design is standard and is the same as at many other plants with thousands of hours of operating experience.
- Adequate safeguards exist at SQN to achieve a safe shutdown following ejection of one thimble tube.

For conclusions relating to section IV.H.6 through 9, refer to section III.H.6.

I. Return of SQN Unit 1 to Power Operations

On May 5, unit 1 reached rated temperature and pressure with no problems encountered at the seal table with thimble tubes. The unit was returned to cold shutdown again on May 6 to repair a leaking pressurizer safety valve. The reactor was taken critical and brought to 30 percent power on May 10. Unrelated to seal table repairs, however, the reactor tripped due to low steam generator water level late in the evening on May 10. The reactor was again brought critical on May 11 and the flux mapping testing was successfully completed May 12 and 13. All thimble tubes worked well (no leakage and no evidence of blockage).

A period of 21 days and a man-rem exposure of 16.5 man-rem was required to restore the unit to the operational status (30 percent) that existed prior to the accident.

J. Accident Investigations (Other than NSRS)

1. NRC Inspection Efforts

The NRC performed an announced inspection of the accident onsite in the areas of radiation protection, preplanning and ALARA considerations in the removal of the highly activated incore thimble during April 23-April 28. The inspection involved one inspector.

Per the inspection report the preplanning and consideration for maintaining exposures ALARA were observed by NRC to be adequate for the operation involving the retrieval and storage of the thimble tube.

The NRC site resident inspector observed some of the planning and practice sessions for the thimble tube recovery effort.

Within the scope of the NRC inspections of the accident, no violations or deviations had been identified by the NRC as of June 1, 1984.

2. TVA Investigation Efforts

a. Reporting the Accident and Preservation of the Accident Scene

The TVA "Serious Accident Investigation Procedure" issued in January 1984 requires that in the event of a serious accident the senior management official in charge of the site will follow notification procedures established in his organization.

The procedures are to provide for notification of the Office Manager, the Designated Agency Safety and Health Officer (DASHO), and the Director of the Division of Occupational Health and Safety (OC H&S) as promptly as possible. Definition of a serious accident includes accidental damage to TVA properly with an estimated value of $100,000 or more excluding operating losses.

In the event of a serious accident, an Accident Investigation Team (AIT) is to report to the accident scene no later than the day following the accident. The senior management official in charge of the site where the accident occurred is responsible for securing the accident scene to prevent any disturbance of the evidence and protect people and property from any hazards associated with the accident until the scene is released by the AIT chairman.

SQN Standard Practice SQS 29, "Accident Reporting and Investigation," revised January 27, 1984, states that during regular work hours, the Plant Manager or the senior plant official present shall report the accident immediately by telephone to the Manager of Nuclear Production. The Manager of Nuclear Production is required to report the accident immediately to the Division Director and the Division Director is required to report the accident within two hours to a designated Office of Power representative. SQS 29 states that the accident scene shall be preserved in the accident configuration until released by the chairman of the AIT.

Notification of the declared Unusual Event was made to the Office Manager's office on April 19 or 20. However, the accident was not immediately reported as a serious accident by plant management in accordance with the TVA procedure as the extent of the damage was not realized until after the initial entries into the instrument room and assessment of the damage had been made. Serious accident notification to the Office Manager, OC H&S, and the DASHO was not made until approximately three weeks after the accident occurred and an investigation had been conducted by NUC PR.

The accident scene was not preserved by the Plant Manager as required by TVA and SQN procedures in that restoration of the area was completed before the serious accident notification was made.

The failure to promptly report the accident as a serious accident after the extent of the damage was realized and the failure to preserve the accident scene represents noncompliance with SQN and TVA procedures.

For conclusions and recommendations relating to this section, refer to section III.I.1.

b. Conduct of the NUC PR Accident Investigation. Standard Practice SQS29 specifies that the Director of Nuclear Power shall establish a division accident investigation committee as soon as practical. The committee shall be responsible for fully investigating all circumstances relating to the accident and shall submit a written report to the division director not later than 15 days after the accident.

(1) Assigned Goals of the NUC PR Committee. A NUC PR accident investigation committee (AIC) was appointed to conduct an investigation and review of the industrial safety aspects of the thimble tube ejection on May 2, 1984. The committee consisted of a chairman who was a manager from the Industrial Safety Engineering Section, another member of the NCO staff, and the SQN FSG supervisor. The committee was directed to accomplish the following:

- Determine if the event should be investigated in accordance with the TVA "Serious Accident Investigation Procedure."
- Identify lessons learned as a result of the event.
- Provide any recommendations which should be considered in the future when performing similar activities.

(2) Committee Investigation. The committee completed the assigned investigation and reported their findings on May 17, 1984 (L05 840517 800). The investigation consisted of the following:

- Inspection of the seal table area.
- Review of procedures, sketches, and drawings.
- Discussions with Westinghouse.
- Interviews with five of the eight employees in the instrument room when the accident occurred.

(3) Committee Findings. The findings of the committee were as follows:

- Adequate prior warning of bubbling and low-volume flow of relatively cool water allowed egress from the most remote point prior to total seal failure and subsequent thimble tube ejection.

  Note: This description of the nature of the leak before the workers began their egress from the area contradicts information obtained by NSRS from the interviews with the workers (see section IV.E.3 of this reaport).

- There were three paths of egress, two of which were remote from each other, and the individuals involved were knowledgeable of them. The airlock was the most desirable and the one used.

<u>Note</u>: While this is true, alternate routes of egress were not discussed in prejob planning. In addition one of these paths involved hazards as it was through the polar crane wall where the workers would be exposed to high radiation dose rates due to the gamma radiation from nitrogen 16 produced while the reactor is operating.

- The airlock had been out of service for periods of time during the day making the inner door inoperative. Had the incident occurred during this work, egress through the airlock would have been delayed or primary egress would have been through the submarine hatch.

  <u>Note</u>: Some of the workers in the instrument room while the airlock was out of service (including the FSG coordinator) were unaware that the airlock was out of service. Egress through the submarine hatch was not discussed in any prejob planning.

- The incident would exceed $100,000 in property damage, cleanup, and restoration. The majority of costs would result from the radiological aspects of the incident. (The DASHO and the Office Manager were notifed of the accident).

  <u>Note</u>: No distinction is made between radiological and industrial accidents in the corporate accident investigation procedure. The DASHO and Office Manager were notified three weeks after the accident.

- The investigation was not significantly hindered due to the restoration of the area prior to their involvement.

  <u>Note</u>: The corporate procedure for accident investigation requires that the accident scene be preserved until released by the AIT appointed by the Office Manager and the DASHO. Restoration of the work area before reporting the accident is a violation of TVA procedure.

- The sequence of events - In the sequence of events the committee stated, "The tube was not observed being ejected, nor was steam observed at this time." Looking back through the airlock portholes they could see steam begin to build in the room. Exit time from the platform to safety in the airlock was no greater than 20 seconds. Under the circumstances, the exit appeared very orderly and there were no injuries.

  Note: The start of the ejection of the thimble tube was almost simultaneous with the development of the leak as the cleaning tool was pulled away from the steamfitter when the leak developed and the tool was connected to the thimble tube. The water was flashing to steam above the workers prior to the beginning of their exit from the platform (see section IV.E.3 of this report). The exit was not altogether orderly (see section IV.E.4 of this report).

(4) Committee Conclusions. The committee concluded the following:

- The reason for the failure was not evident. Four possibilities involving the hardware of the seals were listed.

- The flexing activity of the brushing could have aggravated the hardware conditions leading to the failure.

- The instruction (SMI-0-94-1) states that the procedure is not to be used at power. Since the unit was in Mode 1, the procedure was violated.

(5) Committee Recommendations. The committee included the following recommendations:

- Recommendation No. 1. Cleaning and brushing of thimble tubes should be done with the reactor in cold shutdown (Mode 5).

- Recommendation No. 2. If brushing is required past Mode 5, a prejob safety analysis should be performed and the procedure approved by PORC. A mechanism should be installed to preclude tube ejection and leakage and a clear path of egress should be established.

Note: A prejob safety analysis is required by SQM2 for all maintenance activities performed by an MR, and all work performed on CSSC is required to be performed by PORC-reviewed, plant manager-approved procedures. The quality of the job safety analysis and the procedure that was in use and compliance with existing requirements are the true issues. Improving the quality of the job safety analysis and procedure and compliance with existing requirements should be stressed.

- Recommendation No. 3. The brushing mechanism should be modified to eliminate any stress or flex on the thimble tube connection.

- Recommendation No. 4. All work on any system where there is no secondary pressure boundary should be evaluated on a case-by-case basis and adequate means to mitigate an inadvertent pressure failure should be applied.

- Recommendation No. 5. Ensure the constant availability of the primary egress route, i.e., the airlock. Consideration should be given to leaving the inner door open (with the SE's permission) or providing a person to man the door.

  Note: This recommendation should be revised to delete the consideration to leaving the inner door open as the doors are interlocked and having the inner door open would prevent or delay someone from opening the outer door and entering the containment in an emergency for rescue purposes.

- Ensure that all emergency notification systems are in constant operation.

- Commend the eight employees for their coolness under pressure and their ability to reason through egress options under the stressful situation.

  Note: The eight employees did not have to reason through egress options under the stressful situation since the door to the airlock was opened by the employees.

For conclusions and recommendations relating to this section, refer to section III.I.2.

K. NUC PR Special Testing of Thimble Tube Fittings and the Dry Brushing Tool

The NUC PR Mechanical Branch performed postaccident inspection testing to provide insight to the thimble tube ejection accident and to assist in the determination if SQN unit 1 was safe for restart after the accident. The tests involved the following:

- Inspection of hardware from thimble tube D-12.
- Cross sectioning and examination of various combinations of SWAGELOK and GYROLOK brands of fitting hardware.
- Tensile testing of similar hardware.
- Examination of an alleged identical assembly.

The postaccident inspections of the seal from D-12 indicated that the seal had been properly installed (all components were in place and the nut was reasonably tight after the ejection of the thimble tube). Postaccident testing also indicated that the cleaning tool imposed unusual forces on the assembly and that strains of considerable magnitude resulted from reasonably applied forces on the fixture handle. These strains were of sufficient magnitude to cause separation of the thimble tube from a properly installed mechanical seal at reactor operating pressure of 2250 psig.

It should be noted that the cleaning tool supports were designed by TVA and the use of the tool was unrestricted by procedure. The control over the change of design of the tool was very loose as a temporary base support was fabricated and used during the day shift. Additionally, the base support for the tool in use when the accident occurred was modified prior to use. No technical evaluation or testing was performed to assess the effect of the tool on the mechanical seals. The failure to design, evaluate, and test a proper tool and support and the failure to provide restrictions for the tool, support, and cleaning cable in use are the contributors to the failure of the mechanical seal and the accident and not the tool itself.

For conclusions and recommendations relating to this section, refer to section III.D.1 and III.E.1.

L. Worker Background

The work backgrounds of the eight workers involved in the accident are shows in Table 1 and are summarized as follows:

- Three of the six FSG employees involved in the cleaning activity had not read the work instruction prior to the accident including the steamfitter foreman who performed the job safety analysis.

TABLE I

BACKGROUND OF WORKERS INVOLVED IN THE THIMBLE TUBE EJECTION INCIDENT

Worker Identification	Job Title	Read SMI-0-94-2 Prior to Incident	Previously Cleaned Thimble Tubes	Past Work Experience	Experience Working on Systems at Pressure & Temp
A - Evening shift coordinator in charge of activity	Mechanical Engineer	Yes	No	Primarily construction and outage work	Knew alternate egress routes. Had not normally worked on systems at pressure and temperature. Knew pressure, temperature, and configuration of system.
B - Observer	Mechanical General Foreman	NI	No	NI	Knew alternate egress routes. Knew pressure, temperature, and configuration of system.
C - Counting number of revolutions on handcrank	Steamfitter Foreman	No	No	5 years construction and outage work	Knew alternate egress routes, had not worked at these temperatures and pressures. Knew pressure, temperature and configuration of the system.
D - Turning the handcrank	Steamfitter	NI	Yes (only while unit shutdown)	Steamfitter 15 years, construction and outage	Knew alternate egress routes. Did not normally work on systems at these temperatures and pressures. Knew pressure, temperature, and configuration of the system.
E - Monitoring cable as it came out of container looking for rough spots on kinks	Steamfitter	No	Yes (only while unit shutdown)	Steamfitter 13 years, construction and outage	Knew alternate egress routes. Had worked on systems at temperature and pressure but not that much. Knew pressure, temperature and configuration of the system.

TABLE I (Continued)

BACKGROUND OF WORKERS INVOLVED IN THE THIMBLE TUBE EJECTION INCIDENT

Worker Identification	Job Title	Read SMI-0-94-2 Prior to Incident	Previously Cleaned Thimble Tubes	Past Work Experience	Experience Working on Systems at Pressure & Temp
F- Feeding cable into guide tube	Steamfitter	No	No	Steamfitter 5 Years construction and outage	Knew alternate egress routes. Had worked on systems at temperature and pressure but not that much. Knew pressure, temperature and configuration of the system.
G - Taking dose rates	Health Physics technician	NI	NI	HP technician at power plants for 7 years	NI
H - Taking dose rates	Health Physics technician	NI	NI	HP technician at power plants for 5 years	NI

Note: No information (NI) means that the background in this area was not assessed by NSRS.

- Two of six FSG employees had cleaned thimble tubes prior to the event but only while the unit was shutdown. The evening shift coordinator in charge of the cleaning operation and the steamfitter foreman who did the job safety analysis had never cleaned thimble tubes before the incident.

- Five of the FSG employees involved in the activity had primarily a construction and outage background with units shutdown and depressurized (the general foreman's background was not assessed).

- All six FSG employees knew the alternate egress routes before the incident from past experience (the alternate egress routes were not discussed before the accident).

- Even though some of the FSG had worked on some systems at temperature and pressure this type of work this was the exception and not the rule.

- All six FSG employees knew the pressure, temperatures, and configuration of the system before the accident from past experiences or because they had heard it discussed that evening before they entered the instrument room to do the work.

- The two HP technicians were permanent staff members with at least five years experience each at power reactors.

For conclusions and recommendations relating to this section, refer to sections III.B.2 and III.C.1.

M. Employee Expression of Concerns for Safety

1. TVA Policy on Expression of Staff Views

TVA's policy on expression of staff views is delineated in TVA Code II "Expression of Staff Views." It is TVA policy to encourage and protect the differing views of employees on policy and execution of policy. TVA believes that every responsible view is valuable and ensures that such views are heard and appropriately considered in all decisionmaking processes. TVA encourages expression of safety views involving all aspects of its operations, particularly those associated with the design, construction, and operation of TVA nuclear plants. Responsible views may be voiced without fear of recrimination or retribution. TVA employees are responsible for voicing views about significant issues and are encouraged to deal directly with line management so that corrective action may be handled promptly and at the working level. If the views are not resolved at the line management levels, TVA has established methods for handling the views at higher levels which include referring the views to the NSRS for investigation.

2. SQN Employee Expression of Concerns Before and During the Cleaning Activity

Essentially all employees interviewed by NSRS were asked if they openly expressed any concern for safety (nuclear and industrial) to their supervisors before and during the cleaning operation of the thimble tubes. One worker that had experience cleaning the system did express some concern to the steamfitter foreman and the evening shift coordinator about the new design of the base support system because it was different from the base support they had used before. The response to him was that they had used a tool like this in the past. He indicated that he knew the procedure said not to perform the cleaning operation with the reactor operating, but that they really did not have any "gripes" about it. They knew "the situation of the reactor," in that if they performed the work with "no power you have got to take the reactor off the line." He felt in his opinion that what they were going to do was relatively safe.

The concern for safety increased (primarily radiological concerns) as the job progressed. The FSG supervisor was contacted and further planning conducted. All workers interviewed indicated that they felt that there were no hazards that would have justified not performing the work. Some indicated that the work had to be performed to prevent removing unit 1 from operation. No expression of concern for the safety or the job was related to upper plant management.

For conclusions and recommendations relating to this section, refer to section III.J.1.

N. Program Controls Established by SQN Unit 1 Technical Specifications

Technical Specification requirements applicable to review and control of maintenance activities include the following:

1. Section 6.2.3, "Independent Safety Engineering Group (ISEG)". Section 6.2.3 states that the ISEG shall function to examine plant operating characteristics, NRC issuances, industry advisories, licensee event reports, and other sources which may indicate areas for improving plant safety. Section 6.2.3 further states that ISEG shall be composed of at least five dedicated full-time engineers located onsite and shall be responsible for maintaining surveillance of plant activities to provide independent verification that these activities are performed correctly and that human errors are reduced as much as practical. The ISEG at SQN was not composed of five engineers devoting full attention to ISEG functions and had not been effective in providing independent verification that maintenance activities were performed

correctly and that human errors were reduced as much as practical. (See section IV.Q for details on ISEG activities).

For conclusions and recommendations relating to this section, refer to III.K.1.

2. <u>Section 6.5.1, "Plant Operations Review Committee (PORC)"</u>

The PORC shall function to advise the plant superintendent on all matters related to nuclear safety and is composed of the following members of the plant staff:

- Plant Superintendent (Manager)
- Operations Supervisor
- Results (Engineering) Supervisor
- Maintenance Supervisor
- Assistant Plant Superintendent (Manager)
- Health Physicist
- Supervisor, Quality Assurance Staff (FQE)

PORC responsibilities include the following:

- Review of all procedures required by section 6.8.1 of the Technical Specifications and changes thereto.

- Review of unit operations to detect potential nuclear safety hazards.

SMI-0-94-1 was originally PORC reviewed and approved for the plant superintendent in July 1981 and had not been revised since that time. The quality of the procedure was poor when submitted to PORC. SMI-0-94-2 that was written to clean thimble tubes after the accident and was also of poor quality in that it contained no instructions for disassembling and reassembling the detector drive system from the thimble tubes, no precautions or warnings to alert personnel of the sensitive nature of the mechanical seals and restrictions for working on the system with the reactor pressurized, no postmaintenance inspections to ensure the quality of the seals had not been degraded during the maintenance process, and postmaintenance testing was optional. Use of this instruction could degrade the mechanical seals and if performed at pressure could cause a thimble tube to eject or if not inspected, detected, and corrected could cause an ejection during pressurization and startup of the reactor. Despite these inadequacies and even after the accident the instruction was PORC reviewed and recommended for approval to the Plant Manager. It is apparent that the PORC review was ineffective in identifying the procedure inadequacies in the original instruction and in the instruction recommended for approval by PORC after the accident.

For conclusions and recommendations relating to this section, refer to section III.H.5.

3. <u>Section 6.8, "Procedures and Programs"</u>

a. <u>Section 6.8.1.a</u>. Section 6.8.1.a states that written procedures shall be established, implemented, and maintained covering applicable procedures recommended in Appendix A of Regulatory Guide (RG) 1.33, Revision 2, February 1978. Appendix A, section 9.C of RG 1.33 states that procedures for the repair of the incore flux monitoring system should be prepared prior to beginning work.

As discussed in section IV.D.2.a of this report, SMI-0-94-1 was violated and thus not properly implemented.

b. <u>Section 6.8.2</u>. Section 6.8.2 states that each procedure of section 6.8.1 and changes thereto shall be reviewed by PORC and approved by the plant manager prior to implementation and that each procedure shall be reviewed periodically as set forth in administrative procedures. Administrative Instruction AI-4, "Plant Instructions - Document Control," revised March 9, 1984, states in section 5.3.2 that each instruction shall be reviewed biennially after issuance to determine if changes are necessary or desirable.

Inadequate PORC review of SMIs is discussed in section IV.N.2 above. Additionally, the biennial review process established by AI-4 was inadequate in that the poor quality of SMI-0-94-1 was not corrected and the instruction was almost three years old when the accident occurred and had not been revised since its original issue.

c. <u>Section 6.8.3</u>. Section 6.8.3 states that "temporary changes" to procedures of paragraph 6.8.1 may be made provided:

- The intent of the original procedure is not altered.
- The change is approved by two members of the plant management staff, at least one of whom holds a Senior Reactor Operators License on the unit affected.
- The change is documented, reviewed by PORC and approved by the plant manager within 14 days of implementation.

When asked how SMI-0-94-1 should have been changed to make it appropriate for the dry brushing cleaning operation at power, managers and engineers interviewed responded that a temporary change should have been issued to delete the words concerning "do not use the equipment or procedure at power." A change of that nature would be inappropriate as the intent of the instruction would be changed. This type of response is an indication that the people interviewed were not aware of what quality elements are necessary for a good instruction for assuring that the quality of a CSSC is not degraded during the maintenance process, were not aware of the procedure change process, or were expressing a careless attitude toward procedural compliance. The fact that this lack of awareness or careless attitude was expressed (toward procedures) after review of the accident indicates an alarming lack of appreciation of the importance of adequate procedures and procedural compliance. Effective preventive action to reduce procedure violation errors will not be successful unless and until the lack of awareness or such attitudes are changed.

In summary, there was a significant breakdown in the controls for maintenance activities established by the unit 1 Technical Specifications in that (1) ISEG activities did not comply with the intent of the Technical Specifications and had been ineffective, (2) PORC review of special maintenance instructions for the cleaning of thimble tubes before and after the accident had been inadequate, and (3) there was a significant breakdown in the SQN procedure process for maintenance activities.

O. <u>Prior Findings and Recommendations Following NSRS Investigation of 10-Rem Extremity Exposure at SQN</u>

During September and October 1982 NSRS conducted an indepth investigation into the causal factors associated with a 10-rem extremity exposure at SQN. The findings as reported in NSRS Report No. I-82-21-SQN issued December 1, 1982, indicated that the causal factors for the 10-rem extremity exposure were on inadequate hazard assessment, inadequate prejob planning, lack of training, and inadequate adherence to the TVA safety-first policy. Some of the causal factors for that incident are similar to some of the causal factors for this accident. Recommendations were made by NSRS in December 1982 to correct the causal factors of that incident. It is apparent that some of these recommendations had not been implemented.

For conclusions and recommendations relating to this section, refer to section III.C.3.

P. SQN Licensee Event Report (LER) No. SQRO-50-327/84030

This LER, prepared by the plant Compliance Staff and transmitted to the NRC on May 18, 1984, provided the details concerning ejection of the incore thimble tube.

Paragraph b.(2).ii.I of 10CFR50.73, "Licensee Event Report System," states "the narrative description must include the following specific information as appropriate for the particular event: The method of discovery of each component or system failure or procedural error."

Under "the Event" of the LER the method of discovery was stated as "water was noticed on the seal table."

Paragraphs b.(2)ii.(J)(2)(ii) of 10CFR50.73 states "for each personnel error the licensee shall discuss: whether the error was contrary to an approved procedure. . . or was associated with an activity or task that was not covered by an approved procedure."

There was no mention of inadequate or violation of procedures in the narrative of the LER.

Paragraph b.(4) of 10CFR50.73 states "The Licensee Event Report shall contain: a description of any corrective actions planned as a result of the event, including those to reduce the probability of similar events occurring in the future."

The "corrective actions" stated in the LER were "all short-term corrective action taken has been described in the above text. Per vendor recommendations, the seal table and associated fittings were inspected. This inspection determined that no additional corrective action was required. For long-term corrective action, management has made the decision that future thimble tube cleaning will not be performed during power operations."

LER No. SQRO-50-327/84030 transmitted to the NRC on May 18, 1984, was misleading and did not meet the specified requirements of 10CFR50.73 in that the leak was described as "water was noticed on the seal table." (While this is true it does not accurately describe the true nature of the leak as described to NSRS by the workers.) There was no mention in the LER that the primary work instruction for the activity, SMI-0-94-1 was inadequate, was violated, and the long-term correction specified does not address corrective actions to correct the causal factors of the event that may reduce the probability of an event of a similar nature.

For conclusions and recommendations relating to this section, refer to section III.L.1.

Q. SQN Compliance Staff/ISEG Activities

1. Background

NUREG 0737, "Clarification of TMI Action Plan Requirements," issued November 1980 specified post-TMI requirements for operating reactors and applicants for operating licenses to be incorporated into plant design and methods of operation for the purpose of minimizing the probability of a serious reactor accident. One of those items (I.B.1.2) was the requirement of the establishment of an "Independent Safety Engineering Group (ISEG)." The principal function of the ISEG would be to examine plant operating characteristics, NRC issuances, and other appropriate sources of plant design and operating experience information that may indicate areas for improving plant safety. The ISEG would perform independent review and audits of plant activities including maintenance, operational problems, and aid in the establishment of programmatic requirements for plant activities. Where useful improvements could be achieved, it was expected that this group would develop and present detailed recommendations to corporate management for such things as revised procedures or equipment modifications. Another intended function of the ISEG was to maintain surveillance of plant operations and maintenance activities to provide independent verification that these activities were performed correctly and that human errors were reduced as far as practicable. ISEG would then be in a position to advise utility management on the overall quality and safety of operations.

The ISEG was to be an additional independent group of a minimum of five dedicated, full-time engineers, located onsite but reporting offsite to a corporate official who held a high level, technically oriented position that was not in the management chain for power production. The ISEG would increase the available technical expertise located onsite and would provide continuing systematic and independent assessment of plant activities.

The requirement for the ISEG was made a licensing requirement by NRC for the SQN license and included in the Technical Specifications as discussed in section IV.N.1 of this report.

2. SQN Implemention of the ISEG Requirement

SQN and NUC PR management elected to assign the ISEG function to the existing Plant Compliance Staff. SQN Standard Practice SQA117, "Responsibilities of Nuclear Plant Compliance Staff for Nuclear Safety Engineering" revised March 1984, defines the responsibilities of the Compliance Staff at SQN in meeting the NRC requirement for a safety engineering group. The Standard Practice does not cover all of the responsibilities of the Compliance Staff not related to the ISEG function. The defined responsibilities for fulfilling the safety engineering function and providing an independent onsite assessment of nuclear plant activities include review of plant operation and maintenance activities, review of potential reportable occurrences (PROs), and generation of LERs as applicable. (As of May 18 the Compliance Staff had generated 30 LERs for unit 1.)

Additionally, as a compliance function the Compliance Staff logs and tracks regulatory as well as other commitments. They provide the investigations and the responses to findings by NRC, Office of Quality Assurance, and others and coordinate the interface between the plant staff and the inspection, review, investigation, and audit groups. All of these are considered ISEG functions by the plant Compliance Staff in that they get involved with problems they or others have identified. They stated that they ensure that in the process of investigating and writing the reports, the right corrective actions have been taken, both short and long term, to prevent recurrence. The Compliance Staff advises the plant management and others on regulatory matters including interpretation of Technical Specifications.

The ISEG concept used at SQN had diverged from the original NRC and Technical Specification intent as interpreted by NSRS in that it is not composed of five full-time senior level engineers located onsite dedicated full time to ISEG functions, is involved in line production functions, is not independent from the power production organization to ensure objectivity, and is not in the position to assess and advise utility management on the overall quality and safety of operations.

At SQN the ISEG function was assigned to the Compliance Staff which performed line functions for the Plant Manager. These functions performed by the Compliance Staff do afford the opportunity to review plant operation and maintenance activities but do not afford the opportunity to perform the reviews thoroughly and with independence from pressures of operation of the fac ity. Additionally, the performance appraisals, and thus the promotability in the organization, are performed by the site management. The compliance functions performed by the Compliance Staff are line functions and are subject to operational pressures.

The accident was investigated by the SQN Compliance Staff (ISEG) and the description of the event, the cause of failure and the long-term corrective action specified in LER SQN-50-327/84030 were determined by that group. The Compliance Staff/ISEG conclusions concerning the accident as reflected in the LER failed to recognize any programmatic problems that may adversely impact the safety of plant personnel or plant operations in the future.

In general, the Compliance Staff/ISEG personnel interviewed expressed that their thoughts concerning the accident were that it was an unfortunate event. They thought that the plant had demonstrated through the outage that they had made tremendous headway in conducting outages and getting through them, and this accident was an unfortunate event that occurred and kept the unit from going back to power. Based on what they had seen and what the engineering section had done prior to making the decision to clean at power, they did an adequate evaluation, at least talked to industry people that had experience in this area, and came up with a decision that cleaning at power could and had been done.

The thoughts expressed by the Compliance Staff/ISEG personnel interviewed reflected a line supervisor's attitude and one that was concerned with schedule and not one that was concerned from an independent standpoint for nuclear safety.

The Compliance Staff at SQN has been ineffective in performing the ISEG functions of maintaining surveillance of plant activities to provide independent verification that activities (including maintenance activities) were performed correctly and that human errors were reduced as much as practical. This lack of effectiveness in identifying problem areas with program controls is in itself a program weakness which thus promoted conditions that allowed the accident to occur.

For conclusions and recommendations relating to this section, refer to section III.K.1.

V. PERSONNEL CONTACTED

A. Industry

1.	G. Black	Teleflex Corporation
2.	A. Burger	Beaver Valley Nuclear Plant
3.	R. Cockrell	INPO
4.	M. Garton	North Anna Nuclear Plant
5.	D. Kane	Beaver Valley Nuclear Plant
6.	M. Kwitck	Kewaunee Nuclear Plant
7.	R. Mathieson	Westinghouse (SQN Site Rep.)
8.	W. Mullet	NUS
9.	J. Perry	Trojan Nuclear Plant
10.	A. Stough	NUS
11.	R. Wells	INPO

B. TVA Corporate

1.	J. Thompson	OGM (DASHO)

C. Division of Occupational Health and Safety

1.	H. Linder	OC H&S

D. Office of Power (PWR)

1.	S. Bugg	RHS
2.	H. Kemp	PWR
3.	J. Lobdell	RHS

E. Division of Nuclear Power

1.	H. Abercrombie	NCO
2.	T. Campbell	NCO
3.	J. Fox	NCO
4.	L. Ellis	NCO
5.	R. Kitts	NCO
6.	R. Sessoms	NCO
7.	P. Wallace	NCO

F. Sequoyah Nuclear Plant

1.	D. Albury	FSG
2.	L. Alexander	FSG
3.	C. Baker	FSG
4.	R. Byrant	FSG
5.	J. Clift	FSG
6.	M. Cooper	Compliance Section
7.	D. Crawley	HP Section
8.	M. Edwards	HP Section
9.	R. Fortenberry	Engineering Section
10.	H. Gammage	FSG
11.	M. Harding	Compliance Section
12.	S. Harrison	HP Section
13.	S. Holderford	HP Section
14.	D. Jackson	Safety Section
15.	G. Kirk	Compliance Section
16.	J. Krell	Maintenance Section
17.	D. Love	Maintenance Section
18.	C. Mason	SQN
19.	S. Martin	Document Control
20.	B. McKay	Engineering Section
21.	L. Nobles	SQN
22.	J. Osborne	HP Section
23.	D. Paschal	FSG
24.	J. Record	Master Files
25.	J. Robinson	FSG
26.	B. Schofield	Engineering Section
27.	B. Simpson	Engineering Section
28.	J. Stiegleman	HP Section
29.	V. Taylor	Safety Section
30.	B. Turner	FSG
31.	J. Walker	Operations Section
32.	K. Whitty	Engineering Section

G. Watts Bar Nuclear Plant

1.	W. Byrd	Compliance Section
2.	R. Sauer	Compliance Section

VI. DOCUMENTS REVIEWED

A. Regulatory

1. U.S. NRC Report Nos. 50-327/84-14 and 50-328/84-14, received July 2, 1984

2. U.S. NRC Report Nos. 50-327/84-13 and 50-328/84-13, issued June 21, 1984

3. U.S. NRC NUREG-0737, "Clarification of TMI Action Plan Requirements," November 1980

4. Code of Federal Regulations
   10CFR50.73, "Licensee Event Report System," September 30, 1983
   10CFR50 Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," January 1, 1983

5. U.S. NRC Regulatory Guide 1.33, "Quality Assurance Program Requirements (Operation)," February 1978

6. U.S. NRC IE Information Notice NO. 84-55, "Seal Table Leaks at PWRs," July 6, 1984

7. SQN LER No. SQRO-50-327/84030

8. U.S. NRC NUREG/CR-1369, "Procedures Evaluation Checklist for Maintenance, Test and Calibration Procedures Used in Nuclear Power Plants," September 1982

B. Industry

1. Trojan Nuclear Plant, "Flux Thimble Tube Cleanout at Full Power"

2. Management Oversight and Risk Tree Users Manual, EG&G/DOE, Idaho National Engineering Laboratory, ERDA-76/45-4, November 1976

3. Westinghouse Electric Corporation, "Topical Report - Safety Related Research and Development for Westinghouse Pressurized Water Reactors Program Summaries," WCAP-7856, Fall 1971 - Spring 1972

4. Westinghouse Electric Corporation, "Topical Report - In-Core Instrumentation (Flux Mapping System and Thermocouples)," July 1971

5. Westinghouse Nuclear Energy Systems, "Technical Manual for In-Core Instrumentation - Tennessee Valley Authority Sequoyah Nuclear Plant Unit No. 1 and No. 2"

6. Occupational Safety and Health, Standards and Interpretations, "Subpart E - Means of Egress"

7. Westinghouse Correspondence from R. Howard to R. Mathieson, "Seal Table Fittings Intermix - SEQ 1," May 2, 1981

8. Letter to M. D. Wingo from M. Cuppula, Superintendent of Technical Services, Duquesne Light, "Incore Thimble Maintenance," May 14, 1984

C. Corporate

1. Memorandum from H. N. Culver to W. F. Willis, "Sequoyah Nuclear Plant - Notification of an Unusual Event," April 20, 1984 (GNS 840423 100)

2. Memorandum from H. N. Culver to H. G. Parris, "Sequoyah Nuclear Plant - NSRS Investigation of the Unusual Event on April 19, 1984 - NSRS Report No. I-84-12-SQN," April 25, 1984 (GNS 840425 051)

3. Tennessee Valley Authority, "Severe Accident Investigation Procedure," January 1984

4. Memorandum from H. N. Culver to E. A. Belvin and H. G. Parris, "Sequoyah Nuclear Plant Investigation of 10 Rem Extremity Exposure - Nuclear Safety Review Staff (NSRS) Report No. I-82-21-SQN," December 1, 1982 (GNS 821203 050)

D. Office of Power

1. Office of Power Radiation Plan, Section A, "Nuclear Power Plants," November 2, 1983

2. Memorandum from H. G. Parris to W. F. Willis, "Sequoyah Nuclear Plant - Notification of an Unusual Event," April 20, 1984 (GNS 840423 100)

E. Division of Nuclear Power

1. Operational Quality Assurance Manual Procedure No. N-OQAM, Part II, Section 2.1, "Plant Maintenance," February 7, 1983

2. Divison of Nuclear Power, "Plant New and Escalated Operational Event Report - Sequoyah Plant Status," April 17-30, 1984

3. Division of Nuclear Power, "Directives Manual," November 15, 1983

4. Area Plan Procedure No. 0604.05, "Responsibilities of Nuclear Plant Independent Safety Engineering Group/ Compliance Staff," October 31, 1983

5. Area Plan Procedure No. 0604.04, "Unreviewed Safety Question Determination (USQD - Intent, Method, Review, and Approval," October 13, 1983

6. Operational Quality Assurance Manual Procedure No. SQ-OQAM, Appendix A, "Critical Structures, Systems, and Components (CSSC) List"

7. Operational Quality Assurance Manual, Part III, Section 7.3, "Common-Mode Failures, Maintenance Initiated," January 15, 1981

8. Letter from J. A. Coffee to Mr. Larry Sinter, Director, Tennessee Emergency Management Agency, "Sequoyah Nuclear Plant Notification of Unusual Event - April 20, 1984," April 25, 1984 (GNS 840430 100)

9. Memorandum from R. A. Sessoms to L. C. Ellis, "Sequoyah Nuclear Plant Unit 1 - Incore Thimble Ejection - Investigation and Review of Events for Industrial Safety Implications," May 2, 1984 (L01 840502 802)

10. Memorandum from L. C. Ellis to R. A. Sessons, "Sequoyah Nuclear Plant Unit 1 - Incore Thimble Ejection - Investigation and Review of Events for Industrial Safety Implications," May 17, 1984 (05 840517 800)

F. <u>Sequoyah Nuclear Plant</u>

1. Draft - "Sequoyah Nuclear Plant Unit 1 D-12 Traveling Incore Probe Thimble Tube Separation Special Tests," May 17, 1984

2. Special Maintenance Instruction SMI-0-94-1, "RPV Bottom Mounted Instrument Thimble Tubes Cleaning and Flushing," July 10, 1981

3. Special Maintenance Instruction SMI-0-94-2, "Incore Flux Thimble Cleaning and Lubrication," Revision 0, April 26, 1984

4. Maintenance Request Form, A-238084, April 18, 1984

5. Radiation Work Permit No. 02-1-00102, January 1, 1984

6. Radiation Work Permit Timesheet No. 02-1-00102-0090, April 18, 1984

7. Radiation Work Permit No. 02-1-00005, Issued April 20, 1984

8. Radiation Work Permit Timesheet Nos. 92-1-00005-0002 through 0062, Issued April 20, 1984 through May 1, 1984

9. Whole Body Analysis Records for the following SQN personnel:

J. Clift, FSG	D. Albury, FSG
H. Gammage, FSG	. Baker, FSG
B. Turner, FSG	S. Harrison, HP
B. Simpson, FSG	M. Edwards, HP
D. Paschal, FSG	

10. Radiological Control Instruction RCI-10, "Minimizing Occupational Radiation Exposure," Revision 8

11. Radiological Control Instruction RCI-14, "Radiation Work Permit (RWP) Program," Revision 2

12. Radiological Control Instruction RCI-10, Attachment 1, "ALARA Preplanning," April 19, 1984

13. Potential Reportable Occurrence, PRO No. 1-84-159, April 20, 1984

14. SQN Technical Specifications - Unit 1, Sections:

3.3.3.2	"Movable Incore Detectors"
3/4.3.3.2	"Movable Incore Detectors"
3/4.4.10	"Structural Integrity"
6.2.3	"Independent Safety Engineering Group (ISEG)"
6.5.1	"Plant Operations Review Committee (PORC)"
6.8	"Procedures and Programs"

15. SQN Final Safety Analysis Report, Sections:

3.6	"Protection Against Dynamic Effects Associated With the Postulated Rupture of Piping"
5.2	"Integrity of the Reactor Coolant System Boundary"
7.7.1.9.2	"Movable Neutron Flux Detector Drive System"
13.5	"Plant Instructions"

16. Administrative Instruction AI-4, "Plant Instructions - Document Control," March 9, 1984

17. Administrative Instruction AI-3, "Clearance Procedures," Revision 23

18. Administrative Instruction AI-8, "Access to Containment," Revision 10

19. Administrative Instruction AI-13, "Control of CSSC Equipment," Revision 25

20. Administrative Instruction AI-30, "Nuclear Plant Method of Operation," Revision 6

21. Administrative Instruction AI-8, "Containment Entry Checklists," April 18, 1984 - April 19, 1984

22. Clearance Sheets, Hold Order No. 1, "Incore Probes," January 1, 1984

23. Standard Practice SQA119, "Unreviewed Safety Question Determinaion," Revision 3

24. Standard Practice SQA 128, "Method of Operation - Policy," Revision 0

25. Standard Practice SQA129, "Objectives in Plant Operation - Sequoyah Nuclear Plant," Revision 2

26. Standard Practice SQA 131, "Recovery From a Spill of Radioactively Contaminated Liquid," Revision 1

27. Standard Practice SQS29, "Accident Reporting and Investigation," Revision 3

28. Abnormal Operating Instruction AOI-6, "Small Reactor Coolant Leak," Revision 13

29. Hazard Control Instruction HCI-G1, "Hazard Control Instruction Manual," April 21, 1976

30. Hazard Control Instruction HCI-G2, "The Supervisor," May 26, 1983

31. Hazard Control Instruction HCI-G3, "The Employee," January 31, 1984

32. Hazard Control Instruction HCI-G6, "Clearance Procedure Requirements," May 26, 1983

33. Hazard Control Instruction HCI-G15, "Initial Accident Reporting and Emergency Actions," March 22, 1983

34. Hazard Control Instruction HCI-G16, "General Safe Work Rules and Employee Conduct," May 26, 1983

35. Hazard Control Instruction HCI-G26, "Buddy System in Hazardous Low Accessibility Areas," March 22, 1983

36. Hazard Control Instruction HCI-G29, "Workplace Hazard Assessment," February 14, 1984

37. Quality Engineering Section Instruction Letter No. 5.3, "Maintenance Requests - FQE Section Review," Revision 9

38. SQN Shift Engineers Journal, April 17, 1984 - April 25, 1984

39. SQN Assistant Shift Engineer (SRO) Journals (Unit 1), April 17, 1984 - April 26, 1984

40. SQN Unit Operator Journals (Unit 1), April 17, 1984 - April 23, 1984

41. SQN Health Physics Journals for 690 HP Lab, April 19, 1984 - April 26, 1984

42. "Superintendent's Letter," Sequoyah Nuclear Plant, Volume 1, No. 6, April 30, 1984

G. Watts Bar Nuclear Plant

1. Standard Practice WB6.5.1, "Engineer Assignment to Plant Systems and Equipment," March 14, 1984

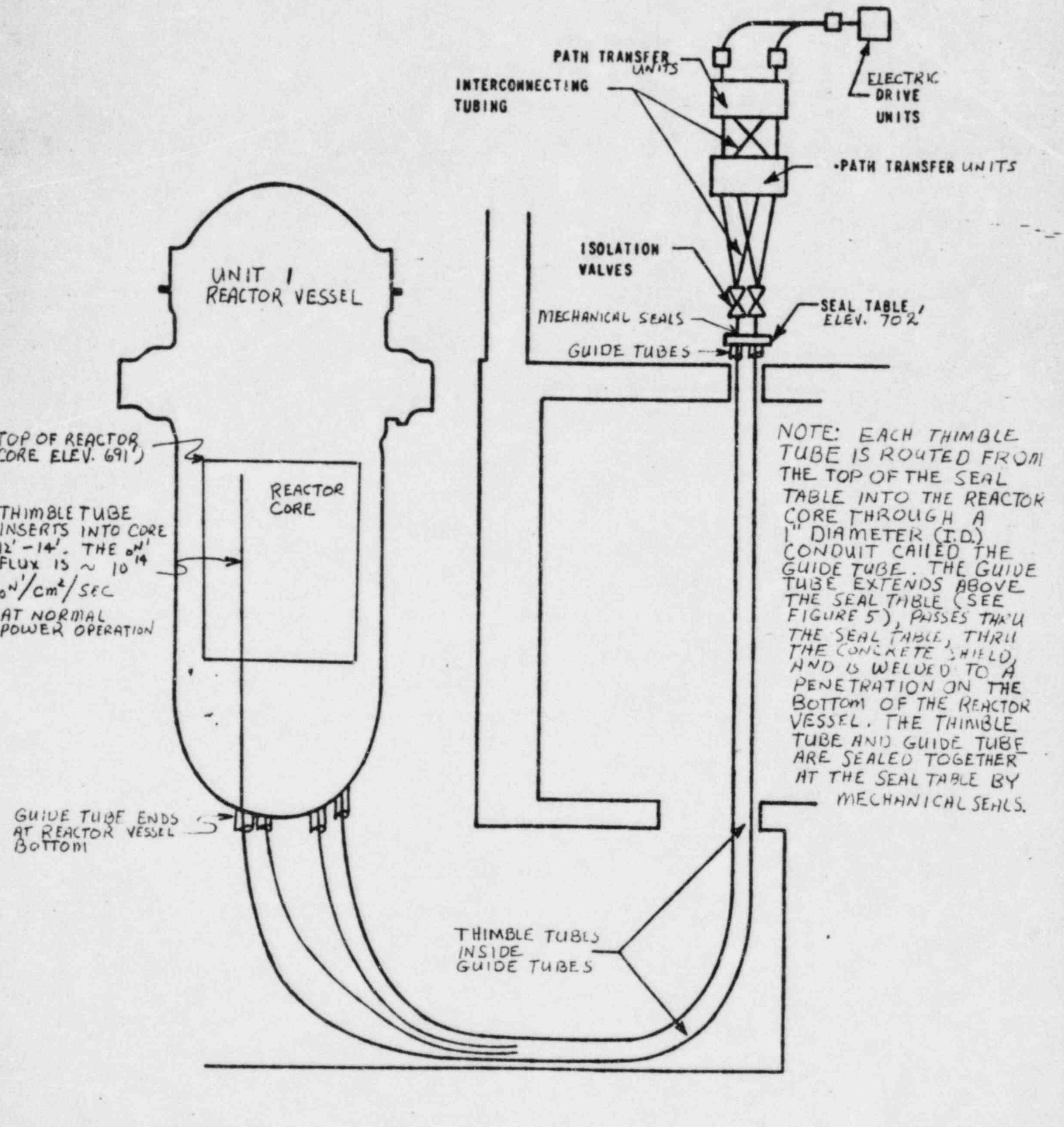
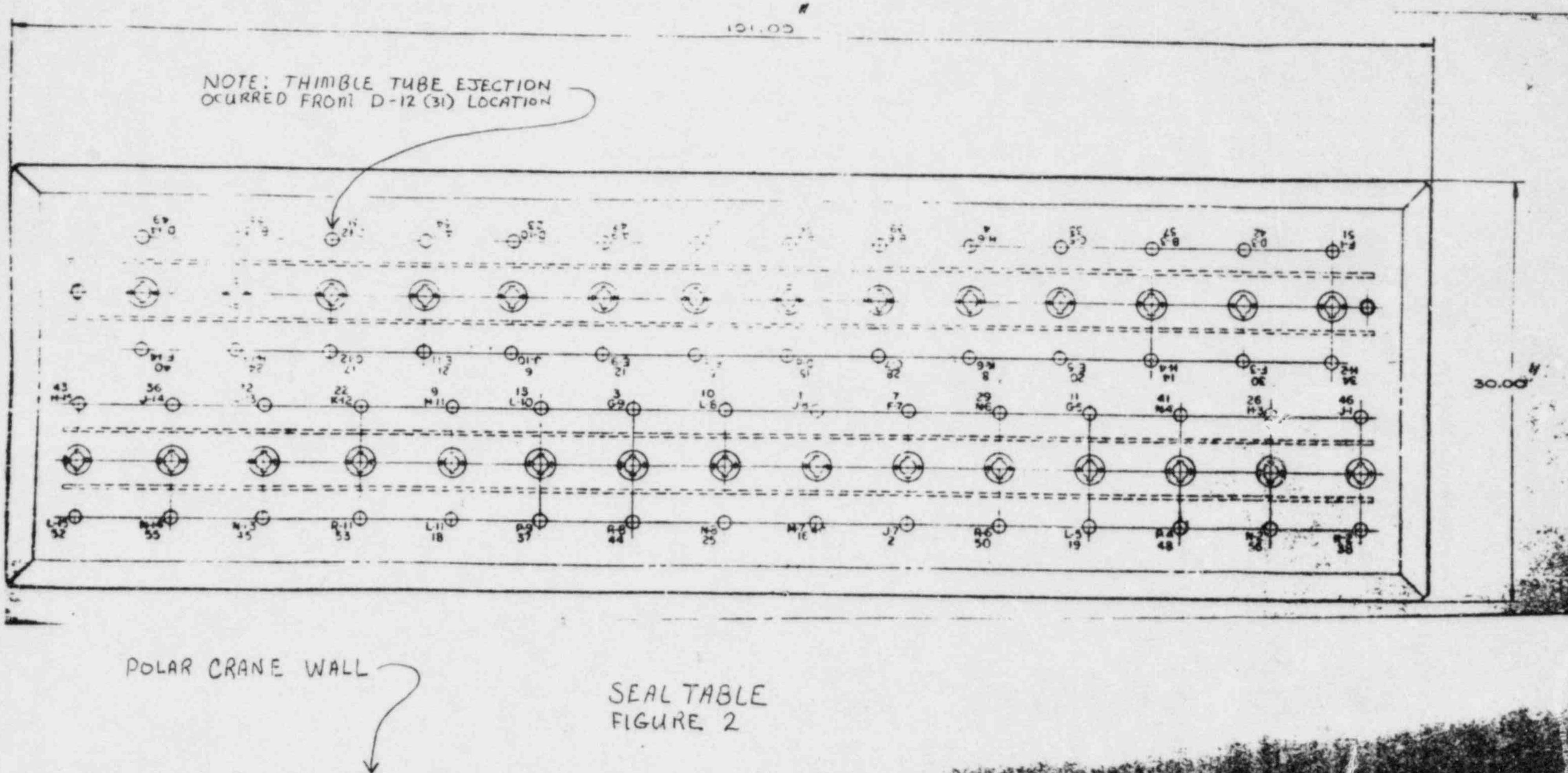
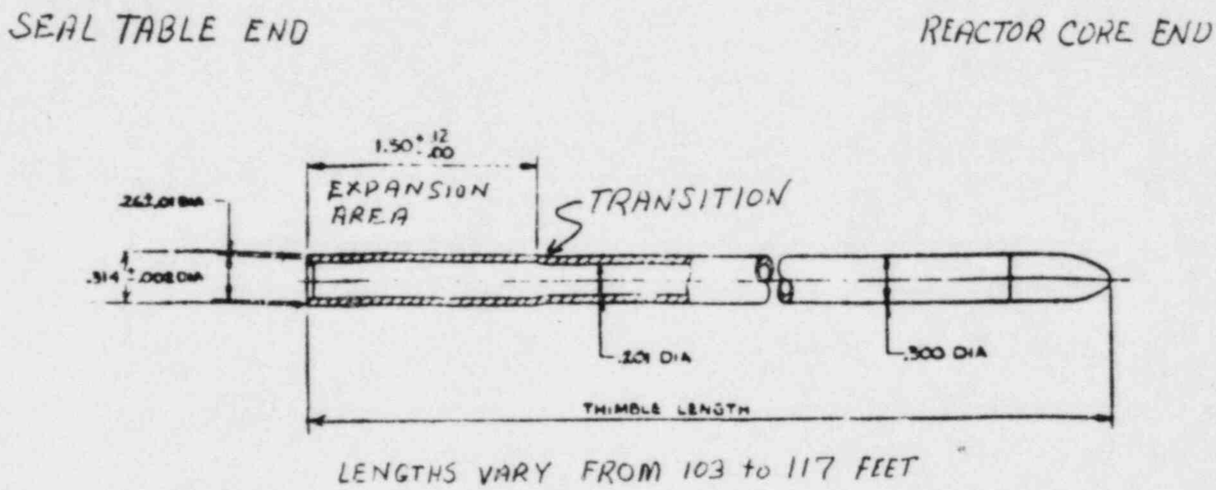


FIGURE 1 INCORE DETECTOR SYSTEM

VIEW N-N (TOP)

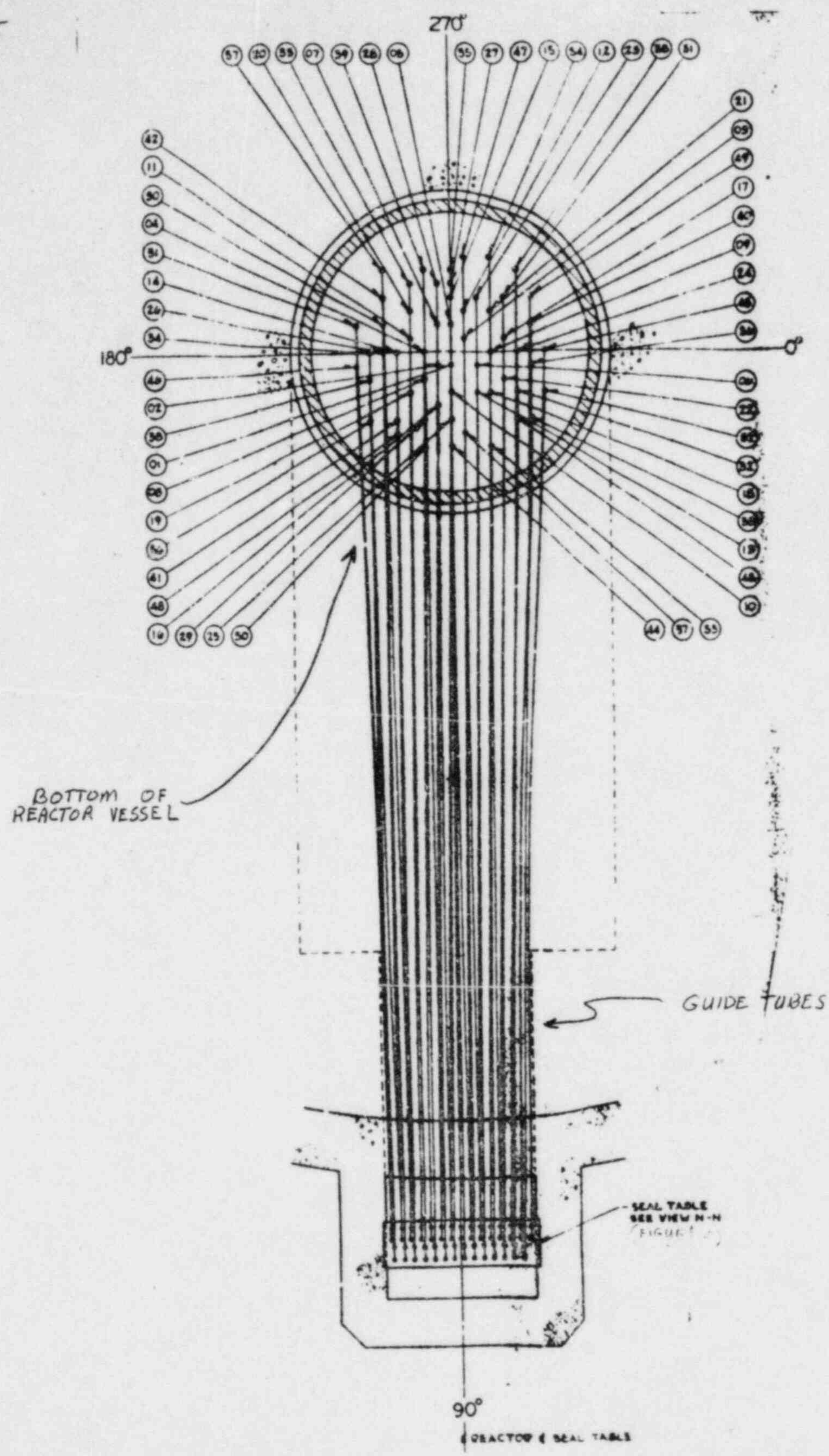


SEAL TABLE
FIGURE 2



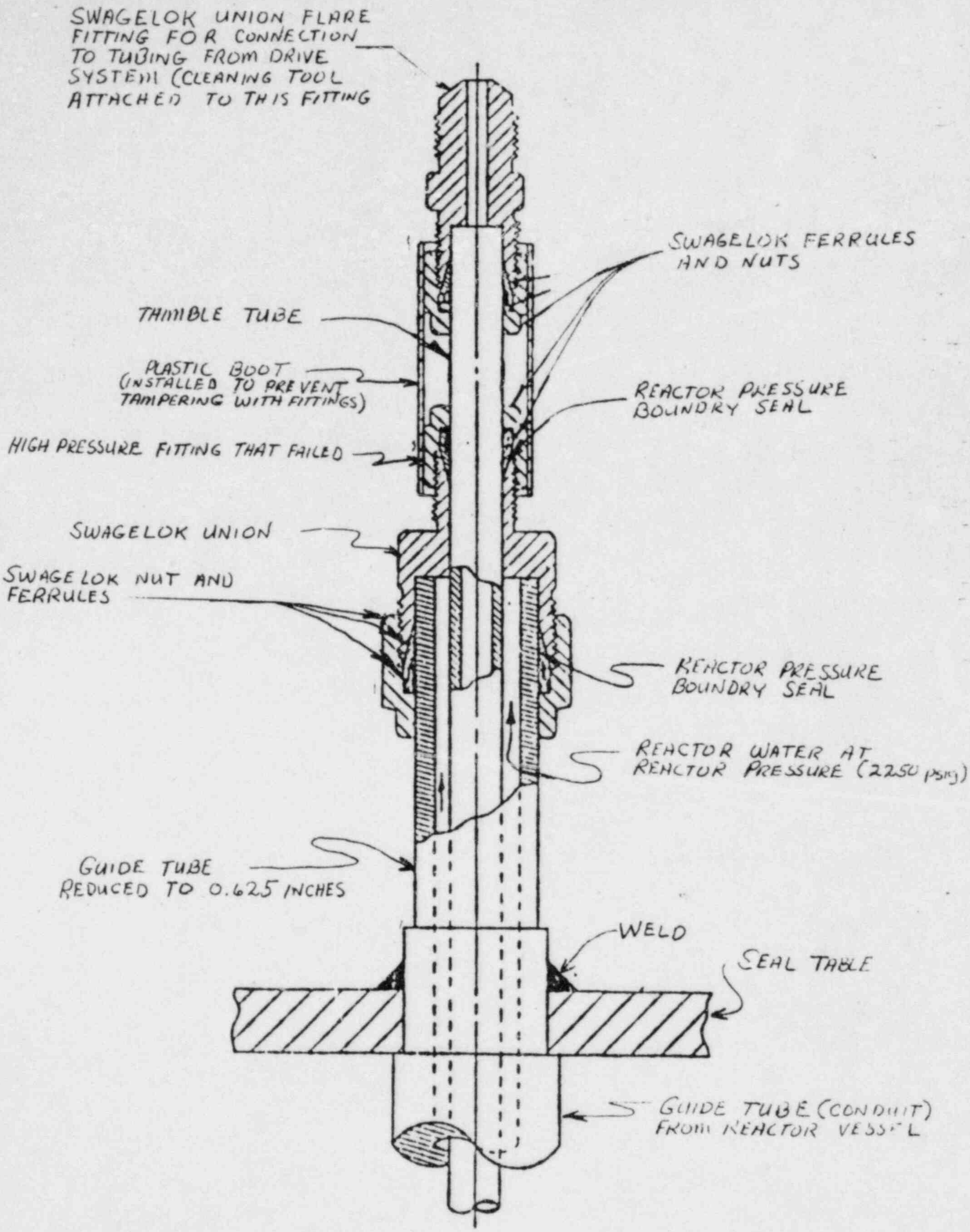
THIMBLE TUBE (SHOWING DESIGN AND EXPANSION FOR MECHANICAL SEALS AT THE SEAL TABLE)

FIGURE 3



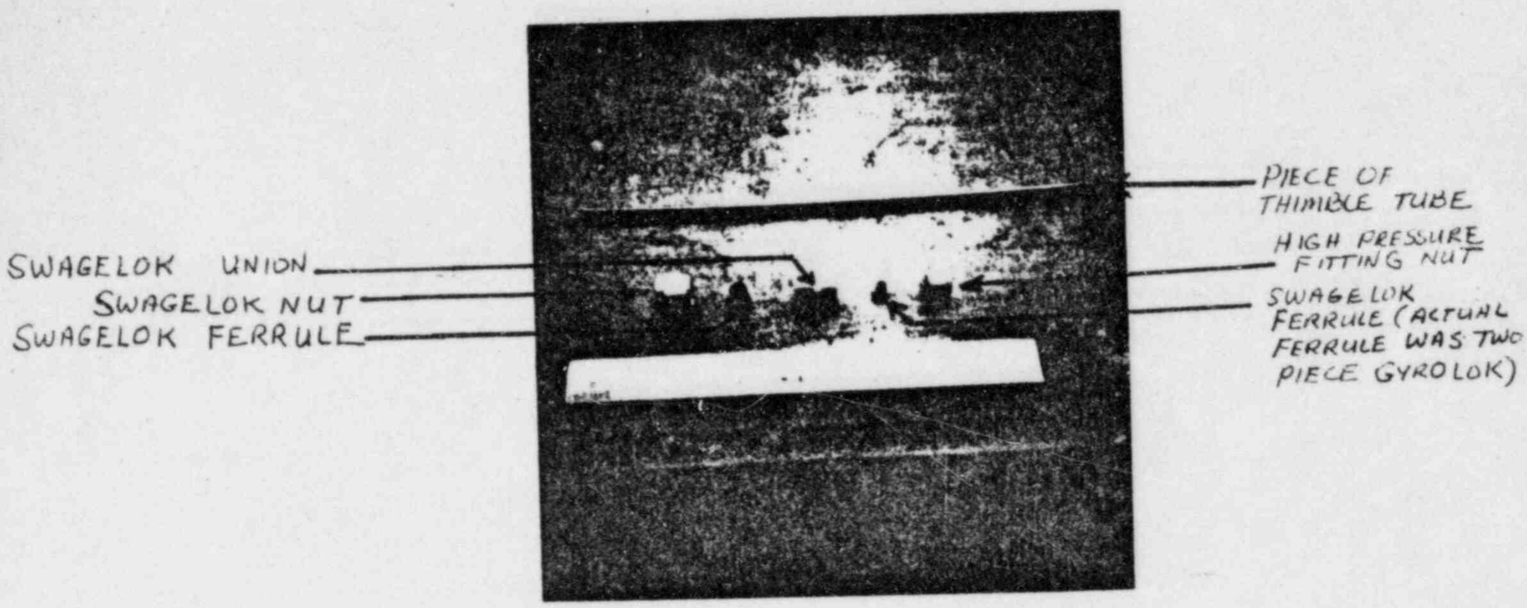
CONFIGURATION SHOWING GUIDE TUBES AND RESPECTIVE THIMBLE TUBES

FIGURE 4



THIMBLE TUBE MECHANICAL SEALS

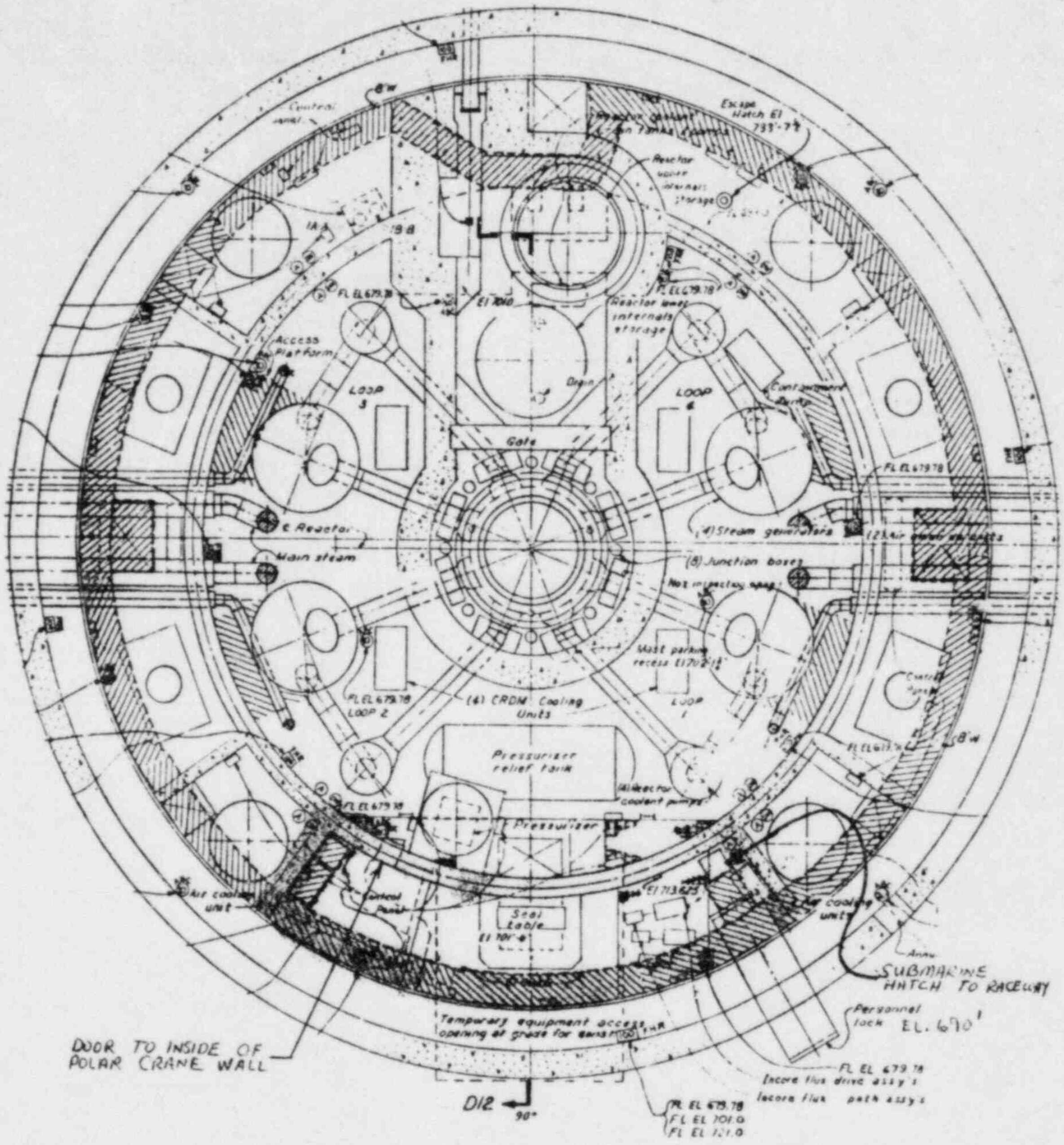
FIGURE 5



PIECE OF THIMBLE TUBE AND TYPICAL SWAGELOK FITTING

NOTE: THE FITTING INVOLVED IN THIS INCIDENT CONTAINED A GYROLOK FERRULE ASSEMBLY CONSISTING OF TWO PIECES (SEE FIGURES 1, 2, 5, AND 6 OF ATTACHMENT 1 FOR MORE DETAIL)

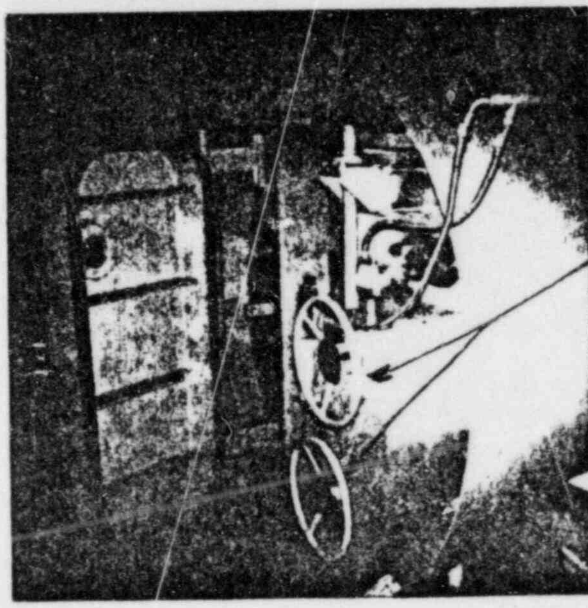
FIGURE 6



PLAN-LOWER COMPARTMENT
REACTOR CONTAINMENT

FIGURE 7A

VIEW FROM INSIDE
THE REACTOR BUILDING
CONTAINMENT

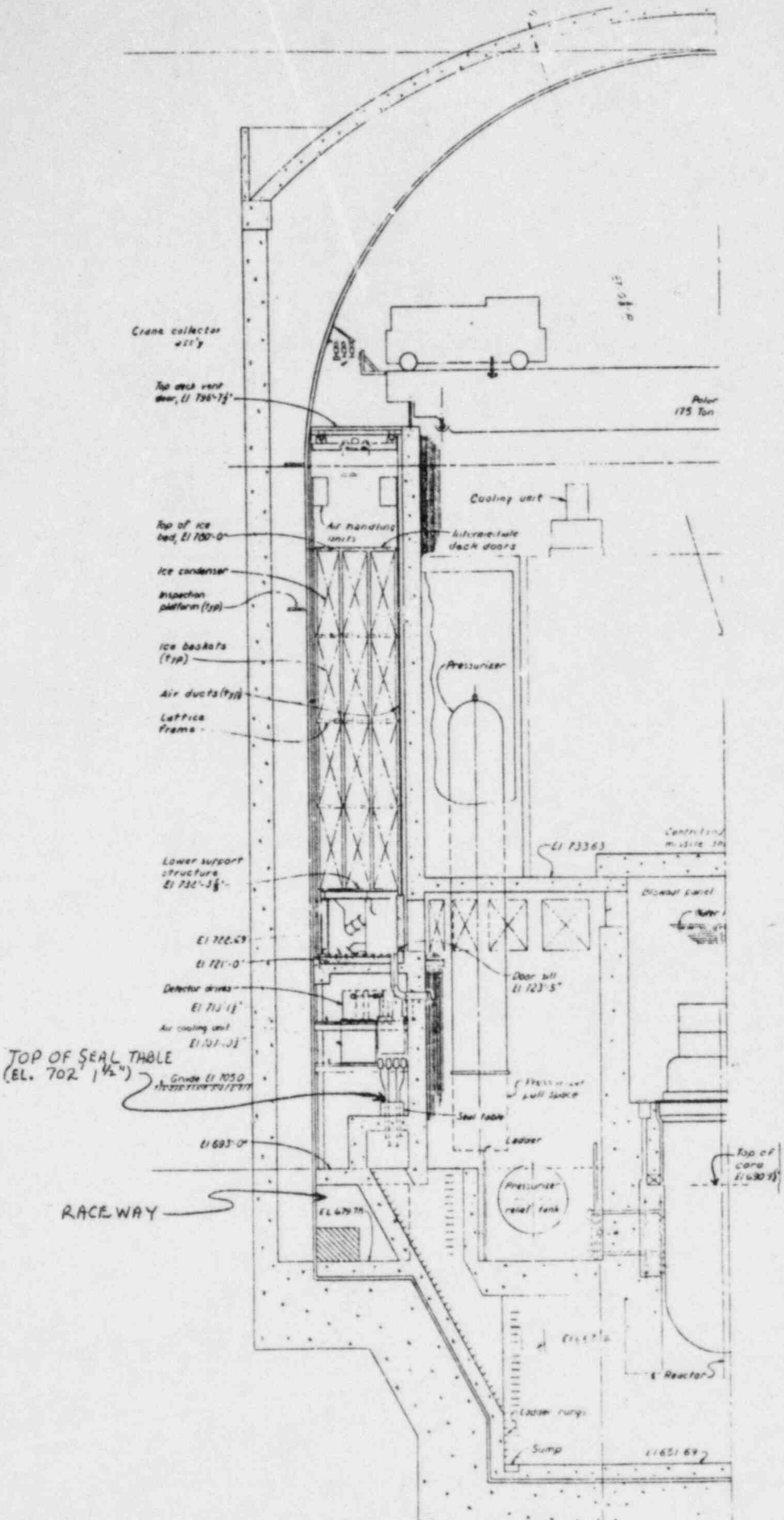


HANDWHEELS TO OPEN AND
CLOSE INNER AND OUTER
DOORS

INSIDE AIRLOCK
IS EQUIPPED WITH
A TELEPHONE

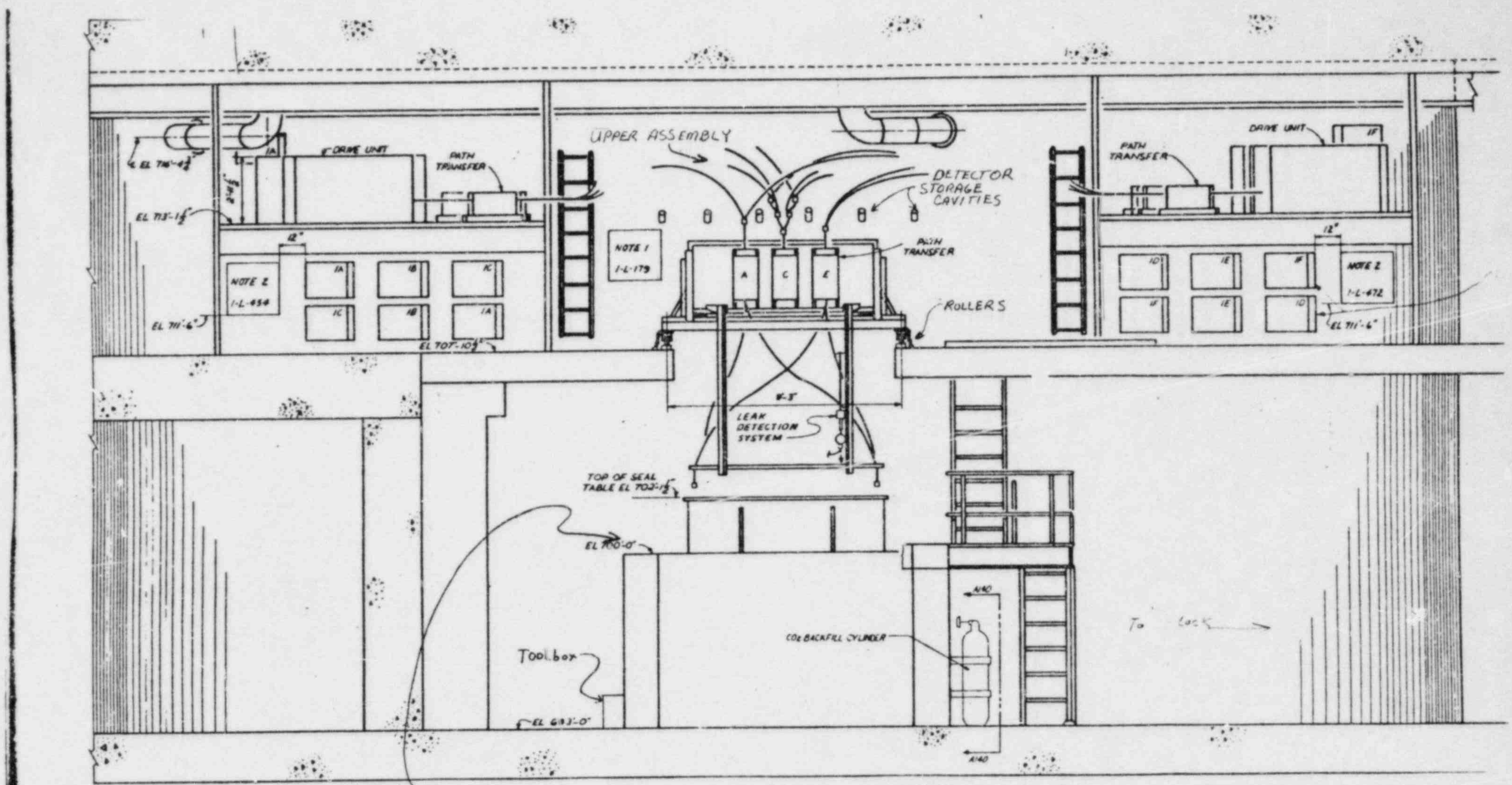
WATTS BAR NUCLEAR PLANT PERSONNEL AIRLOCK
DOOR (SIMILAR TO THE SQN EL 690' AIRLOCK)

FIGURE 7B



ELEVATION DRAWING OF THE REACTOR BUILDING

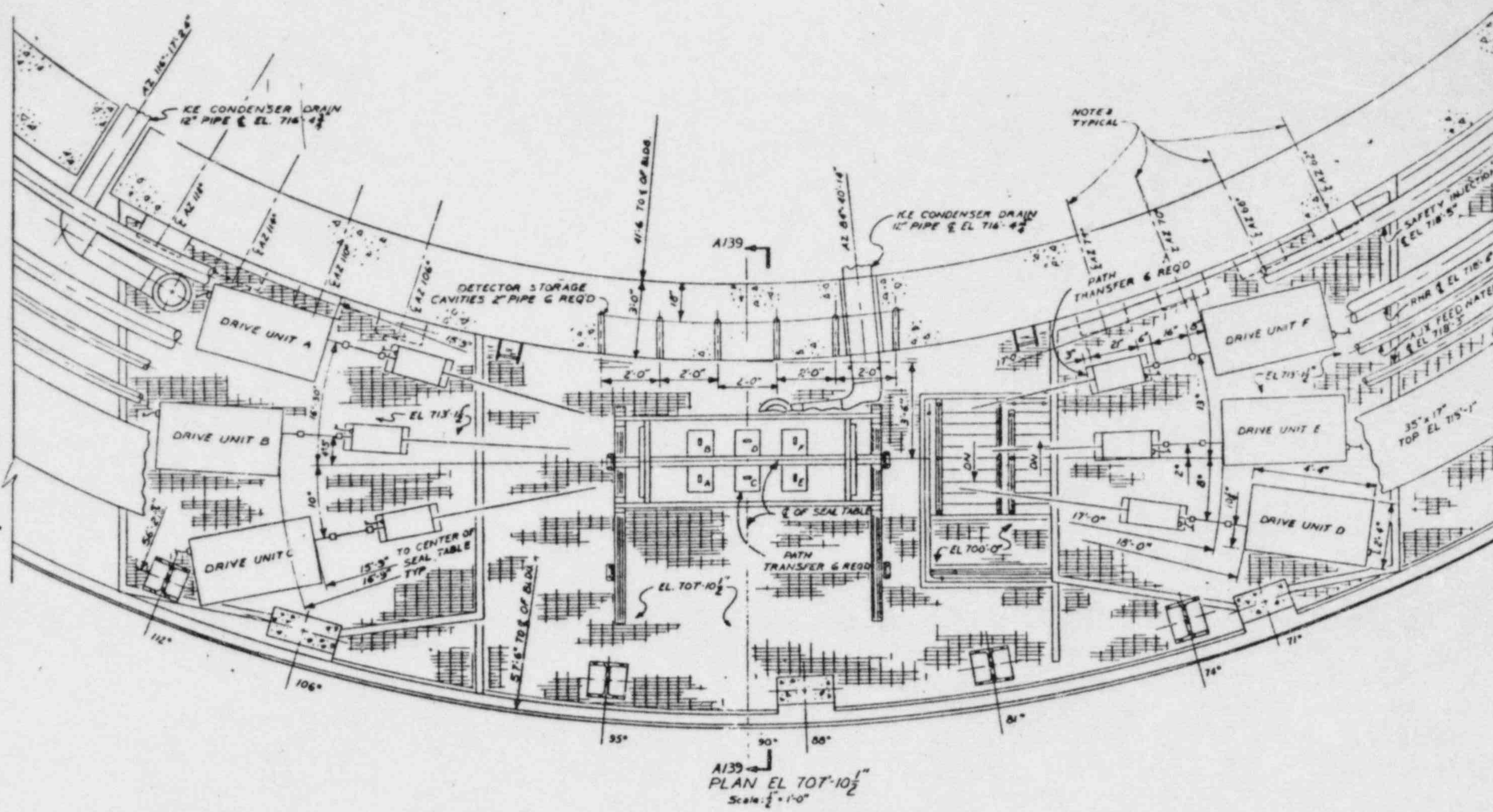
FIGURE 8



NOTE: THE SEAL TABLE PLATFORM AREA IS EQUIPPED WITH A HANDRAIL WHICH IS NOT SHOWN IN THIS DRAWING

LOCATION OF THE INCORE INSTRUMENTATION SYSTEM EQUIPMENT IN THE INSTRUMENT ROOM

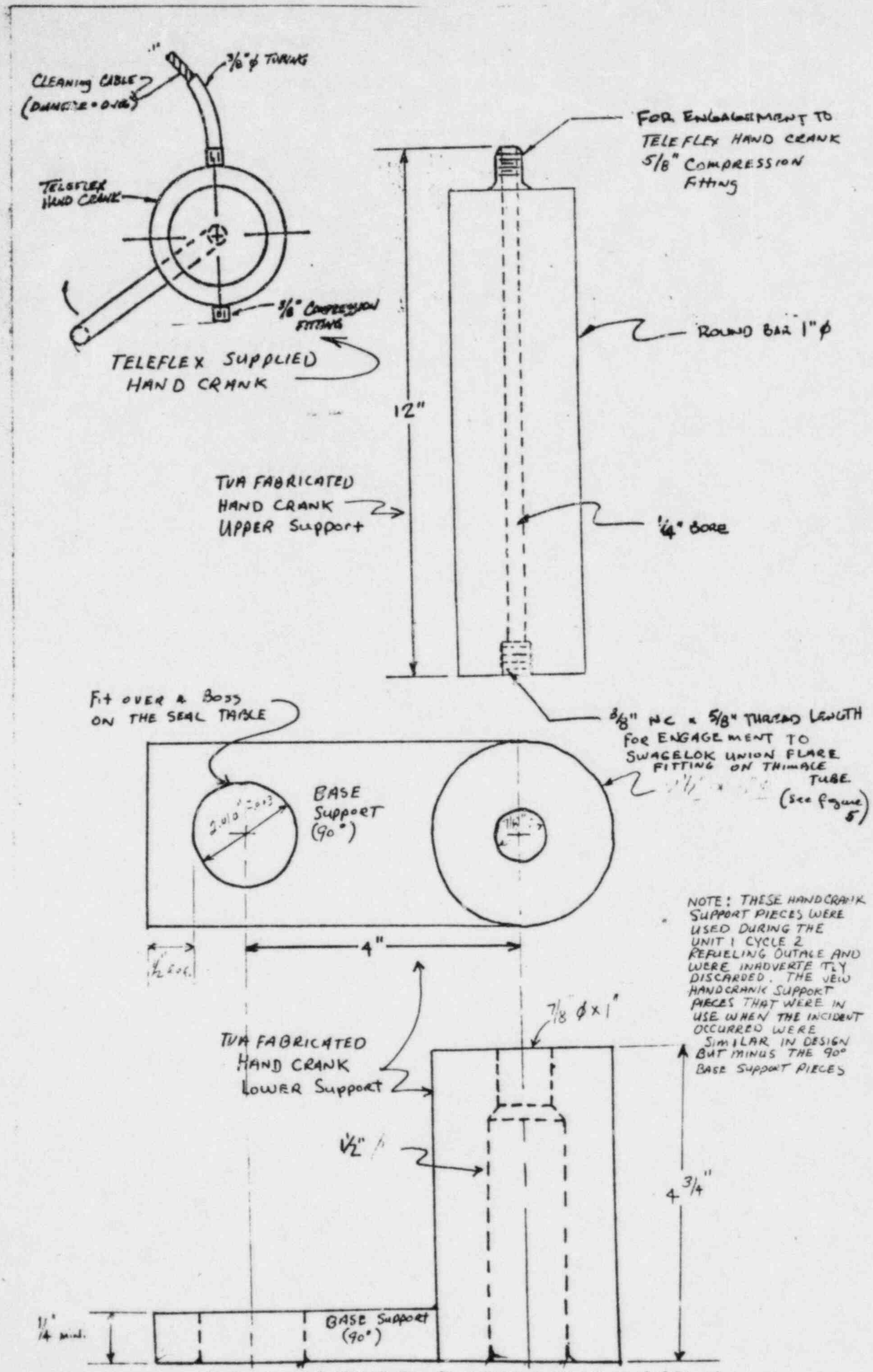
FIGURE 9



PLAN EL 707'-10½"
Scale: ¼" = 1'-0"

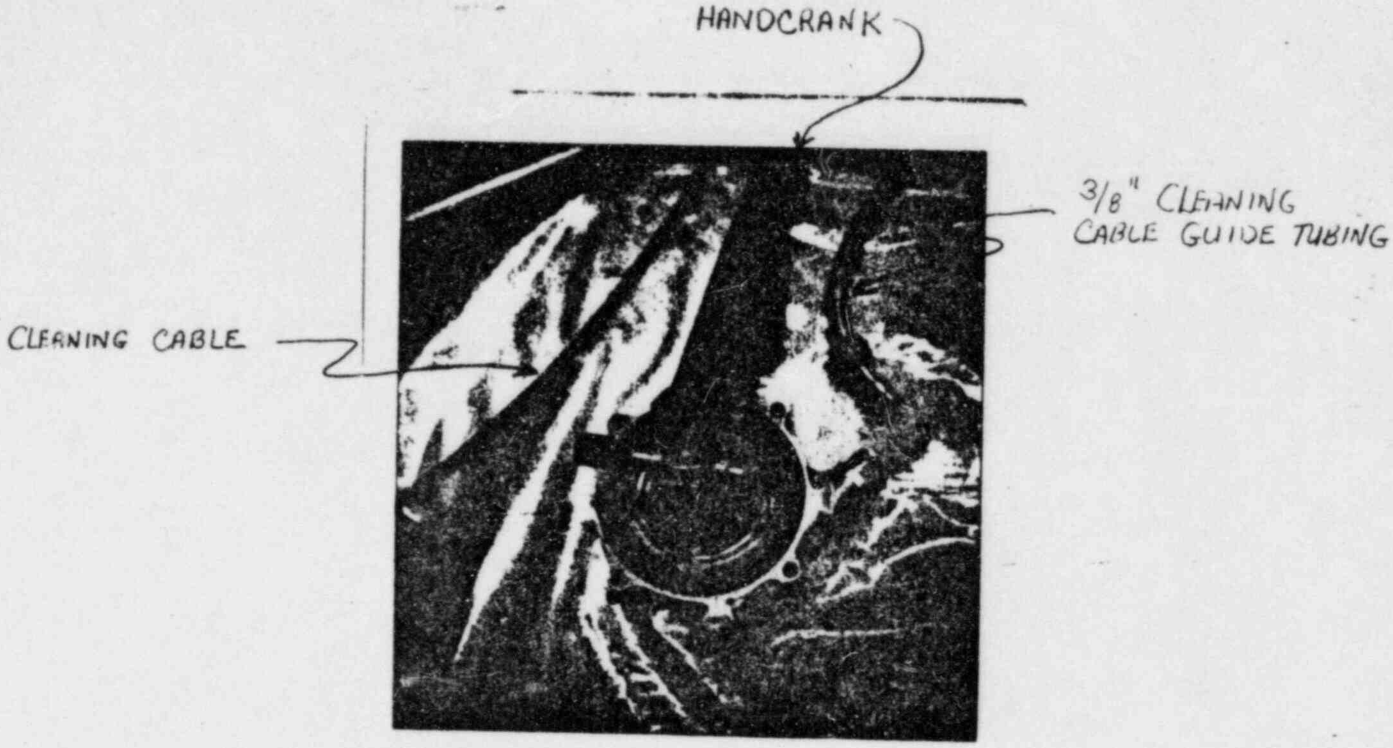
TOP VIEW OF THE INCORE INSTRUMENTATION EQUIPMENT IN THE INSTRUMENT ROOM

FIGURE 10



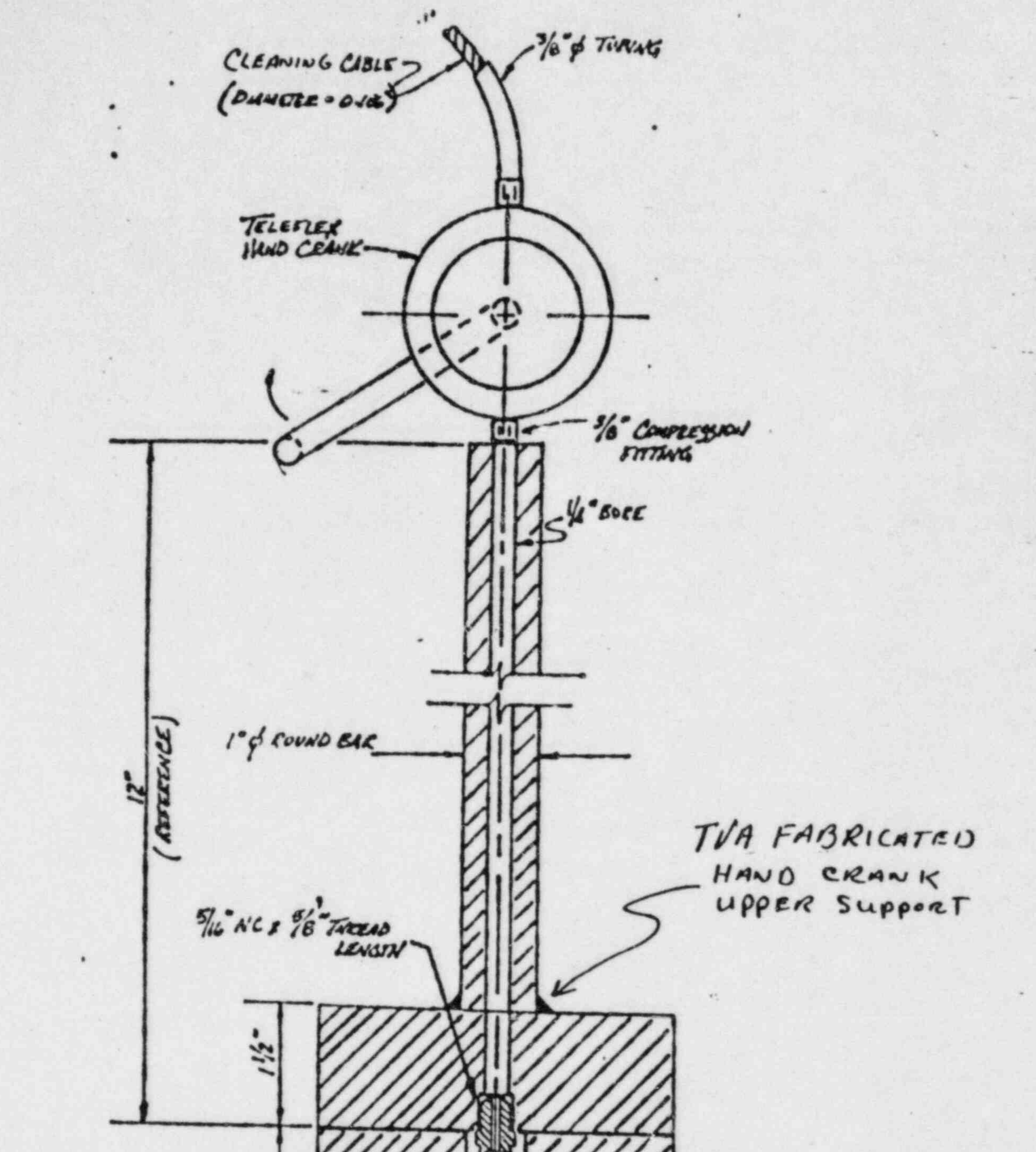
DRYBRUSHING CLEANING TOOL (TELEFLEX SUPPLIED HAND CRANK) AND TVA FABRICATED HANDCRANK UPPER AND LOWER SUPPORT PIECES

FIGURE 11A



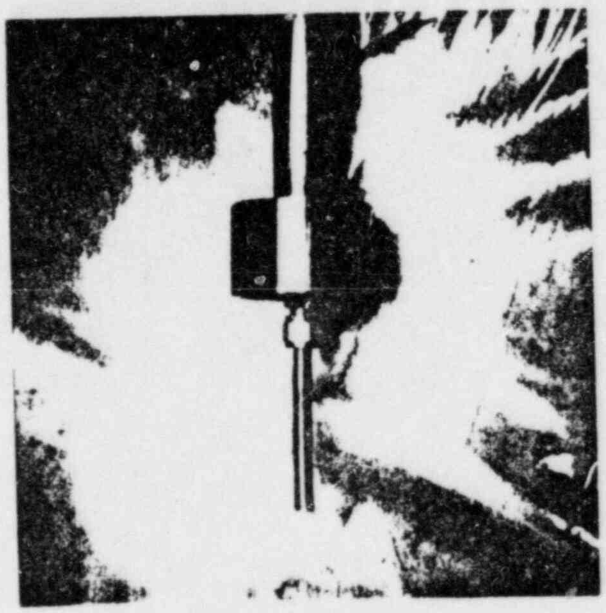
TELEFLEX SUPPLIED HANDCRANK
(DISASSEMBLED)

FIGURE 11B



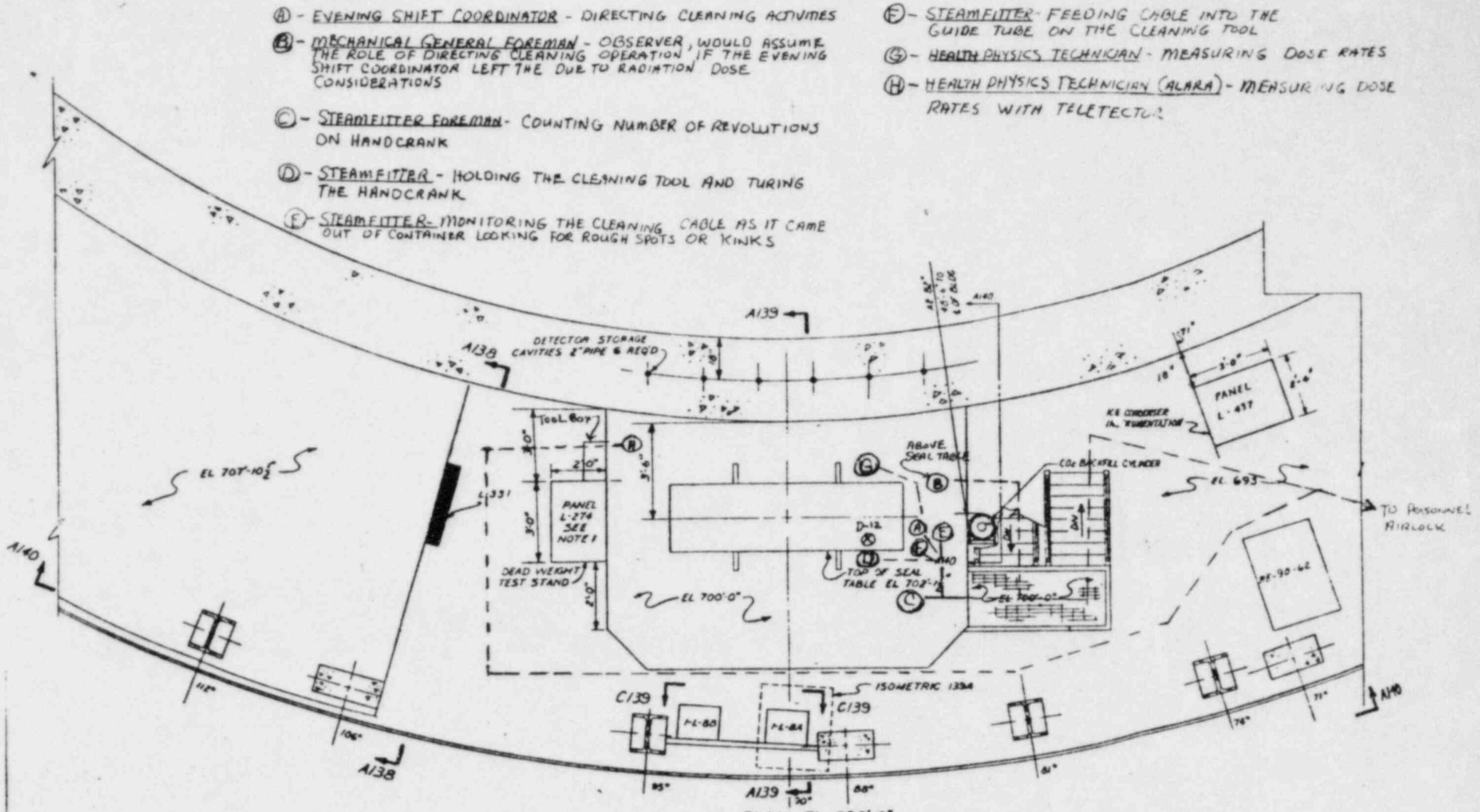
DRYBRUSHING CLEANING TOOL (TELEFLEX SUPPLIED HAND CRANK) AND TVA FABRICATED HANDCRANK UPPER AND LOWER SUPPORT PIECES IN USE WHEN THE THIMBLE TUBE WAS EJECTED

FIGURE 12 A



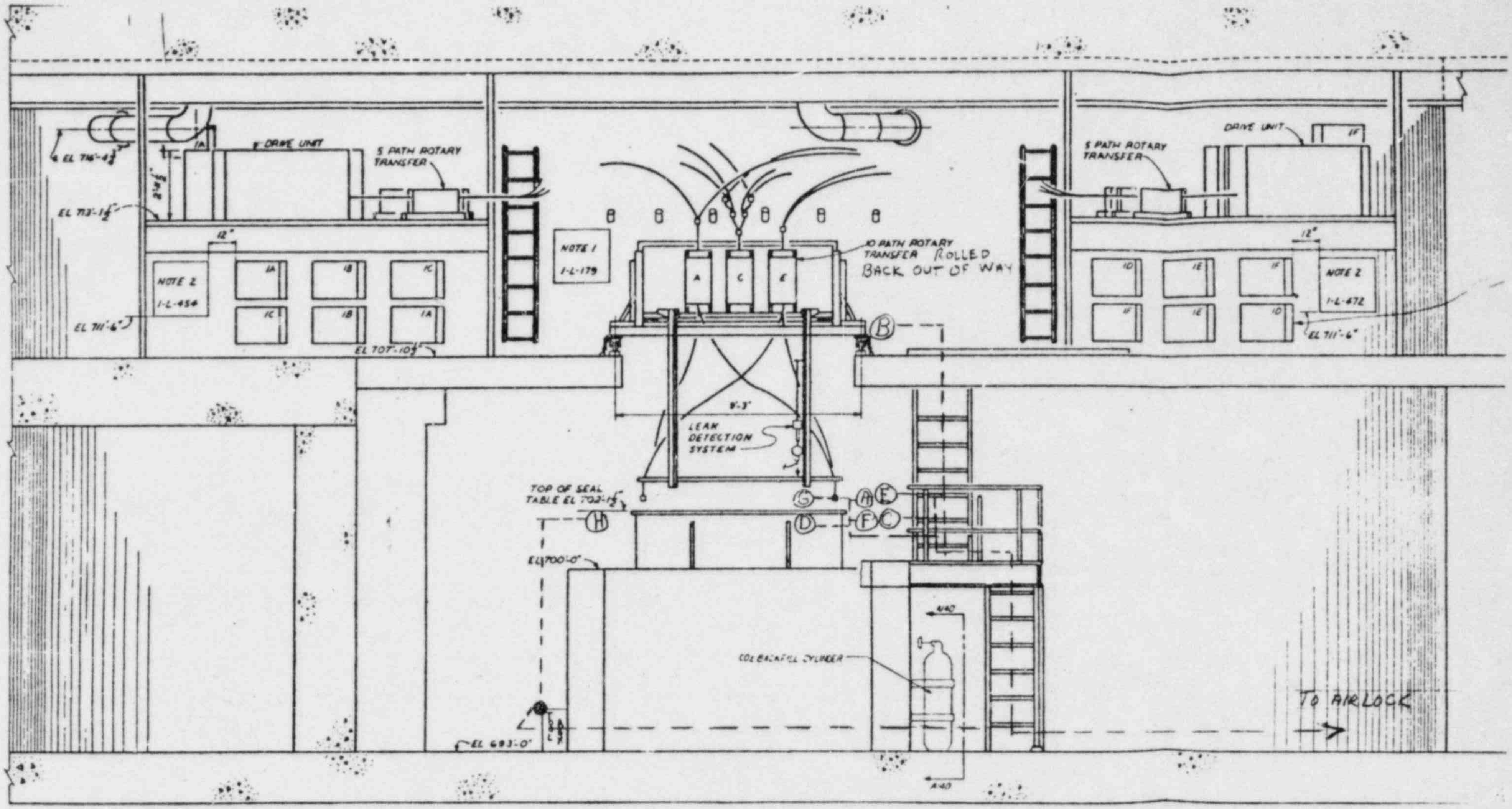
CLEANING TOOL UPPER BASE SUPPORT WITH
PART OF THIMBLE TUBE D-12 STILL ATTACHED
(AFTER THE INCIDENT)

FIGURE 12B



LOCATION OF WORKERS WHEN THE INCIDENT OCCURRED AND EGRESS ROUTES OUT OF THE INSTRUMENT ROOM

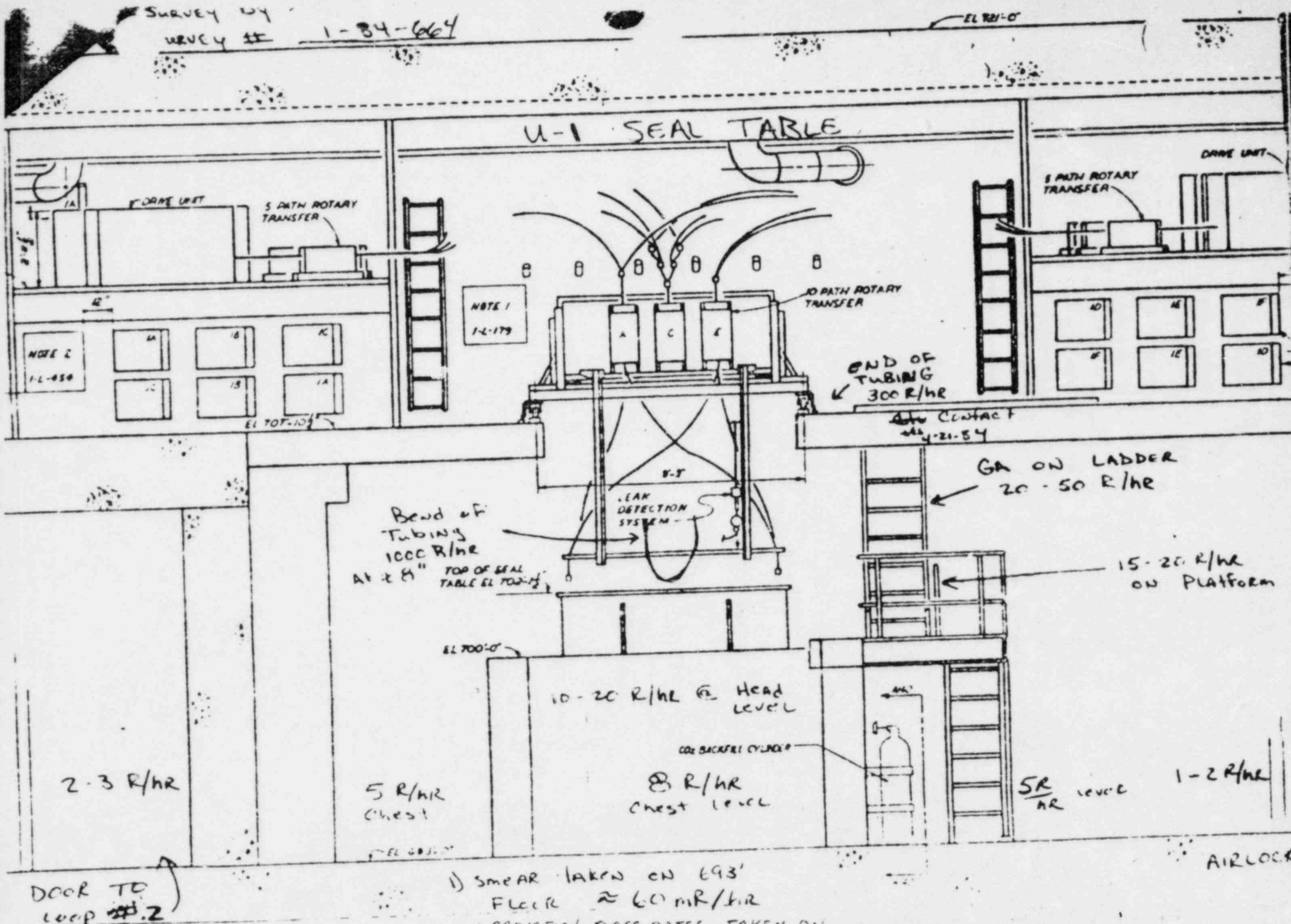
FIGURE 13A



NOTES (H) FLIPPED OR FELL OVER HANDRAIL, HIT TOOL BOX, AND RAN TO THE AIRLOCK

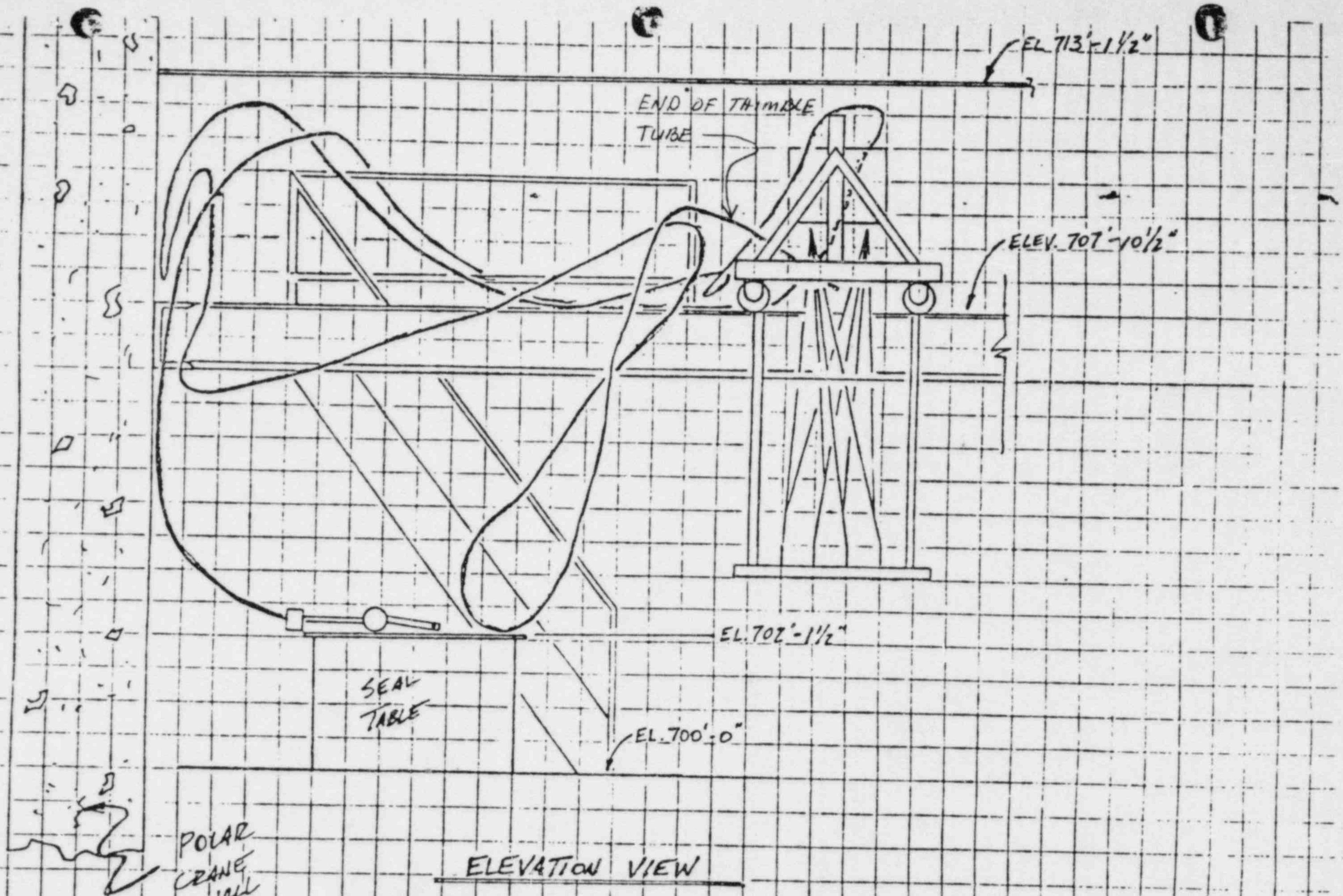
LOCATION OF WORKERS WHEN INCIDENT OCCURRED AND EGRESS ROUTES

FIGURE 13B



RADIATION DOSE RATES TAKEN ON INITIAL ENTRY TO THE INSTRUMENT ROOM

FIGURE 14

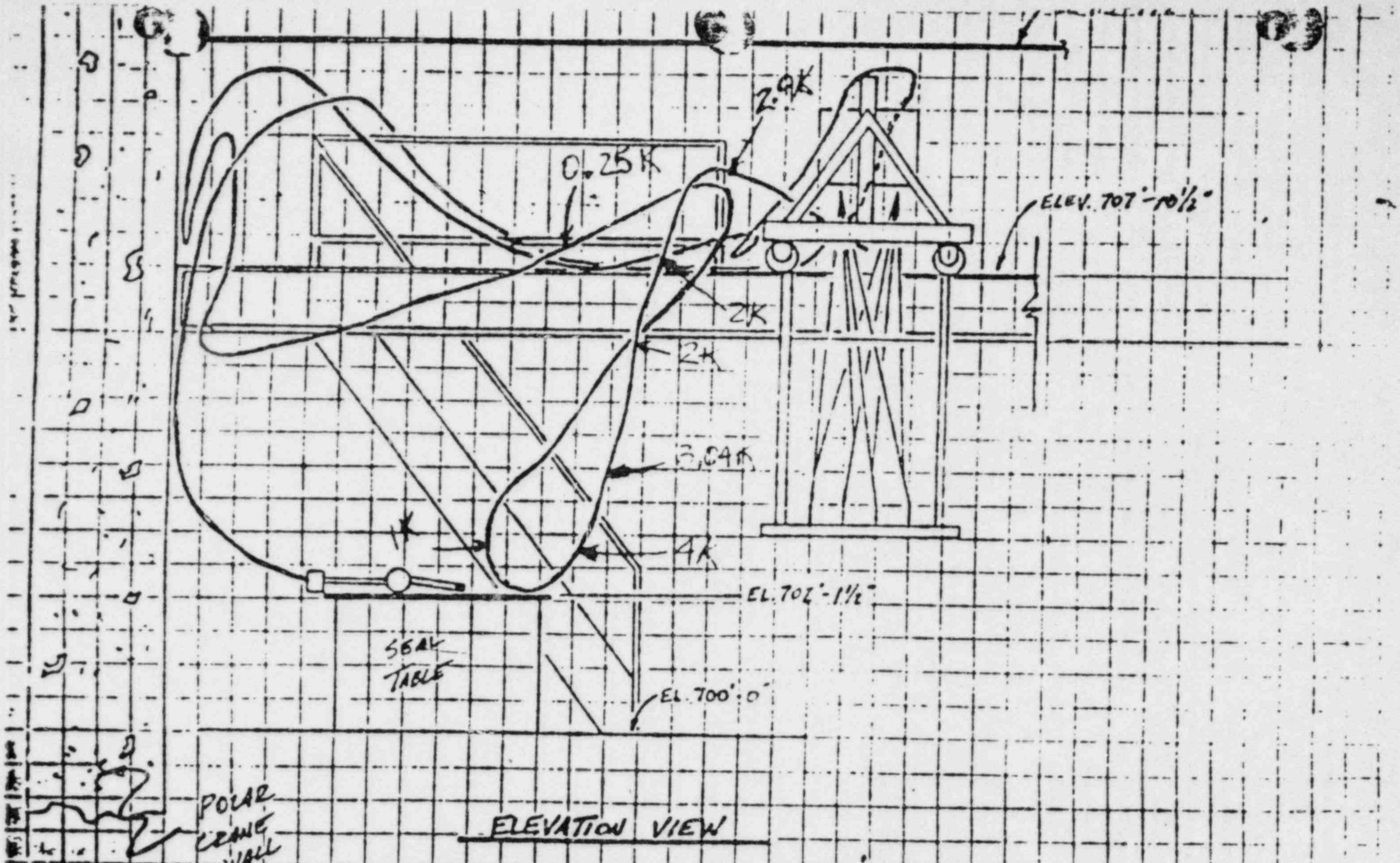


ELEVATION VIEW

(LOOKING TOWARD AIRLOCK)

REPRODUCED DRAWING OF EJECTED THIMBLE TUBE

FIGURE 15



ELEVATION VIEW

(LOOKING TOWARD AIRLOCK)

RADIATION DOSE RATES TAKEN ON EJECTED THIMBLE TUBE (REM/HOUR)

FIGURE 16

IOE ____

BMP ________

ATTACHMENT 1

TROJAN NUCLEAR PLANT

FLUX THIMBLE TUBE CLEANOUT AT FULL POWER

Gary Bair

INCIDENT:

On February 1, 1979 during a routine monthly flux map at 100% power (3411 MWT), block thimbles were discovered at 37 of 58 thimble locations. The blockages were at the bend minima.

HISTORY:

From the Trojan startup in December 1975 until the end of Cycle 1 in March 1978, fifty-three full core flux maps and numerous quarter-core maps had been taken with evidence of only one blocked thimble. Little or no neulube had been used.

The plant was shutdown from March 1978 until January 1979 for refueling/technical specifications and licensing intervention regarding seismic integrity. During the refueling, the tubes were evacuated, flooded with carbon dioxide, and capped off.

During the prolonged outage the flux mapping system was exercised every six weeks.

Between the start of the second cycle in January and the February blockage, nine full core flux maps and several quarter-core maps were taken with no significant problems encountered.

WORK PREPARATIONS:

Arrangements were made with Teleflex, the flux mapping system vendor to be on-site to assist in the brushing operation (using a 22-caliber rifle-cleaning, brass brush machined down to 20-caliber and welded to a dummy detector cable with a helical drive unit). Since Beaver Valley had also done a brushing at power, they were contacted to obtain general information. A ten-foot long, 1/2-inch rigid conduit was obtained to facilitate transfer of the wire brush between thimble locations. A funnel was made to facilitate brush entry into thimble.

Radiation control procedures were developed.

WORK OPERATION:

The flux mapping system moveable "bird cage" was disconnected and rolled out of the way.

The maintenance man with hand-operated helical drive, positioned himself above the seal table on the upper stationary mounting frame.

WORK OPERATION (Contd.):

He drove the brush through the rigid conduit into each thimble location for brushing.

A Radiation Control Technician used a vacuum cleaner to suck up airborne activity produced when the cable and brush were withdrawn.

The area radiation monitor alarmed when brush emerged from thimble into rigid conduit.

RADIATION CONTROL:

Contact radiation levels at brush: 60R/hr average
170R/hr maximum

Prime activation product was copper in brush.
(NOTE: Brush during shutdown cleaning 450 mr on contact)

Contact radiation level on cable: 5R/hr

A vacuum cleaner was used to collect airborne particulate from brush and cable as they were withdrawn from the thimble.

Airborne levels 1.5 MPC were measured when vacuum not held close to source.

Eventually levels were held to 0.3 MPC when improved vacuum cleaner suction maintained.

All personnel wore respirators.

Personnel Exposures

Disassembly	85 m-mr gamma, 10 m-mr neutron
Brushing	2109 m-mr gamma, 74 m-mr neutron highest man - 685 mr, average man - 168 mr
Reassembly	73 m-mr gamma, 17 m-mr neutron
Total Evolution	2267 m-mr gamma, 101 m-mr neutron

(Note total dose for brush and flush at shutdown was 260 mrem.)

SUGGESTIONS:

1. Consider utilizing a brush which does not contain copper if possible. Teleflex recommended bronze, and said stainless-steel is too hard for soft tube. Brush must be brazed on, not just screwed on.

2. Use airfed hood respirators rather than masks for personnel comfort.

3. Use a 12-foot rigid conduit rather than the 10-foot conduit if enough overhead space is available.

4. Consider a motorized helical drive, but be aware of kink potential on hitting obstruction.

5. Provide a support platform for helical drive operator above seal table.

6. Consider routine brushing and flush at refueling shutdowns.

7. Inspect and replace excessively rusting drive cables even if detector still good.

8. During prolonged outage, withdraw detectors back past safety limit switch into heated and shielded drive housing.

9. Use no neulube.

10. Exercise system monthly.

ATTACHMENT 2
INPO ENTRY

RETRIEVE MESSAGES>ALL SUBJECT "THIMBLE TUBE", "SEAL TABLE"

>TEXT "THIMBLE TUBE", "SEAL TABLE" END

OM 514 HALL (PSE&G/SALM) 03-MAY-83 10:59
SUBJECT: INCORE THIMBLE TUBE BLOCKAGE
SALEM UNITS: 4 LOOP WESTINGHOUSE PWRS

TO ALL OPERATING PLANTS:

SALEM UNITS HAVE ENCOUNTERED PROBLEMS WITH THE INCORE DETECTOR SYSTEM OVER THE YEARS. ONE RECURRING PROBLEM IS THE BLOCKAGE OF THE "THIMBLE TUBES" WHICH ARE THE ACCESS PATH FOR THE MINATURE DETECTORS TO REACH THE REACTOR CORE. BLOCKAGES TEND TO BUILD UP IN THESE TUBES AT THE POINT WHERE THEY ENTER THE REACTOR VESSEL. AT THIS AREA THE TUBES GO FROM A RELATIVELY COOL TEMPERATURE (~ 100 DEGREES FAHRENHEIT) TO REACTOR COOLANT SYSTEM TEMPERATURES (~ 550 DEGREES FAHRENHEIT). THESE BLOCKAGES STOP THE DETECTOR/DRIVE CABLE ASSEMBLIES FROM ENTERING THE CORE REGION. LIKE SALEM, MANY WESTINGHOUSE PLANTS HAVE BEEN IN A CONDITION WHERE THEY COULD NOT MEET THE TECHNICAL SPECIFICATION REQUIREMENT FOR 75% OF THE THIMBLES USEABLE.

TO DISCOVER THE SOURCE OF THESE BLOCKAGES SALEM PERSONNEL RECENTLY REMOVED TWO THIMBLE TUBES FROM UNIT 2 THAT WERE KNOWN TO BE BLOCKED. SEVERAL 3 FOOT LONG SAMPLES OF THESE TUBES WERE OBTAINED CONTAINING THE BLOCKAGE. TECHNIQUES WERE USED TO ENSURE THAT NO WATER ENTERED THE TUBES. SALEM STATION IS PRESENTLY RECEIVING PROPOSALS FOR ANALYSIS OF THESE TUBE SECTIONS. ONCE THE ANALYSIS OF THESE SAMPLES IS RECEIVED WE WILL MAKE THE RESULTS KNOWN VIA NOTEPAD, HOPEFULLY DURING THE SUMMER OF 1983.

ALSO, THESE BLOCKAGES HAVE BEEN SUCCESSFULLY REMOVED AT SALEM WITH THE UNIT AT FULL POWER. BY PROBING THE THIMBLE TUBES WITH A TEST CABLE (NO DETECTOR) THE BLOCKAGES CAN BE KNOCKED LOOSE AND GROUND UP. THIS IS DONE MANUALLY FROM INSIDE THE CONTAINMENT NEAR THE SEAL TABLE. WE REMOVE THE INPUT TUBE FROM A 10 PATH TRANSFER DEVICE AND ATTACH A TELEFLEX HAND DRIVE WITH A TEST CABLE LOADED INTO IT. WE DRIVE THE CABLE TO THE AREA OF THE BLOCKAGE AND "PUSH" IT OUT OF THE WAY. CARE MUST BE TAKEN NOT TO DRIVE THE CABLE INTO THE CORE REGION AS IT WILL ACTIVATE THE CABLE VERY QUICKLY (ABOUT 100 R/HR WHEN RETURNED). WE MEASURE THE CABLE INSERTED LENGTH BY COUNTING THE TURNS ON THE MANUAL DRIVE HAND CRANK (1 TURN PER FOOT OF CABLE). WE DRIVE IT UNTIL WE REACH A DISTANCE THAT IS SIX FEET FROM THE CORE. AFTER RETRACTION THE 10 PATH CAN BE ROTATED TO THE NEXT PATH OF INTEREST AND THE PROCESS REPEATED. THIS IS EASY FOR US SINCE OUR 10 PATH DEVICES ARE LOCATED IN AN AREA OF LESS THAN 1 MR/HR AT FULL POWER.

FOR FURTHER INFORMATION CONTACT JEFF JACKSON, SALEM OPERATIONS, AT (609) 339-4472.

INFORMATION CONTACT:

TENNESSEE VALLEY AUTHORITY
Sequoyah Nuclear Plant
Post Office Box 2000
Soddy Daisy, Tennessee 37379

October 11, 1984

U.S. Nuclear Regulatory Commission
Document Control Desk
Washington, DC 20555

Gentlemen:

TENNESSEE VALLEY AUTHORITY - SEQUOYAH NUCLEAR PLANT UNIT 1 - DOCKET NO. 50-327 - FACILITY OPERATING LICENSE DPR-77 - REPORTABLE OCCURRENCE REPORT SQRO-50-327/84030, Revision 1

The enclosed revised licensee event report provides additional details concerning ejection of one incore detector thimble tube. This event was originally reported in accordance with 10 CFR 50.73, paragraph a.2.i and a.2.iv.

Very truly yours,

TENNESSEE VALLEY AUTHORITY

P.R. Walla

P. R. Wallace
Plant Manager

Enclosure
cc (Enclosure):

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Atlanta, Georgia 30323

Records Center
Institute of Nuclear Power Operations
Suite 1500
1100 Circle 75 Parkway
Atlanta, Georgia 30339

NRC Inspector, NUC PR, Sequoyah

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