d. <u>Issue of Hold Order to Person Responsible for the Work</u>

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. <u>Work Activities Related to the Thimble Tube Cleaning Prior to the Accident</u>

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

1. <u>Work Activities During the Evening of April 18 to Approximately 0830 on April 19</u>

a. <u>Fabrication of New Support for the Cleaning Tool</u>

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. <u>Note</u>: 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. <u>Work Activities from 0830 on April 19 until Approximately 1700 on April 19</u>

a. <u>Initial Cleaning of Five Thimble Tubes - 0830-1115 April 19</u>. 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 (~ 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.

<u>Note</u>: 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. Welding Operation in Personnel Airlock During Work Being Performed in the Instrument Room. 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. <u>ALARA Preplanning 1115-1520 on April 19</u>

(1) <u>SQN ALARA Policy</u>. 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 <u>as low as reasonably achievable</u>. 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 <u>potentially</u> 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 <u>prior</u> to job commencement.

(2) Processing of Attachment I to RCI-10

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" Note: 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." Note: 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."

  Note: 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 (~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 (~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 blowing 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. <u>Worker Actions Immediately After the Accident</u> (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. <u>Recovery of the Ejected Thimble Tube</u>

a. <u>NUC PR Area Plan Procedure No. 1200A12, "Emergency Project Management"</u>. 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. <u>Project Manager's Initial Interface with Plant Management</u>. 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. Planning and Preparation for the Recovery Effort

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.

Note: 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 ca[illegible] 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. <u>Note</u>: 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 on 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. <u>Installation of a New Thimble Tube Into Guide Tube D-12</u>
On April 26 an instruction (SMI-1-94-5, "Thimble Tube Installation") 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. <u>Return of SQN Unit 1 to Power Operations</u>

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. <u>Conduct of the NUC PR Accident Investigation</u>. 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.

Note: 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.

  Note: 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).

  Note: 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.

  Note: 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

<u>Note</u>: 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. <u>SQN Employee Expression of Concerns Before and During the Cleaning Activity</u>

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. <u>Program Controls Established by SQN Unit 1 Technical Specifications</u>

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

1. <u>Section 6.2.3, "Independent Safety Engineering Group (ISEG)"</u>. Section 6.2.3 states that the ISEG shall function to <u>examine</u> 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. Section 6.5.1, "Plant Operations Review Committee (PORC)"

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. Section 6.8, "Procedures and Programs"

a. Section 6.8.1.a. 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. Section 6.8.2. 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. Section 6.8.3. 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 Implementation 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 facility. 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. <u>Corporate</u>

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. <u>Office of Power</u>

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. <u>Division of Nuclear Power</u>

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	C. 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. <u>Watts Bar Nuclear Plant</u>

1. Standard Practice WB6.5.1, "Engineer Assignment to Plant Systems and Equipment," March 14, 1984

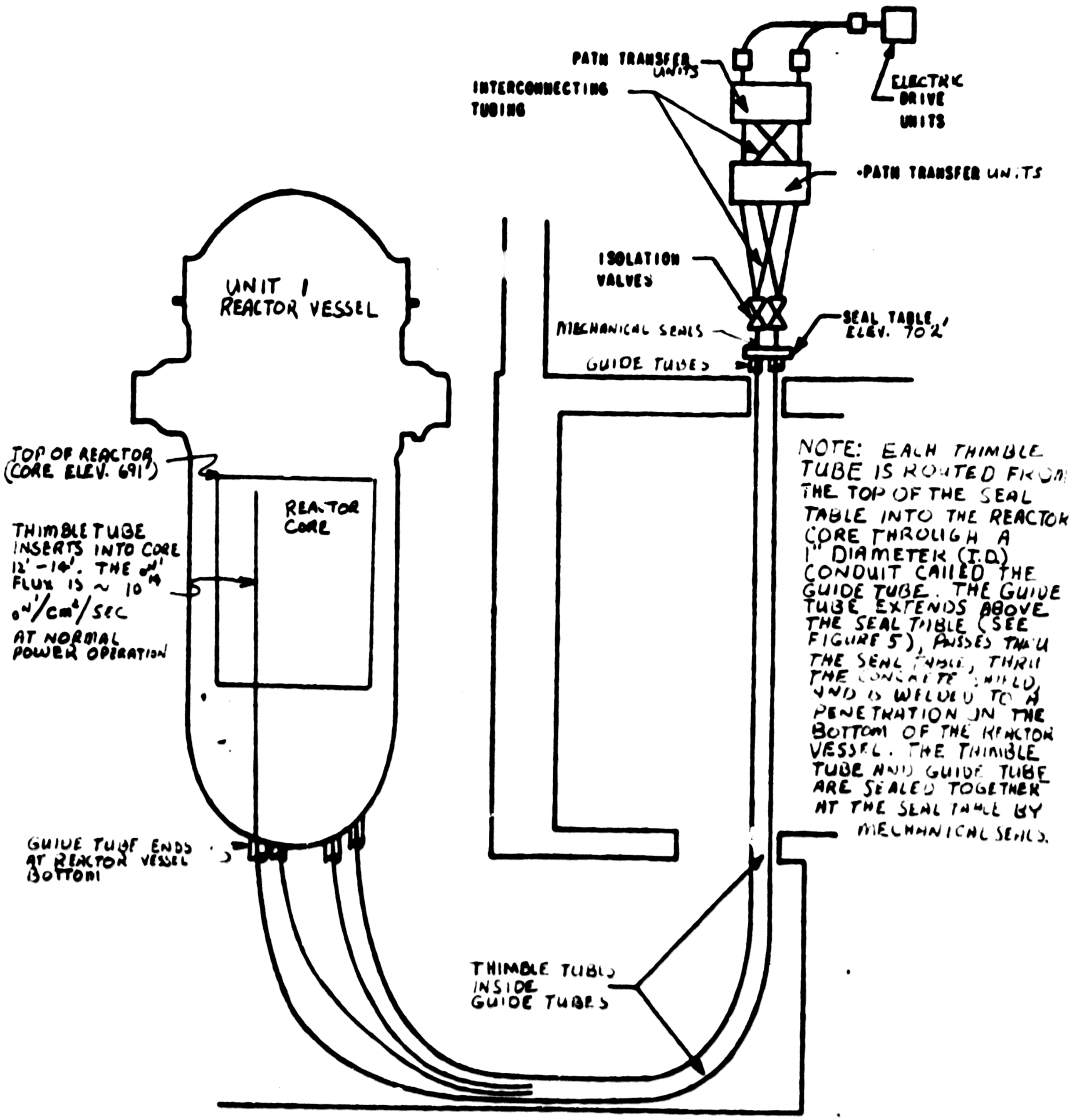
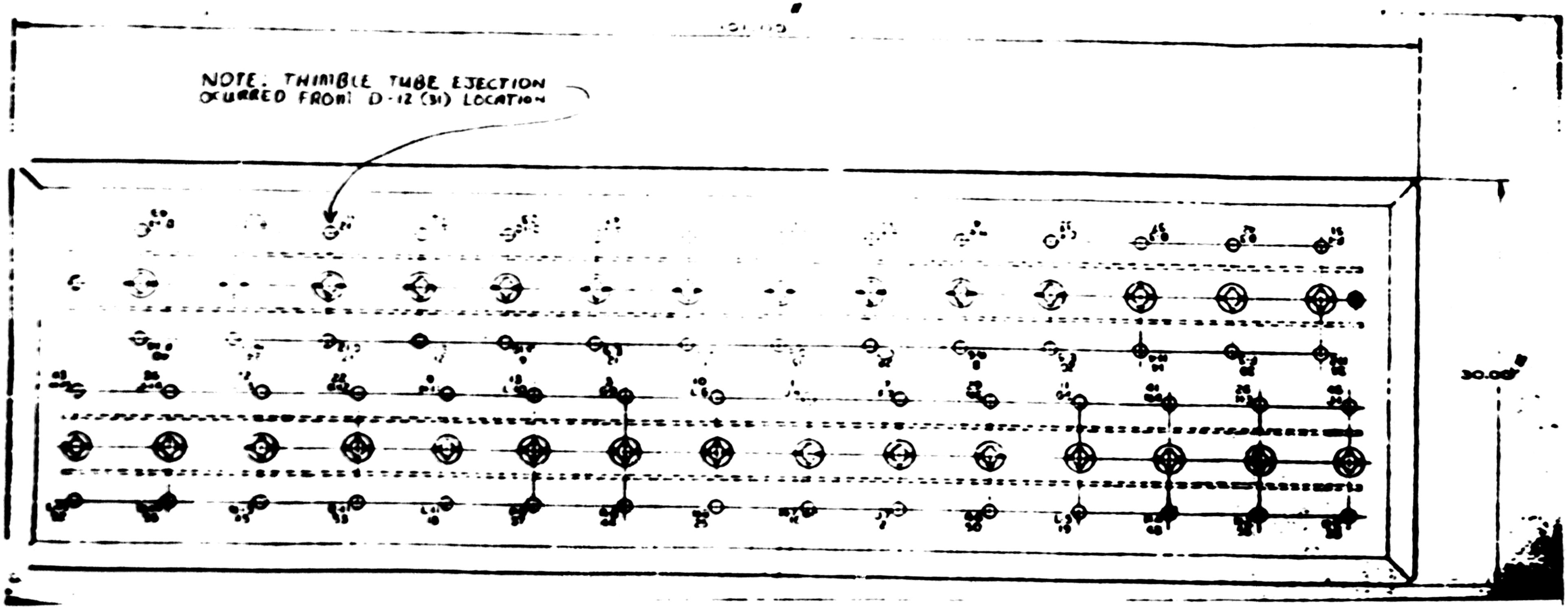


FIGURE 1 INCORE DETECTOR SYSTEM

VIEW N-N (TOP)

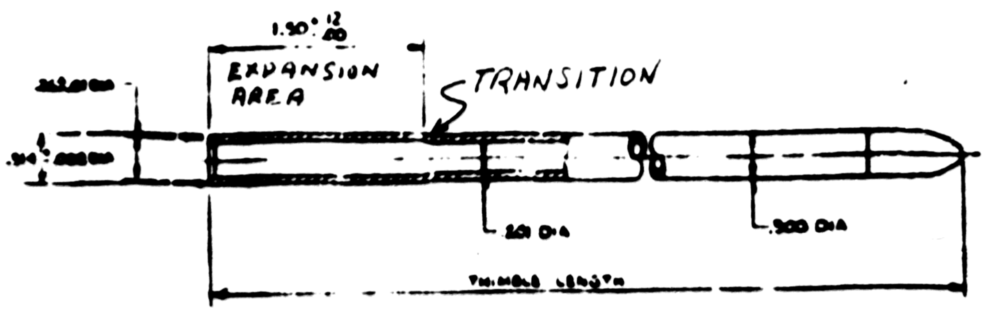


POLAR CRANE WALL

SEAL TABLE
FIGURE 2

SEAL TABLE END

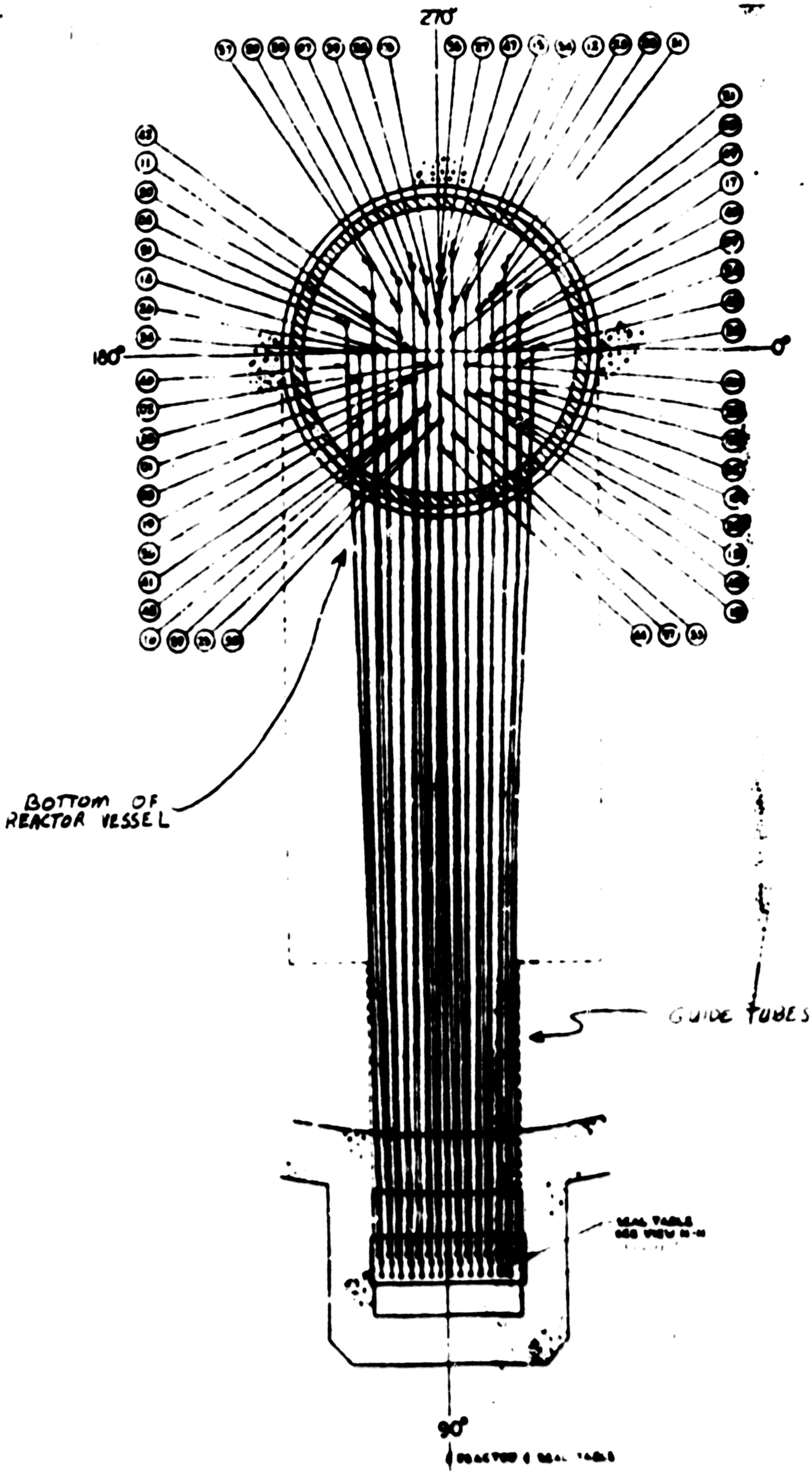
REACTOR CORE END



LENGTHS VARY FROM 10? to 11? FEET

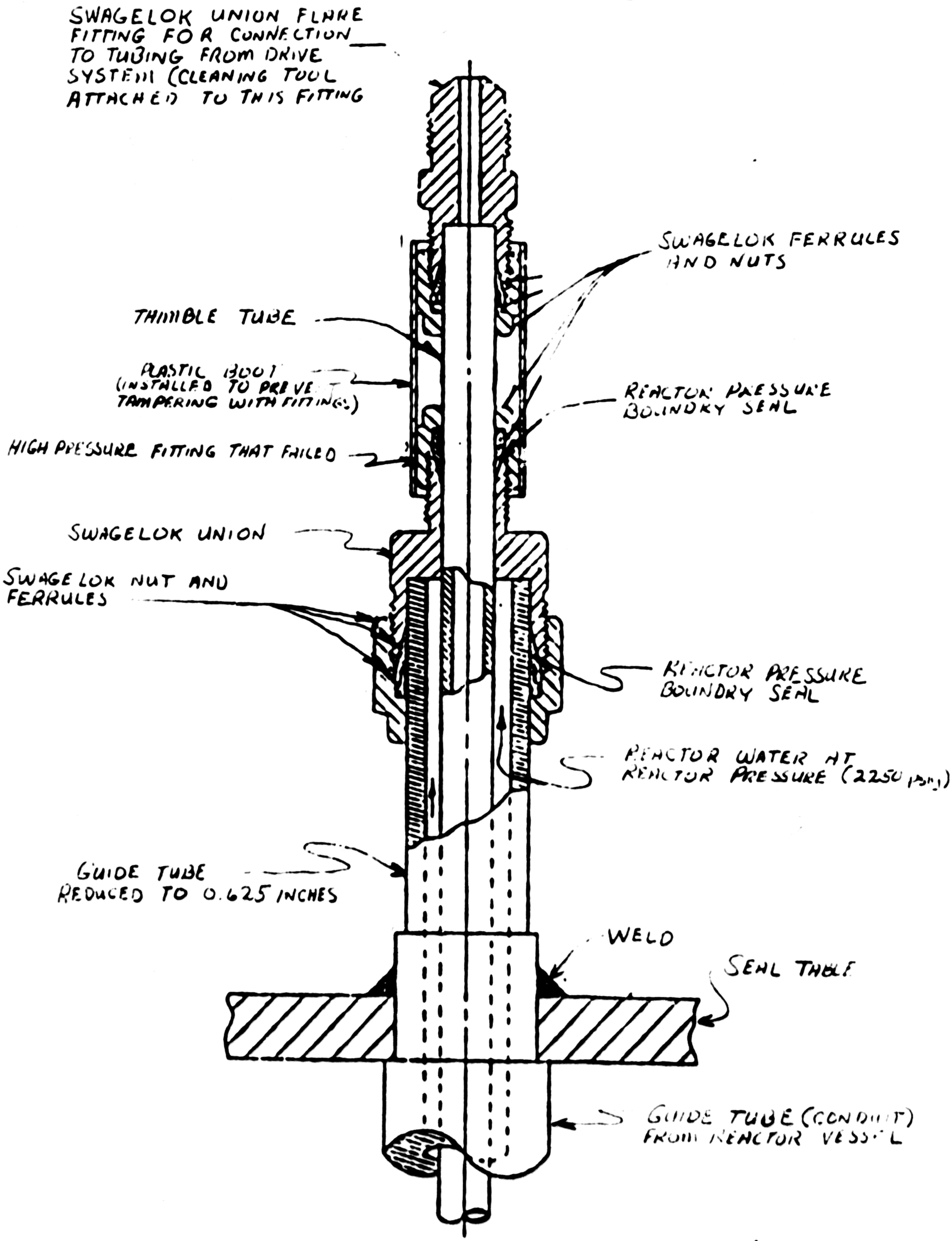
THIMBLE TUBE (SHOWING DESIGN AND EXPANSION FOR MECHANICAL SEALS AT THE SEAL TABLE)

FIGURE 5



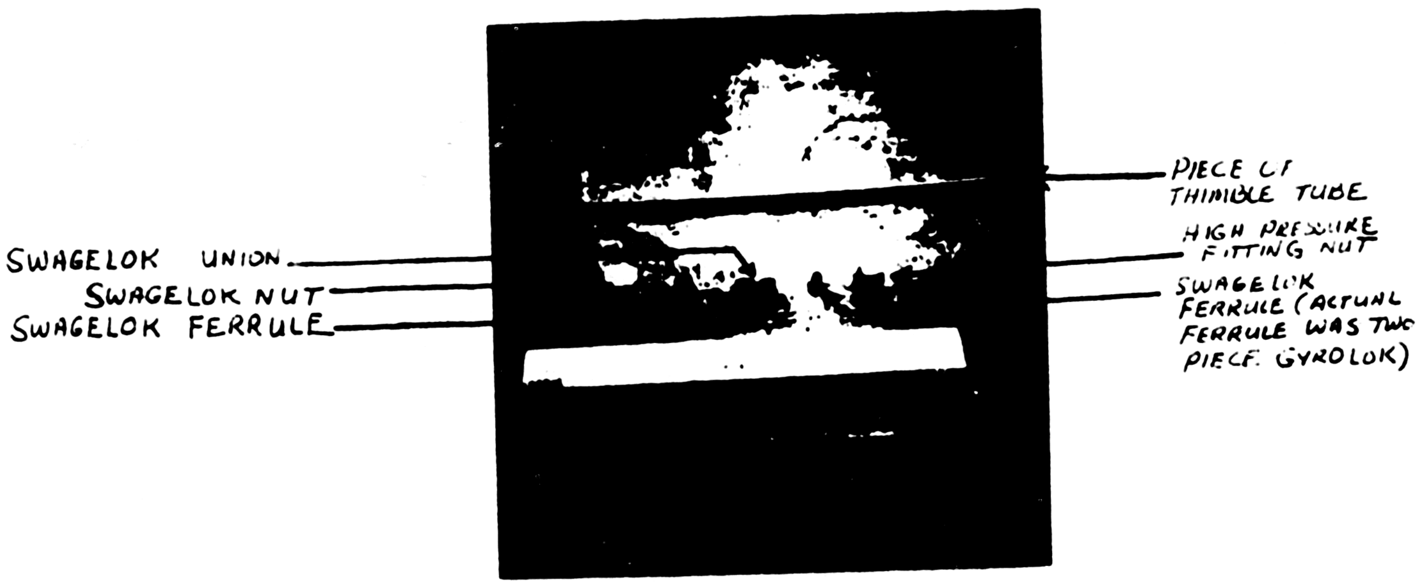
CONFIGURATION SHOWING GUIDE TUBES
AND RESPECTIVE THIMBLE TUBES

FIGURE 4



THIMBLE TUBE MECHANICAL SEALS

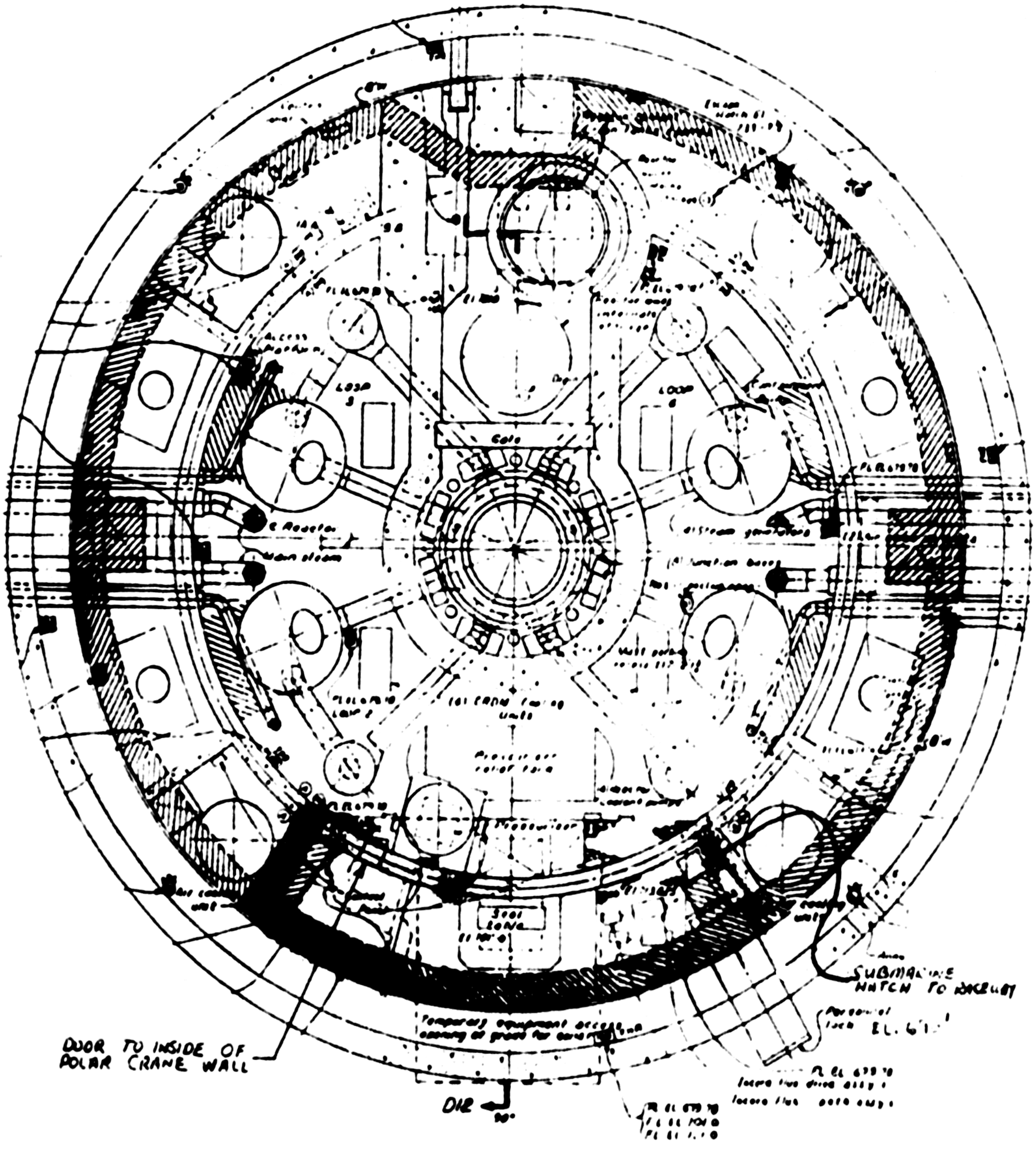
FIGURE 5



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

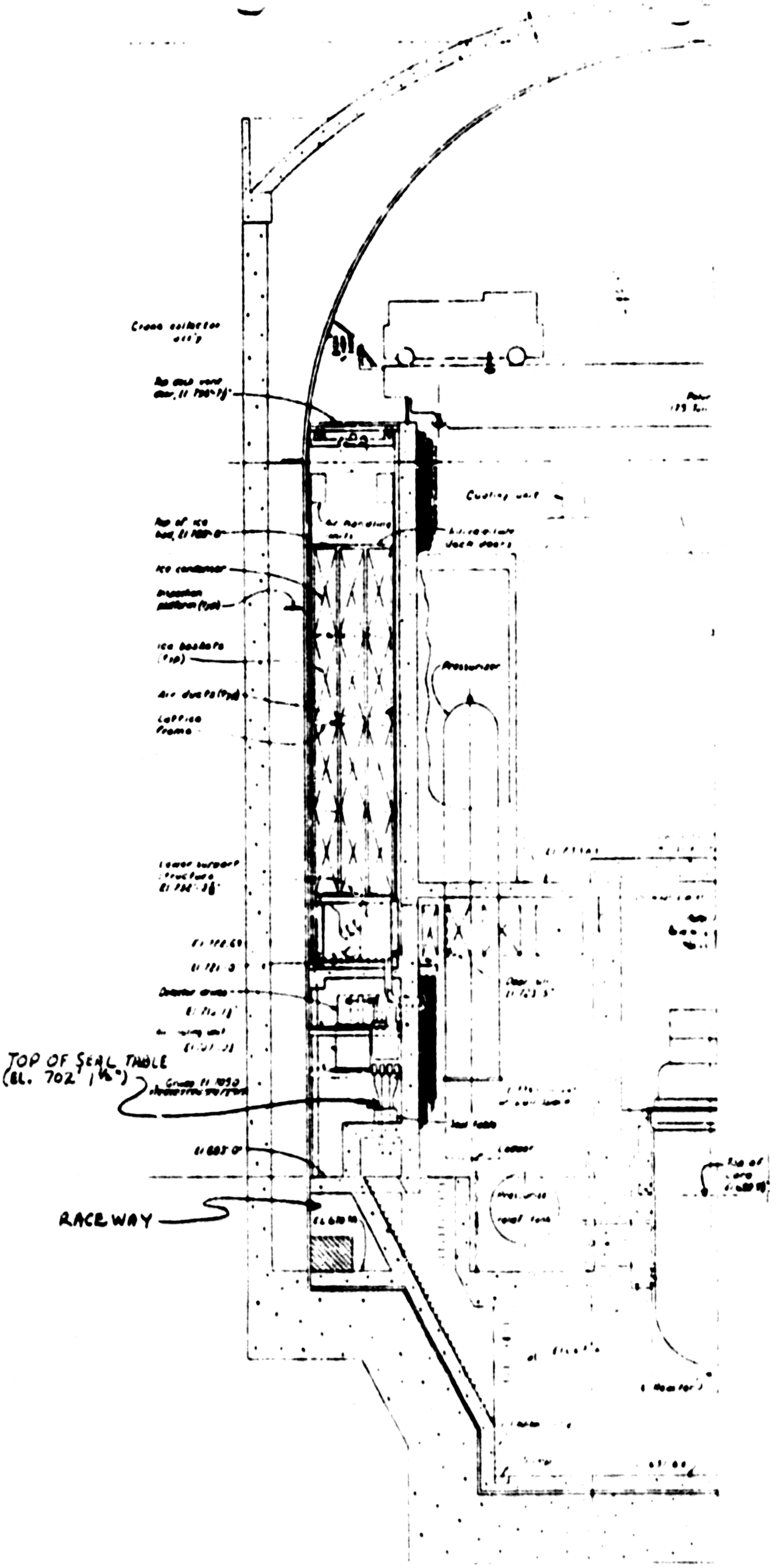
VIEW FROM INSIDE THE REACTOR BUILDING CONTAINMENT

HANDWHEELS TO OPEN AND CLOSE INNER AND OUTER DOORS

INSIDE AIRLOCK IS EQUIPPED WITH A TELEPHONE

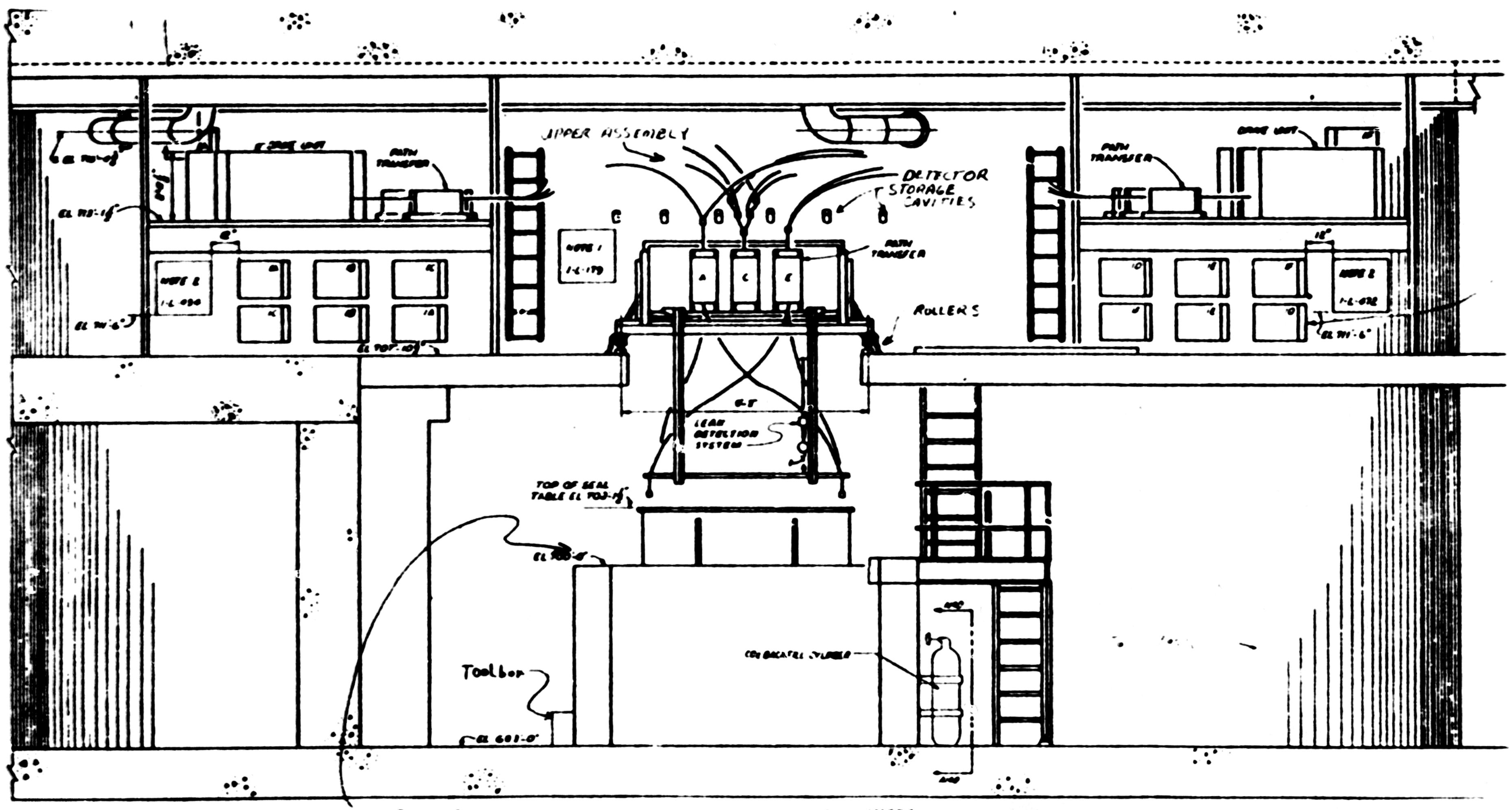
WATTS BAR NUCLEAR PLANT PERSONNEL AIRLOCK DOOR (SIMILAR TO THE SQN EL 690' AIRLOCK)

FIGURE 7B



ELEVATION DRAWING OF THE REACTOR BUILDING

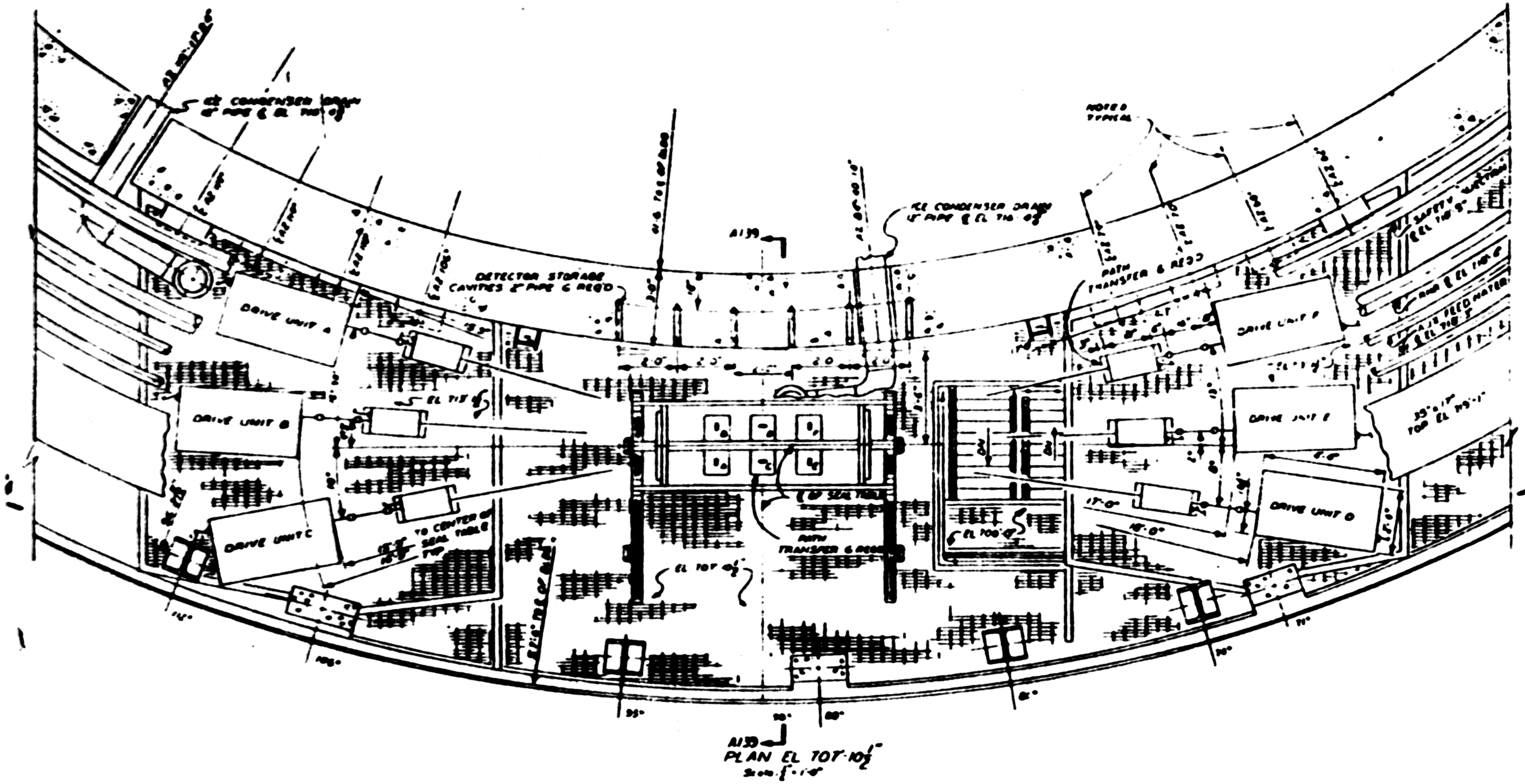
FIGURE 8



NOTE: THE SEAL TABLE PLATFORM AREA IS EQUIPPED WITH A HANDRAIL WHICH IS NOT SHOWN IN THIS DRAWING

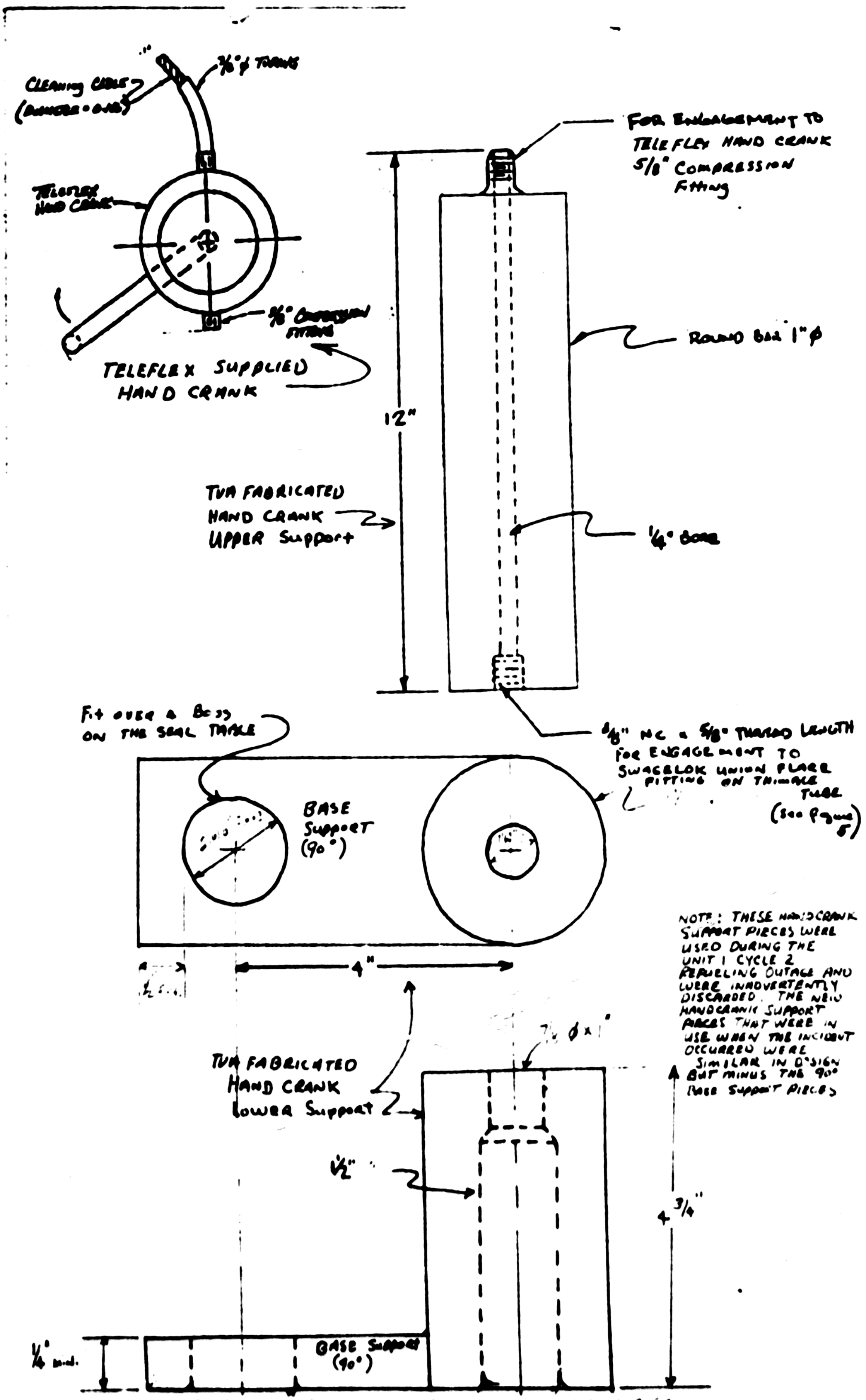
LOCATION OF THE INCORE INSTRUMENTATION SYSTEM EQUIPMENT IN THE INSTRUMENT ROOM

FIGURE 9



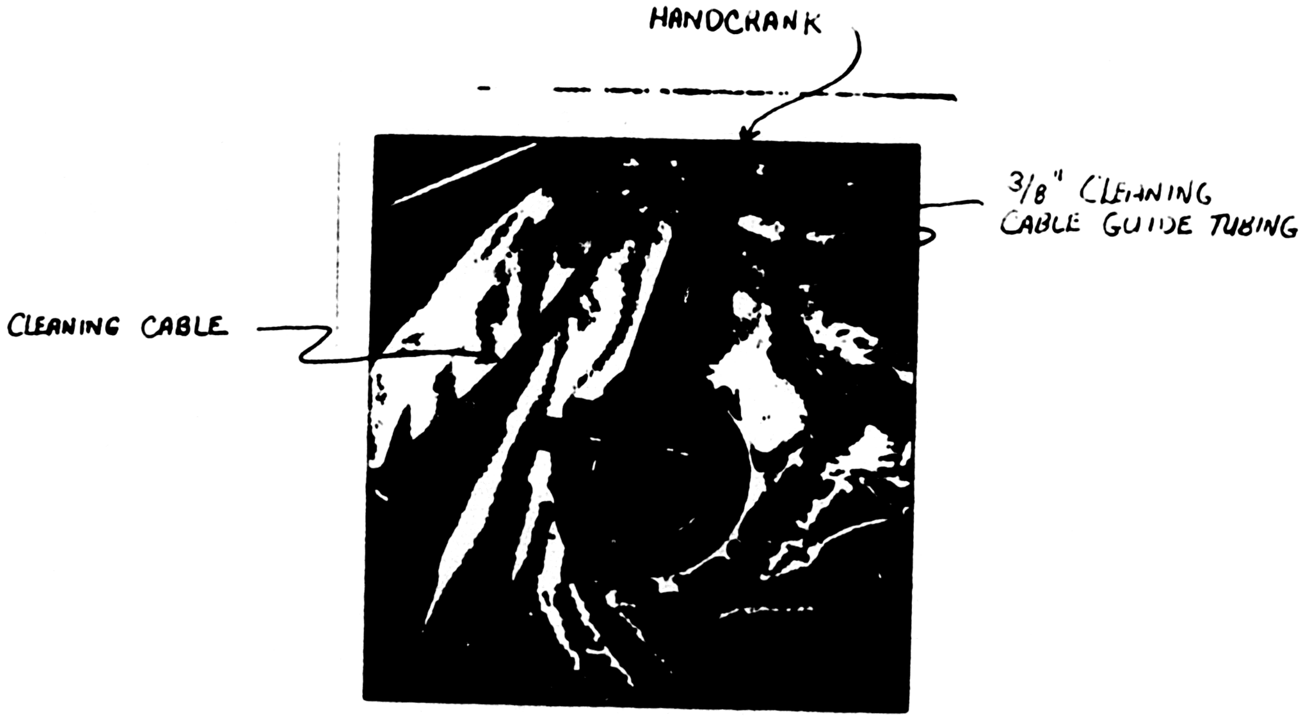
TOP VIEW OF THE INCORE INSTRUMENTATION EQUIPMENT IN THE INSTRUMENT ROOM

FIGURE 10



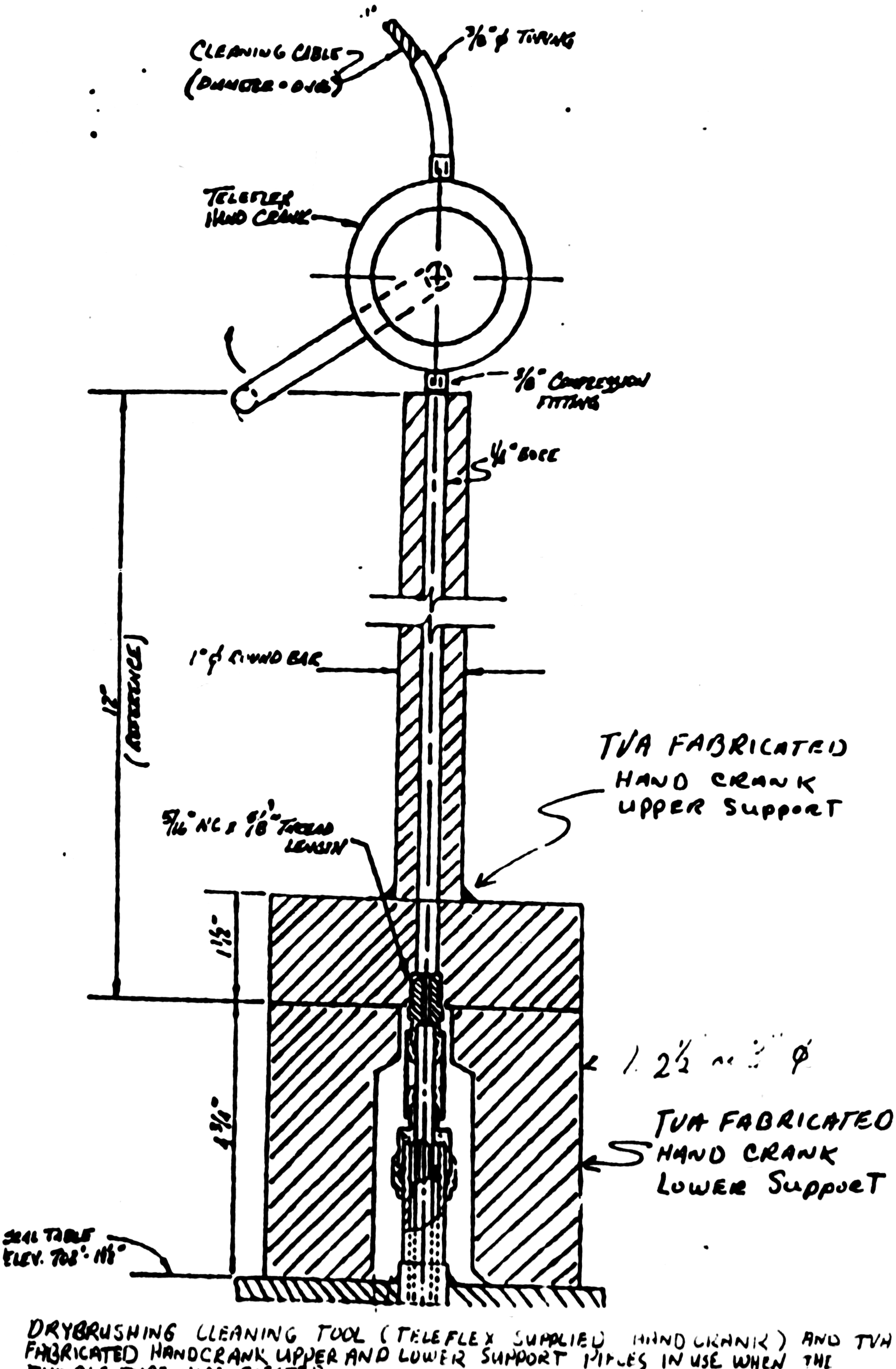
DRYBRUSHING CLEANING TOOL (TELEFLEX SUPPLIED HAND CRANK) AND TVA FABRICATED HANDCRANK UPPER AND LOWER SUPPORT PIECES

FIGURE 11A



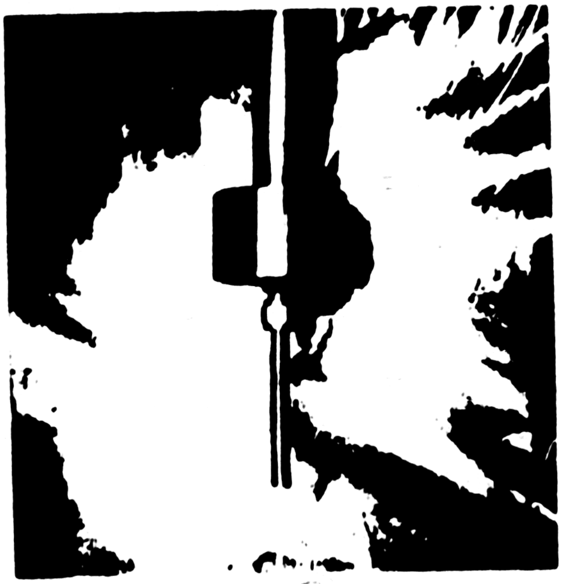
TELEFLEX SUPPLIED HANDCRANK (DISASSEMBLED)

FIGURE 11B



DRYBRUSHING CLEANING TOOL (TELEFLEX SUPPLIED HAND CRANK) AND TVA FABRICATED HANDCRANK UPPER AND LOWER SUPPORT PIPES 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

(A) - EVENING SHIFT COORDINATOR - DIRECTING CLEANING ACTIVITIES

(B) - MECHANICAL GENERAL FOREMAN - OBSERVER, WOULD ASSUME THE ROLE OF DIRECTING CLEANING OPERATION IF THE EVENING SHIFT COORDINATOR LEFT THE [illegible] DUE TO RADIATION DOSE CONSIDERATIONS

(C) - STEAMFITTER FOREMAN - COUNTING NUMBER OF REVOLUTIONS ON HANDCRANK

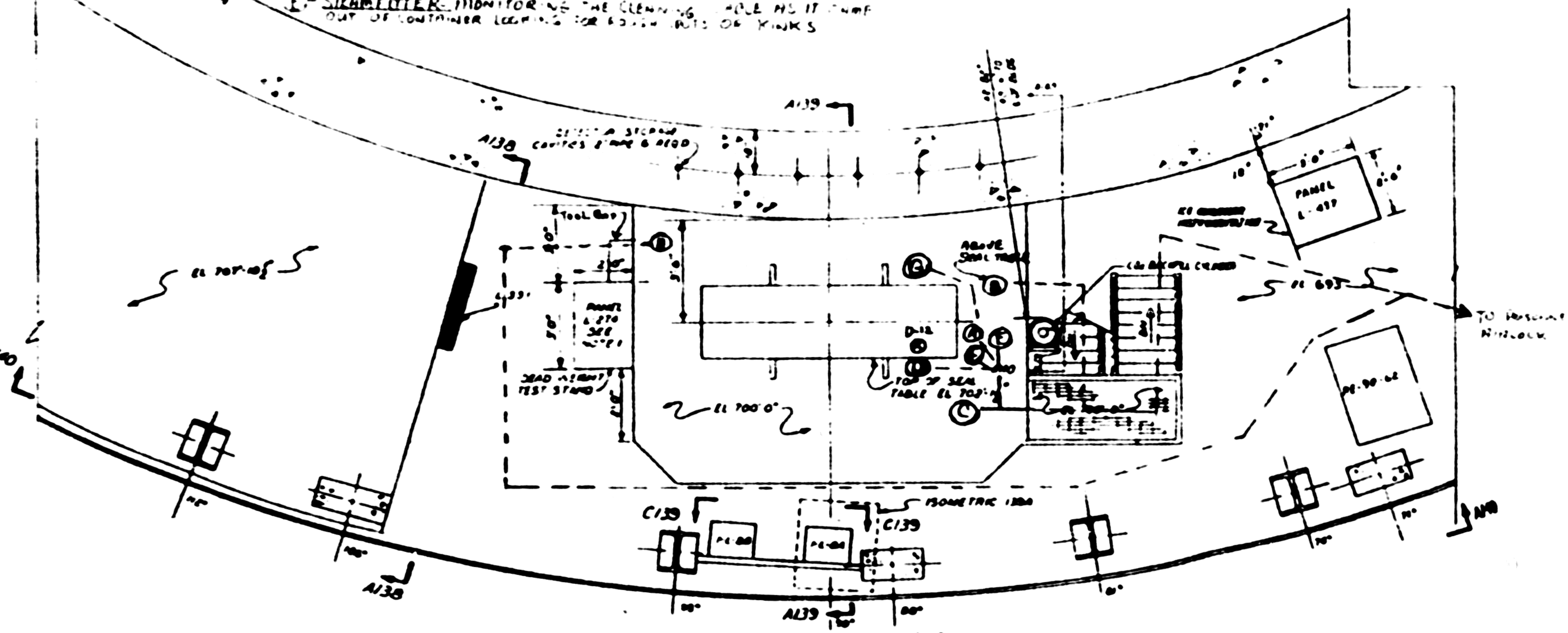
(D) - STEAMFITTER - HOLDING THE CLEANING TOOL AND TURNING THE HANDCRANK

(E) - STEAMFITTER - MONITORING THE CLEANING CABLE AS IT CAME OUT OF CONTAINER LOOKING FOR [illegible] OR KINKS

(F) - STEAMFITTER - FEEDING CABLE INTO THE GUIDE TUBE ON THE CLEANING TOOL

(G) - HEALTH PHYSICS TECHNICIAN - MEASURING DOSE RATES

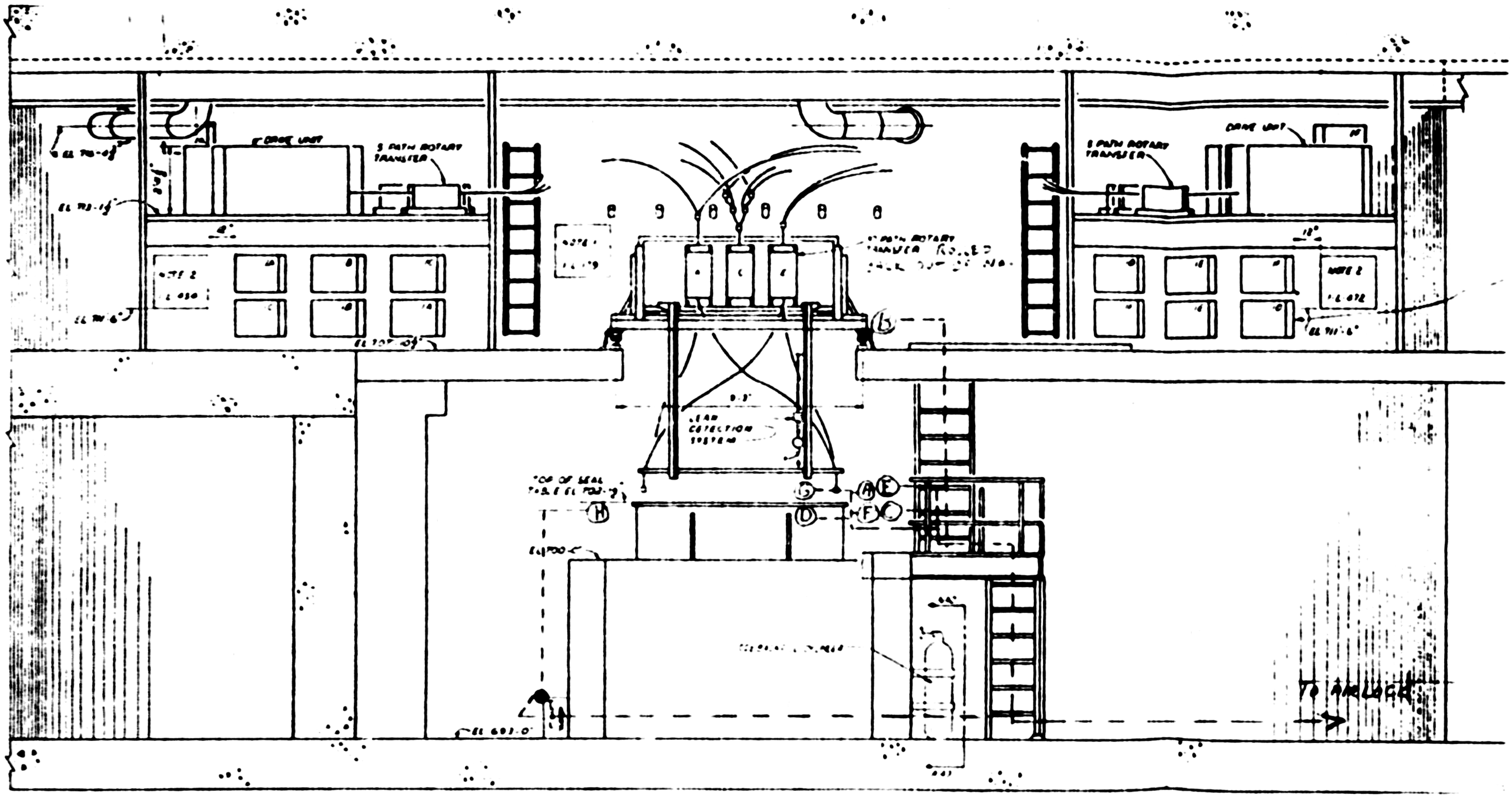
(H) - HEALTH PHYSICS TECHNICIAN (ALARA) - MEASURING DOSE RATES WITH TELETECTOR



PLAN EL 693'-0"

LOCATION OF WORKERS WHEN THE INCIDENT OCCURRED AND EGRESS ROUTES OUT OF THE INSTRUMENT ROOM

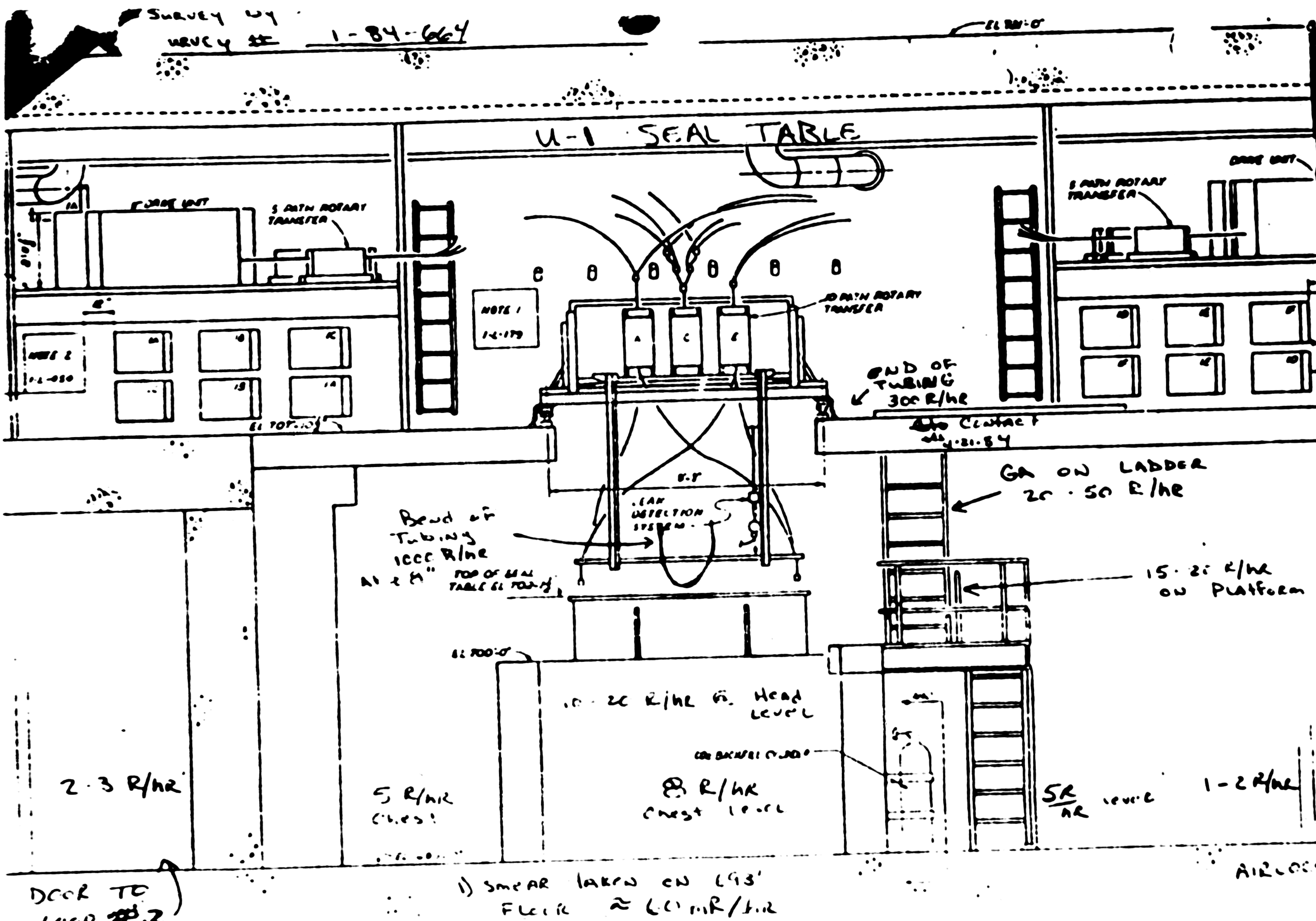
FIGURE 13A



NOTES (H) FLIPPED OR FELL OVER HANDRAIL, HIT TOOL BOX, AND RAN TO THE AIRLOCK

LOCATION OF WORKERS WHEN INCIDENT OCCURRED AND ESCAPE ROUTES

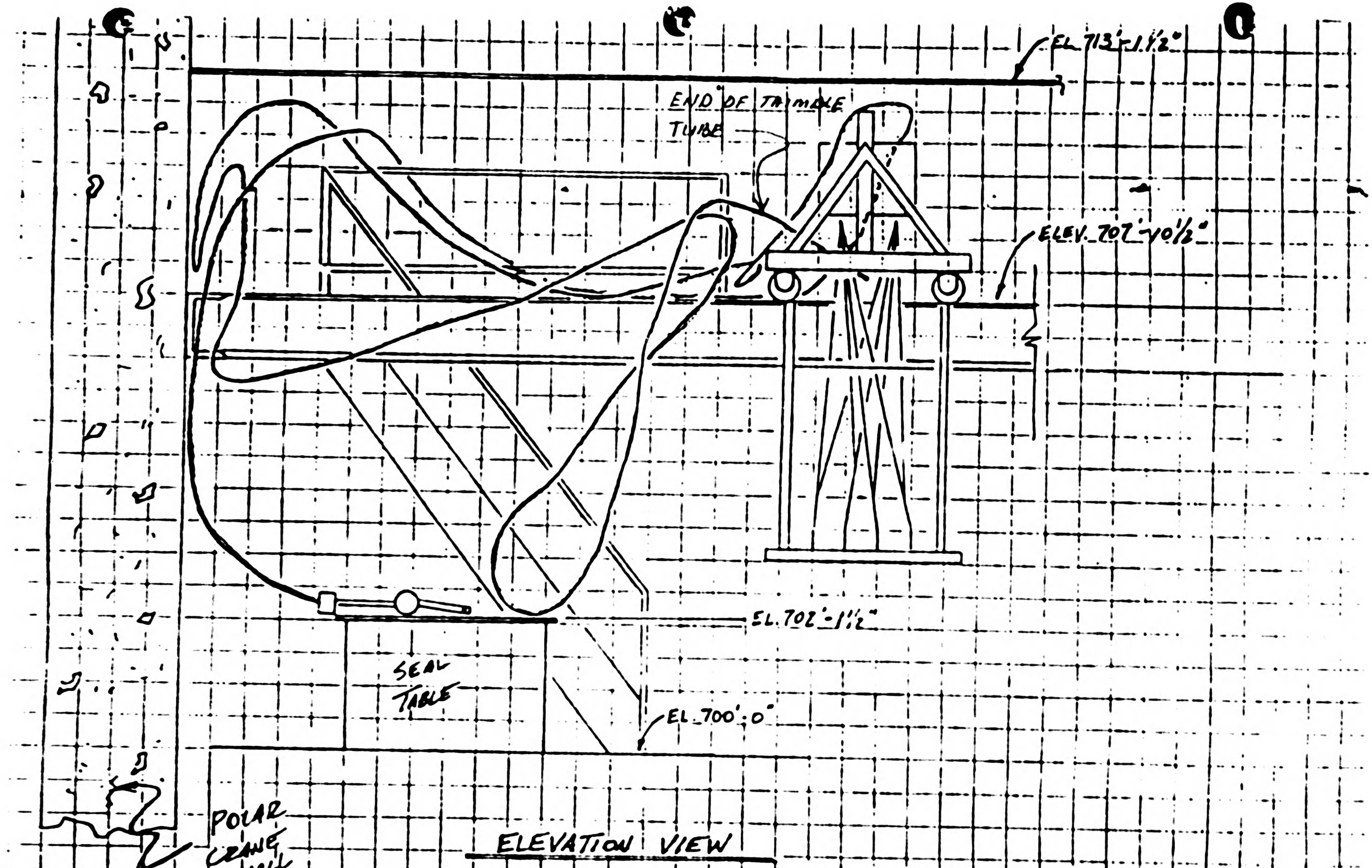
FIGURE 13B



1) Smear taken on 693' Floor ≈ 60 mR/hr

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

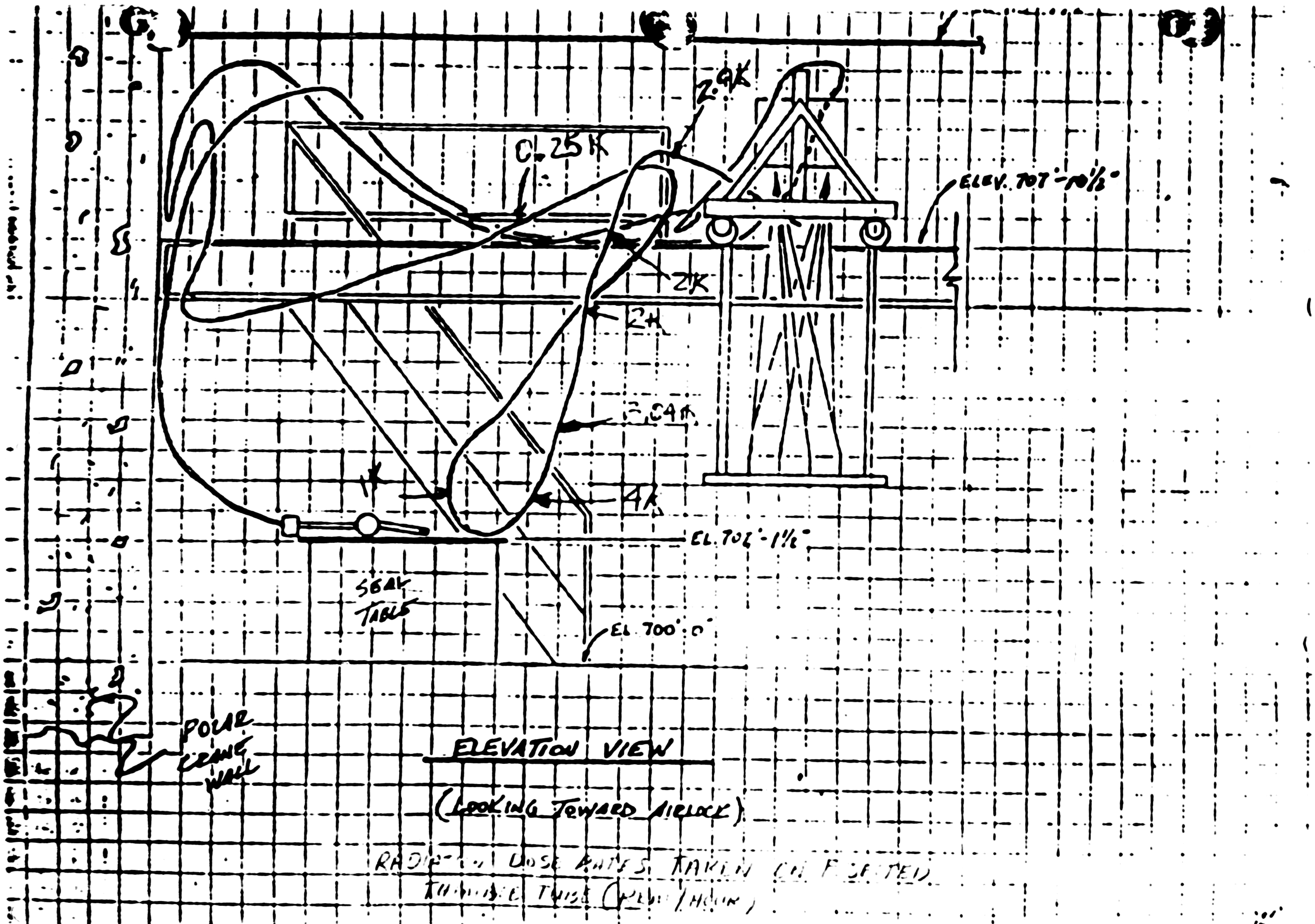

G
E
D
2.9K
0.25K
ELEV. 707'-10½"
2K
2K
2.64K
1K
4K
EL. 702'-1½"
SEAL TABLE
EL 700'-0"
POLAR CRANE WALL
ELEVATION VIEW
(LOOKING TOWARD AIRLOCK)
DOSE RATES TAKEN
/HOUR)

FIGURE 16

IOC ______

BMP ______

ATTACHMENT 1

TROJAN NUCLEAR PLANT

FLUX THIMBLE TUBE CLEANOUT AT FULL POWER

Gary [illegible]ir

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 deve

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 - 655 mr, average man - 164 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

[illegible] MESSAGES>ALL SUBJECT "THIMBLE TUBE", "SEAL TABLE"

TEXT "THIMBLE TUBE", "SEAL TABLE" END

[illegible] 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 MINIATURE 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 [illegible] THE DETECTOR/DRIVE CABLE ASSEMBLIES FROM ENTERING THE CORE REGION. LIKE SALEM, MANY WESTINGHOUSE PLANTS HAVE BEEN [illegible] 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: