Attachment 1
(95 pages)

# ENGINEERING EVALUATION REPORT: INVESTIGATIONS AND GROUTING OF LEAKS ASSOCIATED WITH TENDON SHEATHS H32-009 AND H32-011

## UNIT 2 CONTAINMENT BUILDING

## PALO VERDE NUCLEAR GENERATING STATION

JOB NUMBER 10407
BECHTEL POWER CORPORATION
NORWALK, CALIFORNIA
JUNE, 1983

DEFICIENCY EVALUATION REPORT 82-72

# ENGINEERING EVALUATION REPORT: INVESTIGATIONS AND GROUTING OF LEAKS ASSOCIATED WITH TENDON SHEATHS H32-009 AND H32-011

UNIT 2 CONTAINMENT BUILDING

PALO VERDE NUCLEAR GENERATING STATION


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# 1 INTRODUCTION

This report presents the results of studies performed to determine the locations and characteristics of leak pathways between tendon sheaths H32-009 and H32-011, and the exterior face of the Unit 2 Containment building wall. The report also discusses the repair of these leaks which was based on the study findings. Finally, the report describes the installation and greasing of the two tendons following repair of the leaks.

Studies of the leak locations and characteristics spanned the period from November 1982 through January 1983. Grouting of the leak pathways was conducted during the week of April 4, 1983, and the subject tendons were installed and greased during the week of April 18, 1983.

The results of the air and water testing conclusively demonstrated the absence of large voids within the concrete of the Containment building wall; test results showed the leaks to be confined to narrow localized pathways. Testing also demonstrated that cement grouting of the leak pathways would be an effective repair procedure.

The grouting successfully sealed the area around the tendon sheaths and permitted tendon installation, stressing, and greasing to proceed. The low rates of grout penetration in the leak pathways further verified the absence of open channels or cavities.

Tendons H32-009 and H32-011 were installed, stressed, and greased successfully following grouting after sufficient cure time and verification testing. These subjects are discussed in detail in the following sections of this report.

The report is accompanied by figures and tables which illustrate the discussion. Approved procedures for air and water testing, as well as for grouting, are attached as appendices A and D, respectively. Instrument calibration certificates, sample data sheets, and test reports on grout samples are also attached as appendices.

## 2 BACKGROUND

After each tendon in the Containment building wall has been installed and tensioned, the specification requires the sheath containing the tendon to be pumped full of grease to protect the tendon from corrosion. Often, several tendons are greased simultaneously. As part of the greasing procedure, a preliminary air test of each sheath is routinely performed prior to greasing to assure that the sheath will hold the grease and will not permit uncontrolled escape of grease. Where air leakage is noted between two sheaths, these sheaths are usually greased together to assure complete filling with grease.

Tendons H32-009 and H32-011 are horizontal tendons which extend from buttress no. 3 to buttress no. 2. Figure 1 is a schematic plan of the layout. Figure 2 is an elevation view of these tendons in the area of the main steam pipe penetrations. When these tendons had been installed and tensioned, the preliminary air tests conducted prior to greasing showed that air was escaping from one sheath and emerging in the other, as well as escaping to the outside through a crack in the exterior surface of the concrete wall. The location of this crack was in the 6-inch seismic gap between the Containment wall and the Main Steam Support Structure (MSSS). The location of this crack is shown in figure 2. The same result was obtained when pumping air into either sheath.

It should be noted that, because of the extreme inaccessibility of the location, normal means of investigating the crack were not feasible. A limited amount of chipping was performed from a nearby penetration in the MSSS to better expose the crack, but this added relatively little to the state of knowledge of the problem. A small core hole was drilled into the Containment wall adjacent to penetration no. 3 (see figure 2) but this also was inconclusive. Based on these findings a program of investigation was devised to study the nature and extent of the problem by indirect means, as well as to devise a means of greasing the two subject tendons without uncontrolled escape of grease.

## 3 SUMMARY OF CONCLUSIONS

Conclusions derived from the investigations, grouting work, and experience installing, stressing, and greasing tendons H32-009 and H32-011 are as follows:

A. Each of the two tendon sheaths initially had a single leak extending for a distance of several feet in each sheath. The locations of the leaks are described in section 4.4.1.

B. The leak system exited the Containment wall at several locations, the most significant being a visible crack in the chipped area (see figure 6).

C. The testing conclusively demonstrated the absence of large voids in the leak system. The leaks were shown to be confined to narrow pathways.

D. The total volume of the leak system was conservatively demonstrated to be approximately 5-3/4 cubic feet.

E. The leak system extended no higher in the wall than approximately elevation 134 feet.

F. There was no measurable quantity of water left in the wall following testing.

G. Approximately 5 cubic feet of grout was injected into the wall in two stages effectively sealing the leak pathways and permitting tendon installation, stressing, and greasing to proceed.

H. Tendons H32-009 and H32-011 were installed, stressed, and greased during the week of April 18, 1983. There were no problems encountered during greasing and no traceable escaping of grease from either tendon sheath.

I. Tendons H32-009 and H32-011 are expected to perform as well as other tendons with respect to corrosion.

# 4 INVESTIGATION OF THE LEAK SYSTEM

## 4.1 CONCEPT OF THE LEAK TESTING

Testing was required to provide two types of information, the first being the locations of the leaks inside tendon sheaths H32-009 and H32-011, and the second being the characteristics of the leak system between these leaking sheaths and the ultimate exit points of the leak system at the outside face of the Containment wall. The characteristics of the leak system were determined for two reasons:

A. To verify the absence of large voids in the wall.

B. To devise an effective means of repair.

The testing program was accordingly divided into two parts. The first part consisted of detailed incremental air testing of the entire length of each sheath to determine the precise locations of the leaks. Having established this, the second part consisted of isolating the leaking sections of the sheaths and pumping first air and then water through the leak system to map out all exit points and to study the flow characteristics through the leak pathways. These two phases of the testing program are discussed in greater detail below.

### 4.1.1 LOCATING OF LEAKS INSIDE THE TENDON SHEATHS

In order to incrementally isolate sections of the tendon sheaths for air testing, a system of inflatable rubber packers was devised. As shown in figure 4, the packer system consisted of two cylindrical inflatable rubber packers connected by a chain and having a tow line and tail line attached to the front and rear packers respectively. The packers were inflated by means of an air line to the rear packer from the air supply, and a second air line connecting the two packers. Air or water could be introduced into the space between the two packers through a supply line plumbed through the interior of the rear packer. The forward packer is equipped with identical interior plumbing but this was plugged for these tests.

The entire assembly was moved in increments by towing it through the sheath, then positioned and the packers inflated to isolate a test section. After inflation, air pressure was applied to the isolated portion and leak rates were recorded by noting pressure changes with respect to time. Upon encountering more than a nominal amount of leakage (that which could be entirely attributed to leakage within the packer system), the packer assembly was moved back and forth in even smaller increments to bracket the leaking section to a tolerance of within plus or minus one foot. This procedure was employed in both sheaths H32-009 and H32-011, and the leaks were successfully located in each.

### 4.1.2 DETERMINATIONS OF LEAK PATHS AND FLOW CHARACTERISTICS

Having accurately determined the locations of the leaking portions of the two sheaths, air and water testing of the leak pathways was conducted. This testing employed the packer systems described above, but rather than introducing air through the rear packer to the test interval from a source at buttress no. 2, air and then water were introduced in the space between packers through existing tendon sheathing vent and drain fittings with both packers plugged. In the case of sheath H32-009, access was through a drain line which entered the bottom of the sheath within the leaking interval. For sheath H32-011 access was provided by a vent line which entered the sheath in the leaking interval. These features are shown schematically in figure 5. Both the vent and drain lines exited the Containment building wall at accessible locations in the adjacent wrap-around portion of the Auxiliary building (see figure 1).

The vent and drain lines were plumbed to a special manifold constructed for the purpose of the testing. The manifold incorporated the instrumentation and controls for monitoring both air and water flow into the leaking portions of the tendon sheaths. Flow could be controlled to either sheath separately or both sheaths together. Flow could also be reversed and drained back through the manifold with measurements taken. Figure 5 illustrates the manifold setup schematically.

The packer assemblies were moved into place in both sheaths at locations at which the leaking intervals were bracketed and the packers were sealed in good airtight sections of the sheaths. The packers were inflated to isolate the leaks from the rest of the sheaths.

Appendix A to this report presents the approved test procedures which governed the conduct of this stage of the investigation. The first in this series of tests involved pumping air from the manifold into the leaking sections of both sheaths simultaneously while monitoring pressures both at the manifold and at the injection point to each sheath. Escape of air through the leak pathways was monitored and mapped out by teams of observers stationed at strategic locations in the MSSS near the major pipe penetrations and adjacent to the edges of the MSSS at the seismic gap with the Containment wall (see figures 1 and 2). The observers detected escaping air by inserting probes with flagging on the end into the seismic gap between the MSSS and Containment building. The observers recorded the locations of air leaks with respect to established points on the MSSS.

After pumping air into both sheaths simultaneously, the air was then pumped into one sheath while the pressure in the other sheath was monitored. This process was repeated for both sheaths to check for cross-communication between the sheaths.

Following the air test, five successive tests were performed using water as the flow medium. These water tests used the same packer and manifold set up as the air test with the addition of vertical manometer tubes to monitor water elevation in the leak system. One manometer tube was employed for

each sheath. Water was pumped into either one or both sheaths while flow rates, volumes, pressures, and elevation were recorded versus time. As in the air test, teams of observers accurately measured the locations of water leaks on the outside of the Containment wall, and estimated the rate of leakage at each location. Observers at the buttresses monitored the packer inflation pressure as well as any water leakage through the sheaths. All observations were recorded with time so that the sequence of water leak observations could be compared with the time-history of water injection. Sample data sheets are included as appendix B to this report.

Upon reaching a steady-state condition in which the rate of injection equaled the estimated rate of leakage, the flow was discontinued and the direction reversed with the water allowed to drain back through the leak system and out of a drain at the manifold while measurement recording continued. The volume of water recovered from the system was then compared to the volume injected plus the volume lost through leaks to determine whether there was any water left in storage in the system.

## 4.2 EQUIPMENT AND INSTRUMENTATION

The layout of equipment and instrumentation is shown schematically in figures 3 through 5. The following paragraphs describe pertinent features of the equipment and instruments.

The key pieces of equipment for successful testing were the packer systems, because without an effective means of isolating the leaks within the tendon sheaths, no definitive testing would have been possible. The packer systems consisted of two pairs of packers attached by means of chains and air lines as described earlier and as shown in figures 3 and 4. The packers consist of cylindrical inflatable rubber elements clamped to a rigid steel tube with end caps. The overall length of each packer is approximately 3 feet and the uninflated diameter is 3-1/2 inches.

The packers come from the manufacturer, Diamond Drill Contracting of Seattle, Washington, with a smooth rubber outer surface to provide the seal when inflated. Initial trials showed that this was not sufficient to seal inside the sheath due to the spiral corrugations of the sheath. Experimentation demonstrated that the addition of three or more flexible rubber "O" rings positioned over the cylindrical rubber element and spaced evenly provided an effective seal against the sheath corrugations when the packer was inflated. Each of the four packers was modified in this manner with the "O" rings held in place by a flexible glue. Prior to insertion in the sheaths the packers were liberally coated with grease (the approved sheathing filler).

Internal packer pressure was controlled and monitored at all times by means of a regulator and pressure gauge in the supply line located on the work platform at buttress no. 2.

The instrumentation and controls for the air testing of the sheaths are shown schematically in figure 4. The air supply line to the test interval was provided with a regulator and pressure gauge at the work platform at buttress no. 2.

The instrumentation and controls for the air and water testing of the leak pathways are shown schematically in figure 5. Pressures were monitored by calibrated pressure gauges mounted on the manifold and at the injection points for each sheath. For sheath H32-009 the injection point was the sheath drain line where it exits the Containment wall in the Auxiliary building wrap-around, and for sheath H32-011 the injection point was the sheath vent line where it exits the wall in a similar location but higher in elevation.

The instrumentation selected for flow monitoring included a Hersey model MVR-30 water meter equipped with a Hersey Model R-38 pulser, electronically connected to a Hersey model 1020 digital flow rate indicator with volume totalizer. This system was specially calibrated by the manufacturer both before and after the testing. Calibration certificates are included as appendix C to this report.

A Hewlett-Packard 7132-A 2-channel strip chart recorder was connected to the accessory output jack on the flow rate indicator to provide a continuous graphic time-history of flow rate. This served as backup for manually recorded readings taken from the volume totalizer at 30-second intervals throughout the tests.

Air and water flows were regulated by means of standard pressure regulators in the supply lines, and controlled by means of valves located as shown in figure 5.

Manometer tubes were used to monitor water elevation changes within the leak system as shown in figure 5. These consisted of clear plastic vertical tubes attached to the outside of the Containment wall at the manifold location. Elevations were read from a tape attached to the wall alongside the manometer tubes.

## 4.3 QUALITY PROGRAM

After successfully locating the leaks inside the sheaths all subsequent air and water testing of the leak pathways was conducted under the provisions of an approved quality control program. Procedures for the testing were extensively reviewed by Bechtel engineering, Bechtel construction, Bechtel and APS QC, and QA, Mr. John King, the project consultant, and APS engineering. The NRC site representative also reviewed the procedures. The approved procedures are included in appendix A.

As shown in the test procedures, the quality program included monitoring of test activities by a QC inspector. Each step of each phase of testing was signed-off on the approved procedure as being successfully completed by the designated test director. At the end of each testing phase, the QC inspector verified that all required signatures had been obtained for that phase and then stamped the final signature position as accepting the work up to that point in the procedure.

Calibration documentation was required for all instruments used and this was checked by the QC inspector. All pressure gauges and the strip chart recorder were obtained on site and were supplied with current calibration stickers. The flow meter system was procured separately and was calibrated before and after the tests. The calibration certificates are included in appendix C.

## 4.4 TEST RESULTS

### 4.4.1 LOCATIONS OF TENDON SHEATH LEAKS

The testing described in section 4.1.1 demonstrated the presence of a single leak in sheath H32-009, and a single leak in sheath H32-011. In sheath H32-009 a large leak begins at approximately 91° 30' (see figure 2), continues to 94°, then tapers to a small leak which terminates at approximately 97° 40'. In sheath H32-011, the leak begins as a small leak at 81° 15', then increases to a large leak at approximately 83°. This large leak continues to approximately 93° 10', where it decreases to a small leak terminating at about 98°.

Location of the packer assembly was monitored during the test by measuring the distance, in feet, from the face of the concrete at the sheath portal at buttress no. 2. These measurements were later converted to degrees for comparison with the engineering drawings of the Containment building.

### 4.4.2 AIR TESTING OF LEAK PATHWAYS

Air testing of the leak pathways as described in section 4.1.2 verified cross-communication between the sheaths. Vigorous air flow was observed escaping from the crack in the chipped area just below and slightly to the north of penetration no. 4 (see figure 2), and from the core hole drilled into the Containment wall adjacent to penetration no. 3. The subsequent water tests discussed below proved to be a more positive indicator of additional very small leak exits which were not detected during the air test.

### 4.4.3 WATER TESTING OF LEAK PATHWAYS

A total of five water tests were performed as described in section 4.1.2. These tests provided information on the characteristics of the leak pathways as shown by flow rates, volumes, pressures, and elevation. The tests also revealed a number of leak exits at the face of the Containment wall not discovered during the air test.

Figure 6 is an elevation view similar to figure 2 which shows the locations of all leak exits on the Containment wall. Figure 6 is a composite of the results from all five tests. As is seen in figure 6, minor leakage occurred around the penetration sleeve at penetration no. 10 and along the construction joint in this area. Very minor seepage occurred around the sleeve at penetration no. 8. Major leakage occurred from the crack in the chipped area and from the core hole adjacent to penetration no. 3. Minor seepage occurred around the sleeves in penetrations no. 2 and no. 3.

Table 1 presents a summary of five water tests. The table shows input flow conditions, elapsed times between the start of each test and the observations of significant leaks, volumes injected when the leaks were observed, estimated rates of spillage, and volumes drained back from the leak system after shutting off water inflow. The significance of this information is that in all tests, after adjusting for estimated spillage, the volume drained approximately equaled the volume pumped in within reasonable error limits. This shows that no measurable quantity of water was left in the leak system after draining.

As discussed in section 4.1.2, manometer tubes were connected to the test piping to monitor water elevation during the tests. One manometer tube was connected to sheath H32-009 and one to sheath H32-011. As the water level rose through the leak system the level in the clear plastic manometer tubes also rose, permitting a record to be made of the rate of rise. The rate of rise is a very important indicator of the nature of voids in the wall if such voids exist. Upon encountering a void in the wall, the rate of rise of the water level should pause or slow down as the void fills. When the void was full, the water level rise would resume. This change in the rate of rise would be detected in the manometer tubes, and the elevation of the void would also be apparent.

In water tests 1 and 2, the manometer tubes were inaccurate due to the configuration of the test plumbing system which caused misleading water level elevations to register in the tubes. Some minor modifications were made and the manometer tube for sheath H32-009 was used successfully in tests 3, 4, and 5. The manometer tube for sheath H32-011 continued to suffer the effects of head losses, and could not be successfully corrected due to the physical limitations of the system. However, because of the cross-communication between the sheaths, the manometer tube for sheath H32-009 provided an accurate and complete record of water level for the final three tests.

Tests 3, 4, and 5 conclusively demonstrated the absence of large voids in the leak system and showed that the leak system consisted of narrow, confined pathways. Figures 7, 8, and 9 show the graphs of manometer elevation versus time for sheath H32-009 in tests 3, 4, and 5. As can be seen from the curves, the history of rise between the filling of sheath H32-009 and the appearance of leakage in the chipped area is characterized by a steep, approximately straight line in all three tests. If a large void was present in the system, the curves would flatten for the time it took to fill the void, then resume a steep climb. This feature is not observed in any of the test plots. The curves do flatten following the appearance of leakage at the chipped area but this is due to the leakage itself.

In the first four water tests, when the water level rose to the elevation of the crack in the chipped area, all of the flow spilled from this crack and the water level in the system could not be raised further. The core hole adjacent to penetration no. 3 was slightly higher than the elevation of the chipped area and water could not be driven up toward this higher elevation. It was known from the air test that the leak system communicated with this

core hole, so it was considered necessary to cause the water to leak out of the core hole by raising its elevation inside the wall. In addition, it was considered necessary to determine the highest elevation of the leak system in the Containment wall.

To accomplish these objectives a special form was constructed to cover the chipped area in an attempt to seal the leakage and drive the water higher up the leak system inside the wall. This form was inserted in the seismic gap and braced against the MSSS wall.

Test 5 was performed with this form in place. Although minor leakage did occur from the formwork, the objective of raising the water level was achieved. Water was caused to spill from the core hole adjacent to penetration no. 3. This core hole was then plugged and water continued to be pumped into the system with very careful monitoring of pressures. Almost immediately following the plugging of the core hole the leak system started to become pressurized, indicating the highest point in the system had been encountered. A slight amount of seepage was noted from around the sleeve in penetration no. 3 at an elevation slightly higher than the core hole. As the pressure continued to increase, flow increased from leaks already encountered lower down on the wall indicating that no additional pathways for leakage existed in the system. Following this, flow was reversed and the system drained.

Test 5 is considered to provide the most complete information and the most reliable characterization of the leak system. From the data collected in test 5, the total volume of the leak pathways is shown to be on the order of 5-3/4 cubic feet. This was determined by comparing the volume of water pumped in with the volume of water required to fill the sheaths between the packers, the volume of water retained behind the form over the chipped area (determined from figure 9), and the volume of water spilled through leaks.

The relative ease with which water could flow through the system indicated that cement grout could be injected into the leak pathways in order to provide an adequate seal against uncontrolled escape of grease following tendon stressing.

## 4.5 SUMMARY OF CONCLUSIONS FROM TESTING

The principal conclusions reached from the air and water tests described in preceding sections are as follows:

A. Each of sheaths H32-009 and H32-011 had a single leak which extended for a distance of several feet in each sheath. The locations of the leaks have been described in section 4.4.1.

B. The leak system exited the Containment wall at several locations, the most significant being the crack in the chipped area (see figure 6).

C. There were no large voids in the leak system within the Containment wall. The leaks were confined to narrow pathways.

D. Total volume of the leak system is conservatively determined to have been approximately 5-3/4 cubic feet.

E. The leak system extended no higher in the wall than approximately elevation 134 feet.

F. There was no measurable quantity of water left in the wall following testing.

G. Water flow characteristics indicated that cement grout would be an effective sealing agent.

# 5 REPAIR OF THE LEAK SYSTEM

The testing program provided information which showed that cement grout could be pumped into the leak system to provide an adequate seal to permit greasing of the tendons without uncontrolled escape of grease. Mr. John King, the project grouting consultant, assisted in the preparation of a grouting program which would accomplish this objective.

Of primary concern was the need to effectively seal the area around the leaking tendon sheaths without permitting grout to set up inside the sheaths, thereby preventing the tendons from being installed. For this reason it was decided to devise a means of grouting from the face of the Containment wall through the leaks and into the tendon sheaths. Upon encountering the sheaths the grout would need to be immediately prevented from penetrating further, or constantly removed, to prevent blockage of the sheaths. The easier grouting approach would have been to grout from the sheaths outward through the leaks, but since grout might set up in the sheaths, this was considered too risky.

To prevent grout invading and hardening in the sheaths it was decided to employ water pressure inside the sheaths at all times during grouting operations. The water would be permitted to flow through the sheaths under controlled pressures which would be balanced with grouting pressures to achieve the desired results.

The following sections present a summary of the preparatory work, the grouting procedures employed, equipment and materials, quality program, results of grouting, results of post-grouting verification tests, and conclusions.

The official set of approved grouting procedures are included as appendix D to this report.

The grouting work was performed during the week of April 4, 1983, and resulted in the areas around tendon sheaths H32-009 and H32-011 being effectively sealed with no grout entering either sheath. Cross-communication between the two sheaths was also eliminated.

## 5.1 PREPARATORY WORK

Having selected the grouting approach to be taken, it was necessary to do some preliminary work. This work consisted of drilling three 2-inch diameter coreholes into the Containment wall adjacent to penetration no. 10 (see figure 10). The first of these holes was drilled to provide information on the leak pathways in the vicinity of the seepage observed in penetration no. 10 during the water tests. The additional holes were drilled immediately adjacent to the first to provide additional access for grouting.

The core holes are shown schematically in the sketch in figure 11. The core sample taken from the first hole, drilled on a slight downward slope, revealed a system of rather confined and narrow leak pathways very close to the surface of the wall. Further into the wall, the core passed through the

mortared construction joint and into the well-consolidated upper portion of the underlying concrete lift where the hole then terminated. The core also passed through the steel flange of the adjacent penetration sleeve.

From this information it was apparent that the hole would need to be sealed at the surface of the wall in order to force the grout into the near-surface leak pathways. To accomplish this a steel plate was fabricated to fit over all three core hole openings with an edge seal which would surround the openings. The plate was fitted with a grout nipple for simultaneous grouting of the three holes.

A special form similar to the one used in water test no. 5 was fabricated to fit over the chipped area. This form also included a sealing gasket and a grout nipple, and was provided with a valved vent tube at the top. The form could be lowered into place in the seismic gap, positioned over the chipped area, and braced against the MSSS wall.

A special plug, fitted with a valved vent tube, was inserted into the core hole adjacent to penetration no. 3.

The packer system used in the air and water tests was refitted with hoses leading to both buttress no. 2 and buttress no. 3 (see figure 12). With this setup, water could be pumped in from buttress no. 2 and drained to buttress no. 3. Additional water could be either drained or added between the packers from the sheath vent and drain lines controlled by the manifold devised for the water tests (see figure 12). This would permit close control of water flows and pressures within the sheaths during grouting operations.

Between each pair of packers, a steel "rabbit" was attached to the connecting chain. These rabbits were designed to forceably clear any grout obstruction within the sheaths. In this event, the packers could be deflated and the assembly moved back and forth rapidly to allow the rabbit to break through blockage.

Prior to grouting, the leak system was soaked with water to wet the narrow leak passages and to assist in grout curing. All free water was then drained back from the system.

## 5.2 SUMMARY OF GROUTING PROCEDURES

Detailed grouting procedures are given in appendix D. This section presents a summary of the pertinent features of the program.

For maximum grouting efficiency, a two-stage program was devised with the lower part of the leak system grouted in the first stage. The second stage involved grouting the upper part of the leak system after the first stage grout had set up.

For Stage 1, grout was pumped through the plate over the core holes adjacent to penetration no. 10, while water flowed through the sheaths. Grout take was very low in this stage because of the confined nature of the leak pathways in this area.

After the grout pumped in Stage 1 had taken an initial set, the formwork was installed over the chipped area in preparation for Stage 2. The Stage 2 grouting consisted of pumping grout behind the form and into the crack in the chipped area while venting the leak system through the valved plug installed in the core hole adjacent to penetration no. 3, which was higher in elevation than the chipped area (see figure 11). Water flow was maintained in the sheaths during these operations. Upon observation of grout at the vented core hole adjacent to penetration no. 3, the grout supply hose was disconnected from the form and connected to the vent in the core hole. Grout was then injected at this location. Finally the grout hose was reconnected to the nipple in the form and pumping continued to refusal.

In both Stages 1 and 2 the initial grout mix was designed to produce a standard flowcone time of 13 ±2 seconds (per ASTM C939). The procedure called for thickening to an 18 ±2-second grout if the 13-second grout penetrated easily. The 18-second grout would then be followed by a 25 ±3-second grout mix if the 18-second grout penetrated easily. In Stage 1, refusal was encountered with the initial 13-second mix. In Stage 2, refusal occurred with the 18-second mix. Because of the confined nature of the leak pathways, the thicker 25-second grout could not be used.

Upon completion of grouting, the sheaths were flushed, the packers deflated, and the rabbits were pulled back and forth through both sheaths. No evidence of grout was found inside the sheaths either in the flush water or on the packers or rabbits.

## 5.3 GROUTING EQUIPMENT AND MATERIALS

The grout used is marketed under the name IN-PAKT by the Concrete Chemical Company of Cleveland, Ohio. This is a neat cement grout containing flyash, aluminum powder, and a water reducing retarder. At normal mix consistencies this grout will expand 3 to 5 percent at 3 hours after mixing when measured in accordance with ASTM C827. The mix temperature was maintained between 40 and 50 degrees by the use of ice as required.

The grout was mixed and delivered to the injection point by means of a Chemgrout double tub mixer equipped with a Moyno progressive cavity pump and recirculating line. Grout pressures were controlled by a valve and pressure gage at the injection point. A turbine-type flowmeter was initially used to measure grout volumes but rapidly became plugged and had to be removed from the line to continue grouting.

The leaking portions of tendon sheaths H32-009 and H32-011 were isolated by means of the same packer assemblies used for the air and water testing. Water flow through the sheaths during grouting was controlled by means of the testing manifold described in section 4.1.2 and shown in figure 5.

5.4 QUALITY PROGRAM

As with the air and water testing, all grouting operations were performed under the provisions of an approved quality control program. A grouting procedure was first written up and then thoroughly reviewed by Bechtel, APS, Mr. John King, and the NRC site representative. After incorporating comments, the procedures were approved for use.

After satisfactorily completing each step of the grouting work, the designated grouting director would sign-off the approved procedures in a space adjacent to the description of each step. An independent QC inspector monitored the progress of the work and then affixed his stamp to the approved procedures after verifying that the grouting director had properly signed-off the work.

Although grout strength was not of primary importance in the repair of the sheaths, grout samples were mixed and obtained both prior to, and during, the grouting work. The samples taken prior to the work were used to establish compressive strengths with which to compare the samples taken during the work. The purpose of this was to demonstrate the consistency of the grout properties. The test results of both sets of grout samples compare quite well. These results are included in appendix E.

5.5 RESULTS OF GROUTING

Section 5.2 has described the conduct of the grouting work. As discussed in that section, Stage 1 grouting consisted of pumping grout into the core holes drilled in the Containment wall adjacent to penetration no. 10. Because of the very tight nature of the leak pathways in this area, grout take was very low. An estimated total of 1 cubic foot of grout was injected into the wall during this stage. Most of this volume was required to fill the core holes.

After curing of the Stage 1 grout for about 40 hours as specified in the approved procedure, Stage 2 grouting was performed through the form covering the chipped area. Grout take was much better in this second stage owing to the greater width of the leak pathways in this area. An estimated total of 7 cubic feet of grout was injected in the wall during this stage, of which approximately 2 cubic feet were required to fill the space behind the form.

The estimated total volume of grout injected into the leak pathways in both stages was 5 cubic feet. It was conservatively determined from the water testing that the volume of the leak pathways was 5-3/4 cubic feet (refer to section 4.4.3). It is therefore concluded that the leak system has been effectively filled with grout.

The exact volume of grout injected could not be determined because of plugging of the flowmeter. At the very low flows passing through the meter the cement particles were adhering to and obstructing the vanes of the turbine. The meter had to be disconnected from the line in order to continue grouting. This plugging effect occurred during both Stages 1 and 2. The grout volume estimates given in this report are based on consumption of dry grout and water at the mixer.

No grout entered either sheath during the grouting operations. No grout appeared in the flushing water during the grouting and none appeared on the packers or rabbits after termination of grouting.

## 5.6 POST-GROUTING VERIFICATION TESTS

Following completion of grouting, and after sufficient cure time, air tests were performed on the previously leaking section of sheaths H32-009 and H32-011. These tests were performed by isolating the leaking sections of both sheaths with the packer assemblies described in section 4.2 and elsewhere, and pressurizing each sheath between the packers by introducing air from the control manifold. Air was pumped into sheath H32-009 through the sheath drain line, and into H32-011 through the sheath vent line (see figure 5).

The results of these tests conclusively demonstrated that the grout had successfully sealed the area around the sheaths to an acceptable degree to permit greasing of the tendons. The grout had also cut off the cross-communication between the two sheaths. Figure 13 shows a comparison of the air test results for the leaking portions of the sheaths prior to and following grouting. Also shown is a representative control air test performed on a good section of sheath. The small rate of air leakage in the reference test, and in the post-grouting tests, can be completely attributed to normal leakage through fittings and seals in the test equipment.

## 5.7 CONCLUSIONS FROM GROUTING

The grouting work described in the preceding sections successfully sealed the leaking tendon sheaths H32-009 and H32-011 to an acceptable degree to permit tendon installation and greasing to proceed without uncontrolled escape of grease.

Cross-communication between the two sheaths was cut off.

No grout entered the sheaths during or after grouting. The sheaths were left in an unobstructed condition ready for tendon installation.

## 6 DISCUSSION OF TENDON INSTALLATION FOLLOWING GROUTING

Tendons H32-009 and H32-011 were reinstalled and stressed during the week of April 11, 1983. Tendon H32-009 was successfully greased on April 19, 1983, with no escape of grease. Tendon H32-011 was successfully greased on April 20, 1983, also with no escape of grease. Table 2 presents pertinent greasing data for these two tendons.

Table 1

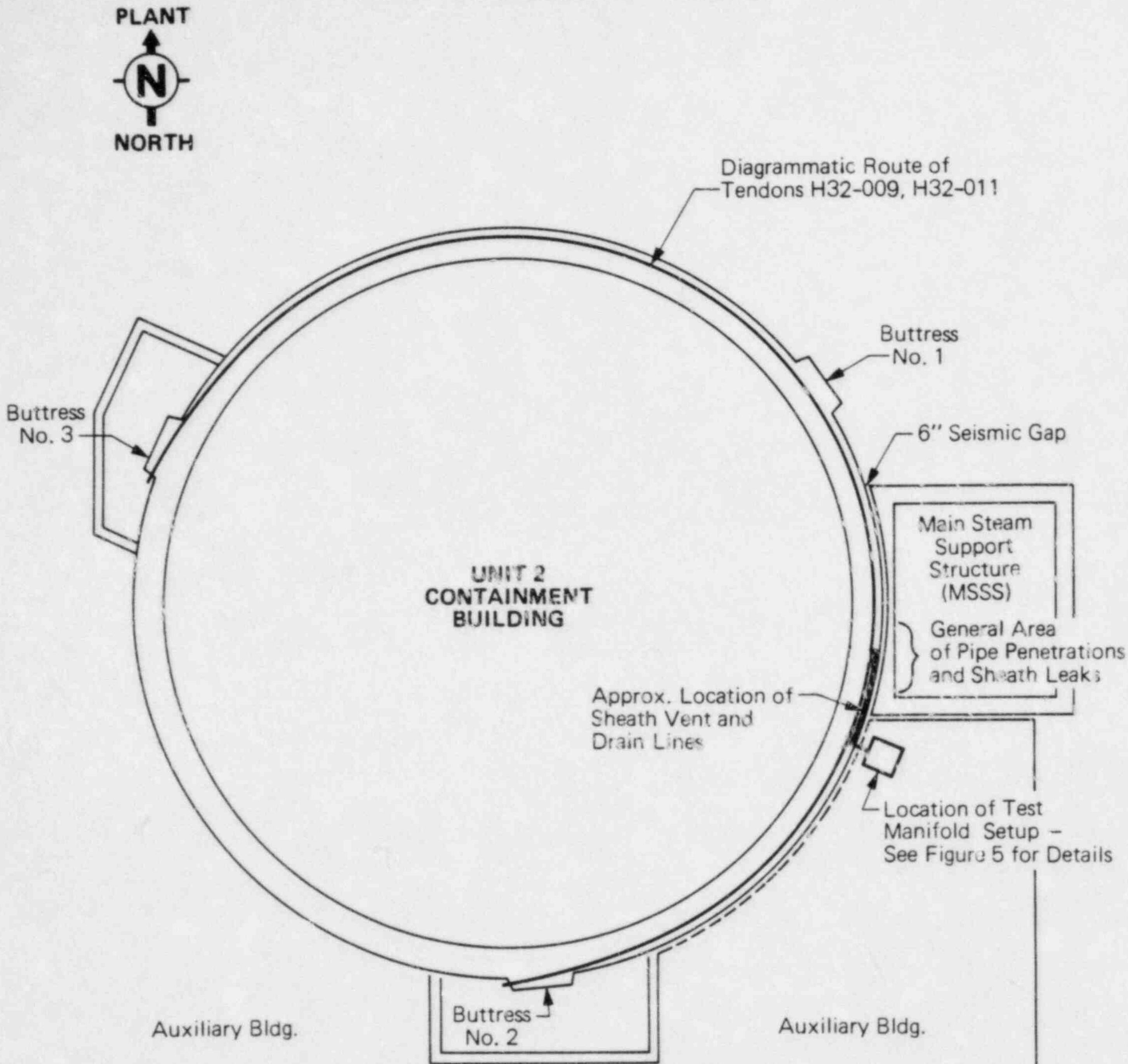
WATER TEST SUMMARY

| TEST NO. | DESCRIPTION OF FLOW CONDITIONS | INITIAL OBSERVATION ELAPSED TIME (MIN:S) | | | INITIAL OBSERVATION INPUT VOLUME (GAL) | | | EST. "Q" FROM OTHER LEAKS (GAL/MIN) | VOLUME DRAINED (GAL) | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|
| | | FIRST LEAK | CHIPPED AREA | PEN #3 CORE HOLE | FIRST LEAK | CHIPPED AREA | PEN #3 CORE HOLE | | | |
| 1. | LOW FLOW INTO #009 | 7:00 | 8:48 | - | 38 | 48 | - | <1 | 46 | |
| 2. | VERY LOW FLOW→HIGH FLOW INTO #009 | 8:01 | 14:36 | - | 21 | 37 | - | 1/2 | 44 | |
| 3. | VERY LOW FLOW→HIGH FLOW INTO #011 | 20:04 | 23:37 | - | 54 | 65 | - | <1 | 59 | |
| 4. | LOW FLOW→HIGH FLOW #011→#009 #011 | 13:18 | 18:29 | - | 60 | 81 | - | 5.8 | 47 | PACKER LEAK AT #011 |
| 5. | HIGH FLOW→LOW FLOW →VARIABLE FLOW INTO #011 | 5:14 | 12:13 | 18:54 | 51 | 90 | 130 | 1/2 | 91 | PACKER LEAK AT #011; FORM IN PLACE OVER CHIPPED AREA |

Table 2

GREASING DATA

| TENDON NO. | DATE GREASED | GREASE TEMP. | | INJECTION PRESSURE AT INLET (PSI) | ELAPSED TIME OF GREASE PUMPING (MIN:SEC) |
|---|---|---|---|---|---|
| | | TANK | EXIT POINT | | |
| H32-009 | 4/19/83 | 170°F | 135° | 8 psi for 10 min.<br>35 psi momentarily<br>15 psi for 25 min. | 35:00 |
| H32-011 | 4/20/83 | 165° | 139° | 20-35 psi fluctuating | 8:45 |




**NOTES:**

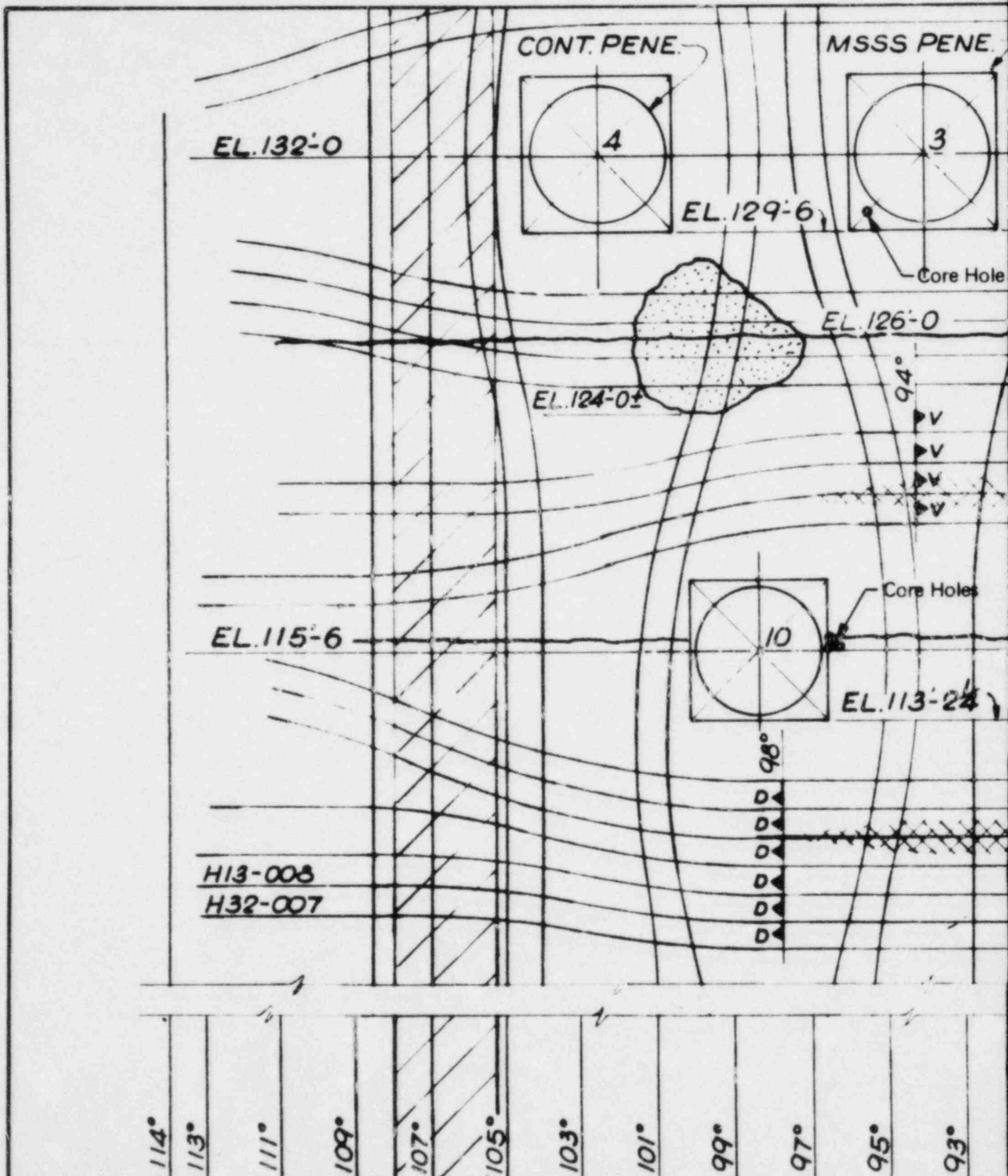
1. This figure is schematic only and does not represent the structures in true proportion to one another.

2. Refer to following figures for specific details.

**LOCATION PLAN**

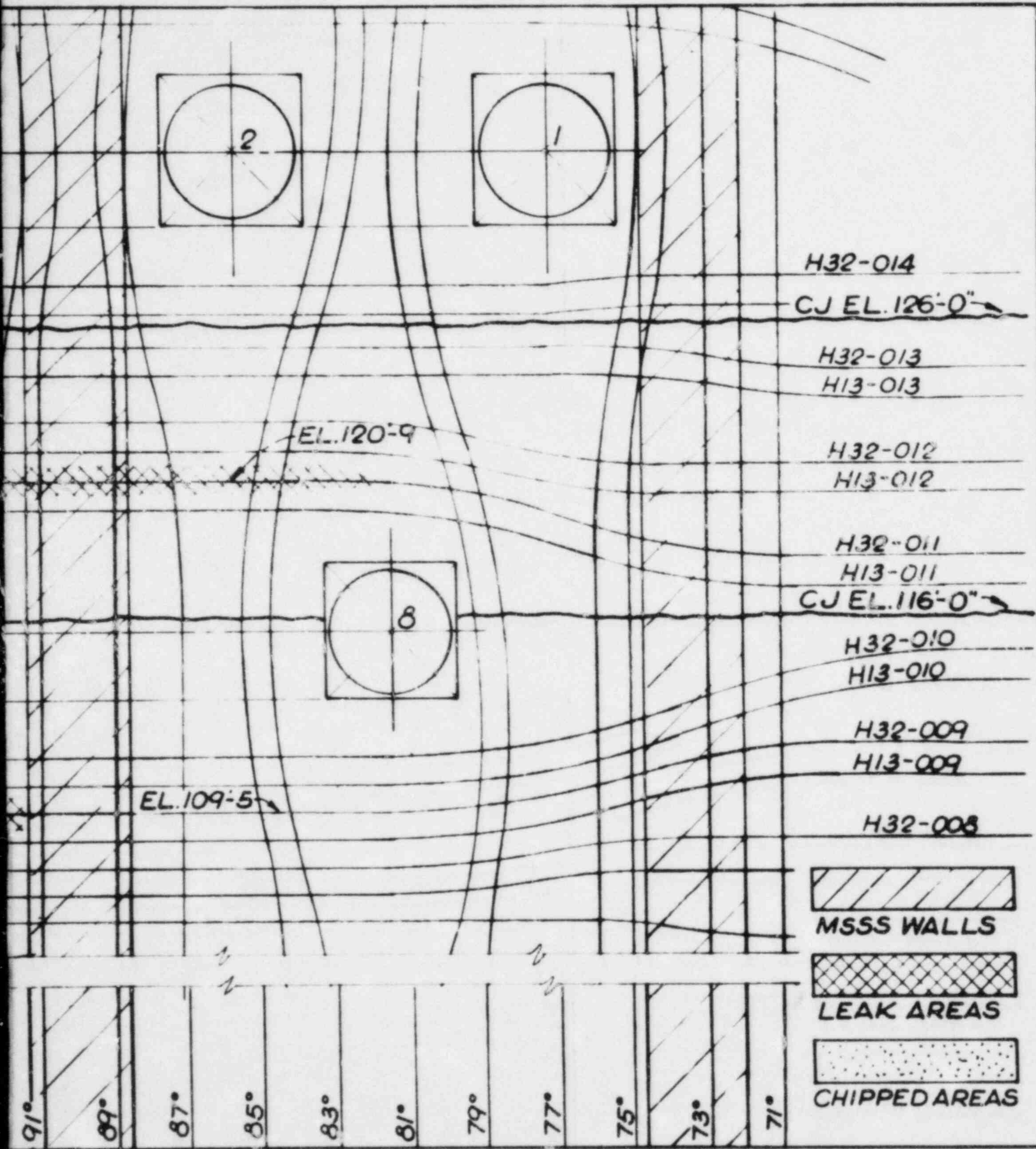
Not to Scale

**FIGURE 1**




Also Available On
Aperture Card

PRC
APERTURE
CARD




**ELEVATION VIEW OF TENDON AND PENETRATION LOCATIONS**

FIGURE 2

8307120303-01

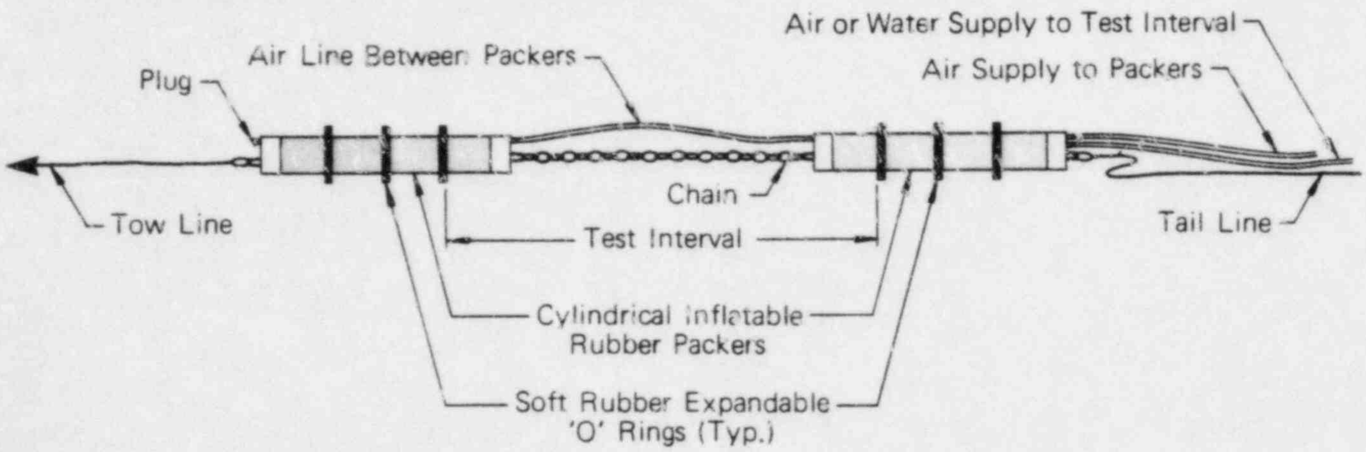
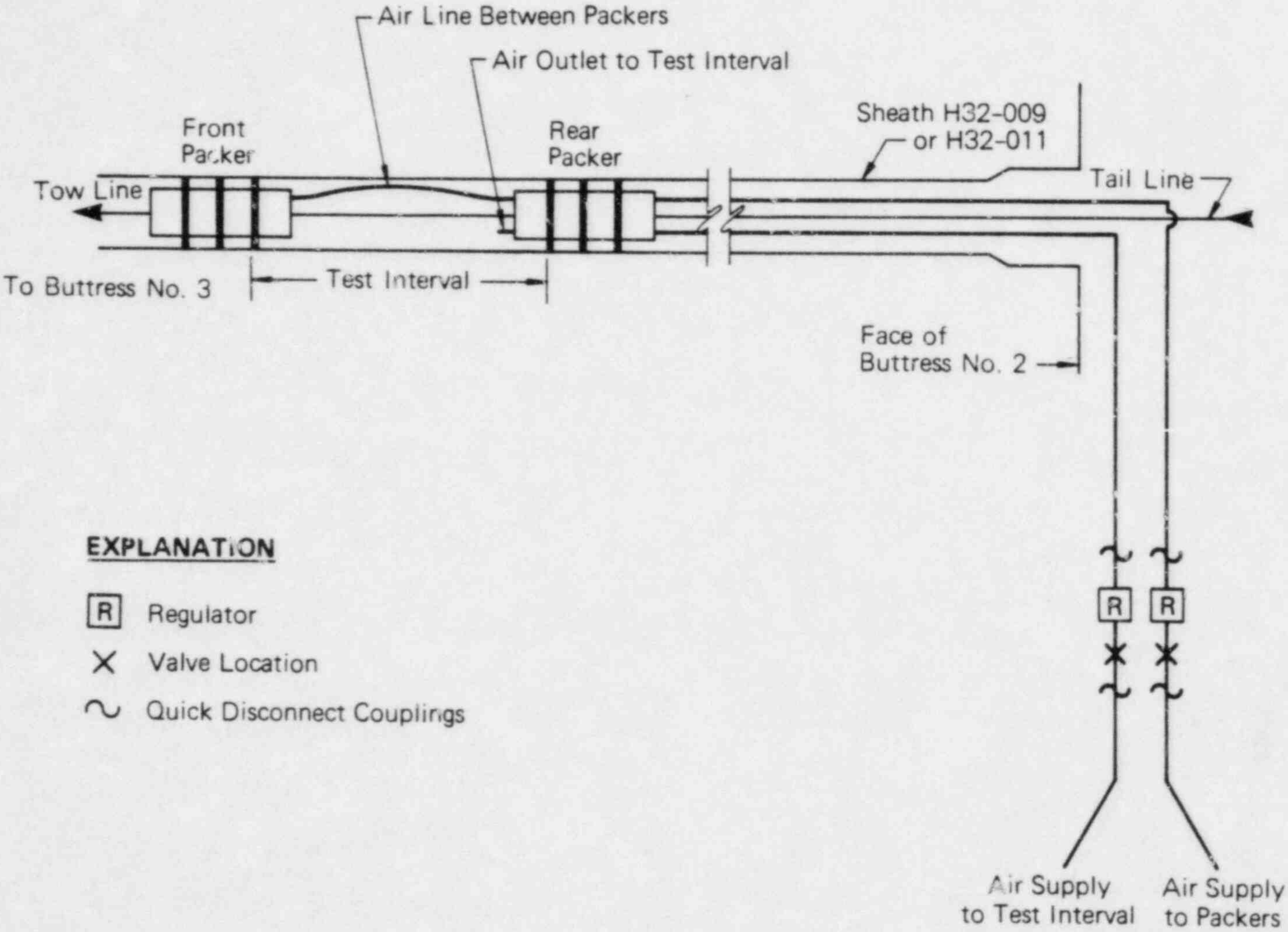



**DIAGRAM OF PACKER ASSEMBLY**

Not to Scale

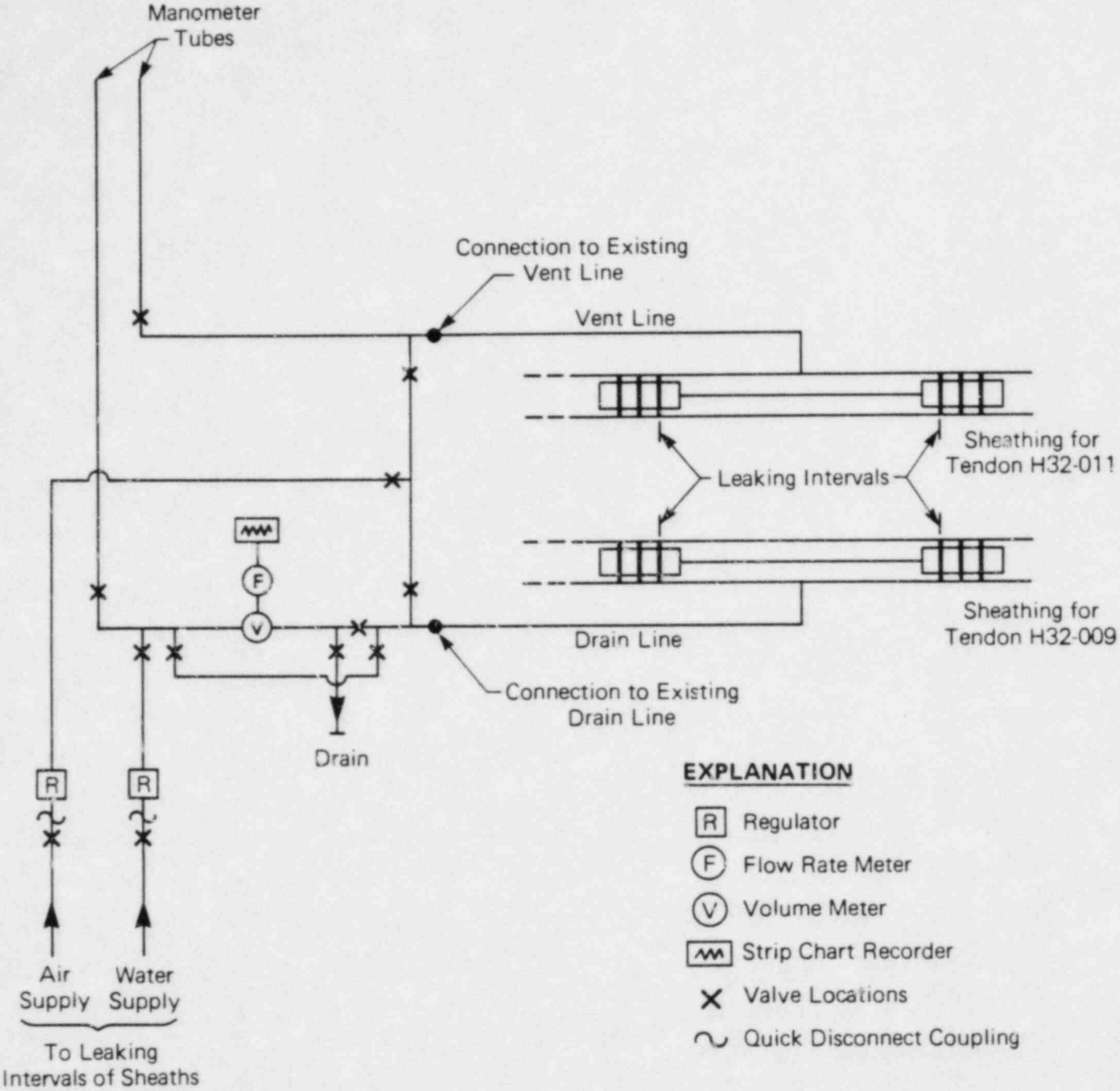
**FIGURE 3**




**SCHEMATIC DIAGRAM OF SHEATH TEST SETUP**

Not to Scale

**FIGURE 4**



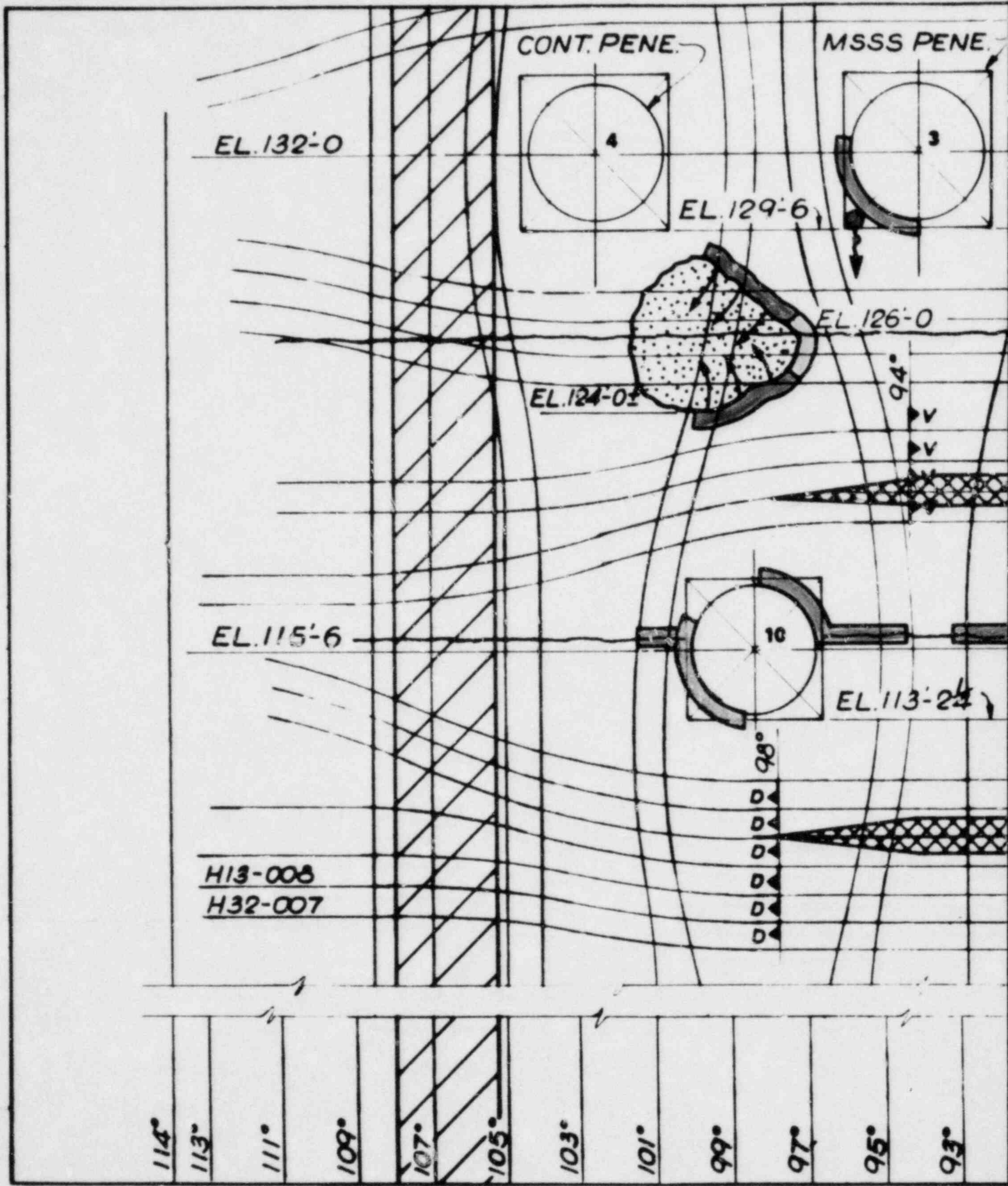

**NOTES**

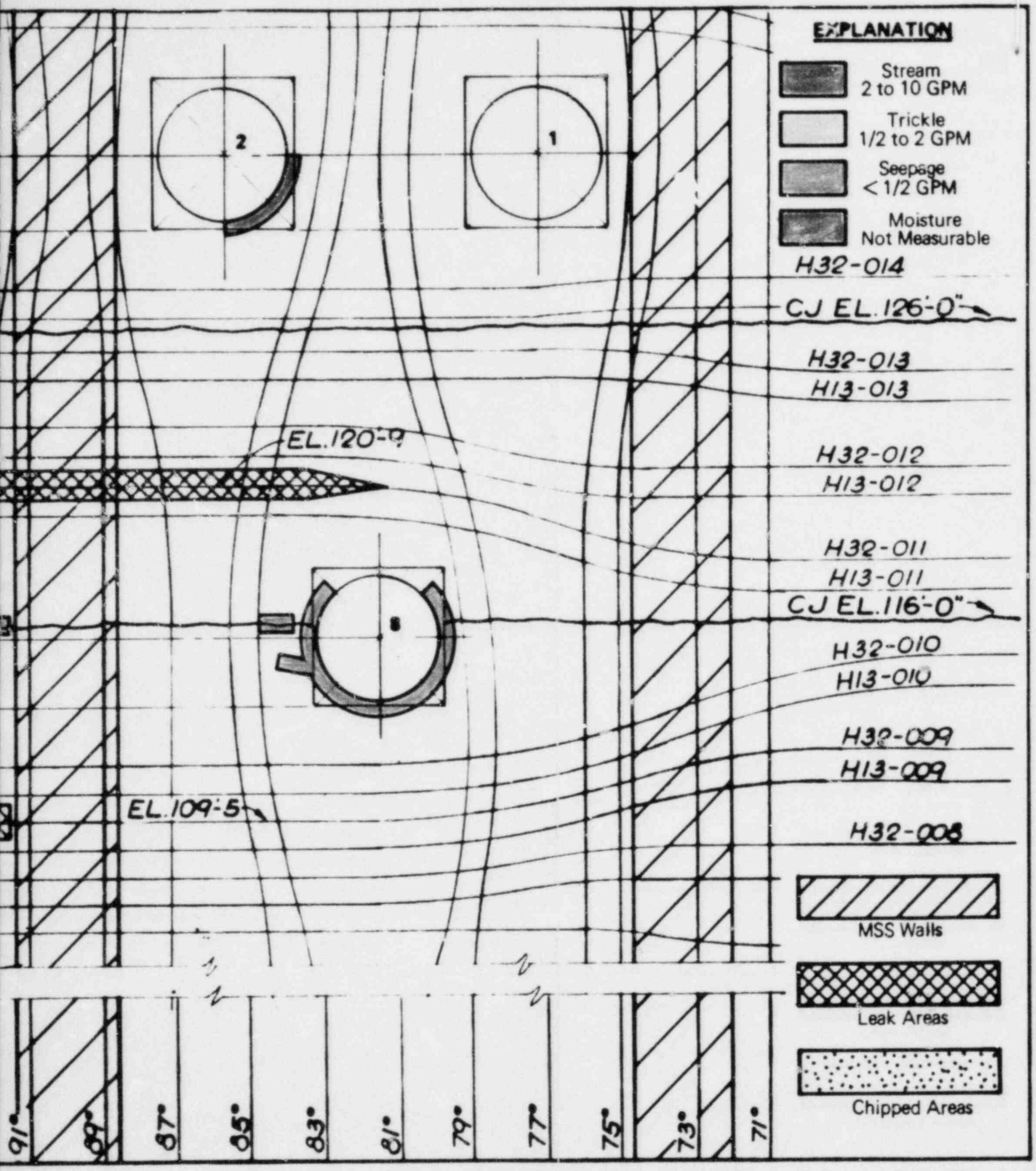
Air supply to packers plumbed from buttress #2 – See Figure 3

**SCHEMATIC DIAGRAM OF LEAK PATH TEST SETUP**

Not to scale

**FIGURE 5**

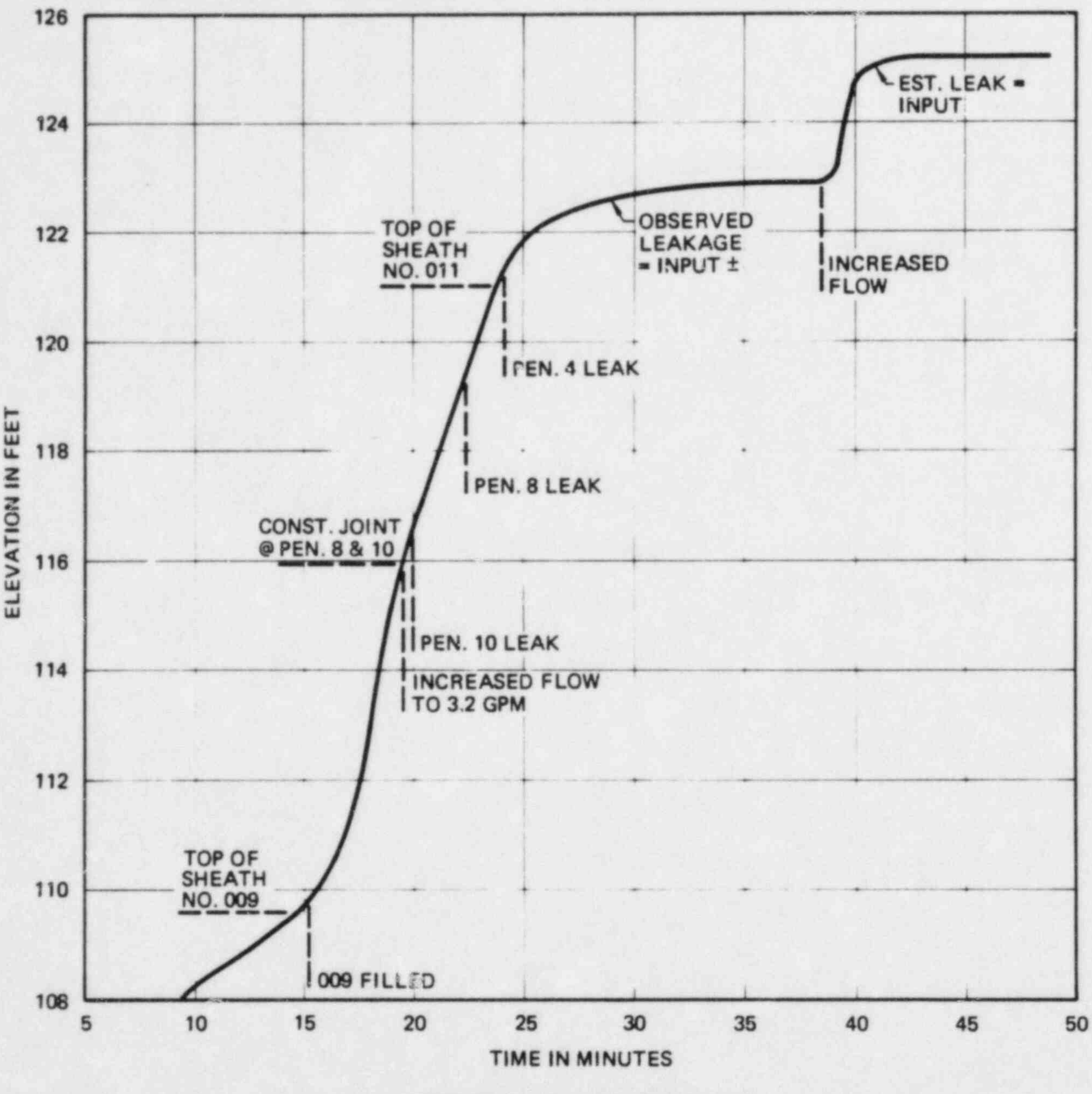

CONT. PENE.
MSSS PENE.
4
3
EL. 132'-0
EL. 129'-6
EL. 126'-0
EL. 124'-0½
94°
EL. 115'-6
10
EL. 113'-2¼
98°
H13-008
H32-007
114°
113°
111°
109°
107°
105°
103°
101°
99°
97°
95°
93°




8307120303-02

COMPOSITE DRAWING OF LEAK EXITS

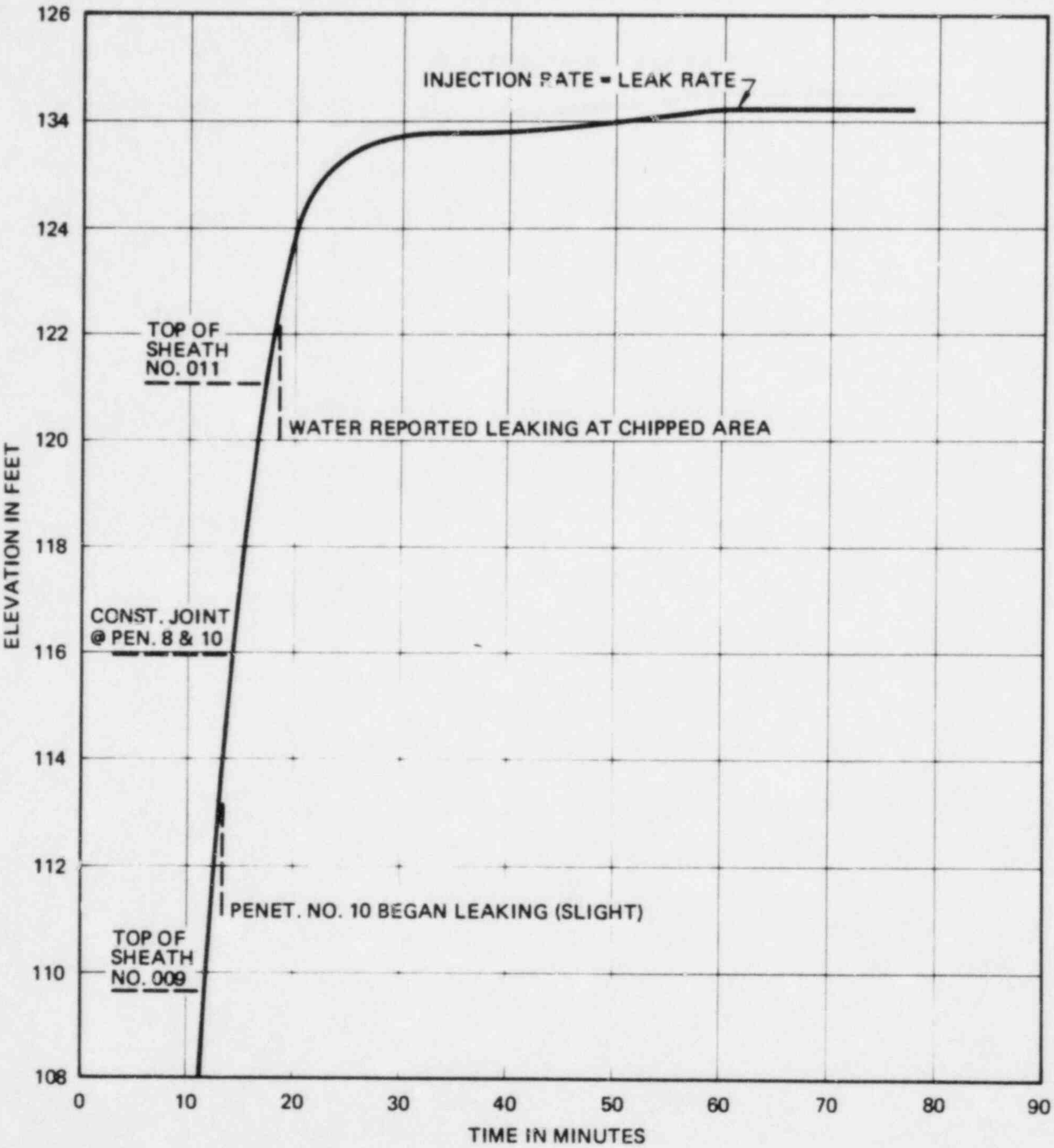
FIGURE 6




TEST 3 1-26-83 (AFTERNOON)

MANOMETER ELEVATION
VS TIME
SHEATH 009

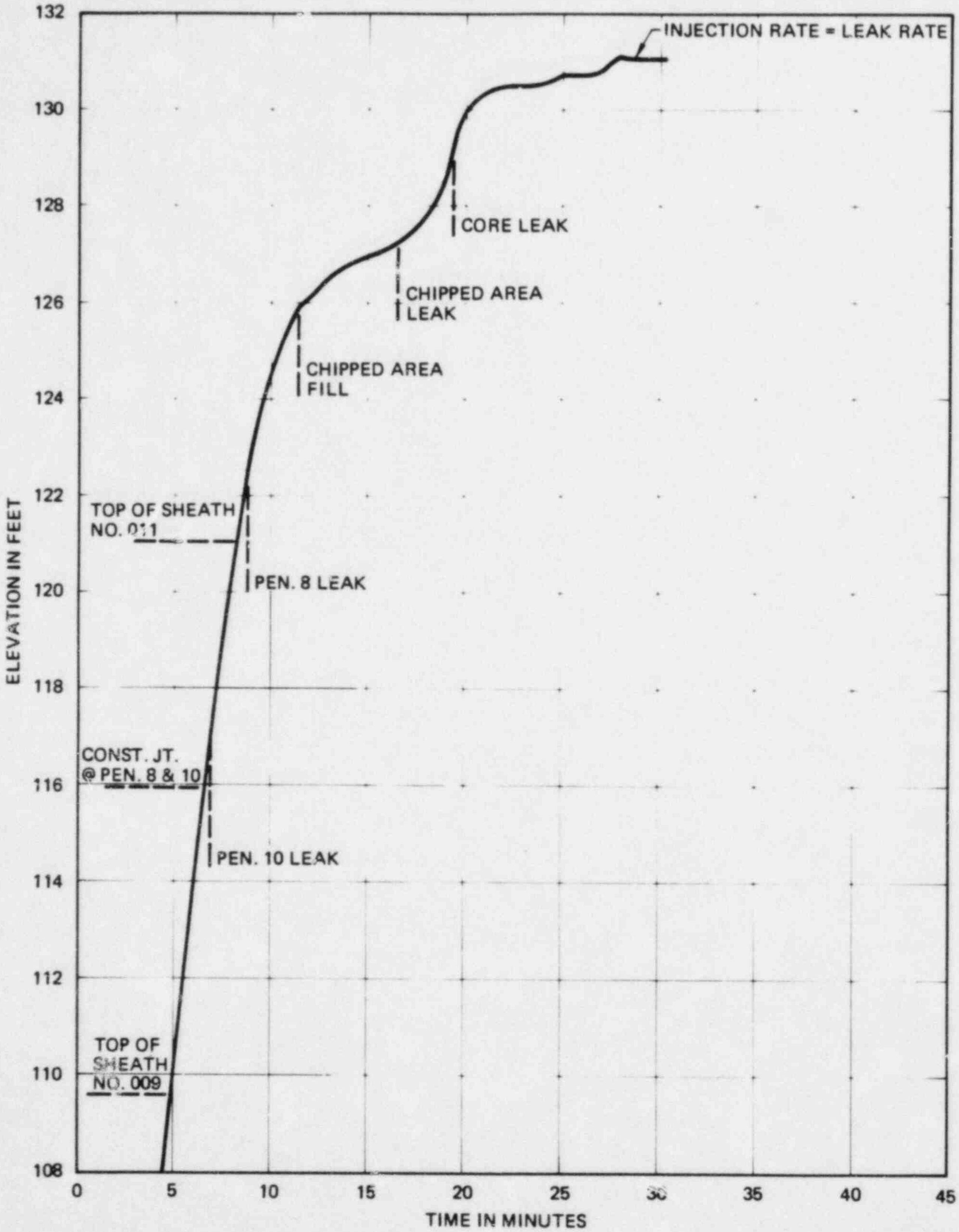
FIGURE 7




TEST 4 1-27-83 A.M.

MANOMETER ELEVATION
VS TIME
SHEATH 009

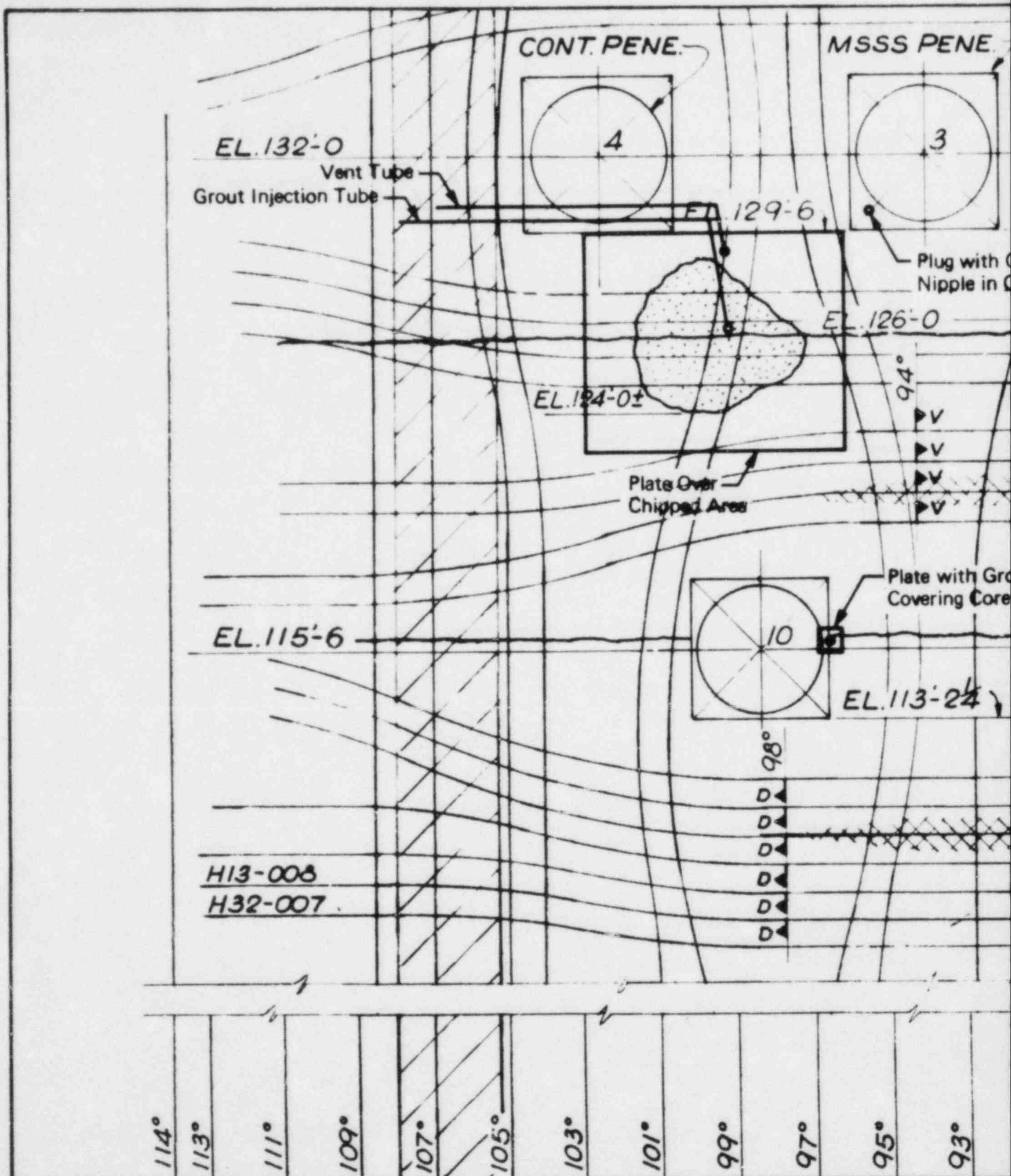
FIGURE 8

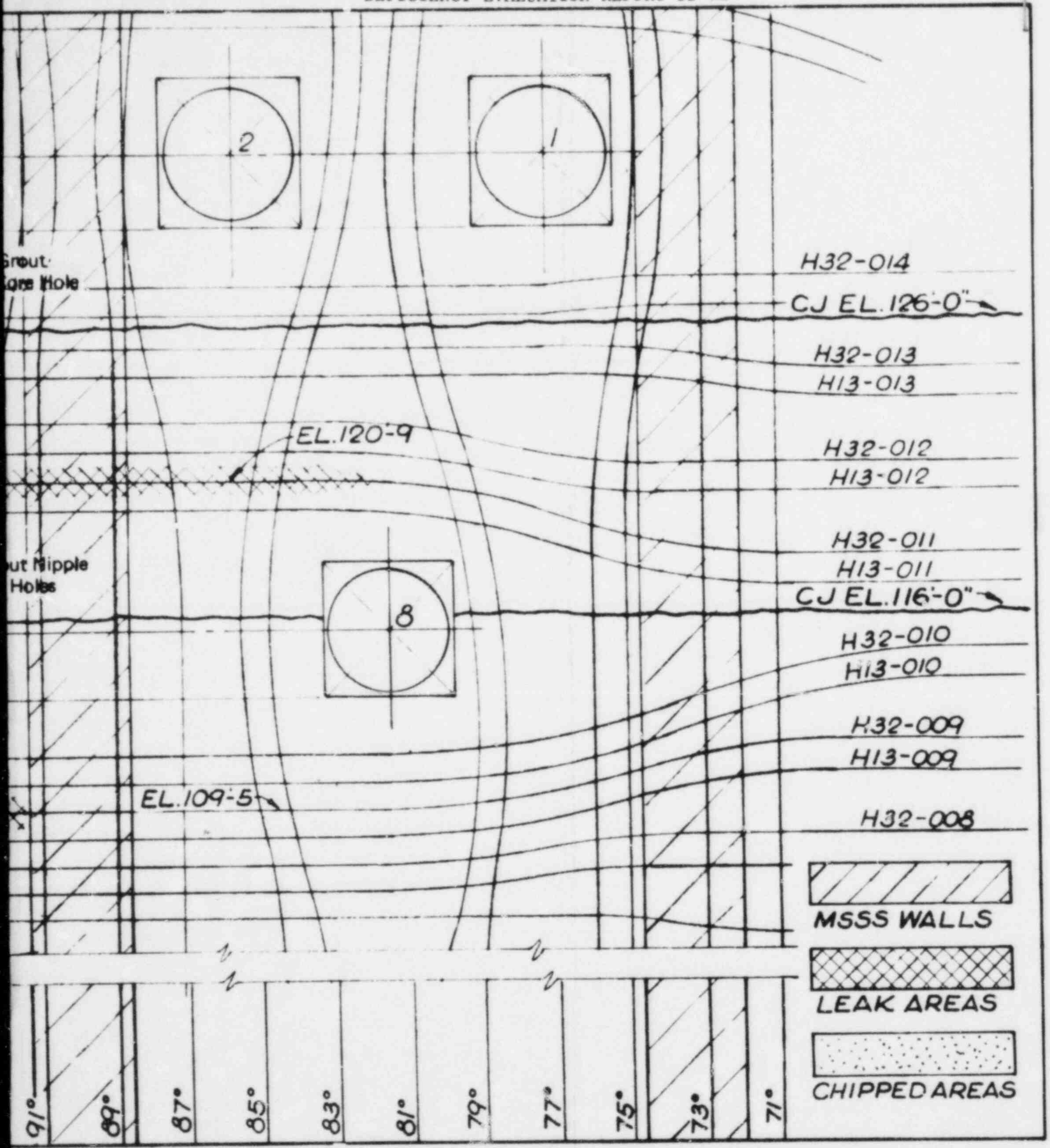



TEST 5 1-27-83 (AFTERNOON)

MANOMETER ELEVATION
VS TIME
SHEATH 009

FIGURE 9


CONT. PENE.
MSSS PENE.
4
3
EL.132'-0
Vent Tube
Grout Injection Tube
129'-6
Plug with C
Nipple in C
EL.126'-0
94°
EL.124'-0±
Plate Over
Chipped Area
Plate with Gro
Covering Core
EL.115'-6
10
EL.113'-2¼
98°
H13-008
H32-007
114°
113°
111°
109°
107°
105°
103°
101°
99°
97°
95°
93°

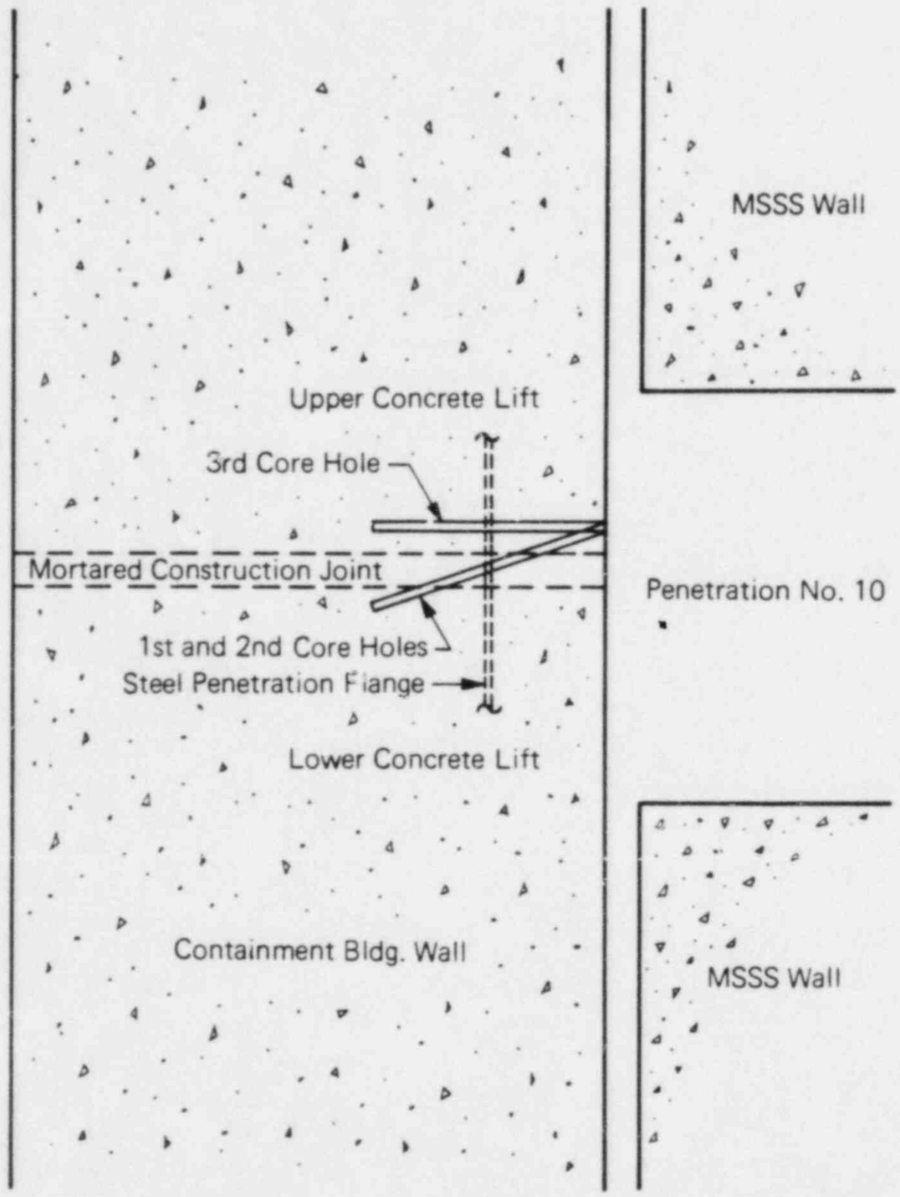



**GROUT INJECTION LOCATIONS**

Not to Scale

FIGURE 10

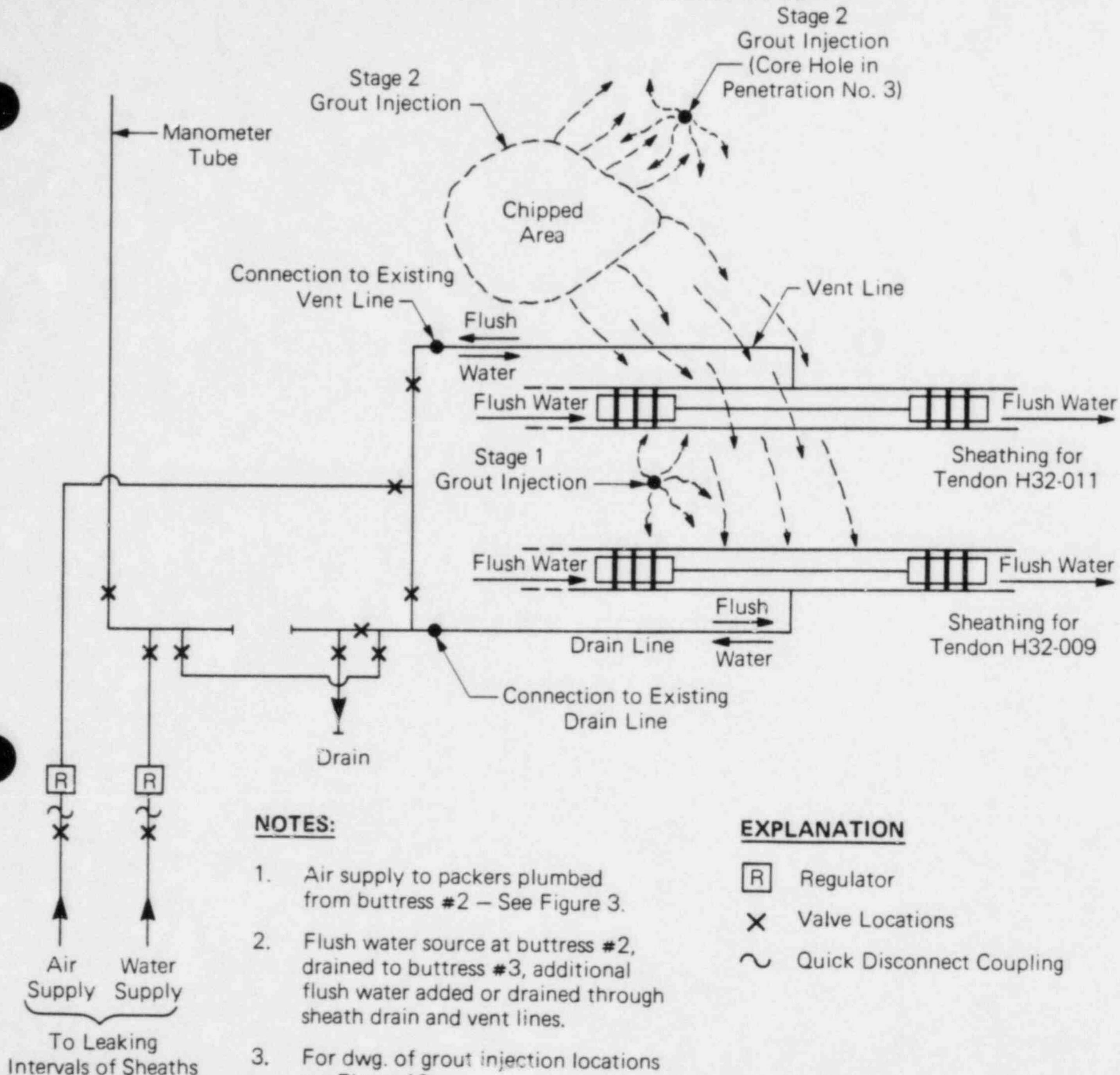
8304120303-03




**SCHEMATIC DIAGRAM OF CONTAINMENT WALL AND CORE HOLE DRILLED FROM PENETRATION NO. 10**

Not to Scale

**FIGURE 11**




**NOTES:**

1. Air supply to packers plumbed from buttress #2 – See Figure 3.
2. Flush water source at buttress #2, drained to buttress #3, additional flush water added or drained through sheath drain and vent lines.
3. For dwg. of grout injection locations see Figure 10.
4. The above plumbing was based on the best plumbing shown in Figure 5.

**EXPLANATION**

R Regulator

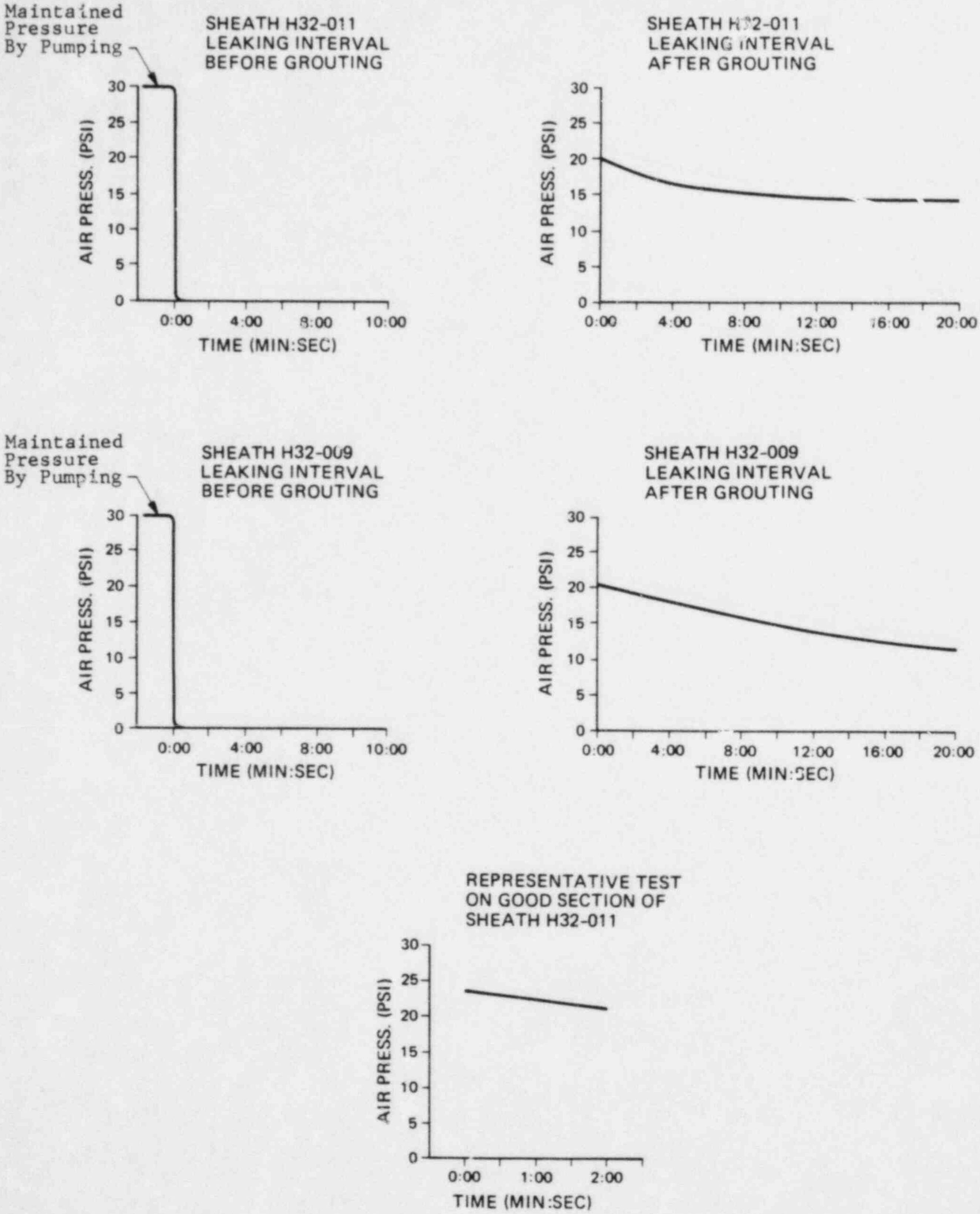
× Valve Locations

∿ Quick Disconnect Coupling

**SCHEMATIC DIAGRAM OF GROUTING SETUP**

Not to Scale

**FIGURE 12**




INTERVAL 150'-9"-175'-9"
(Measured Along Sheath from Face of Buttress No. 2)

**COMPARISON OF PRE- AND POST-GROUTING AIR TESTS**

**FIGURE 13**

# APPENDIX A

# AIR AND WATER TEST PROCEDURES

APPENDIX A

NCR C-C-3805

Attachment A

Deficiency Evaluation Report No. 82-72

Air and Hydraulic Test Procedures

For Evaluating the Tendon Sheathing

Air Leaks in the Containment Building

At the Palo Verde Nuclear Generating Station,

Unit 2

Phoenix, Arizona

Prepared by:

Bechtel Power Corporation

Norwalk, California

Job Number 10407

1983

Revision 0

Date 1-17-83

PFE [signature]

PQAE [signature] 1/10/83

PQCE [signature] 1/17/83

Originator [signature]

PE [signature]

AIR AND HYDRAULIC TESTING OF

UNIT 2 CONTAINMENT BUILDING TENDON SHEATHING

TABLE OF CONTENTS

Exhibit B: Schedule

Exhibit C: Sample Data Collection Form - Water Meter Quantity versus Time

Exhibit D: Sample Data Collection Form - Containment Wall Surface Observation

Exhibit E: Sample Data Collection Form - Manometer for Tendon Sheath H32-009

Exhibit F: Sample Data Collection Form - Manometer for Tendon Sheath H32-011

## AIR AND HYDRAULIC TESTING OF UNIT 2 CONTAINMENT BUILDING TENDON SHEATHING

### 1.0 OBJECTIVES

The objectives of the hydraulic leak testing of tendon sheaths H32-009 and H32-011 are to:

A. Locate concrete cracks on the exterior of the containment wall which communicate with these leaking tendon sheaths.

B. Verify the absence of significant concrete voids.

C. Gather information on water flow characteristics (flow rate, volume) through the crack(s) to identify water paths and determine optimum sealing method.

D. Provide the basic data needed for grouting should this be the selected sealing method.

2.0 TEST CRITERIA

2.1 The maximum hydraulic pressure to be applied to the containment sheathing shall be 25 psi. Source: Engineering Requirement.

2.2 The maximum air pressure to be applied to the containment sheathing in any portion of the sheathing capable of holding pressure shall be 25 psi. Source: Engineering Requirement.

2.3 The maximum air pressure to be applied to the containment sheathing in any portion of sheathing not capable of holding pressure shall be 60 psi. Source: Engineering Requirement.

2.4 Each packer in the packer assemblies, when in the sealed position, shall be maintained at a minimum pressure of 62 psi and maximum pressure of 68 psi, or 65 ± 3 psi. Source: Engineering Requirement.

3.0 REFERENCES

3.1 WCS Drawing No. PS-112 Wall Tendon Locations

3.2 WCS Drawing No. PS-131 Vent and Drain Locations

3.3 Deficiency Evaluation Report 82-72

3.4 Non-Conformance Report CC-3805

3.5 Interoffice Memo Wolff/Schechter, December 7, 1982

4.0 QUALITY CRITERIA

4.1 Only the test director and his designee are authorized to verify that the requirements for the testing program have been met. The test director is also the test engineer.

Each step in the preparation for and in the conducting of each test is defined in the test procedure and has a line preceding the step. Upon completion of the requirements for each step the test director or his designee will indicate, by initialing the line preceding the step, that all the requirements of that step have been met.

4.2 The last item in the prerequisite section in each test section will include a space for sign off and a statement indicating that a Quality Control representative has monitored the activities of each test section and verified that those requirements are in compliance with the test procedure.

5.0 PREREQUISITES

| Sign-Off Column | Prior to initiating the testing the following conditions shall be met. |
|---|---|
| ________ | 5.1 All equipment (Section 7.0) has been procured, delivered and inspected. |
| ________ | 5.2 All required work platforms, scaffolding, etc., have been properly positioned. Requirements will be established by the test director prior to testing. |
| ________ | 5.3 All construction interferences have been removed or repositioned. |
| ________ | 5.4 The seismic gap area between the containment and MSSS walls has been protected from weather. In addition, the seismic gap area has been sealed below the test area to protect against materials falling into the gap. |

_______ 5.5 Telephone communications have been installed and checked between control point and observation stations (requirements are outlined in Section 9.6.2).

_______ 5.6 All test plumbing including vertical standpipes (manometer tubes) have been installed.

_______ 5.7 All test observers including gauge readers and leak monitors have been briefed in a pre-test orientation session.

_______ 5.8 All observers (leak monitors) are equipped with air leak detection equipment (rods, flagging, measuring tapes, etc.) and accurate timepieces.

_______ 5.9 QC final acceptance for Section 5.

6.0 SPECIAL PRECAUTIONS

6.1 Scaffolding, work platforms, etc., shall conform to OSHA standards.

6.2 Test pressures may not exceed those specified in Section 2.0.

6.3 At no time may the static pressure between packers exceed 60 percent of the internal pressure of the packers, i.e., 39 $\pm$ 2 psi.

6.4 Packer assemblies must be connected to winches by tow and tail lines at all times during testing.

## 7.0 TEST EQUIPMENT

| Item | to be provided by |
|---|---|
| Air and water supply | Construction |
| Air regulator pressure gauges, valves, approx. 300 feet of air hose | Construction |
| Water hose (1") - approx. 300 feet, valves, pressure regulator, 1" manifold plumbing | Construction |
| Clear plastic tubing (1/2-1") - approx. 60 feet to be used as manometer | Construction |
| Volumetric water meter with pulse transmitter | Engineering - to be procured from supplier |
| Flow rate indicator | Engineering - to be procured from supplier |
| Strip chart recorder with event marker | Bechtel Instrument Calibration Lab (jobsite), may be borrowed from APS |
| Packer assemblies (2) - made up according to diagram in Figure 1 | Construction - procured from supplier (already on jobsite) |
| Pressure gauges (2) | Construction |
| 55-Gal. drums (2) for calibrating the meter and for catching spilled water (1 to be placed beneath sheaths at each buttress) | Construction |
| Hard wire telephone (4 lines) and walkie-talkies | Construction and/or Western Concrete |
| Lights to illuminate crack area | Construction |
| Precision stopwatches | Individual Observers/ Construction/Engineering |
| Observers rods with flagging, folding rules, tape measures (6 sets) | Construction |
| Work platforms | Construction |
| Assorted small tools, winches | Western Concrete |

8.0 INITIAL CONDITIONS

Tendons H32-009 and H32-011 were tensioned and, in preparation for greasing, the sheaths were pressurized with air using approved procedures to verify the absence of leaks which would permit the escape of grease. Neither sheath would hold the air pressure. While pumping air into each of the sheaths, air was observed to return through the other sheath as well as to escape through a crack in the exterior face of the concrete wall. This crack is located near a main steam supply pipe penetration. The results were identical for both sheaths.

The tension was released from the two tendons and they were removed from the sheaths. At the present time all other horizontal and vertical tendons have been installed, tensioned and greased. Additional, more detailed, air testing was performed to locate the leaking areas inside both sheaths. This air testing, which employed a packer assembly identical to those to be used in this procedure, succeeded in locating the leaks in the sheaths with good accuracy. The results of this testing were reported in Interoffice Memorandum Wolff/Schechter dated December 7, 1982 (reference 3.5).

In addition to air testing, inspection of the concrete in the vicinity of the crack was performed. This consisted of chipping out an area around the crack (Figure A-3) and drilling a small core hole near penetration #3. This inspection revealed that the concrete is in good condition in these areas. No voids or other deleterious conditions were found. Review of documentation covering construction procedures in this area has not indicated any problems with concrete placement or with materials which might affect the quality of the concrete.

9.0 PROCEDURE AND DATA COLLECTION

Sign-Off Column

9.1 Stage 1 - Preparation and Testing of Packer System

_______ 9.1.1. Packer system is assembled as shown in Figure A-1.

_______ 9.1.2. Packer system is tested to verify absence of air leaks through fittings couplings and connections.

_______ 9.1.3. Packer system is tested in a portion of sheathing known not to leak.
Packer Pressure = 65 psi ± 3 psi.
Sheathing Pressure = 22 psi ± 3 psi.

_______ 9.1.4. Water meters, flow meters, recorders and all associated equipment obtained from commercial sources are supplied with a statement of calibration. After Stages 1, 2, 3, and 4 have been completed, the equipment will be returned to supplier who will again calibrate and submit a statement to that effect.

_______ 9.1.5. QC final acceptance for 9.1.

9.2 Stage 2 - Air Testing of Sheathing and Concrete

_______ 9.2.1. Place packer assemblies in sheaths H32-009 and H32-011 so that rear face of each rear packer is 103 feet ± 6 inches from face of buttress number 2 (See Figures A-1 and A-2 for details of packer assembly). The location of packer placement was based on the locations of the leaks as defined in reference 3.5.

_______ 9.2.2. Observers, who were previously oriented, stationed in position at penetrations in MSSS and Containment Building.

_______ 9.2.3. Communications in place and operating.

_______ 9.2.4. Packers inflated to 65 psi ± 3 psi.

_______ 9.2.5. Air introduced through drain of Tendon Sheath H32-009 and through vent of Tendon Sheath H32-011 (See Figure A-2). Pressure of applied air at 22 psi ± 3 psi.

_______ 9.2.6. Observations made at penetrations by observers in item 9.2.2. above (Refer to Section 9.6 for observation procedures).

_______ 9.2.7. Air pressure at the injection point increased to 60 psi ± 3 psi (Note: This does not violate Section 6.3 because the sheathing between the packers leaks and will not hold static pressures).

_______ 9.2.8. Observations made at penetrations by observers in item 9.2.2. above.

_______ 9.2.9. Test complete.

_______ 9.2.10. QC final acceptance for 9.2.

9.3 Stage 3 - Hydraulic Test at Low Flow

_______ 9.3.1. Packer assemblies placed in Tendon Sheaths H32-009 and H32-011, in same position as in 9.2.1.

_______ 9.3.2. Observers stationed in positions at penetrations #1, 2, 3, 4, 8 and 10 (See Figure A-3 for penetration numbers) between the MSSS Building and the Containment Building.

_______ 9.3.3. Observers stationed at Containment Building wall at approximately the 114° point to record water level in stand pipes for H32-009 and H32-011 versus time.

_______ 9.3.4. Gauge Readers and Monitors in position and standing by record quantity of flow versus time at water meter.

_______ 9.3.5. Flow recorder operable and standing by.

_______ 9.3.6. Communications in place and operating.

_______ 9.3.7. Packers inflated with air to 65 psi $\pm$ 3 psi.

_______ 9.3.8. Water injected into isolated portion of sheath H32-009 through the drain and time 0 marked to begin all observations. Initial flow rate of 5 gpm $\pm$ 2 gpm. (Flow may vary as affected by flow characteristics of system.) Water pressure not to exceed 25 psi.

_______ 9.3.9. Observations made at all stations.

_______ 9.3.10. Steady state flow conditions reached.

_______ 9.3.11. Inspection made inside Containment Building in vicinity of main steam and feedwater line penetrations to verify absence of water leakage to inside of Containment.

_______ 9.3.12. Flow of water discontinued.

_______ 9.3.13. Standpipe (manometer tube) readings taken with time as system is drained.

_______ 9.3.14. Test concluded.

_______ 9.3.15. QC final acceptance of 9.3.

9.4 Stage 4 - Hydraulic Test at Low Flow (Repeat of Stage 3).

_______ 9.4.1. Packer assemblies located in Tendon Sheaths H32-009, and H32-011, in same positions as in 9.3.1.

_______ 9.4.2. Observers stationed at positions at penetrations #1, 2, 3, 4, 8 and 10 between the MSSS Building and the Containment Building.

_______ 9.4.3. Observers stationed at Containment Building wall at approximately the 114° point to record water level in stand pipes versus time.

_______ 9.4.4. Gauge Readers and Monitors in position and standing by to record quantity of flow versus time at water meter.

_______ 9.4.5. Flow recorder operable and standing by.

_______ 9.4.6. Communications in place and operating.

_______ 9.4.7. Packers inflated with air to 65 psi ± 3 psi.

_______ 9.4.8. Water injected into isolated portion of Sheath H32-009 and time 0 marked to begin all observations. Initial flow rate of 5 gpm ± 2 gpm. (Flow may vary as affected by flow characteristics of system). Water pressure not to exceed 25 psi.

_______ 9.4.9. Observations made at all stations.

_______ 9.4.10. Steady state flow conditions reached.

_______ 9.4.11. Flow of water discontinued.

_______ 9.4.12. Leak down readings complete.

_______ 9.4.13. Test concluded.

_______ 9.4.14. QC final acceptance of 9.4.

9.5 Hydraulic Test at Maximum Flow.

_______ 9.5.1. Packer assemblies located in Tendon Sheaths H32-009, and H32-011, at same locations as 9.4.1.

_______ 9.5.2. Observers stationed at positions at penetrations #1, 2, 3, 4, 8 and 10 between the MSSS Building and the Containment Building.

_______ 9.5.3. Observers stationed at Containment Building wall at approximately the 114° point to record water level in stand pipes versus time.

_______ 9.5.4. Gauge Readers and Monitors in position and standing by to record quantity of flow versus time at water meter.

_______ 9.5.5. Flow recorder operable and standing by.

_______ 9.5.6. Communications in place and operating.

_______ 9.5.7. Packers inflated with air to 65 psi ± 3 psi.

_______ 9.5.8. Water injected into H32-009 and H32-011 at maximum flow achieved with applied pressure of 25 +0, -3 psi. (Flow rate determined by flow characteristics of the system.) Water pressure not to exceed 25 psi.

_______ 9.5.9. Observations made at all stations.

_______ 9.5.10. Steady state flow conditions reached.

_______ 9.5.11. Flow of water discontinued.

_______ 9.5.12. Leak down readings complete.

_______ 9.5.13. Test concluded.

_______ 9.5.14. QC final acceptance of 9.5.

9.6 Observation Procedures

9.6.1. Gauge Monitors

The gauge monitors will consist of two observers, one of whom will read the gauges on the water meters, versus time and the second of whom will read water level elevations

in the manometer tubes versus time. Both monitors will record initial readings prior to the start of Stage 3 testing. Both monitors will record readings at time zero, or the precise moment that the supply valve is opened. Thereafter, both monitors will record readings at 15-second intervals. At the discretion of the test director, the intervals between readings may be increased to 30 seconds or longer based on the progress of the test. Readings will be recorded during fill and drain cycles of the test.

Readings will be recorded on forms as shown in Exhibits C, E, and F unless otherwise directed by the lead engineer.

9.6.2. Leak Observers

Six two-man teams of observers will be required to man inspection stations surrounding the crack area. Each two-man team will consist of one observer and one recorder. The stations will be at wall penetrations and will be distributed in such a way as to cover an area below, above, and on both sides of the crack (See Figure A-3). This will ensure that all leaking water will be detected.

It will be extremely important for all observers to record the precise time of <u>any</u> observation so that this may be compared with the time history of flow. For this reason all observers must have accurate synchronized timepieces. The area where the observations are to be made shall be completely lighted with

temporary floodlights. In addition, where required, observers will have flashlights.

Upon the appearance of leaking water at any point on the wall, detailed estimates of flow rate, quantity, and exact location must be made. Observers should be familiar with what various flows look like. This will be accomplished in an orientation session to precede the test.

Communications via hard wire telephone must be established between the meter point outside the MSSS, the crack area, Buttress #2 and Buttress #3. A second extension phone will be required between a central control point at the crack area and one or more of the observers who will be separated from this central point by the thick center wall of the MSSS building.

All observations will be recorded on a form as shown in Exhibit D unless directed otherwise by the lead engineer.

10.0 DOCUMENTATION OF RESULTS

All time-dependent meter readings, pressure readings, and observations of locations and quantities of leakage will be recorded on the forms shown in Exhibits C, D, E, and F. Total volume readings will be recorded as field notes. All field records will be signed and dated by the observer and will be kept in a file which will constitute the original field data set. The strip chart recording of flow time history will be dated and signed off by the lead engineer. A test log will be prepared by a designee of the test director. The log will describe the sequence of events during the tests and will include dates, times, etc.

A report will be prepared by Engineering describing the test methods, results obtained, and conclusions reached.

11.0 INTERPRETATION OF DATA

The volume of the crack system in the wall will be determined by measuring the total volume during the test, and subtracting the total volume of the sheathing between the packers, the plumbing to the test intervals downstream of the meter, water spilled from leaks in the wall, and water returning through sheathing to either Buttress #2 and #3.

The results of the fill cycle and the drain cycle for the Stage 3 test will be compared with each other for verification. If the drain cycle test volume is less than the fill cycle test volume then this will indicate the relative quantity of the crack system which is undrained. Comparison of the results with subsequent hydraulic tests number 9.4 and 9.5 will be made to back up the findings in test number 9.3.

The time history of flow as well as the sequence of water appearance at leaks will be studied for inferences regarding the nature of the leak system. This information will help to reveal the spatial distribution of the crack system and the degree of resistance to flow through the cracks. If voids in the concrete are present they will be detected. The time-history of water rise in the manometer tubes will indicate the elevations of voids if they exist.

The results of the Stage 2 air test will be used in conjunction with the results of hydraulic testing to determine whether any cracks exist from which the water was not able to exit. For example, the water may spill from cracks at lower elevations and may not rise to the point of filling all cracks. This would be factored into any volume estimates.

12.0 RESTORATION

12.1 All test equipment shall be demobilized from the area.

12.2 All water shall be removed from the tendong sheaths by blowing with air, swabbing, or any other Engineering approved nondestructive means necessary.

12.3 All construction interferences removed or repositioned for the test shall be dispositioned as directed by the lead engineer or test director.

12.4 All temporary weatherproofing in the Containment - MSSS gap shall be dispositioned as directed by the lead engineer or test director.

12.5 All spilled water shall be cleaned up.

13.0 ATTACHMENTS

Exhibit A: Figures

A-1 Schematic Diagram Showing Test Equipment Setup

A-2 Detailed Schematic of Test Piping and Controls

A-3 Unit 2 Containment Wall Study

Exhibit B: Schedule

Exhibit C: Sample Data Collection Form - Water Meter Quantity versus time

Exhibit D: Sample Data Collection Form - Containment Wall Surface Observation

Exhibit D: Sample Data Collection Form - Manometer for Tendon Sheath H32-009

Exhibit D: Sample Data Collection Form - Manometer for Tendon Sheath H32-011

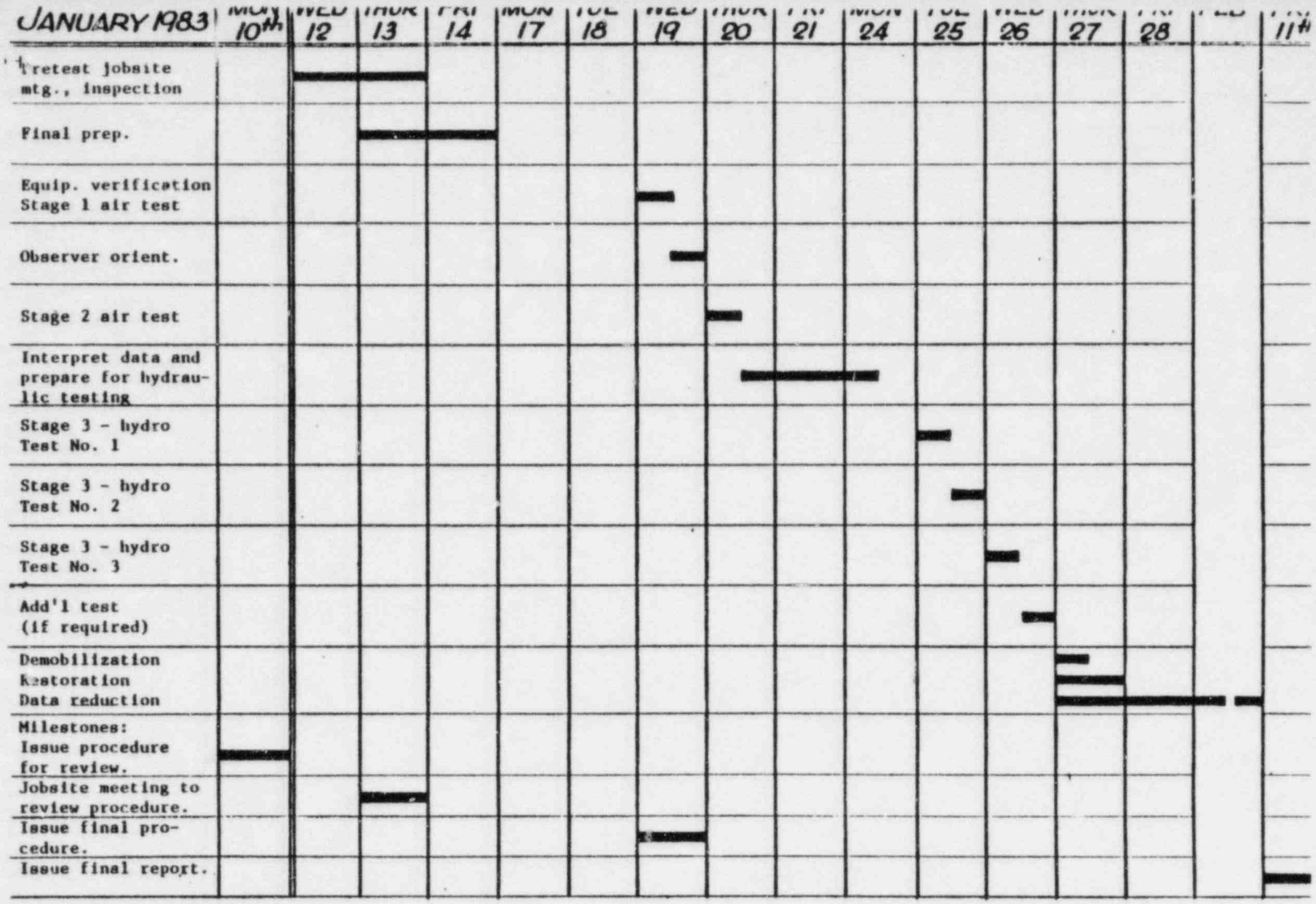



EXHIBIT B - SCHEDULE

AIR & HYDRAULIC TEST PROCEDURE

FOR UNIT 2 CONTAINMENT BUILDING

TENDON SHEATHING

DATE- TEST NO.- APPROX. TIME OF DAY-

## WATER METER QUANTITY vs TIME

| TIME | | QUANTITY GALLONS | REMARKS |
|---|---|---|---|
| Min. | Sec. | | |
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EXHIBIT "C" Recorded by-

Sheet of

| Reference | AIR & HYDRAULIC TEST PROCEDURE<br>FOR UNIT 2 CONTAINMENT BUILDING<br>TENDON SHEATHING | LEGEND<br>1-Trickle<br>2-Small Stream<br>3-Large Stream<br>4-Gushing |
|---|---|---|

DATE- TEST NO.- APPROX. TIME OF DAY-

## CONTAINMENT WALL SURFACE OBSERVATION

| OBSERVE FROM PENETRATION# TIME OF OBSERVATION | | ELEV. | LOCATION HORIZ. DISTANCE FROM REFERENCE * | REMARKS WHAT OBSERVED AND QUANTITY (SEE LEGEND ABOVE) |
|---|---|---|---|---|
| Min. | Sec. | | | |
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EXHIBIT "D" Recorded by-

Sheet of

**AIR & HYDRAULIC TEST PROCEDURE**

**FOR UNIT 2 CONTAINMENT BUILDING**

**TENDON SHEATHING**

DATE- TEST NO.- APPROX. TIME OF DAY-

MANOMETER FOR TENDON SHEATH H32-009

WATER ELEVATION vs TIME

| TIME | | ELEV. OF WATER LEVEL | REMARKS |
|---|---|---|---|
| Min. | Sec. | | |
| | | | |
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EXHIBIT "E" Recorded by-

Sheet of

AIR & HYDRAULIC TEST PROCEDURE

FOR UNIT 2 CONTAINMENT BUILDING

TENDON SHEATHING

DATE- TEST NO.- APPROX. TIME OF DAY-

MANOMETER FOR TENDON SHEATH H32-011

WATER ELEVATION vs TIME

| TIME | | ELEV. OF WATER LEVEL | REMARKS |
|---|---|---|---|
| Min. | Sec. | | |
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EXHIBIT "F" Recorded by-

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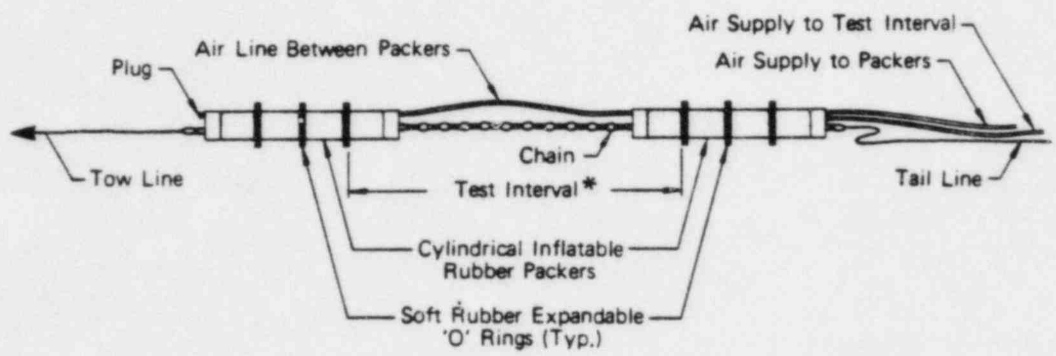
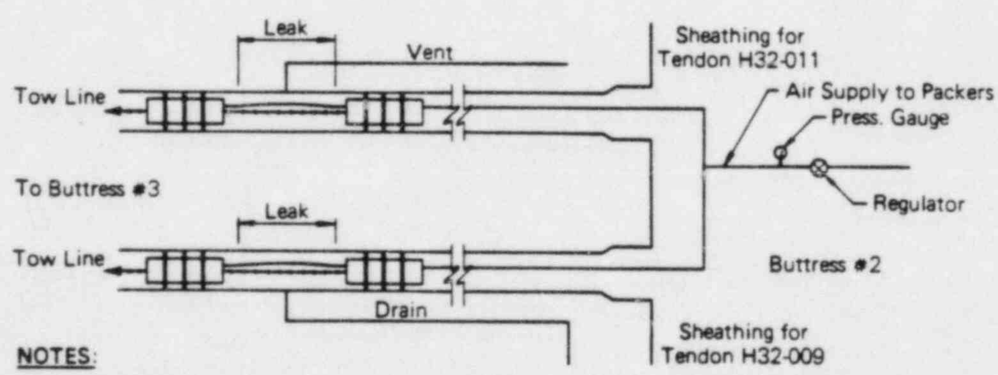



*Test Interval = 20 feet in H32-009, 30 feet in H32-011

DETAILS OF PACKER ASSEMBLY
(Not to Scale)

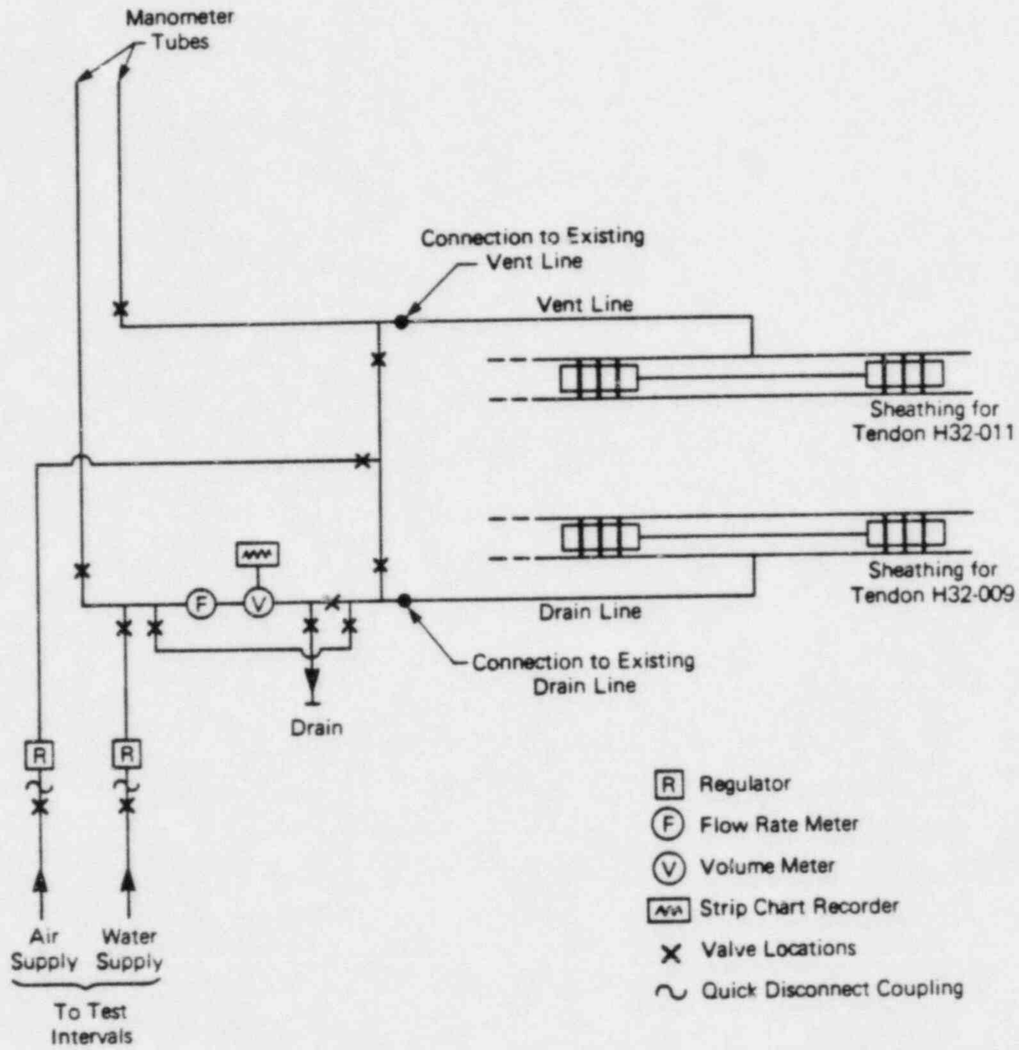



NOTES:

1. Not to scale
2. For details of test plumbing see Figure A-2
3. All connections, fittings to be completely leak tight

SCHEMATIC DIAGRAM SHOWING TEST EQUIPMENT SETUP

FIGURE A-1

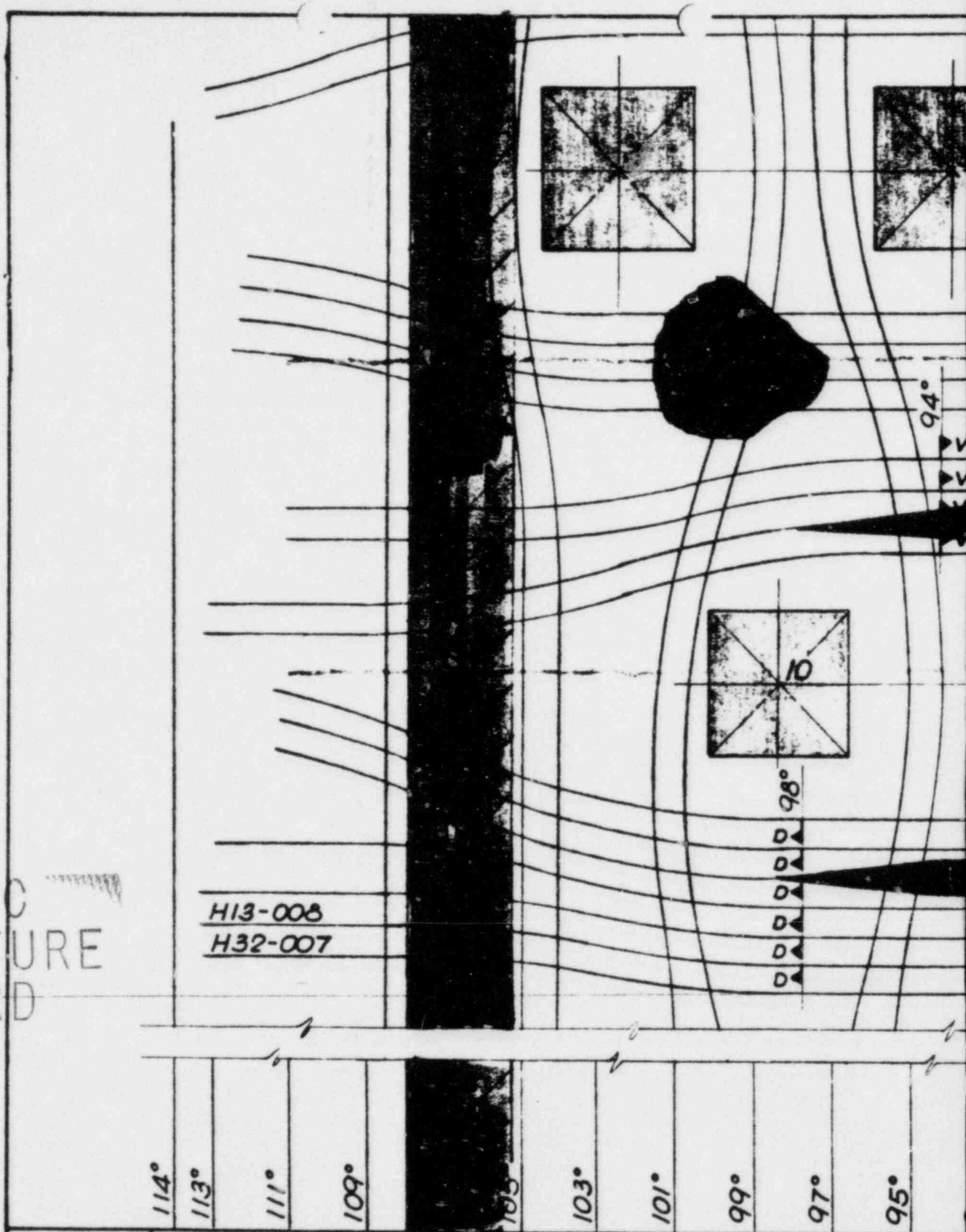



**NOTES:**

1. Air supply to packers is plumbed from buttress #2 – See Figure A-1
2. All connections, fittings to be completely leak tight
3. Not to scale

DETAILED SCHEMATIC OF TEST PIPING AND CONTROLS

FIGURE A-2

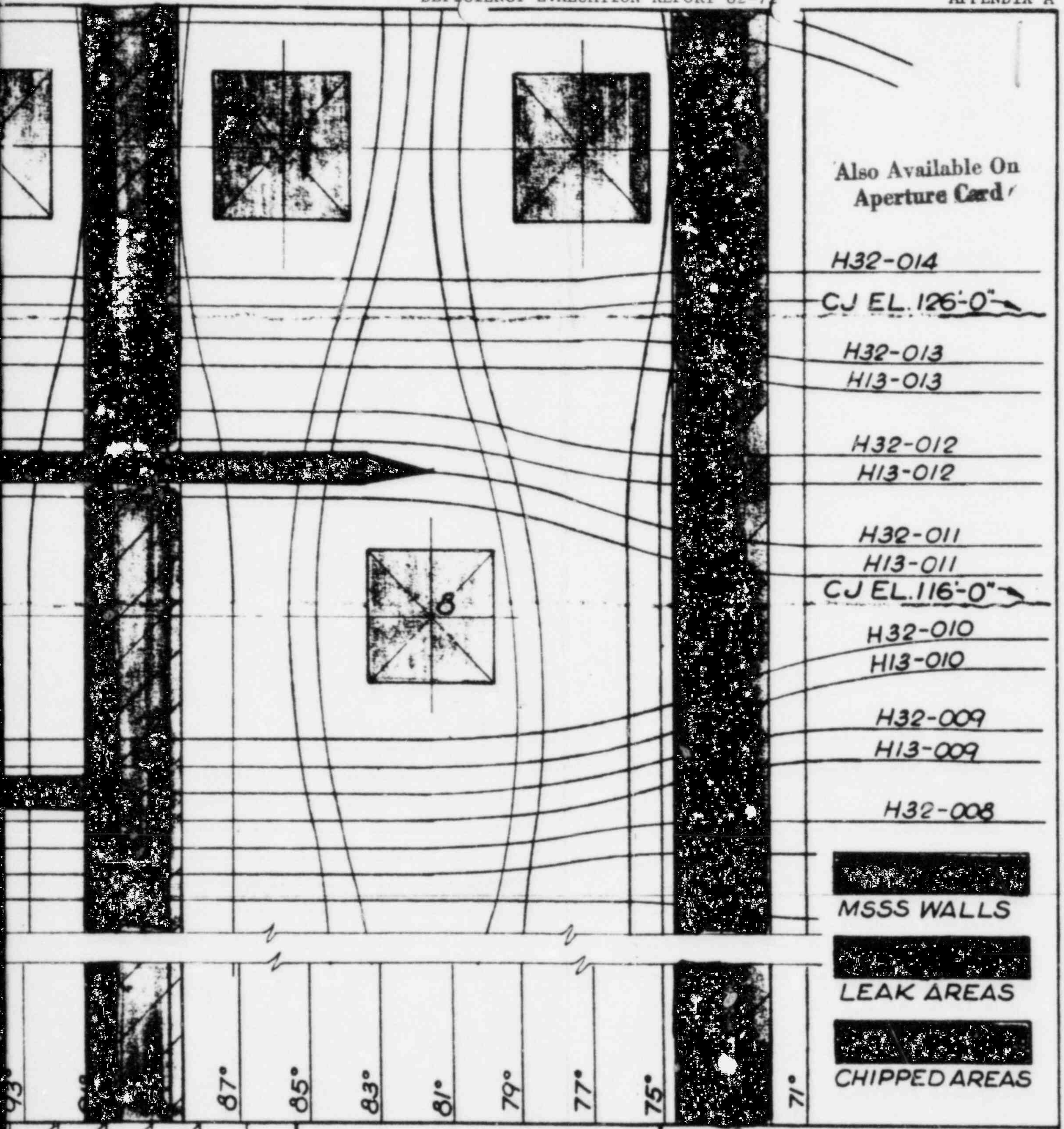





| DWG NO | REFERENCE | REV | DATE | REVISIONS |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | SYSTEM ISO | 0 | | ISSUED FOR CONSTRUCTION |

PF 1142 (10407) 6-77

Also Available On Aperture Card




**BECHTEL**
**LOS ANGELES**

UNIT 2
CONTAINMENT WALL STUDY

ARIZONA NUCLEAR POWER PROJECT
PALO VERDE NUCLEAR
GENERATING STATION

| JOB NO | DRAWING NO. | REV |
|---|---|---|
| 10407 | FIGURE A-3 | 0 |



8307120303-04

# APPENDIX B

## SAMPLE DATA SHEETS

APPENDIX B

AIR & HYDRAULIC TEST PROCEDURE

FOR UNIT 2 CONTAINMENT BUILDING

TENDON SHEATHING

DATE- 27 JAN 83 TEST NO.- FIVE APPROX. TIME OF DAY- 1:22 BEGIN TEST

## WATER METER QUANTITY vs TIME

| TIME | | QUANTITY GALLONS | FLOW RATE GPM | REMARKS |
|---|---|---|---|---|
| Min. | Sec. | | | |
| 00 | 00 | 4034 | - | |
| 00 | 30 | 4041 | 11 | |
| 1 | 00 | 4047 | 11 | |
| | 30 | 4053 | 11 | |
| 2 | 00 | 4059 | 11 | |
| | 30 | 4065 | 11 | |
| 3 | 00 | 4070 | 8 | |
| | 30 | 4075 | 8 | |
| 4 | 00 | 4079 | 5 | |
| | 30 | 4081 | 4 | |
| 5 | 00 | 4084 | 4 | |
| | 30 | 4086 | 4 | |
| 6 | 00 | 4089 | 4 | |
| | 30 | 4092 | 4 | |
| 7 | 00 | 4095 | 4 | |
| | 30 | 4097 | 4~5 | |
| 8 | 00 | 4100 | 4 | |
| | 30 | 4103 | 4 | |
| 9 | 00 | 4106 | 4 | |
| | 30 | 4109 | 4 | |
| 10 | 00 | 4112 | 4 | |
| | 30 | 4115 | 4 | |
| 11 | 00 | 4118 | 4 | |
| | 30 | 4120 | 4 | |
| 12 | 00 | 4122 | 4 | |
| | 30 | 4126 | 4 | |
| 13 | 00 | 4129 | 4 | |
| | 30 | 4132 | 4 | |
| 14 | 00 | 4135 | 4 | |
| | 30 | 4137 | 4 | |
| 15 | 00 | 4140 | 4 | |
| | 30 | 4143 | 5 | |
| 16 | 00 | 4146 | 5 | |
| | 30 | 4149 | 5 | |
| 17 | 00 | 4152 | 5 | |
| | 30 | 4155 | 5 | |
| 18 | 00 | 4158 | 5 | |
| | 30 | 4161 | 5 | |
| 19 | 00 | 4164 | 5 | WET CORE HOLE |
| | 30 | 4167 | 5 | |
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EXHIBIT "C" Recorded by- DRSn[illegible]

Sheet 21 of

APPENDIX B

| Reference: LOWER RIGHT CORNER | AIR & HYDRAULIC TEST PROC... FOR UNIT 2 CONTAINMENT BUILDING TENDON SHEATHING | LEGEND: 1-Trickle 1 gal/min; 2-Small Stream 3 g/m; 3-Large Stream 6 g/m; 4-Gushing 10 g/m |
|---|---|---|

DATE- 1/27/83 TEST NO.- 5 - WATER APPROX. TIME OF DAY- 1:22 PM

## CONTAINMENT WALL SURFACE OBSERVATION

| OBSERVE FROM PENETRATION 10 | | | LOCATION | REMARKS |
|---|---|---|---|---|
| TIME OF OBSERVATION | | ELEV. | HORIZ. DISTANCE FROM REFERENCE * | WHAT OBSERVED AND QUANTITY (SEE LEGEND ABOVE) |
| Min. | Sec. | | | |
| 5 | 14 | | | 9:00 PEN SLEEVE SPOT OF WATER |
| 7 | 00 | | | 9:00 ≈ 1/2 gpm AROUND SLEEVE |
| 7 | 18 | | | CRACK @ 11.00 (SLIGHT) |
| 7 | 55 | | | PINHOLES (SLIGHT) |
| " | " | | | SOUTH CONST JOINT (SLIGHT) |
| 9 | 08 | | | NORTH CONST JOINT (SLIGHT) |
| 16 | 25 | | | WATER DRIPPING FROM ABOVE |
| | | | | (NOT FROM THE BOTTOM SEAL) |
| 18 | 56 | | | ≈ 1 1/2 gpm SOUTH [illegible] |
| 19 | 22 | | | 1 gpm NORTH SIDE (NOT THE SEAL) |
| 20 | 46 | | | SOUTH EDGE OF SEAL (TE [illegible]) |
| 22 | 00 | | | ≈ 3-4 gpm TOTAL FROM ABOVE |
| 24 | 00 | | | 4 gpm TOTAL |
| 25 | 00 | | | " " " |
| 25 | 30 | | | NORTH SIDE D[illegible] |
| | | | | SOUTH SIDE [illegible] |
| 26 | 00 | | | 3 1/2 gpm TOTAL NORTH SLOWED |
| 26 | 22 | | | 4 gpm TOTAL |
| 26 | 36 | | | 3 1/2 gpm TOTAL NORTH [illegible] |
| 27 | 00 | | | 4 gpm " |
| 28 | 00 | | | 4 " " |
| 28 | 24 | | | 5 gpm SOUTH INCREASED |
| 29 | 00 | | | 5 gpm TOTAL |

EXHIBIT "D" Recorded by- [signature]

Sheet 1 of 3

AIR & HYDRAULIC TEST PROCEDURE

FOR UNIT 2 CONTAINMENT BUILDING

TENDON SHEATHING

DATE- 1-27-83 TEST NO.- [illegible] APPROX. TIME OF DAY- 1:15

# MANOMETER FOR TENDON SHEATH H32
# WATER ELEVATION vs TIME

| TIME | | ELEV. OF WATER LEVEL | | REMARKS |
|---|---|---|---|---|
| Min. | Sec. | PIPE 011 | PIPE 009 | |
| 0 | 00 | | ≈ 1½' | 009 - initially at about 1½' |
| | | | up | slowly rising |
| | | | " | " |
| | | | " | " |
| 1 | | | " | " |
| | | | " | " |
| | | | " | speed has picked |
| | | | 6'5" | |
| | | | 7'1" | |
| | | | 8'3" | |
| | | | 9'10" | |
| | | | 11'8" | |
| 6 | | | 13'8" | |
| 6 | | | 15'6" | |
| 7 | | | 17'2" | |
| 7 | | | 18'9" | |
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EXHIBIT "E" Recorded by- [signature] Sheet 1 of [illegible]

# APPENDIX C

## INSTRUMENT CALIBRATION CERTIFICATES

**Hersey** PRODUCTS INC Industrial Measurement Group

2425 South Eastern Avenue, Los Angeles, Calif. 90040 Telephone (213) 726-8467 Telex 674-314

January 18, 1983

W. R. Ladewig
5618 East Washington Blvd.
Los Angeles, California 90040

REF: MVR 30 - #8121167
Model 1020 - #8116631

Gentlemen:

This is to certify that we have this date tested the above water meter using test tanks certified by California Bureau of Weights and Measures with the following results:

| GPM | PERCENT |
|---|---|
| 1 | 100.4% |
| 3 | 100.5% |
| 25 | 100.1% |

We trust this is the information you need, and if we can be of any further assistance, please let us know.

Sincerely,

Paul Gorman

Paul Gorman
Service Engineer

PG/jb

Hersey PRODUCTS INC Industrial Measurement Group

2425 South Eastern Avenue, Los Angeles, Calif. 90040 Telephone (213) 726-8407 Telex 674-314

February 3, 1983

W. R. Ladewig
5618 E.Washington, Blvd.
LOS Angeles, California 90040

REF: MVR 30 - #8121167

Model 1020 - #8116631

Gentlemen:

This is to certify that we have this date tested the above water meter using test tanks certified by California Bureau of Weights and Measures with the following results:

| GPM | PERCENT |
|---|---|
| 1 | 100% |
| 3 | 101.8% |
| 25 | 99.8% |

We trust this is the information you need, and if we can be of any further assistance, please let us know.

Sincerely,

Paul Gorman
Paul Gorman
Service Engineer

PG/jb

# APPENDIX D

## GROUTING PROCEDURE

RETENTION TIME LT YRS.

NCR ~~NRC~~ C-C-3805
ATTACHMENT B
WCOS 4/14/83
4/14/83
4/14/83

Deficiency Evaluation Report No. 82-72

# Procedure for Grouting Concrete Irregularities in the Containment Building

Palo Verde Nuclear Generating Station

Unit 2

Phoenix, Arizona

Prepared by:

Bechtel Power Corporation

Norwalk, California

Job Number 10407

1983

PFE [signature]
PQAE [signature] 4/14/83
PQCE [signature] 4/14/83

OK to Proceed 4/4/83

Revision 0
Date 3/4/83
Originator [signature] WCOD 4/14/83 FOR
PE [signature] 4/14/83

NRC

RETENTION TIME LT YRS.

1.0 OBJECTIVES

The objectives of this grouting work are to: (1) fill the crack system in the Unit 2 containment wall associated with the leaking tendon sheaths H32-009 and H32-011; (2) fill the crack observed in the exterior face of the wall in the vicinity of the leaking tendon sheaths, and the associated chipped out area; (3) prevent leakage of grease from the tendon sheaths; and (4) prevent further crack propagation and restore continuity to the affected section.

The primary objective of this program is the sealing of the leaking sheaths; therefore, the grout strength does not necessarily need to be as great as that of the structural concrete. This aspect will be discussed in detail in the engineering evaluation report for DER 82-72.

2.0 PRESSURE CRITERIA

2.1 The maximum hydraulic pressure (water or grout) to be applied to the tendon sheathing (either externally or internally) shall be 25 psi. Pressure shall be measured at the grout injection point with provision made for differences in elevation between sheaths and injection points. Source: Engineering Requirement.

2.2 The maximum air pressure to be applied to the containment sheathing in any portion of the sheathing capable of holding pressure shall be 25 psi. Source: Engineering Requirement.

RETENTION TIME LT YRS,

2.3 The maximum air pressure to be applied to the containment sheathing in any portion of sheathing not capable of holding pressure shall be 60 psi. Source: Engineering Requirement.

2.4 Each packer in the packer assemblies, when in the sealed position, shall be maintained at a minimum pressure of 62 psi and maximum pressure of 68 psi, or 65 ± 3 psi. Source: Engineering Requirement.

3.0 REFERENCES

3.1 WCS Drawing No. PS-112, Wall Tendon Locations

3.2 WCS Drawing No. PS-131, Vent and Drain Locations

3.3 Deficiency Evaluation Report 82-72

3.4 Non-Conformance Report C-C-3805

3.5 Interoffice Memo Wolff/Schechter, December 7, 1982

3.6 (Test Report)

4.0 CONCEPTUAL SUMMARY

The work to be accomplished consists of (1) preparation for grouting by establishing a flow pattern after preparing the concrete surface and

installing appropriate packers in the tendon sheaths; and (2) pressure grouting by pumping grout into the crack system with special emphasis being given in the procedure to assure that the crack system is filled as completely as practicable and that the tendon sheaths remain open for later insertion of the tendons.

5.0 QUALITY CRITERIA

5.1 Only the grouting director and his designee are authorized to verify that the requirements for the testing program have been met. Each step in preparation for the grouting work as well as in the work itself is defined in this procedure and has a line preceding the step. Upon completion of the requirements for each step the grouting director or his designee will indicate, by initialing the line preceding the step, that all the requirements have been met.

5.2 The last item in each applicable section will include a space for sign off and a statement indicating that a Quality Control representative has monitored the activities of each section and has verified that compliance has been achieved for the requirements listed in the procedure.

RETENTION TIME LT YRS.

6.0 PREREQUISITES

| | | |
|---|---|---|
| Sign-off Column | 6.1 | Prior to initiating preparatory work operations the following conditions shall be met: |

INITIAL RS IS THE GROUTING DIRECTOR, MR. RUDY SENKZYSZYN 9/15/83

| | | |
|---|---|---|
| RS 5 83 | 6.1.1 | All equipment (Section 8.2) has been procured, delivered, inspected and documentation required for this effort is valid and on site. |
| RS 5 83 | 6.1.2 | Calibrated instruments are installed as required. |
| RS 5 83 | 6.1.3 | All required work platforms, scaffolding, etc., have been properly positioned. Requirements will be established by the grouting director prior to initiating preparatory work. |
| RS 5 83 | 6.1.4 | All construction interferences have been removed or repositioned. |
| RS 5 83 | 6.1.5 | The seismic gap area between the containment and MSSS walls has been protected from weather. In addition, the seismic gap area has been sealed below the working area to protect against material falling into the gap. |
| RS 5 83 | 6.1.6 | Telephone communications have been installed and checked between control point and observation stations. |

RETENTION TIME LT YRS

RS APR 5 '83 6.1.7 QC final acceptance for Section 6.1.

6.2 Prior to initiating grouting operations the following conditions shall be met:

RS APR 5 '83 6.2.1 All materials (Section 8.1) have been procured, delivered, and inspected. All required documentation is accepted.

RS APR 5 '83 6.2.2 Grouting equipment and materials are in place and the equipment is prepared for operation.

RS APR 5 '83 6.2.3 All required plumbing, valves, gauges, hoses, etc., are in place along with provisions for wasting grout and water in the system. All instruments have been calibrated and documented.

RS APR 5 '83 6.2.4 Formwork is ready for use during Stage 2 grouting (see Section 8.4).

RS APR 5 '83 6.2.5 Observers have been properly briefed on the day's operation during an orientation session.

RS APR 5 '83 6.2.6 Test personnel and equipment are in-place to monitor the production of grout.

APR 5 '83 6.2.7 QC final acceptance for Section 6.2.

7.0 PREPARATORY WORK

7.1 Establishment of a flow pattern.

7.1.1 Two holes of 2 inch diameter have been drilled into the containment wall adjacent to penetration No. 10 in locations and to depths designated by the grouting director. The cores from these holes have been visually examined and preliminary tests have indicated some communication between the holes and the sheaths and the crack system.

7.1.2 Verify the interconnection of the cores as designated by the grouting director by pressurizing the newly drilled core holes with water and/or air and plugging the tendon sheaths with packers. Observe flows available at the tendon sheaths and any other cracks that exude water and/or air.

7.2 Concrete preparation and formwork.

7.2.1 The chipped concrete surface on the containment structure will be prepared by hydroblasting or sandblasting.

7.2.2 The chipped concrete surface will be covered by a steel form with an edge seal effective enough to hold the

RETENTION TIME LT YRS.

specified grout to the satisfaction of the grouting director. At the seal, the form shall be no more than 1/2 in. away from the existing containment structure surface and the entire form shall follow the curvature of the containment structure surface. The form shall be fitted with a valved grout nipple. The form shall be in position at the start of the 2nd stage of grouting.

7.2.3 The core hole at penetration 3 shall be fitted with a plug or grouting plate as specified by the grouting director and equipped with a vent tube and valve.

7.2.4 The core hole at penetration #10 shall be fitted with a plug equipped with a valve and a nipple for first stage grout injection.

7.2.5 Installation of the formwork shall be verified by pressurizing with water from the newly drilled core hole and observing flows at both tendon sheaths and the core hole in penetration 3.

7.2.6 The formwork and crack system shall be left filled with water for a period of time specified by the grouting director prior to commencement of grouting.

RETENTION TIME LT YRS.

8.0 GROUTING WORK

8.1 Material -- IN-PAKT grout (neat, without sand) as manufacturered by the Concrete Chemical Company, Cleveland, Ohio. Three different mixes of grout will be used. As measured by ASTM C939, the three mixes will have flow times of 13 ± 2 sec., 18 ± 2 sec., and 25 ± 3 sec. The 25 sec. mix shall expand 3 to 5 percent at three hours after mixing when measured in accordance with ASTM C827, Early Volume Change of Cementitious Mixture. Water used for mixing grout shall be of equal quality as that available from the on-site concrete batch plant. Ice used for mixing grout shall be obtained from the batch plant. Grout shall be mixed at a temperature as near 40°F as feasible with 50°F as a maximum. Temperature shall be controlled with the addition of ice as required.

8.2 Equipment -- Use Chemgrout double tub mixer equipped with a Moyno pump. Use 1 1/4 in. hose, and 1 in. or 1 1/4 in. connections, and plug valves as required for movement of grout. Equip the upper portion of the steel form or core hole at penetration 3 with a 50 psi range pressure gage (may use 60 psi range if 50 psi not available). Provide a spare pressure gage for use if needed. Provide packers suitable for connecting each core hole to the flow pattern. Continue using the packer system set up for the previous test work, but add valved hose connections to each end so that the space between can be flushed with water. Fit Sheath #009 drain and #011 vent tubes with valves at their outlet points in the Auxiliary Building.

RETENTION TIME LT YRS.

Sign-off 8.3 Grouting Procedure - Stage 1

CL APR 5 '83 8.3.1 Provide a recirculating line to return excess grout to the pump and provide a 50 psi range gauge at the grout injection point.

CL APR 5 '83 8.3.2 Provide freshly mixed grout for pumping as needed by mixing grout for 5 minutes prior to pumping with sufficient water to maintain a 13 ± 2 second flow.

CL APR 5 '83 8.3.3 Sample grout to check flow and compressive strength at least once for each fifteen bags of grout mixed (per ASTM C939, and ASTM C942), and at least once for each different mixture of grout used.

R.S. APR 5 '83 8.3.4 Packers in place and inflated to 65 ± 3 psi.

R.S. APR 5 '83 8.3.5 Chipped area readily visible to check for grout appearance.

RS APR 5 '83 8.3.6 Compressed air blown through crack system from newly drilled core hole to remove excess water to satisfaction of grouting director.

RETENTION TIME LT YRS.

RS 8.3.7 Circulate water at low pressure (not to exceed 25 psi) through sheath #009 through hose connection to packers from buttress 2. Observe water returns through hose at buttress 3 as well as through drain and vent lines from the sheath. Do not circulate water in sheath #011 at this point. At all times the water pressure in the sheaths shall be maintained below the grouting pressure to insure that water does not enter the concrete and dilute the grout.

RS 8.3.8 Pump the 13 ± 2 sec. grout into core holes adjacent to penetration #10. Pressure not to exceed 25 psi in any sheath. When fresh undiluted grout appears in crack at chipped area, or at the direction of the grouting director after an orderly sequential change to the 18 ± 2 sec. grout begin pumping the 18 ± 2 sec. grout. At the direction of the grouting director as above, begin pumping the 25 ± 3 sec. grout.

Grout refusal at 13.5psi

RS 8.3.9 Begin circulating water in sheath #011 immediately following grout appearance in the chipped area. Follow same procedure as for #009 in 8.3.7 above. Continue circulating water in #009.

No Grout in either Sheath 009 or 011 and no grout appeared in chipped area Stopped grouting @ Grout refusal. R. Sampson.

RETENTION TIME LT YRS

RS 5 '83 8.3.10 If grout subsides in crack resume pumping grout until fresh undiluted grout reappears at chipped area.

RS 5 '83 8.3.11 Hold pressure on grout for about one (1) hour or as directed by grouting director. Continue circulating water through tendon sheathing 009. Run rabbit through tendon sheathing 011.

RS 5 '83 8.3.12 If grout again subsides in chipped area discontinue water circulation, fill sheaths with water and hold water pressure at 20 psi for about 1 hour or as directed by the grouting director. During this time pump additional grout as necessary to maintain grout at the chipped area.

RS 5 '83 8.3.13 Cease water circulation, remove packers, and work rabbit through sheaths to clear any grout plugs. Continue to work rabbit until well after initial setting time of grout.

RS 5 '83 8.3.14 Allow grout to begin curing.

(QC 197) 5 '83 8.3.15 Final QC acceptance of 8.3.

11

RETENTION TIME LT YRS.

8.4 Grouting Procedure - Stage 2

RS 8.4.1 Grout placed in Stage 1 has been allowed to cure a minimum of 40 hours.

RS 8.4.2 Install packers in sheaths H32-009 and 011. Inflate packers to 65 ± 3 psi.

RS 8.4.3 Air test sheaths 009 and 011 to a pressure of 8 psi ± 1 to evaluate effectiveness of stage 1 grouting.

RS 8.4.4 Remove air pressure in sheaths 009 and 011 and prepare to circulate water through sheaths.

RS 8.4.5 Install form over chipped area.

RS 8.4.6 Circulate water through tendon sheathing per ~~8.3.6.~~ 8.3.7.

RS 8.4.7 Check for watertightness of seal around form. Discontinue circulation and make any adjustments or corrections if water leakage appears. Reestablish water circulation in both tendon sheaths.

RS 8.4.8 Pump 13 ± 2 sec. grout through nipple in form at chipped area. Pressure not to exceed 25 psi at sheath 009.

RETENTION TIME LT YRS.

R.S. 8.4.9 Continue pumping grout until grout shows at other leaks or water or air ceases to flow from them. Allow grout to flow from core hole vent in penetration 3 until good grout shows there. Follow the 13 ± 2 sec. grout with 18 ± 2 sec. grout as in Stage 1. At the direction of the grouting director, follow with the 25 ± 3 sec. grout. Sample the grout as in 8.3.3. Refusal with 13 ± 2 sec grout went to 18 ± 2 sec grout immediately refused.

RS. 8.4.10 Close valve in core hole vent at penetration 3 and hold pressure on system up to a maximum of one hour or at the direction of the grouting director.

RS 8.4.11 Upon completion of grouting, flush the tendon sheath system throughly with water until the outflow is clean. The grouting director shall determine, based on stiffening of grout samples from the pumped grout, when the tendon sheath packer system may be removed.

RS 8.4.12 After packer removal, a suitable rabbit shall be worked in the tendon sheaths along with sufficient water to assure that the sheaths are clean.

R.S. 8.4.13 After grout has cured for not less than 7 days sheaths 9 and 11 will be air pressure tested at 17 ± 2 psi to check for leak tightness and/or cross communication.

TIME LT YRS.

RS APR 13 '83 8.4.14 Blow air through tendon sheaths to dry up water.

RS APR 13 '83 8.4.15 Remove formwork, core hole plugs, patch and repair areas as needed, etc., after grout has cured for seven days.

APR 13 '83 8.4.16 Final QC acceptance of 8.4.

R.S. APR 13 '83 8.4.17 Unit 2 containment structure grouting is complete and construction activities, that were interrupted for this procedure, may continue.

# APPENDIX E

## TEST REPORTS ON GROUT SAMPLES

**WESTERN TECHNOLOGIES, INC.**

3737 East Broadway Road
P.O. Box 21387
Phoenix, Arizona 85036
(602) 268-1381

**LABORATORY REPORT**

**COMPRESSIVE STRENGTH OF ~~CYLINDRICAL CONCRETE~~ GROUT SPECIMENS** WS 4-6-83

**Palo Verde Nuclear Generating Station**

**Units 1, 2 and 3**

**Bechtel Power, Inc. Job No. 10407 Contract No. 13-CM-191**

Job No. 614-750
Lab No. 040583-1
Date of Report 7-5-83

Structure: CONTAINMENT BLDG. - UNIT 2

Placement No.: REF.: DER 82-72, NCR C-C-3805
Ticket Number: —
Truck Number: —
Batch Size, ~~cu yds~~ (WS 4-8-83): 12 BAGS
*Mix Identification: IN-PAKT, LOT # 30201-1
Design Strength, psi: (NONE / SPECIFIED) days
Max. Size Aggregate, in.: —
Time in Mixer: — hrs. — min.
Water Added on Job, gal.: —

Measured Slump, in.: —
Measured Air Content, %: —
~~Concrete~~ GROUT Temperature, °F: 57
Ambient Air Temperature, °F (WS 4-8-83): 65
Plastic Unit Weight, pcf: —
Sampled By: D. PIPER Date: 4-5-83
Authorized By: W. STURM @ 11:35
Specimens ~~6 in. x 12~~ 2x2x2 in. Cross Sectional Area ~~28.27~~ 4 sq. in. (WS 4-8-83)
Defects in Specimens/Caps. Note if Any:
Test Procedures: Tested ASTM ~~C39-72, C143-74, C231-74, C138-75~~ ~~Sampled ASTM C31-69~~ C942, C939 WS 4-6-83

Remarks:
* MIX: 13 QTS. WATER / BAG IN-PAKT GROUT
FLOW = 14.40 SECONDS

| Date Tested | Specimen Age in Days | Compressive Strength Maximum Load: Pounds Force | Compressive Strength Maximum Load: psi | Type Fracture If Other Than Cone | Defects in Specimens/Caps If Any | Tested By |
|---|---|---|---|---|---|---|
| 4-12-83 | 7 | 9200 | 2300 | | | WS |
| 4-19-83 | 14 | 11800 | 2950 | | | WS |
| 5-3-83 | 28 | 15600 | 3900 | | | WS |
| 5-10-83 | 35 | 15000 | 3750 | | | WS |
| 5-17-83 | 42 | 15025 | 3760 | | | WS |
| 5-24-83 | 49 | 16900 | 4225 | | | WS |
| 6-7-83 | 63 | 18600 | 4650 | | | WS |
| 7-5-83 | 91 | | | | | |
| 7-5-83 | 91 | | | | | |

Remarks: (9 CUBES)
PLACEMENT STOPPED - FORMS DAMAGED; GROUT WASHED OUT.

Reviewed By: ______

FOR BECHTEL POWER CORPORATION USE ONLY

REMARKS: ______

A.I. DESIGNATED HOLD POINTS: ______

Q.C. REVIEW/ACCEPTANCE BY: ______

WESTERN TECHNOLOGIES, INC.
3737 East Broadway Road
P.O. Box 21387
Phoenix, Arizona 85036
(602) 268-1381

LABORATORY REPORT

**COMPRESSIVE STRENGTH OF ~~CYLINDRICAL CONCRETE~~ GROUT SPECIMENS** WS 4-6-83

Palo Verde Nuclear Generating Station
Units 1, 2 and 3
Bechtel Power, Inc. Job No. 10407 Contract No. 13-CM-191

Job No. 614-150
Lab No. 040583-2
Date of Report 7-5-83

Structure CONTAINMENT BLDG. - UNIT 2
Placement No. REF: DER 82-72, NCR C-C-3305
Ticket Number —
Truck Number —
Batch Size, ~~cu yds~~ 9 BAGS (WS 4-6-83)
* Mix Identification IN-PAKT, LOT # 30201-1
Design Strength, psi (NONE / SPECIFIED) days
Max. Size Aggregate, in. —
Time in Mixer — hrs. — min.
Water Added on Job, gal. —

Measured Slump, in. —
Measured Air Content, % —
~~Concrete~~ GROUT Temperature, °F 57 (WS 4-6-83)
Ambient Air Temperature, °F 68
Plastic Unit Weight, pcf —
Sampled By D. PIPER Date 4-5-83
Authorized By W. STURM @ 14:20
Specimens ~~6 in. x 12~~ 2x2x2 in. Cross Sectional Area = ~~28.27~~ 4 sq. in. (WS 4-6-83)
Defects in Specimens/Caps, Note if Any
Test Procedures Tested: ASTM ~~C39-72, C143-74, C231-74, C138-75~~ ~~Sampled: ASTM C31-69~~ C942, C939 (WS 4-6-83)

Remarks
* MIX: 14 QTS. WATER / BAG IN-PAKT GROUT

FLOW = 11.8 SECONDS

| Date Tested | Specimen Age in Days | Compressive Strength Maximum Load: Pounds Force | psi | Type Fracture If Other Than Cone | Defects in Specimens/Caps If Any | Tested By |
|---|---|---|---|---|---|---|
| 4-12-83 | 7 | 6200 | 1550 | | | WS |
| 4-19-83 | 14 | 8400 | 2100 | | | WS |
| 5-3-83 | 28 | 11700 | 2925 | | | WS |
| 5-10-83 | 35 | 11100 | 2775 | | | WS |
| 5-17-83 | 42 | 12300 | 3075 | | | WS |
| 5-24-83 | 49 | 12450 | 3110 | | | WS |
| 6-7-83 | 63 | 13150 | 3290 | | | WS |
| 7-5-83 | 91 | | | | | |
| 7-5-83 | 91 | | | | | |

Remarks (9 CUBES)

Reviewed By ____________

FOR BECHTEL POWER CORPORATION USE ONLY

REMARKS: ____________
A.I. DESIGNATED HOLD POINTS: ____________
Q.C. REVIEW/ACCEPTANCE BY: ____________

WESTERN TECHNOLOGIES, INC.
3737 East Broadway Road
P.O. Box 21387
Phoenix, Arizona 85036
(602) 268-1381

LABORATORY REPORT

**COMPRESSIVE STRENGTH OF ~~CYLINDRICAL CONCRETE~~ GROUT SPECIMENS** WS 4-7-83

Palo Verde Nuclear Generating Station
Units 1, 2 and 3
Bechtel Power, Inc. Job No. 10407 Contract No. 13-CM-191

Job No. 614-750
Lab No. 040783-1
Date of Report 7-7-83

Structure CONTAINMENT BLDG. - UNIT 2

Placement No. REF: DER 82-72, NCR 1C-C-3805 — Measured Slump, in. —
Ticket Number — — Measured Air Content, % —
Truck Number — — ~~Concrete~~ GROUT WS 4-7-83 Temperature, °F 56
Batch Size, ~~cu yds~~ 12 BAGS (WS 4-7-83) — Ambient Air Temperature, °F 57
* Mix Identification IN-PAKT, LOT # 30001-1 — Plastic Unit Weight, pcf —
Design Strength, psi (NONE SPECIFIED) days — Sampled By D. PIPER Date 4-7-83
Max. Size Aggregate, in. — — Authorized By W. STURM @ 9:35
Time in Mixer — hrs. — min. — Specimens ~~6 in x 12 in~~ 2X2X2 — Cross Sectional Area = ~~28.27~~ 4 sq. in (WS 4-7-83)
Water Added on Job, gal. — — Defects in Specimens/Caps. Note if Any

Remarks
*MIX: 14 QTS. WATER/BAG IN-PAKT GROUT
FLOW = 11.43 SECONDS

Test Procedures: Tested ASTM ~~C39-72, C143-74, C231-74, C138-75~~ C942, C939; ~~Sampled ASTM C31-69~~ WS 4-7-83

| Date Tested | Specimen Age in Days | Compressive Strength Maximum Load: Pounds Force | psi | Type Fracture If Other Than Cone | Defects in Specimens/Caps If Any | Tested By |
|---|---|---|---|---|---|---|
| 4-14-83 | 7 | 8950 | 2240 | | | WS |
| 4-21-83 | 14 | 10925 | 2730 | | | WS |
| 5-5-83 | 28 | 13600 | 3400 | | | WS |
| 5-26-83 | 49 | 15625 | 3910 | | | WS |
| | | | | | | |
| 7-7-83 | 91 | | | | | |
| 7-7-83 | 91 | | | | | |
| | | | | | | |
| | | | | | | |

Remarks (6 CUBES)

Reviewed By ______

FOR BECHTEL POWER CORPORATION USE ONLY

REMARKS: ______ A.I. DESIGNATED HOLD POINTS: ______

Q.C. REVIEW/ACCEPTANCE BY: ______

APPENDIX E

WESTERN TECHNOLOGIES, INC.
3737 East Broadway Road
P.O. Box 21387
Phoenix, Arizona 85036
(602) 268-1381

LABORATORY REPORT

## COMPRESSIVE STRENGTH OF ~~CYLINDRICAL CONCRETE~~ GROUT SPECIMENS

WS 4-7-83

**Palo Verde Nuclear Generating Station**

**Units 1, 2 and 3**

**Bechtel Power, Inc. Job No. 10407 Contract No. 13-CM-191**

Job No. 614-750
Lab No. 040783-2
Date of Report 7-7-83

Structure: CONTAINMENT BLDG. — UNIT 2

Placement No.: REF: DER 82-72, NCR C-C-3805
Ticket Number: —
Truck Number: —
Batch Size, ~~cu yds~~: 12 BAGS (TOTAL 24 BAGS) (WS 4-7-83)
*Mix Identification: IN-PAKT, LOT # 30201-1
Design Strength, psi: (NONE SPECIFIED) days
Max. Size Aggregate, in.: —
Time in Mixer: — hrs. — min.
Water Added on Job, gal: —

Measured Slump, in.: —
Measured Air Content, %: —
~~Concrete~~ GROUT Temperature, °F: 64 (WS 4-7-83)
Ambient Air Temperature, °F: 61
Plastic Unit Weight, pcf: —
Sampled By: D. PIPER Date: 4-7-83
Authorized By: W. STURM @ 10:15
Specimens: 2X2X2 ~~6 in. x 12~~ in. (WS 4-7-83) Cross Sectional Area = 4 ~~28.27~~ sq. in
Defects in Specimens/Caps. Note if Any: 
Test Procedures: Tested ASTM C~~39-72, C143-74, C231-74, C138-75~~ ~~Sampled ASTM C31-69~~ C942, C939 (WS 4-7-83)

Remarks:
* MIX: 14 QTS. WATER/BAG IN-PAKT GROUT
FLOW = 11.57 SECONDS

| Date Tested | Specimen Age in Days | Compressive Strength Maximum Load: Pounds Force | psi | Type Fracture If Other Than Cone | Defects in Specimens/Caps If Any | Tested By |
|---|---|---|---|---|---|---|
| 4-14-83 | 7 | 9625 | 2410 | | | WS |
| 4-21-83 | 14 | 10250 | 2560 | | | WS |
| 5-5-83 | 28 | 12950 | 3240 | | | WS |
| 5-26-83 | 49 | 15750 | 3940 | | | WS |
| | | | | | | |
| 7-7-83 | 91 | | | | | |
| 7-7-83 | 91 | | | | | |
| | | | | | | |
| | | | | | | |

Remarks (6 CUBES)

Reviewed By ______

FOR BECHTEL POWER CORPORATION USE ONLY

REMARKS: ______
A.I. DESIGNATED HOLD POINTS: ______
Q.C. REVIEW/ACCEPTANCE BY: ______

**WESTERN TECHNOLOGIES, INC.**

3737 East Broadway Road
P.O. Box 21387
Phoenix, Arizona 85036
(602) 268-1381

LABORATORY REPORT

**COMPRESSIVE STRENGTH OF ~~CYLINDRICAL CONCRETE~~ GROUT SPECIMENS** (4-7-83)

**Palo Verde Nuclear Generating Station**

**Units 1, 2 and 3**

**Bechtel Power, Inc. Job No. 10407 Contract No. 13-CM-191**

Job No. 614-750
Lab No. 040783-3
Date of Report 7-7-83

Structure CONTAINMENT BLDG - UNIT 2

Placement No. REF: DER 82-72, NCR CC-3805

Measured Slump, in. —

Ticket Number —

Measured Air Content, % —

Truck Number —

~~Concrete~~ GROUT Temperature, °F 69 (4-7-83)

Batch Size, ~~cu yds~~ 4 SK BAGS (TOTAL 28 BAGS) (4-7-83)

Ambient Air Temperature, °F 62

*Mix Identification IN-PAKT, LOT # 30201-1

Plastic Unit Weight, pcf —

Design Strength, psi (NONE SPECIFIED) days

Sampled By O. PIPER Date 4-7-83

Max. Size Aggregate, in. —

Authorized By W. STURM @ 10:55

Time in Mixer — hrs. — min.

Specimens ~~6 in x 12~~ 2X2X2 in. Cross Sectional Area = ~~28.27~~ 4 sq. in (4-7-83)

Water Added on Job, gal —

Defects in Specimens/Caps. Note if Any

Remarks
*MIX: 12 QTS. WATER / BAG IN-PAKT GROUT
FLOW = 18.04 SECONDS

Test Procedures Tested ASTM ~~C39-72, C617-76, C231-78, C138-75~~ ~~Sampled ASTM C31-69~~ C942, C939 (4-7-83)

| Date Tested | Specimen Age in Days | Compressive Strength Maximum Load Pounds Force | psi | Type Fracture If Other Than Cone | Defects in Specimens/Caps If Any | Tested By |
|---|---|---|---|---|---|---|
| 4-14-83 | 7 | 13450 | 3360 | | | WS |
| 4-21-83 | 14 | 15125 | 3780 | | | WS |
| ~~4~~5-5-83 | 28 | 19650 | 4910 | | | WS |
| 5-26-83 | 49 | 20000 | 5000 | | | WS |
| | | | | | | |
| 7-7-83 | 91 | | | | | |
| 7-7-83 | 91 | | | | | |
| | | | | | | |
| | | | | | | |

Remarks (6 CUBES)

Reviewed By ______

FOR BECHTEL POWER CORPORATION USE ONLY

REMARKS: ______

A.I. DESIGNATED HOLD POINTS: ______

Q.C. REVIEW/ACCEPTANCE BY: ______

ATTACHMENT 2 to DER 82-72


**JOHN C. KING, P.E.**

CONSULTING ENGINEER

101 East 252 Street / Cleveland, Ohio 44132

(216) 731-0977


June 13, 1983

W. G. Bingham
Project Engineering Manager
Los Angeles Power Division
Bechtel Power Corporation
PO Box 60860, Terminal Annex
Los Angeles, California 90060

Subject: Arizona Nuclear Power Project
Bechtel Job 10407
Engineering Evaluation Report
Investigations and Grouting of
Leaks Associated with Tendons
H32-009 and H32-011
File: CM-158

Dear Mr. Bingham:

Per your request in letter dated June 6, 1983, I have closely reviewed the subject report and find that it accurately reflects all phases of the work with which I was directly involved as well as the portions of the testing work done when I was not present but which I talked about with those involved either by telephone or at the site at considerable length.

I am also in complete agreement with the conclusions which are based not only on the grout "take" but also on pressure testing of the sheaths after the grout had hardened and on the end result, filling of the sheaths with grease of which none escaped.

Yours very truly,

John C. King
John C. King
Registered Professional Engineer
State of Ohio # E-017426
State of Colorado # 773

**JOHN C. KING, P.E.**
CONSULTING ENGINEER

101 East 252 Street / Cleveland, Ohio 44132
(216) 731-0977

June 13, 1983

W.G. Bingham
Project Engineering Manager
Los Angeles Power Division
Bechtel Power Corporation
PO Box 60860, Terminal Annex
Los Angeles, California 90060

Subject: Arizona Nuclear Power Project
Bechtel Job 10407
Engineering Evaluation Report
Investigations and Grouting of
Leaks Associated with Tendons
H32-009 and H32-011
File: CM-158

Dear Mr. Bingham:

I have examined laboratory reports Nos 040583-1,-2 and -3 dated 7-5-83, 7-7-83 and 7-7-83, respectively and find the reported cube strengths more than adequate for the use to which the tested grout was put.

Although these strengths are lower than the strength of the cracked concrete into which the grout was injected, it should be borne in mind that the compressive strength exhibited by a grout that has been formed in a cube mold bears little relationship to that which will be exhibited by a relatively thin layer of grout in a crack between two masses of concrete. The reason for this is that the length/width ratio of a cube is 1.0, i.e., there is no lateral restraint acting on the width of the specimen. The thin sheet of grout, however, has a length/width ratio approaching zero (the length is very short; the width comparatively great). This means that all of the grout in the sheet is infinitely restrained by other grout and by the body of the concrete. Thus the solid grout cannot be crushed because there is no place for the particles to move to.

Because the primary purpose of the grout was to attain maximum penetration into the finer voids, I had earlier recommended that the grout pumped be much more fluid than that at which the grout was initially qualified. The end result was that the cracks in the concrete were sealed not only to the outside face of the wall but between the sheaths as well with a grout that has hardened in position to provide strength in excess of that needed for stability of the concrete structure.

Very truly yours,

John C. King
Registered Professional Engineer
State of Ohio # E-017426
State of Colorado # 773

cc: Joe A. Cazares
Bechtel Power Corporation
PO Box 49
Palo Verde, Arizona 85343