REBOUND, SETTLEMENT AND SUBSIDENCE INSTRUMENTATION FOR THE PALO VERDE NUCLEAR GENERATING STATION

For:

NUS Corporation

and

Arizona Nuclear Power Project

By:

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INTRODUCTION

In order to provide a means by which the actual settlements experienced by plant structures could be determined, an instrumentation system was established. The following rebound-settlement and subsidence monitoring program for the ANPP Palo Verde Nuclear Generating Station is intended to monitor foundation and ground movements during and after plant construction. In addition to monitoring settlements as they occurred, the instrumentation program was designed to determine the soil rebound occurring during excavation. By establishing the rebound which occurs, the accuracy of the settlement analysis can be assessed. This gives the opportunity to reevaluate the settlement analysis from a safety standpoint as well as provides an opportunity to revise structural designs in order to reflect the actual settlements likely. The instrumentation installed to monitor settlement will also be used to monitor ground subsidence. In addition to the dual use that the settlement instrumentation will serve, specific instrumentation is intended to monitor possible ground subsidence.

This monitoring program being implemented at the site is designed to meet the objectives outlined in the ANPP Palo Verde Nuclear Generating Station PSAR, Section 2T.7 of Appendix 2T.

INSTRUMENTATION PROGRAM

The basic rebound, settlement, and subsidence monitoring system is composed of three basic components. The first is a system

of multiple position extensometers which provides rebound, settlement, and subsidence data from three depths at each installation. These instruments possess remote readout capability so they can be left in place beneath structures and will continue to provide settlement data for an extended period of time. Figures 1, 2, and 3 show the location of each instrument station. Each multiple position extensometer is anchored in rock at a depth in excess of 300 feet below the ground surface. Anchors with displacement sensors (Strain Meter, SINCO Model No. 51703) are located at three levels above the rock anchor. For the location of the individual displacement sensors and the basal rock anchor, refer to the boring logs, Appendix A.

A description of multiple position extensometer installation techniques is provided in Appendix B.

The second component of the instrumentation program is a system of eighteen (18) mechanical rebound stations. These instruments are designed to yield information on the rebound system which occurs as a result of the site excavations. In addition to providing rebound data, the mechanical rebound system provides an independent check on the data gathered from the multiple position borehole extensometers. Details of the installation techniques are presented in Appendix C. The mechanical rebound station locations are shown on Figures 1, 2, and 3.

The third major component of the settlement-rebound monitoring program is a system of survey monuments and control points set

within the structures. In a typical power block there will be thirty-eight (38) points at which settlements will be monitored, Figure 4. These stations will be installed as soon after the construction sequence allows as possible. An integral component of the survey monitoring program is the establishment of two benchmarks on rock outcrops. Four additional benchmarks are located in the vicinity of the three power blocks, Figure 5. These benchmarks are designed to monitor potential ground subsidence associated with groundwater withdrawal. Figure 5 shows the location of the benchmarks which, as installed on a basalt flow, will provide site elevation control.

FREQUENCY OF MONITORING

The monitoring schedule is as follows:

Benchmarks

- Monthly for first 3 months of monitoring.
- Annually to end of construction.
- Annually for first year of operation.
- 5-year intervals during operation.

Extensometers and Mechanical Rebound Anchors

- Until failure or abandoned, or
- Weekly to completion of overlying mat foundation.
- Monthly for 18 months after first concrete.
- 3-month intervals to end of construction.
- Annually for first year of operation.
- 5-year intervals during rest of operation.

Control Points on Structures

- o Monthly for 18 months after first concrete (all points).
- o 3-month intervals to end of construction (all points).
- o Annually for first year of operation (one point each unit).
- o 5-year intervals during rest of operation (one point each unit).

Groundwater levels will be measured with the same frequency as the benchmarks during the operating period. The groundwater data will be compared to the subsidence monitoring data. Any anticipated movement of the monitoring benchmarks will occur from groundwater withdrawal.

The weekly readings in the pre-excavation stage are intended to provide a check on the repeatability of the in-place system. The monitoring program is intended to be flexible enough so that if the frequency of readings needs to be increased at any particular stage of construction the increased frequency will be implemented.

ANALYSIS OF DATA PROGRAM

The analysis of data gathered during the excavation-construction phases will be evaluated with the following objectives:

1) Establishing the degree of conformance of actual rebound-settlement data to the original estimated values. Since the original settlement analysis incorporated very conservative assumptions, the comparison of actual to calculated values will enable a final assessment of the degree of conservatism which exists in the settlement analysis.

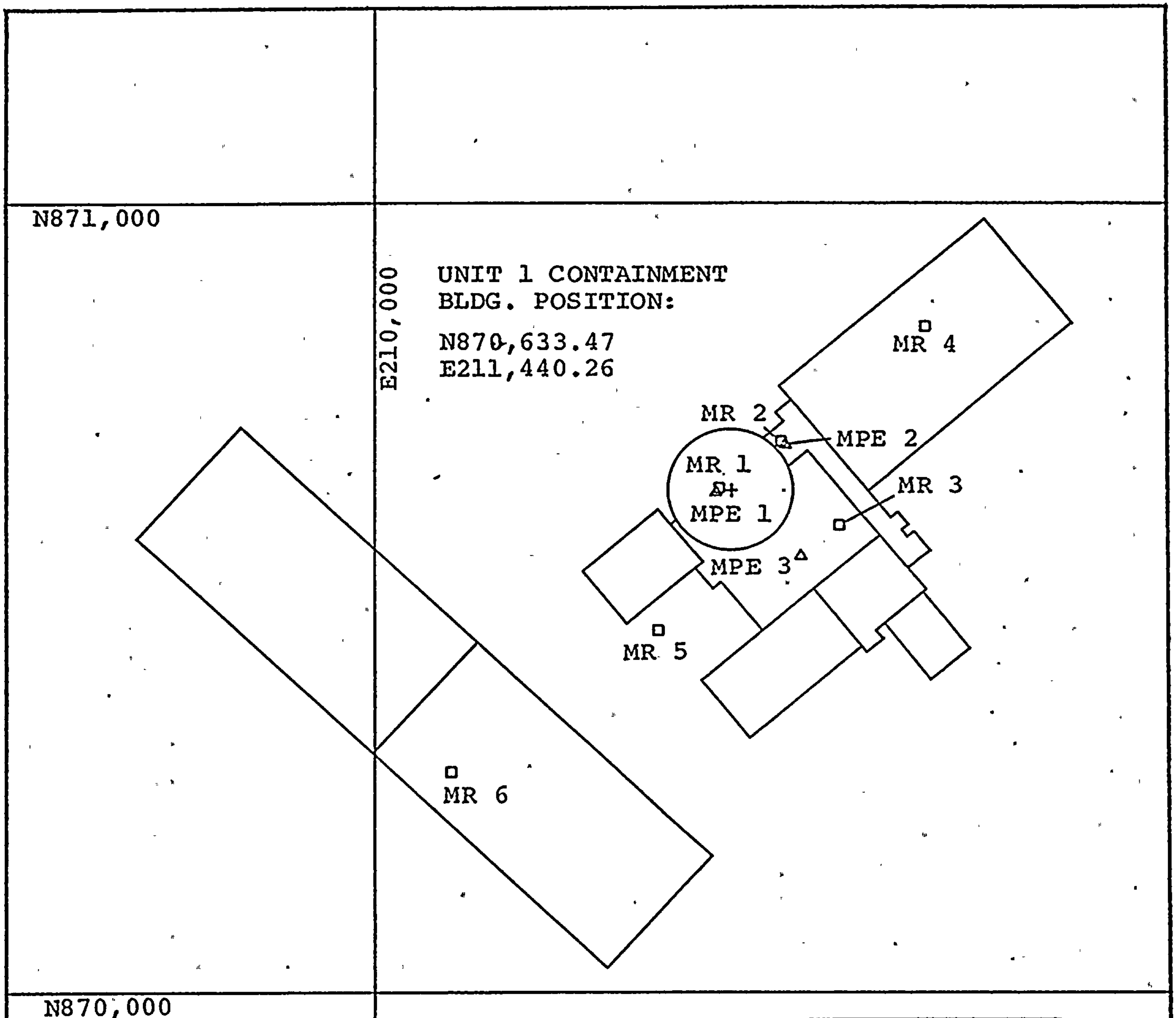
2) Assessing the compatability of the actual rebound-settlement patterns with those calculated. This would include evaluating differential rebound-settlement values as overburden release or structure loading rates vary between the structures.

3) Assessing the adequacy of the time dependent rebound-settlement assumptions based on actual data.

4) Review of assumed soil parameters to insure that assumed soil-groundwater conditions were conservative with respect to actual soil behavior. If the measured data indicates the assumed soil parameters are not conservative, the soil parameters will be revised to conform to observed rebound-settlement data using known unloading-load conditions.

5) Comparison of mechanical rebound data with data generated by the multiple position extensometers. In this manner a constant check between the two types of instrumentation will enable the reliability of data gathered by each instrument to be assessed.

By the time the excavations are complete, the rebound data should allow an assessment of the adequacy of the settlement-rebound analysis to be made. If the soil-groundwater conditions used in the analysis are not conservative the magnitudes of rebound would exceed the calculated values. Should the actual values of rebound exceed the calculated values, then the settlement analysis will be modified by using soil parameters which are compatable with the observed magnitudes of settlement.



LOCATION OF SETTLEMENT REBOUND OBSERVATION POINTS					
MPE 1	N870,630.09 E211,426.01	MR 1	N870,637.58 E211,438.15	MR 4	N870,839.11 E211,684.98
MPE 2	N870,690.44 E211,508.77	MR 2	N870,696.21 E211,504.53	MR 5	N870,456.20 E211,353.28
MPE 3	N870,551.17 E211,528.37	MR 3	N870,592.35 E211,578.82	MR 6	N870,277.36 E211,099.44

△ MPE – MULTIPLE POSITION EXTENSOMETER
□ MR – MECHANICAL REBOUND STATION

SCALE
200 0 200
FEET

NOTE:
COORDINATES ARE BASED ON ARIZONA STATE GRID SYSTEM

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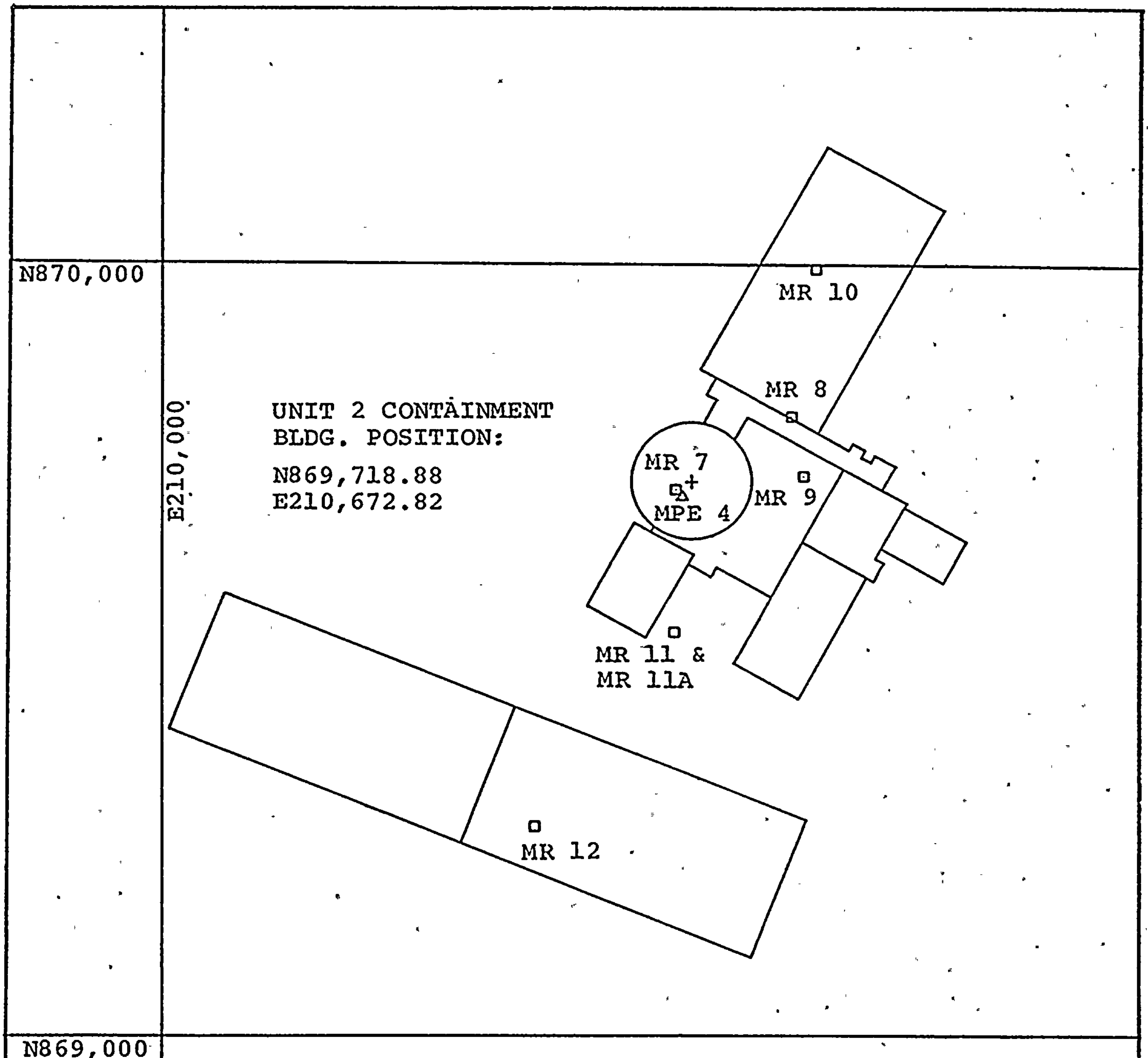
SETTLEMENT MONITORING LOCATIONS
UNIT 1

Figure 1



LOCATION OF SETTLEMENT REBOUND OBSERVATION POINTS					
MPE 4	N869,710.03 E210,660.51	MR 7	N869,706.60 E210,653.71	MR 10	N869,996.11 E210,833.08
		MR 8	N869,802.36 E210,709.37	MR 11A	N869,522.58 E210,651.71
		MR 9	N869,728.54 E210,817.01	MR 12	N869,266.91 E210,475.34

△ MPE - MULTIPLE POSITION EXTENSOMETER

□ - MECHANICAL REBOUND STATION

SCALE

200 0 200

FEET

NOTE:
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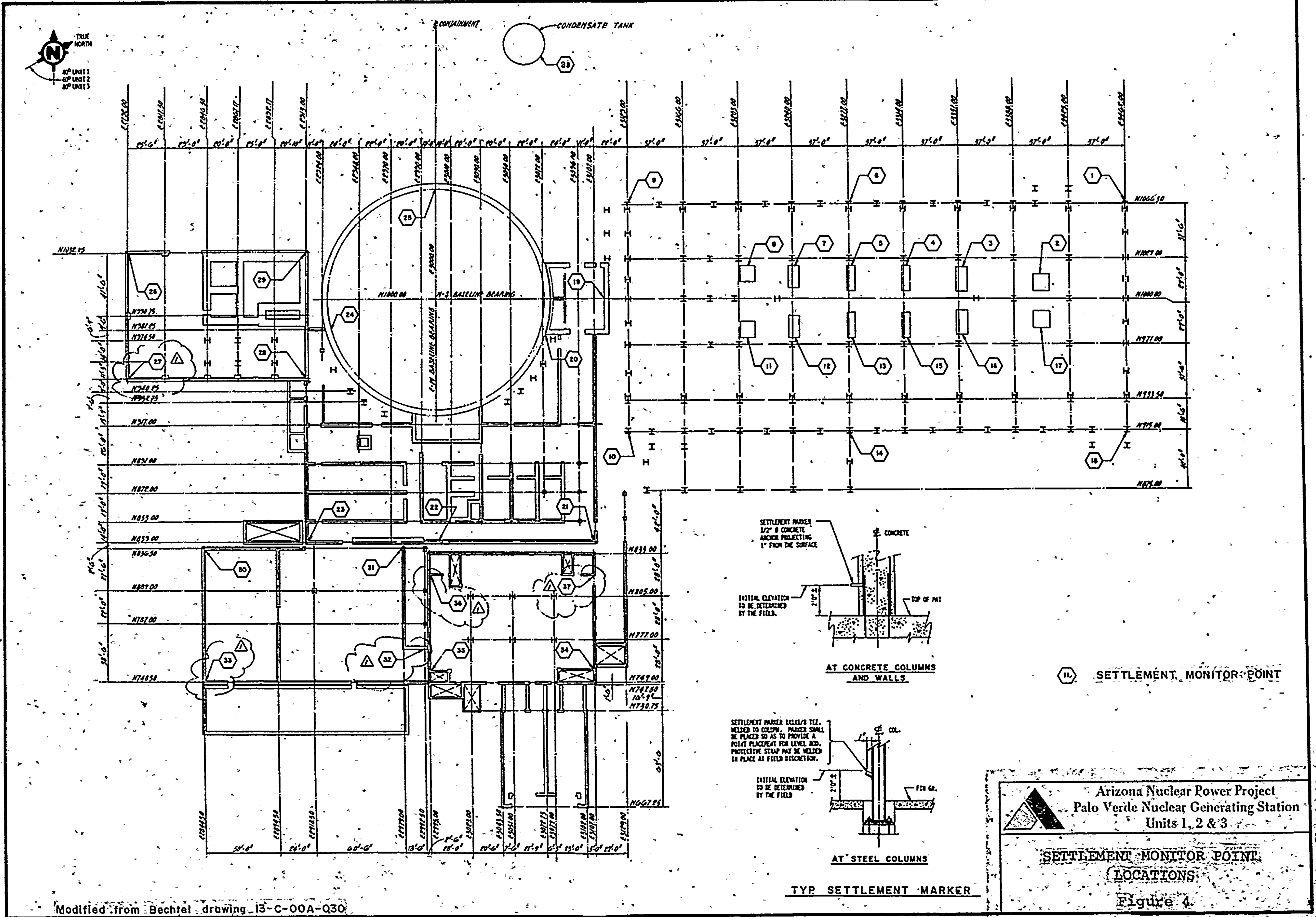
SETTLEMENT MONITORING LOCATIONS
UNIT 2

Figure 2



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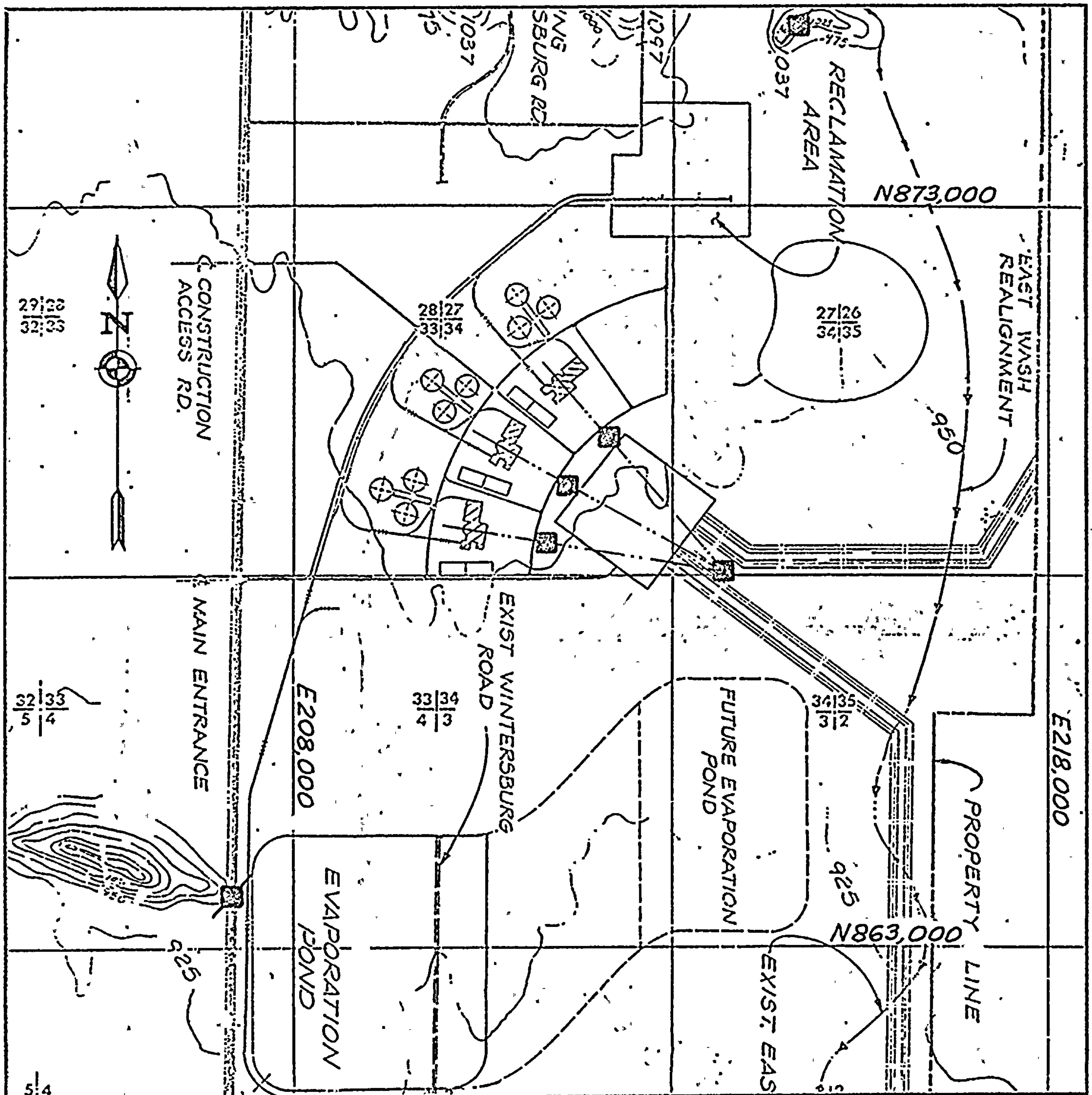

EXPLANATION

PERMANENT BENCHMARK ON ROCK

PERMANENT BENCHMARK ON SOIL

NOTE: Coordinates are based on Arizona state grid system. Vertical control from U.S.C. & G.S. bench mark F-362, elev. 1003.17'.

Modified from Bechtel drawing 13-C-ZVA-006

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PERMANENT BENCHMARK LOCATIONS

Figure 5

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APPENDIX A

BORING LOGS

APPENDIX B

MULTIPLE POSITION EXTENSOMETER INSTALLATION TECHNIQUES AND DETAILS

INSTALLATION PROCEDURE

Strain Meter, Model 51703

The following procedures were followed for the 15 Stain Meters installed at five locations (3 Strain Meters were placed per boring location at three different depths) at the Palo Verde Nuclear Generating Station Units 1, 2, and 3 in Arizona. The borings were drilled with a Failing 1500, rotary drill rig, truck mounted. The first three holes were initially about 8 inches in diameter, the last two borings reduced to 6.5 inches in diameter. To install the Strain Meters, the following preparations were made for preassembly of components and installation of the instrumentation equipment. Refer to figures B-1, B-2, and B-3 for visual explanation of component terminology.

PREASSEMBLY

1) One PVC component Schedule 40 PVC slip coupling was connected and cemented to one end of each 10-ft. length of 3/4" PVC Schedule 80 pipe.

   Since there were to be three sensors in the borehole, each end of each length of 3/4" PVC pipe was painted using a can of spray paint. Also, the electrical cable was painted at intervals along its length. The same color was used for one instrument (sensor, riser pipe, and cable). The following color code was used throughout the project: bottom sensor component materials - red; middle sensor component materials - green; top sensor component materials - white.

2) The preassembled 10-ft. lengths of 1/4" OD stainless steel rod were slipped inside 10-ft. lengths of 1/2" OD Polyethylene

tubing. A 3/8" OD stainless backup ring was inserted inside each end of 1/2" OD tubing.

A 1/4" galvanized pipe coupling was then attached to the end of each 1/2" Polyethylene tube and the pipe coupling color coded, as in 1), above.

3) The hydraulic anchor and bottom adapter (figure B-3) were shop assembled together and shipped as a single unit. The hydraulic pressure tubing was attached to the anchor, pre-fitted with oil, and color coded, as in 1), above.

4) The bottom adapter and anchor were connected to the drill rod (N-size) by means of the special coupler which had left hand threads. This coupler was welded to a sub furnished by the driller to match the drill rod. The first two installations were made with this drill rod, which had 3-inch diameter couplings. The remaining three installations were attached to 2-inch diameter galvanized water pipe.

5) The lifting line for the drill rod with swivel was attached and suspended over the borehole from the drill rig.

6) While the drill rod and bottom anchor and adapter were suspended from the drill rig, a 2-ft. length of 1/4" stainless steel rod was attached to the bottom adapter.

INSTALLATION

The following steps were repeated with each of the three instruments in the borehole during installation.

1) A 10-ft. length of preassembled 1/4" OD stainless steel

rod and 1/2" OD Polyethylene tubing was raised vertically over the 2-ft. length, attached to the bottom adapter, and the two 1/4" rods were tightened.

2) The 1/2" OD Polyethylene tube (with 1/4" coupling at the top) was slid down and threaded into the bottom adapter.

3) The bottom anchor and adapter were then lowered into the hole, pulling down the 1/2" tubing and 1/4" rod in 10-ft. lengths. As these lengths were added, the joints in the 1/2" tubing were made with the 1/4" galvanized pipe couplings.

4) Measurements of the stickup of the 1/4" rod out of the 1/2" tubing were taken periodically as lengths were added and as the instruments were lowered into the hole. Flotation of the tubing caused this stickup to decrease from upward pressure due to the density of the drilling fluid.

To obtain the desired distance between bottom anchor and sensor, the last section of 1/4" rod was a selected length, depending on the total length required, and the depth at which the sensor was to be installed.

5) The distance between the top of the last 1/2" OD tubing and the top of the last 1/4" rod was measured and a piece of 1/2" tubing cut to a length 6 inches less than that measured. The blank end was threaded with a 1/4" pipe thread die. This short length was slipped over the top of the last rod and threaded into the last 1/4" pipe coupling on the 1/2" tubing.

6) After the correct length of 1/4" stainless steel rod and 1/2" OD Polyethylene tubing was added, it was threaded to the 1/4" rod of the sensor which, in turn, was attached to the hydraulic anchor by means of four tubing clamps.

7) With the sensor attached to the 1/4" rod and attached to the anchor, the 1/2" OD Polyethylene tubing was tensioned, thus keeping the sensor reading at zero (sensor rod in retracted position inside the sensor). The length of the top piece of 1/2" OD Polyethylene tubing was adjusted, as necessary, to obtain sufficient tension to maintain zero reading.

8) A length of 3/4" PVC pipe was then threaded over the 3-wire SJO electrical cable and cemented to the sensor.

9) The instruments were lowered into the hole adding 10-ft. lengths of 3/4" PVC pipe after threading over the 3-wire SJO cable from the first sensor, and 10-ft. assemblies of 1/4" rod and 1/2" tubing connected for the additional two sensors.

10) The sensors were tested with SINCO's 51811 Portable Indicator in the field against the calibration sheets provided for each sensor by SINCO prior to their use and assembly.

11) The completed sensor was connected to the indicator and readings taken periodically as the instruments were lowered into the hole. The 3/4" PVC riser pipe was also pulled up to obtain a change in reading on the sensor. Tension in the 1/2" tubing would return the sensor reading to zero.

12) Buoyancy of the 3/4" PVC pipe changed the sensor reading. To overcome this, a 2-1/2-foot length of 1-3/8" steel tubing was slipped over each 10-ft. length of 3/4" PVC pipe. This weight was to balance the flotation of the 3/4" pipe. The number of weights depended upon the density of the drilling fluid. Only the second boring required this procedure. The remaining borings did not require any metal tubing to overcome flotation.

13) When the bottom hydraulic anchor and adapter was in position at the required depth, the 51811 Portable Indicator was connected and the sensor reading checked. By pulling up on the 3/4" PVC pipe, the proper reading was obtained. The 3/4" PVC pipe was fastened in to the drill rig to maintain the proper reading.

14) The bottom anchor pressure tubing was then attached to the hydraulic pump and the bottom hydraulic anchor prongs expanded by operating the pump. The amount of oil pumped was measured in the reservoir gauge attached to the pump. The extension of the prongs were determined by means of the calibration curve; all prongs were extended about 12 inches diameter using as much as 2500 to 3000 psi oil pressure.

When the anchor was set in the rock, the drill rod was rotated clockwise one or more turns to make sure the threads were detached and the rod separated.

15) The hole was filled up with high-density drilling fluid during the time of installation to increase the uplift of the

drilling fluid which, in turn, supported the equipment in the center of the boring. One batch of grout, approximately 300 gallons, was mixed and pumped through the drill rod (or 2" diameter pipe in the later installations - see drawing of anchor) discharging it out the bottom anchor adapter.

Grout mixtures used were determined by the Fugro personnel who obtained batch samples during each installation. For the bottom portion, 14 bags of cement and 150 gallons of water were used. The top portion was grouted by using 5 bags cement, 5 bags of bentonite, and 325 gallons of water. All installations were made in two stages except for the first installation which was completed by continuous grout placement in one day. All other installations, however, were installed in two stages. The first stage grouted the bottom anchor with a heavy cement batch and the bottom sensor was grouted with cement and bentonite. The second stage was completed the following day, whereby the middle and upper sensors were grouted using mixtures of cement and bentonite.

After the first batch of grout had been placed in the hole, the drill rod was disconnected from the bottom anchor by rotating clockwise. The drill rod was raised to just below the top of the first batch placed in the hole and the grouting continued until its level was at least 10 feet above the sensor.

16) The drill rod was withdrawn until the bottom was approximately five feet above the lowest sensor.

17) The sensor reading was continuously checked on the Portable Indicator making certain that the sensor reading was at the setting desired by raising or lowering the sensor with the 3/4" PVC pipe before the prongs of the anchors were jacked out.

As described before, the sensor anchor prongs were expanded by operating the pump. The sensor reading on the Portable Indicator was checked for any changes while expanding the anchor prongs.

18) Additional grout was pumped into the hole until a level above the next sensor was reached. The drill rod was then raised to a position above the next sensor.

19) The second sensor anchor was expanded as described before, and repeated for the third sensor.

20) The hole was then filled to the top with grout and all drill rods were removed.

21) The PVC pipes were firmly attached to the drill rig and the grout allowed to set before the drill rig was demobilized and moved to the next location.

22) The sensors were monitored with the Portable Indicator and recorded as initial readings. The results of the readings obtained during the time of installation are attached.

23) The PVC pipes were cut above the ground and the readout cable rolled up and secured in a 6" diameter casing.

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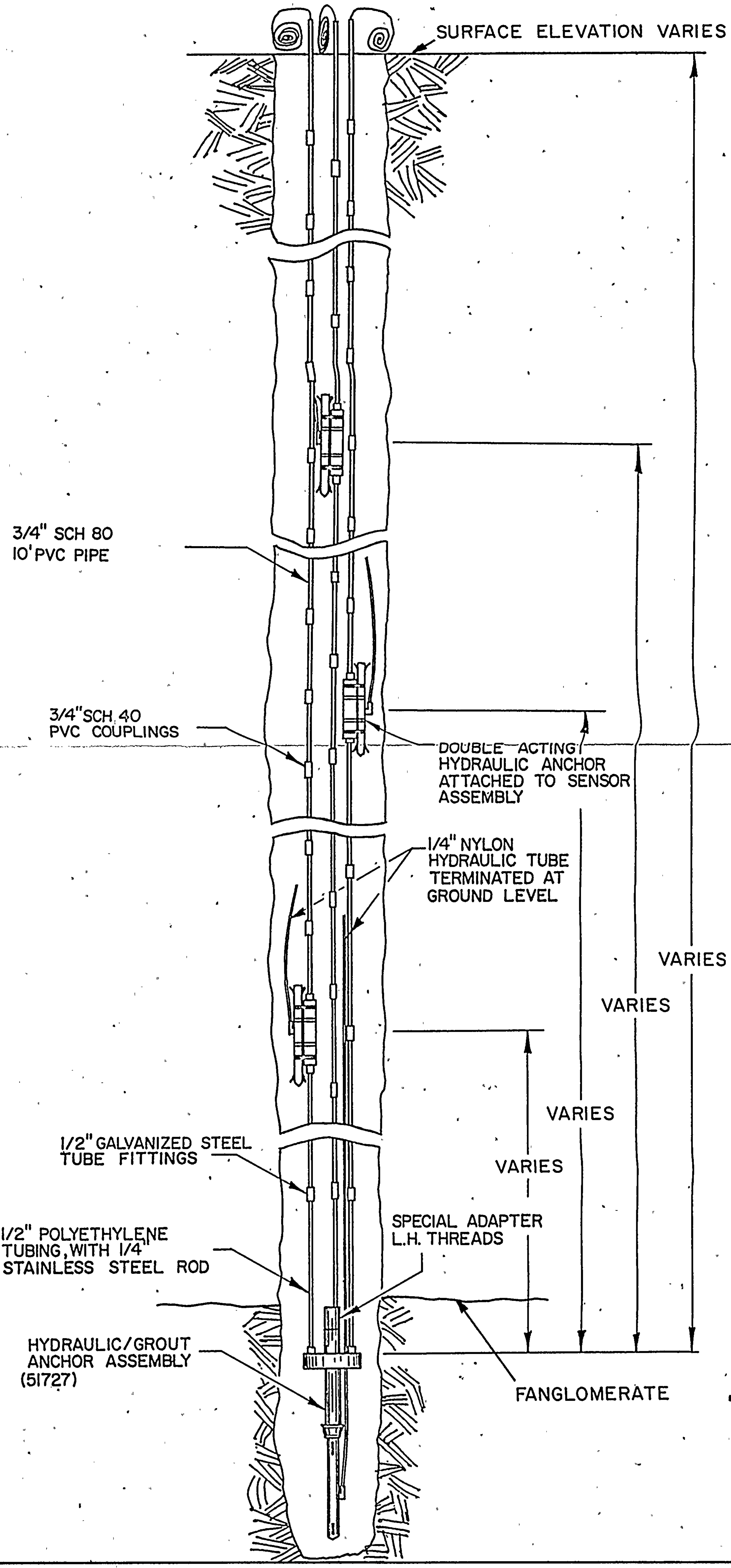

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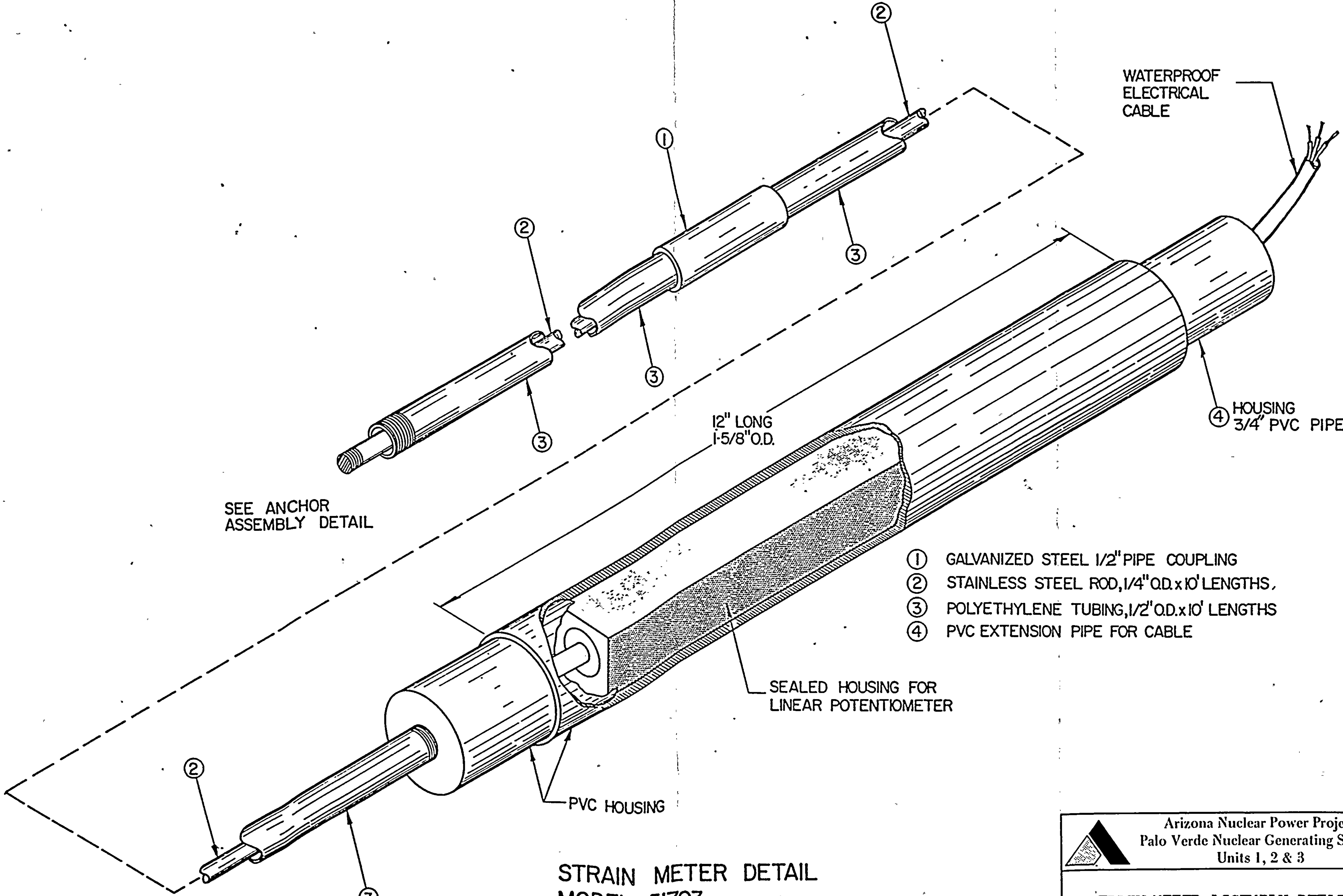
BOREHOLE ROD EXTENSOMETER
GENERAL LAYOUT

Figure B-1



STRAIN METER DETAIL
MODEL 51703

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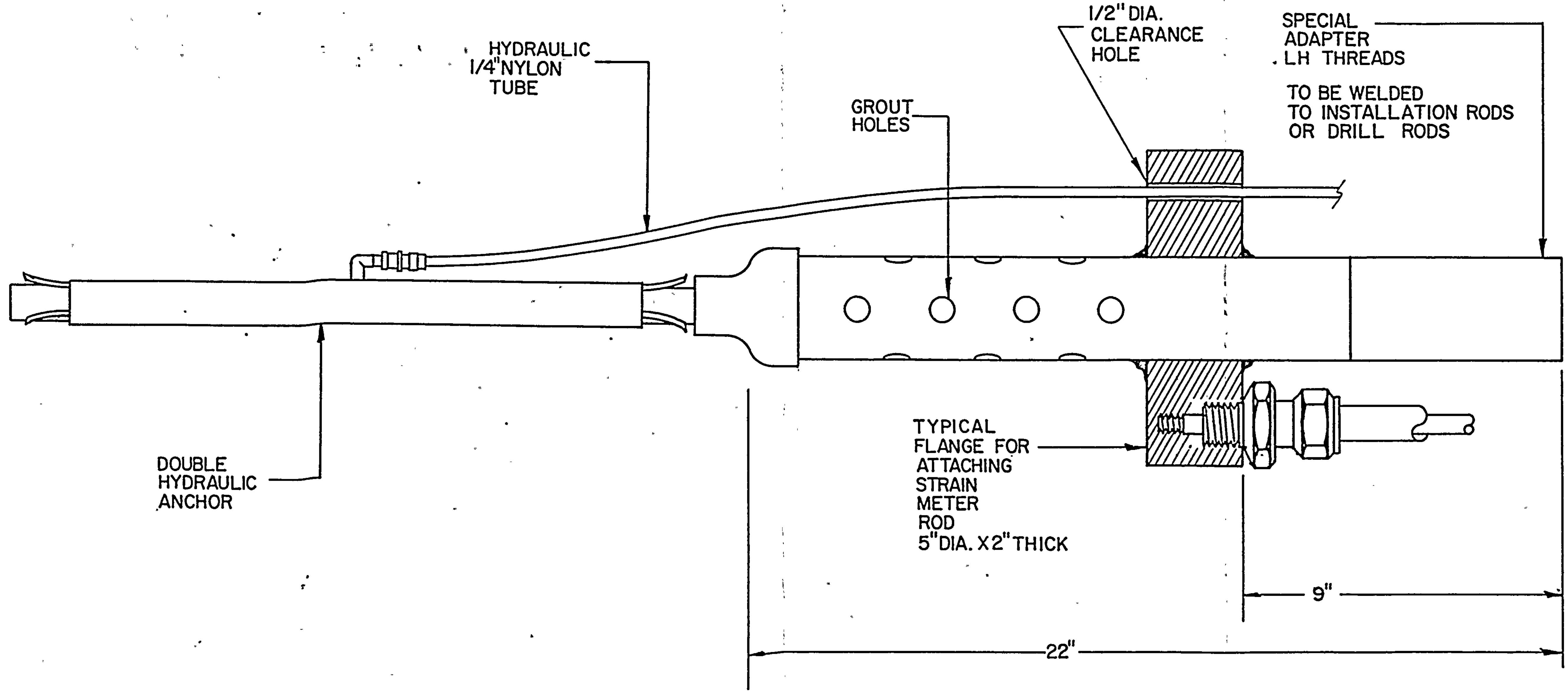
STRAIN METER ASSEMBLY DETAIL

Figure B-2



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BOTTOM ANCHOR DETAIL

Figure B-3

APPENDIX C

MECHANICAL REBOUND STATION CONSTRUCTION TECHNIQUES AND DETAILS

INSTALLATION PROCEDURES FOR THE MECHANICAL REBOUND STATIONS

Refer to figure C-1 for description of component terminology.

1) Drill borings with 8" hollow stem auger (3-3/8" ID) to 4 feet below depth of excavation.

2) Assemble 2" PVC casing (2.975" OD coupling) with cap on bottom. The bottom cap will be drilled with a 1-1/2" hole in the bottom to allow the anchor pin to pass through.

3) Measure length of PVC accurately.

4) Clean out auger with 3" diameter drive sampler (go about 3" below the bottom of the auger)..

5) Install the PVC casing into the borehole and push down into loose soil. The casing should go a few inches below the bottom of the auger.

6) Using a shear pin, attach the "A" rod to the monitor pin. Lower the monitor pin to the bottom through the PVC and drive it until the tip of the pin is 24" below the tip of the PVC. Record the number of blows of a 140-pound hammer dropping 30 inches.

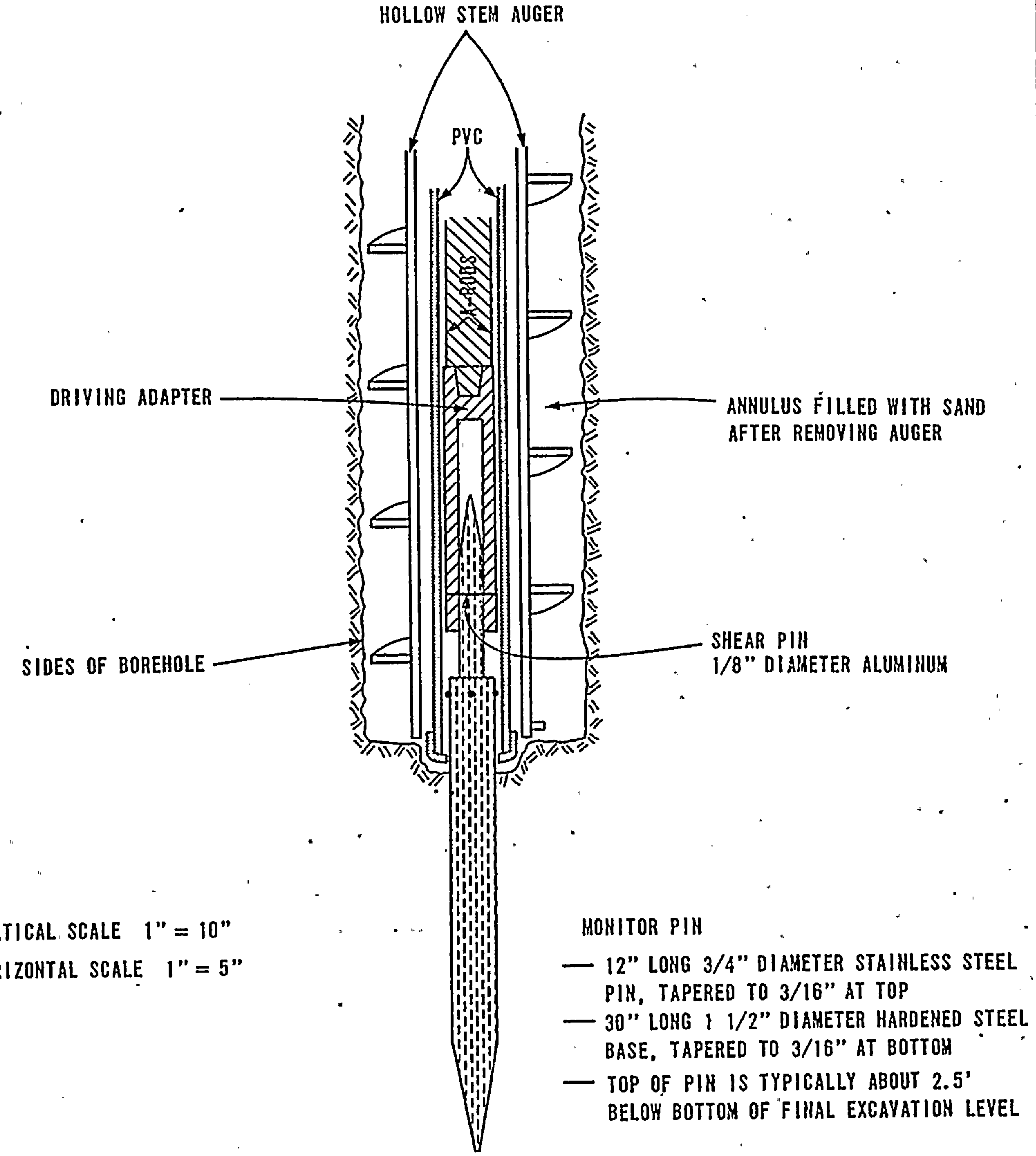
7) Withdraw "A" rods and hollow stem auger.

8) Backfill the area between the PVC and soil with white sand.

9) Put on removable PVC cap.

A readout rod was also included as a part of the system. It consisted of 3 and 4-foot long surveying range rods calibrated for length. A 1-1/2" diameter piece of steel was used on the

bottom contact piece. The assembly of rods would be lowered to rest on the monitor pin and the top elevation of the rod would be monitored using normal surveying techniques.



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MONITOR PIN DETAIL

Figure C-1