CONTAINMENT LINER TEST CHANNEL
AT
BEAVER VALLEY POWER STATION - UNIT NO. 1

MARCH 1, 1979

PREPARED BY
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for
DUQUESNE LIGHT COMPANY

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ATTACHMENTS

1. Welding Procedure 205, 224

2. NDT Procedures

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5. Testing of Protective Coatings Under Design Basis Accident Environment, April 1973, by the Franklin Institute Research Laboratories (referenced only)

NOTE: This report will consist of the text which includes Sections 1, 2 and 3. All the referenced figures and a number of the referenced attachments were distributed in a meeting with the NRC in Bethesda, Maryland on January 23, 1979.

Attachments 3 and 4 were not distributed because their use is only as a reference and because of their size.

Attachment 5, also a larger document, was not distributed since it had already been submitted to the Commission under a different docket (50 -338).

All the listed figures are reproduced and included in this report for reference.

SECTION 1

INTRODUCTION

This report has been prepared for Duquesne Light Company (DLC) by Stone & Webster Engineering Corporation (S&W) to document the presentation given to the Nuclear Regulatory Commission (NRC) by DLC and S&W, on January 23, 1979, relative to the containment liner test channels at Beaver Valley Power Station - Unit No. 1.

The purpose of the presentation and of this report is to provide sufficient information relative to the evaluation of the function and the predicted performance of both the containment liner and test channels to demonstrate that the existing containment system presently provides and will continue to provide a leaktight enclosure.

Our evaluation shows that although the containment liner test channels were provided primarily for the testing of the liner seam welds during construction, and although they were not designed as a part of the leaktight membrane, they are completely compatible with the liner. The test channels are capable of withstanding all loads that might be imposed on them during normal test and upset conditions without any loss of function and the presence of the test channels does not in any way impair the performance of the containment liner itself.

Although the test channels were not designed as a part of the pressure boundary, they clearly provide additional containment leak protection.

Section 2 of this report presents a general description of the containment system which includes the containment structure, the containment liner, and the related test channels. This section describes the configuration, materials, construction procedures, and the tests and inspections employed in construction of the containment system.

Section 3 of this report presents responses to the NRC questions which were received by DLC on January 3, 1979.

SECTION 2

DESIGN OF CONTAINMENT LINER AND TEST CHANNELS

The containment liner is a continuously welded carbon steel membrane, supported by and anchored to the inside of the containment structure. Its function is to act as a leak tight membrane in the event of an accident. The liner is not a code vessel.

The basic shape of the containment structure consists of a cylindrical portion, anchored at its base to the foundation mat and closed at the upper end with a hemispherical dome. The reinforced concrete shell varies in thickness from 4 1/2 ft on the cylinder to 2 1/2 ft in the dome area. The inside diameter of the containment structure is 126 ft and the interior vertical height is 185 ft measured from the top of the foundation mat to the interior apex of the dome.

The cylindrical portion of the liner is 3/8 in thick, the hemispherical dome liner is 1/2 in thick, the flat floor covering the mat is 1/4 in thick, with the exception of areas where the transfer of loads requires a reinforced thickness. The bottom mat liner plate is covered with 2 ft of reinforced concrete that insulates it from transient temperature effects.

The 3/8 in thick liner served as the internal form for the concrete containment during construction. All liner seams are double butt welded, except for the lower 30 ft of the cylindrical shell liner plate where the liner plates are welded using a backing bar. The liner is continuously anchored to the concrete shell with concrete anchor studs.

The 1/2 in thick hemispherical carbon steel plate dome liner served as an internal form for the containment reinforced concrete dome during construction. All seams in the liner dome are double butt welded. The liner dome also is continuously anchored to the reinforced concrete containment dome with welded anchor studs.

The wall to dome liner junction is a double butt welded joint.

All welded seams in the mat, cylindrical liner wall, hemispherical dome, and liner penetrations are covered with continuously welded test channels. The non-destructive examination of primary containment liner seam welds is described by Specification No. BVS-136 and by NDE procedures submitted by the Erector.

Liner Materials

The ASME Boiler and Pressure Vessel Code, Section III, Division 1, Nuclear Vessels, was used as a guide in the selection of materials and fabrication of the steel containment liner.

The liner materials are: SA 537 Gr B (quenched and tempered) for the first 30 ft, starting at the mat level of the cylindrical portion. The remainder of the liner is built with SA 516 Gr 60 (fine grain practice). The SA 537 Gr B quenched and tempered material has a specified minimum tensile strength of 80,000 psi, a minimum guaranteed yield strength of 60,000 psi, and a guaranteed minimum elongation of 22 percent in a standard 2 in specimen.

The SA 516 Gr 60 has a specified minimum tensile strength of 60,000 psi, a minimum guaranteed yield strength of 32,000 psi and a guaranteed minimum elongation of 25 percent in a standard 2 in specimen. The nil ductility transition temperature (NDTT), for both materials, was tested not to exceed -20 F. The plates of SA 516 Gr 60 are heat treated for improved notch toughness and both materials are certified to the mechanical and chemical limits specified in the ASME code. Refer to Figure 1.

The test channels were fabricated of ASTM-131 Gr C material throughout. Impact tests were not specified for the plate used because of its thickness: 3/16 in.

As described, all three grades of carbon steel referenced above were purchased to fine grain practice with full mill test documentation (chemicals and physicals). All materials were required to be capable of being cold bent 180 degrees with no cracking.

Tests and Inspections

A testing and surveillance program was in effect during construction and operation to establish that the containment can perform its intended function. The program consisted of construction testing, a structural acceptance test, an initial leakage rate test, periodic leakage rate retesting, continuous subatmospheric pressure monitoring, and periodic surveillance tests.

All applicable welding procedures and tests specified in Section IX of the ASME Boiler and Pressure Vessel Code for Welding Qualifications 1968 were adhered to for qualifying the welding procedures, the performance of welding machines, and welding operators who were engaged in the construction of the containment liner including the test channels. The welding qualification included 180 deg bend tests of weld material. These procedures ensure that the ductility of welded seams is comparable to the ductility of the containment liner plate material.

Production quality control was exercised through random radiography per paragraph UW-52 of Section VIII of the ASME Boiler and Pressure Vessel Code for Unfired Pressure Vessels, 1968. As shown in Figure 1 the radiography for the liner seams was 100 percent for the first 10 ft of each position, each welder. Total RT exceeded 2 percent. Other NDT's are tabulated on Figure 1 - Additional tests of quality include visual, dye penetrant and pressure testing.

Construction testing included provisions for testing the leaktightness of all penetrations and liner welds during construction.

To facilitate construction testing, steel test channels were welded over all weld seams. These channels were segmented, and leak tests were performed section by section. On the bottom and cylindrical portions of the liner, the test channels are on the inside of the liner. On the dome portion of the liner, the test channels are on the outside (concrete side) of the liner.

Before halogen leak testing, all the test channel welds were soapsud tested by pressurizing the void with air to 50 psig and checking for visible leakage. After the air test and any subsequent repairs, if required, the test channels were evacuated to a pressure of 1.0 to 0.5 psia by utilizing a vacuum pump. This ensured a homogeneous test gas throughout the channel when the channel is subsequently pressurized at 50 psig with Freon R-22. For the bottom and vertical portions of the liner, where the test channels were placed on the inside, all test channel seal welds were leak tested using a halogen leak detector. After testing, the gas was vented from the channels and the threaded connections were plugged.

For the dome portion of the liner, where the test channels are on the outside, the test channel welds, the liner seam welds and the dome plugs were also leak tested using a halogen leak detector since all welds were accessible.

The containment structure was subjected to structural acceptance test in accordance with Safety Guide 18 during which the containment internal pressure was 1.15 times the containment design pressure. This test was performed after the liner was completed, the last concrete placed, and all penetration sleeves and hatches installed and closed or blanked off.

Containment Leakage Rate Tests

The containment leakage rate tests are performed in accordance with the guidelines of Appendix J of 10CFR50, "Primary Reactor Containment Leakage Testing for Water Cooled Power Reactors," as published in the Federal Register February 14, 1973.

The containment leakage testing program includes the performance of Type A tests, to measure the containment overall integrated leakage rate, Type B tests, to detect local leaks or to measure leakage of certain containment components, and Type C tests, to measure containment isolation valve leakage rate.

The measured overall integrated leakage rate of the containment during Type A testing must not exceed 0.1 percent per 24 hr of the weight of containment air at the calculated peak containment pressure of 38.3 psig.

Beaver Valley - Unit No. 1 successfully passed the Type A tests required by Tech. Sec. 3.6.1.2 and the Surveillance Requirements 4.6.1.2 during November 1978, in an identical manner to the original test performed in July-August 1975.

SECTION 3

NRC QUESTIONS AND RESPONSES

This section presents responses to the list of NRC questions which were received by DLC on January 3, 1979 and which were answered verbally at the meeting with the NRC in Bethesda on January 23, 1979.

It should be noted that Sections A, B and C of the questions, which deal with the wall, dome and floor channels (boxes) respectively, are all introduced with a statement to the effect that the information and analyses which are requested are required to determine the acceptability of the test channels as part of the leakage barrier. As indicated in the introduction of this report, our evaluation shows that although the test channels were not designed as a part of the leakage barrier they are completely compatible with the liner in terms of materials, construction procedures and tests and the ability to withstand all of the loads and associated differential movements which might be imposed during all normal, test and upset conditions.

A. Wall Boxes

In order to determine the acceptability of these channel boxes as part of the containment leakage barrier, the following information and analyses are requested.

Question
A.1 Materials Identification and Construction Procedures

Provide the details of the materials used and procedures for construction for all wall boxes and specify by elevation or location, where differences occur. Provide procedure 205 used in the welding of horizontal and vertical test channels. Provide the procedures for welding the test connection to the channel boxes and the procedures for tightening (torquing) the plugs.

Response

A.1 The details of the materials used in the construction of the containment liner and test channel boxes are listed on Figure 1, 2 sheets, attached. The liner plate materials and the test channel material were purchased with extensive mill documentation, chemicals and physicals, to assure the level of quality required for fabrication and design service.

Figures 3a, b, and c illustrate the different test channel types provided for the floor, shell, and dome sections.

The material used for the liner is ASTM A537 Gr. B from the bottom up to El. 720 ft-11 in on the shell. Above that elevation and including the dome, the material is ASTM A516 Gr. 60.

Test channels were ASTM A131 Gr. C material throughout. Figure 2C shows where the differences in test channel configurations occur.

Attachment No. 1 is Procedure 205 used by Graver Tank, the Fabricator-Erector, which addresses manual welding performed on the liner plate of A516 material and test channels. It also addresses the welding used in attaching the test connections to the test channels. Procedure 224 addresses the welding of test channels to A537 Gr. B plates.

Test channel plugs are 1/8 in NPT pipe plugs, with socket hex heads.

There was no written procedure for tightening or torquing the test plugs.

Question

A.2 Testing and Inspection

Provide identification of the channel welds that were tested (pressure and nondestructive examination, e.g., penetrant or magnetic particle testing) and the procedures used in the test. List and describe any deviations from Reg. Guide 1.19

(listed as Safety Guide 19 in Beaver Valley Unit No. 1 Final Safety Analysis Report). Describe the testing, if any, of the leak tightness of the installed plugs.

Response

A.2 All test channel welds were 100% visually and dye-penetrant inspected. Attachment No. 2 includes the pressure test and dye-penetrant procedures used for testing of the channel welds. The welds on the test channels were also pressure tested simultaneously with the liner seam welds.

Safety Guide 19 which is Reg. Guide 1.19 was issued in 1972 after the testing of test channel and liner seam welds at Beaver Valley Unit No. 1.

The following is a list of deviations taken by Unit No. 1:

Requirement

a. Radiography - minimum 2 percent including first ten feet of weld for each welder, each position.

DEVIATION - none

Requirement

b. In areas where radiography is not feasible or where the weld is located in areas which will not be accessible after construction, entire length of the weld should be examined by the magnetic particle method or the ultrasonic method.

DEVIATION - Welds in this category were 100% visually examined, 100% dye penetrant examined, and 100% pressure tested.

Requirement

c. All liner seam welds are to be tested using a soap solution with a vacuum box under a 5 psi differential.

DEVIATION - By using welded test channels the liner seam welds were subjected to an air pressure of 50 psig using a soap solution for leak detection. Each test channel section was also pumped down to a 1 psia vacuum. Subsequently freon was introduced up to a pressure of 50 psig. All accessible welds were "snifted" for leakage.

Requirement

d. Where leak-chase system channels are installed over liner welds, channel to liner plate welds should be tested for leak tightness by pressurizing the channels to containment design pressure and held for 2 hours. Leaks are to be detected with a soap solution.

DEVIATION - All test channels were pressure tested to 5 psi over containment design pressure with air and with a halogen. Channel to liner plate welds were checked with a soap solution and with halogen detection equipment.

After the wall channels were tested, the test plugs were installed. There was no means of testing the leak tightness of the plugs installed in the wall channels.

Question

A.3. Structural Integrity of Channel Boxes (For Maintaining Leak Tightness)

Provide an analysis which would demonstrate that the channels and channel welds will be capable of carrying the differential movement or expansion of the liner. Consider liner buckling or bulging due to Loss-of-Coolant Accident (LOCA) temperature and dynamic pressure effects and seismic loads. Provide a comparative analysis to demonstrate leak channels and their welds meet the requirements of the ASME Boiler and Pressure Vessel Code Section 3, Div. 2, as appropriate.

Response

A.3 The reinforced concrete containment structure is designed to withstand the combined effects of a DBA and DBE occurring concurrently without any strength credit being taken for the liner. Since the liner is anchored to the containment structure by closely spaced anchor studs, forces on the liner are displacement limited by the structural response of the containment structure. The liner materials were chosen to provide the necessary ductility to withstand the displacements of the containment structure and perform their design function of providing a leaktight membrane for the containment. The liner thicknesses were chosen to facilitate construction, i.e., to act as a form for pouring concrete. At the time the liner was designed, there were no directly applicable industry codes in effect, nor were there any industry codes available which recognized displacement (strain) limits. The 1968 ASME Code, Sections III and VIII, was used as a guide in establishing liner stress limits and stress calculations were made to ascertain the design adequacy of the liner.

Stresses are calculated in the containment liner in a very conservative manner. A liner finite element model was developed by representing the composite reinforcing steel and liner steel (Fig. 8.1) as an equivalent orthotropic shell, neglecting any strength contribution by the concrete. This model was subjected to the combined axisymmetric loadings of deadweight, DBA pressure, and DBA temperature in order to establish the membrane and bending stresses in the liner. The total seismic shear force in the reinforced concrete containment wall (neglecting the strength of the liner) was then assumed to be totally applied to the liner in order to establish a very conservative estimate of liner shear stress. The shear stress was combined with the liner finite element model membrane and bending stresses to determine the maximum stress intensity range (Fig. 8.2). This stress range was compared to and found to be less than the established allowables.

The current industry code applicable to the design of containment liners is ASME Section III, Division 2. This code recognizes that liner forces are displacement limited and provides liner allowables in inch/inch of strain. In order to compare stress results with current code strain limits, the membrane and bending stresses calculated by elastic theory have been converted to strain (by dividing stresses by the Modulus of Elasticity) and are plotted in Figure 5, Curve No. 1. Since these strains are mostly membrane strain, they are conservatively compared in the figure to the lower code allowable for membrane strain of 5×10^{-3} in/in. (The code allowable for membrane plus bending is 14×10^{-3} in/in.)

The above approach was checked by consideration of displacement compatibility between the liner and the reinforced concrete wall using the resulting displacements from the analysis of the reinforced concrete structure. This results in lower liner strains as indicated by Curve No. 2 in Figure 5.

In this case, the seismic shear was assumed to be totally reacted by the reinforced concrete, since it was a design requirement to take no strength credit for the liner. A comparison of liner stiffness to reinforced concrete stiffness used for Seismic Analysis indicates that 90 percent of the shear will be carried by the reinforced concrete, which shows that this assumption is reasonable. Strain in the mat liner is also less than the allowables since the mat liner strain peaks at 1.15×10^{-3} in/in at the corner knuckle region and then diminishes to less than 0.11×10^{-3} in/in on the mat floor.

Test channels (TC's) were welded to the liner in order to leak test liner welds during construction. They are not safety-related since the liner itself is conservatively designed to provide the pressure boundary function, and the reinforced concrete containment structure is designed to withstand all applied forces, neglecting any strength contribution of the liner or of the TC's. The TC's, however, do inherently provide additional containment leak protection since they cover all liner seam welds and were fabricated with material and weld quality comparable to that of the liner.

The TC's, similar to the liner itself, are deformation limited by the structural response of the containment structure, and will continue to provide added leak protection for all design loads. This is particularly true for the design loads where the liner is in a general state of compression due to the DBA containment temperature effects. (Buckling or bulging for this condition is precluded by providing sufficient anchorage to the reinforced concrete.) Any undetected flaws in the welds or elsewhere would not propagate in a state of compression. In this regard, the pressure testing of the containment provides a much more severe environment for the liner than the DBE plus DBA design loads because the test pressure produces a general state of tension in the liner and TC's. We know of no failure of liner seam welds due to pressure testing a containment.

In order to evaluate the adequacy of the TC's, a conservative estimate of their overall ability to withstand the unlikely event of a DBA concurrent with a DBE can be made by assuming that the strain in the TC is the same as that of the liner to which it is attached. (This is conservative since the liner strains are very conservatively calculated.) As indicated in Figure No. 5, liner strains (and, therefore, TC strains) are well below the ASME allowable membrane strain of 5×10^{-3} in/in. Calculations indicate that the liner has a factor of safety of 1.8 against buckling based on the very conservative liner stress calculation. The local presence of test channels tends to stiffen the liner, thereby further reducing any potential for buckling. Since bending stresses are small, the TC attachment welds are subjected primarily to the same membrane strains as the liner and would have the same margin against the 5×10^{-3} in./in. code strain allowable.

To further quantify the adequacy of the dome test channel welds to the containment dome liner (Figure 6) for shear forces which may exist between the liner and reinforced concrete structure, a horizontal ring of dome liner was isolated and the forces acting on this ring identified as indicated in Figure 8.3. The limits of the ring were chosen to be midway between adjacent horizontal dome test channels. Forces identified as acting on this ring segment are:

T_1, the membrane force acting on the bottom of the ring

T_2, the membrane force acting on the top of the ring

q, the net radial pressure acting on the ring

V, the shear force acting on the test channel

Several other load paths which share the shear force with the test channel were neglected in order to simplify the analysis. This provides a very conservative upper bound for the shear force on the test channel since this approach analytically requires the test channel to withstand all the shear force between the liner and reinforced concrete. These other shear force load paths include:

a) The 5/8 in dia welded anchor studs on nominal 1 ft by 1 ft centers, which alone can withstand the total shear force.

b) The liner to concrete bond stress.

c) The friction between the liner and concrete surfaces which are pressed together by containment pressure and temperature.

d) Additional shear anchors provided at the dome to cylinder bend line and at the dome apex.

Proceeding with this upper bound approach, vertical equilibrium was satisfied by setting the sum of the vertical components of the four forces equal to zero and solving for the shear force, V, acting on the test channel as indicated in Figure 8.4.

Although the current ASME III, Div. 2 code for containment liners permits liner anchors to be designed to 50 percent of their ultimate displacement capacity (Table CC-3730-1), a more conservative approach was chosen to evaluate the shear stress in the dome test channel welds. Test channel weld shear stresses were compared to the current code allowable for liner brackets and attachments (CC-3750) which provides design allowables as given in AISC Manual for Steel Construction, Part 5, Specification for Design, Fabrication and Erection of Structural Steel for Buildings for the Test Condition. For earthquake or accident loads, CC-3750 permits the AISC allowable to be increased by a factor of 1.5. For the materials and electrodes used for test channel fabrication, this results in weld shear stress allowables of 21 ksi for the Test Condition and 31.5 ksi for the Design Condition.

The results of the analysis of the dome test channel welds is presented in Figure 8.5. For the Test Condition, the upper bound shear force is shown to be 2,518 lb/in which produces a weld shear stress of 9.50 ksi and a factor of safety of 2.21 when compared to current code limits. Similarly for the Design Condition (DBA + DBE), the upper bound shear force is 5,367 lb/in which produces a weld shear stress of 20.25 ksi and a factor of safety of 1.56.

The TC's are attached to the liner with full (3/16 in) fillet welds. Channel-to-channel welds are full penetration groove welds. The pressure testing of the TC's provides assurance that the liner seam welds and the TC welds are leaktight. This meets the minimum examination requirements of the ASME III, Division 2, code for TC welds (CC-5525). TC welds are also 100 percent dye penetrant and visually examined to ensure weld integrity. These welds preclude any concern for the TC's becoming detached from the liner for any design or test loadings.

We have seen other containment designs which use external structural angles instead of weld studs to anchor the dome liner to the concrete. These angles are welded to the liner using 3/16 in fillet welds skip welded 4 in out of 12 in on both sides. The full length 3/16" fillet welds on the BV-1 dome test channels provide added assurance of their ability to withstand all test and design loads.

The TC material, ASTM A-131 Gr C, is a high quality structural steel used for ship construction, and is very similar to the liner materials, SA-A516 Gr 60 and SA-537 Gr B, which are used for pressure vessels for moderate and lower temperature service. All three steels are made to fine grain practice. The specifications for the three steels require that the material be capable of being bent cold through 180 deg without cracking on the outside of the bent portion. Although impact tests were not required for the A-131 Gr C material (nor are they required by the current ASME III, Division 2, code), the bend test requirements, fine grain practice, and similarity to SA-516 Gr 60 and SA-537 Gr B, provide confidence that the TC material is sufficiently ductile to withstand the combined effects of a DBA and DBE.

Refer to Figure 1(b) for a comparison of the mechanical and chemical properties of the liner plate and test channel materials.

Question

A.4 Surface Treatment

Describe the surface treatment to the inside walls of the containment on the wall channels, plugs, and liner. Provide details of application, inspection, periodic maintenance and surveillance. Describe any treatment to the liner, welds, and interior of the channel boxes.

Response

A.4 All exposed interior surfaces of the Beaver Valley Unit No. 1 reactor containment liner were coated in accordance with Stone & Webster Specification BVS-493, "Protective Coatings Within the Reactor Containment Structure." This specification incorporates the requirements of ANSI N101.2, "Protective Coatings for Light Water Reactor Containment Facilities and the draft ANSI

N101.5.7" Quality Assurance for Protective Coatings applied to Nuclear Facilities (later published as ANSI N101.4)."

The surface preparation of the exposed carbon steel prior to coating was performed in accordance with The Steel Structures Painting Council, SSPC-SP10, "Near White Blast Cleaning." A prime coat, 3 mils thick, of Carboline Carbo Zinc 11 inorganic zinc primer was then applied to the properly prepared substrate. The finish coat consisted of 2 mils of Du Pont Corlar Epoxy Cnemical Resistant Enamel.

When the liner plates were shop painted, the field weld preps were masked of paint within 2 in. of these edges. A temporary rust preventative coating was then applied to the unpainted areas. On site, during liner erection, the rust preventative coating, as well as all oil, grease and other contaminants were removed prior to welding in accordance with the approved welding procedures.

After welding, each reactor containment liner weld seam was dye penetrant inspected in accordance with approved procedures. The approved procedures required that the weld seam and adjacent base metal be solvent cleaned, utilizing Spotcheck SKC-NF low halogen cleaner after completion of weld inspection. This cleaning would also remove any residual mill contamination from those portions of the liner surface which would be later covered by test channels.

The test channel interior surfaces were cleaned during the installation process. Cleanliness of the test channel material was checked visually during erection in accordance with a specific step on the fabricator's "Erection Control Sheets" entitled, "Clean Test Channel." Contaminants such as road dirt, construction debris, etc. were removed by appropriate methods at this time.

After the test channels were installed and used for testing the liner seam welds, as previously described, the channel plugs were installed and the channels were sealed from contamination. The exterior surface of the test channels and associated fillet welds, as well as the adjacent uncoated liner plate, were cleaned of slag, weld spatter, etc. and prepared and painted with the Carbo Zinc 11/ Corlar Epoxy System detailed above.

The coating system described above should require little or no maintenance during plant life. However, a visual examination is performed inside the containment prior to each Type A Integrated Leak Rate Test, at which time any significant coating failures would be noted and appropriate remedial action taken. At this time, no specific inservice inspection requirements exist for inspection of reactor containment coatings. It should be noted that the coating system applied to the interior exposed carbon steel and concrete surfaces of the Beaver Valley I containment liner aids in decontamination only and is not required by any existing code or standard.

Question

A.5 Condensation and Corrosion Inside Boxes

For plugged boxes with an undetected failed box weld or loose plug, provide analysis of condensation inside the box, chemical analysis of any condensed liquid, and corrosion rates of the liner, welds and channel boxes inside the boxes.

Response

A.5 During the testing of the liner seam welds, each test channel was pressurized with air. If an in-line air dryer were not used, or if the air dryer malfunctioned, moisture carry-over into the test channel could have occurred, resulting in condensation forming within the channel.

After erection of the reactor containment, and postulating an undetected failed test channel fillet weld or removed plug, condensation within the test channel could result from containment pressure/temperature transients or from moisture produced by primary or secondary system leakage inside the reactor containment.

The fluid which could condense within the test channels as a result of condensation from either of the above sources would be similar in nature to normal power plant condensate, which has a low ionic content and which is normally contained in carbon steel systems. As such, corrosion data relating to condensate in carbon steel piping was used in the evaluation of the potential corrosion within the test channels.

The effect of pH upon corrosion rate in the range of <u>all</u> fluids present within the reactor containment was examined. Fluids ranging in pH from 10.5 (reactor coolant high end and sodium hydroxide caustic spray) to 4.2 (boric acid in the safety injection accumulators at 2,200 ppm boron concentration) are, or may be present within the reactor containment. Figure 7, extracted from Uhlig's CORROSION HANDBOOK, Fifth Edition, is a plot of corrosion rates at various temperatures versus pH. The zone of interest, with a pH ranging from 4 to 10.5, has been highlighted. The curves demonstrate that, as pH is increased from 4, the corrosion rate will either remain contant or decrease with increasing pH.

The worst cast of potential corrosion inside the test channels would occur where a failed fillet weld or removed plug allowed oxygen supply replenishment to the test channel interior. Since relative humidity in the channel would be less than 100 percent, corrosion would occur only in the portion of the test channel interior which was immersed in condensate. The condensate would be stagnant (less than 2 fps flow rate) and at a temperature of approximately 100 F.

Corrosion allowances published by the General Electric Corporation which are directly applicable to carbon steel condensate systems, with system conditions the same as those present in the worst-case test channel scenario, (that is, stagnant, fully oxygenated condensate at a temperature of 100 F, with full oxygen supply replenishment), specify a corrosion allowance of 88 mils for a forty-year lifetime. There is a sufficient margin in the containment liner thickness to easily accommodate a total, worst case corrosion of 88 mils over the life of the plant.

Any corrosion which would occur within the test channels would be general in nature. Review of technical literature and discussions with Professor Emeritus HHUhlig, of the Massachusetts Institute of Technology has determined that, given the nature of the condensed fluids described above coupled with the material cleaning requirements described in Response A-4, pitting corrosion will not occur within the test channels.

In summary, corrosion within the Beaver Valley Unit 1 reactor containment test channels will not present a problem during the plant lifetime.

<u>Question</u>

A.6 <u>Surveillance and Removal of Failed Boxes</u>

Describe the surveillance for failed channel boxes and loose plugs and provide procedures for removal of damaged boxes, inspection and testing of the uncovered liner seam weld, and preparation of the exposed liner surface.

Response

A.6 As described in previous sections, the test channel materials, welds and workmanship are such that they are not easily damaged. Routine activities inside the containment would not result in failure of test channels and if a channel were damaged during unusual activity, the damage would be reported. There have been no damaged test channels or missing plugs reported at Beaver Valley - Unit No. 1.

Visual surveillance of interior containment liner surfaces is performed prior to periodic Type A leakage testing.

A visual survey of the liner was performed in October 1978 prior to the recent Type A test at Beaver Valley. No damaged test channels were found during this detailed survey.

No procedures for repair of test channels have been developed. If a channel were found damaged, the cause would be evaluated and the extent of the damage determined. The affected test channel could be removed, repaired, replaced, or accepted as is, depending on the nature of the damage.

B. Dome Boxes

In order to determine the acceptability of the dome configuration as a containment leak barrier for the service life of the plant, the following information and analyses are requested.

Question

B.1 Materials Identification and Construction Description

Provide as-built descriptions and drawings of the dome channel details specifically the plug assembly in the liner seam welds. Provide construction assembly procedures and address the immediate surroundings of the channel boxes on the exterior of the liner. Provide the basis for assuring these channel welds will hold against the shear forces if the liner moves against the concrete structure.

Response

B.1 Figures 3c, 4 and 6 illustrate the details of the dome test channels.

The liner was erected in accordance with the Fabricator's approved procedures including approved welding and nondestructive test procedures and work was supervised by Stone & Webster.

As discussed in the response to question A.3, the basis for assuring that dome test channel welds will hold against shear forces is an upper bound analysis which conservatively neglects assistance from welded anchor studs, liner to concrete bond strength, liner to concrete friction, and additional embedded anchors at the dome bend line and apex. This conservative approach results in calculated factors of safety for the weld of 2.21 for test loads and 1.56 for the combined effects of a DBA acting concurrently with a DBE as indicated in Figure 8.5.

Question

B.2 Testing and Inspection

Provide the procedures for tightening the plugs, including any torquing requirements, and subsequent testing for leaks around the plug.

Response

B.2 There were no requirements for torquing or for tightening of channel test plugs or the plugs in the dome liner.

The dome test channel arrangement includes a test plug on the liner seam as well as on the test channel. The procedure for leak testing provides for testing for leaks around the plug in the seam weld.

The dome seam plugs were installed with sufficient torque to prevent leakage as indicated by sensitive halogen leak testing performed by applying 50 psig to the test channel cavity with Freon R-22 from the exterior sockets in the test channels while the seam plugs were in place (see Fig. 6). This test was more severe on the seam plugs than the DBA environments since the test pressure in the channel tended to push the seam plug out of the tapered hole while DBA pressure would act on the containment side tending to retain the plugs in the tapered hole. The seam plugs in the dome liner were covered with the Corlar Epoxy System coating when the liner was coated and they have not been moved since they were leak tested.

The test plugs are pipe plugs with tapered pipe threads which are self-locking.

These are unlike set screws with untapered machine threads which require significant torque to remain in place.

In industrial applications, a release compound is often applied to pipe plugs prior to installation so that they may be subsequently removed. No such release compound was specified for the dome liner plugs. The dome plugs are not subjected to vibratory loadings since the mass of the containment structure is not excited by operating machinery and a DBE would produce only a few cycles of strong motion and these cause negligible stresses (less than 1 ksi) in the dome liner.

Question

B.3 Structural Integrity of Dome Seam With Plug

Provide an analysis of the ability of the seam welds in the dome with plugs to withstand LOCA dynamic pressures and temperature effects and seismic loads. If the analysis does not support welds with plugs in place, provide procedures for weld replacement of plugs, inspection and testing.

Response

B.3 As discussed in the response to question A.3, when the containment is subjected to LOCA pressure and temperature effects and seismic loads, the liner is put into a general state of compression. Any undetected flaws in the dome seam welds, or elsewhere, would not propagate in a state of compression. The presence of plugs in the dome seam welds also has no significant effect on compressive stresses in the weld. The NDTT of -20°F for the dome liner material provides assurance of its ability to withstand the small compressive strains indicated in Figure 5 particularly as the liner temperature approached the 280°F design temperature.

Question

B.4 Dome Surface Preparation and Protective Coating

Provide the details of the coating on the dome, including the surface preparation, construction application, and any testing or qualification of the coating to withstand operational atmospheres and LOCA dynamic pressures and temperatures. Provide information on the coating adhesion to the dome liner, welds, and specifically the plugs. Provide an analysis of the coating's ability to seal leaks and provide anti-rotational fix on the dome plugs. Describe the surveillance requirements on the dome coating to assure its integrity.

Response

B.4 The coating system applied to the reactor containment liner dome at Beaver Valley Unit No. 1 is the same as that applied to the walls, as described in the response to Question A-4 above.

The coating system was qualified by special testing to resist damage caused by design basis loss of coolant accidents. Coating sample panels were prepared in accordance with a Stone & Webster Specification entitled "Test Panels for Design Basis Accident Environment Test," and tested in accordance with a Stone & Webster Specification entitled "Testing of Protective Coating for Design Basis Accident Environment." Testing was performed by the Franklin Institute Research Laboratories.

The test samples were placed in a special environment chamber and exposed to heat, caustic spray, and radiation simulating the exposure it would receive during a loss of coolant accident. During the first hour, the samples were exposed to 280°F, caustic spray of a pH of 10.5 and about 1×10^6 roentgens of gamma radiation. After the first hour and continuing through 7 days, the samples were exposed to 150°F caustic spray of a pH of 8.0 and about 9.9×10^7 roentgens of gamma radiation.

After testing, the samples were evaluated against ASTM criteria for chalking, blistering, flaking, scaling, checking, and cracking, as well as for other detrimental effects such as delamination.

The Franklin Institute Research Laboratories' report and the Stone & Webster test specifications were filed with the NRC previously under Docket 50-338.

Adhesion testing of the Beaver Valley Unit No. 1 containment liner dome coating performed immediately prior to commercial operation indicated adhesion strength in excess of 500 psi.

No quantitative data are available, to our knowledge, concerning the antivibrational or leak sealing properties of the Beaver Valley I containment liner coating system.

Although we are all familiar with the sealing ability of epoxy paint and the difficulty in moving fasteners which have been painted, were have no quantative basis for claiming credit for the sealing and retention of plugs by the 5 mils of prime and finish painting applied after the dome plugs were installed and leak tested.

C. Floor Mat Boxes

Assuming nothing further is done to the boxes beneath the floor and on top of the mat liner, the following information is requested.

Question

C.1 Describe the provisions to prevent water seepage through the plugs or plug extensions into the channel boxes. Describe the surveillance procedures in effect or contemplated to assure the plugs or extensions remain intact.

NOTE: In all of the above where procedures are requested but may not exist, describe the information or process in sufficient detail to permit NRC evaluation.

Response

C.1 Plugs are installed in test channel test port panels to prevent seepage into the channels. These clusters of test connections are located in regions of the mat away from low spots inside containment and consequently would not trap water. Figure 2a locates the various test panels in the floor.

The floor of the containment is sloped to one corner where a sump provides entrapment of any moisture or condensation. Pumps are provided to remove any accumulation.

Approximately 80 percent of the test channel test connections are terminated in test port panels on vertical concrete surfaces 2-3 ft above the concrete floor.

The test channel extensions are under no load and because of their location are protected from damage. As previously discussed, even if water were introduced, corrosion would not pose a problem.

CONTAINMENT STRUCTURE
BEAVER VALLEY POWER STATION-UNIT NO. 1
DUQUESNE LIGHT COMPANY

	LINER PLATE	TEST CHANNEL
1. MATERIAL SPECIFICATION		
(a) EL 690'-11" TO 720'-11" (SHELL)	ASTM-A537, GR. B QUENCHED & TEMPERED	ASTM-A131, GR. C
IMPACT TEST ON THE ABOVE -	MIN NDTT-50°F	N/A
CHEMICALS AND PHYSICALS	YES	YES
(b) EL 720'-11" TO 813' (SHELL DOME AND BOTTOM PLATE)	ASTM-A516, GR. 60, FINE GRAINED AND NORMALIZED	ASTM-A131, GR. C -
IMPACT TESTS	MIN NDTT-20°F	N/A
CHEMICALS AND PHYSICALS	YES	YES
2. WELDING		
(a) METHOD	FULL PENETRATION BUTT	FILLET
(b) CODE (WELDING QUALIFICATIONS)	BOILER & PRESSURE VESSEL CODE, SECT. IX, SEC. III	BOILER & PRESSURE VESSEL CODE, SECT. IX, SEC. III
(c) PROCEDURE NO. (SHELL RING 4)		
1 - VERTICAL	205	205
2 - HORIZONTAL	137	205
3. TESTING AND INSPECTIONS		
(a) VISUAL - 100%	YES	YES
(b) MAG. PARTICLE	NO	NO
(c) DYE PENETRANT - 100%	YES	YES
(d) RADIOGRAPH - 2% (PLUS FIRST 10 FT EACH WELDER FOR EACH POSITION - 100%)	PARA. UW52, SECT. VIII PRESSURE VESSEL CODE	N/A
(e) AIR PRESSURE TEST - 50 PSI	YES	YES
(f) HALOGEN LEAK TEST - 50 PSI	YES (ABOVE EL 720'-11")	YES

FIG. 1 SHEET 1 OF 2
DETAILS OF MATERIALS
LINER AND TEST CHANNELS

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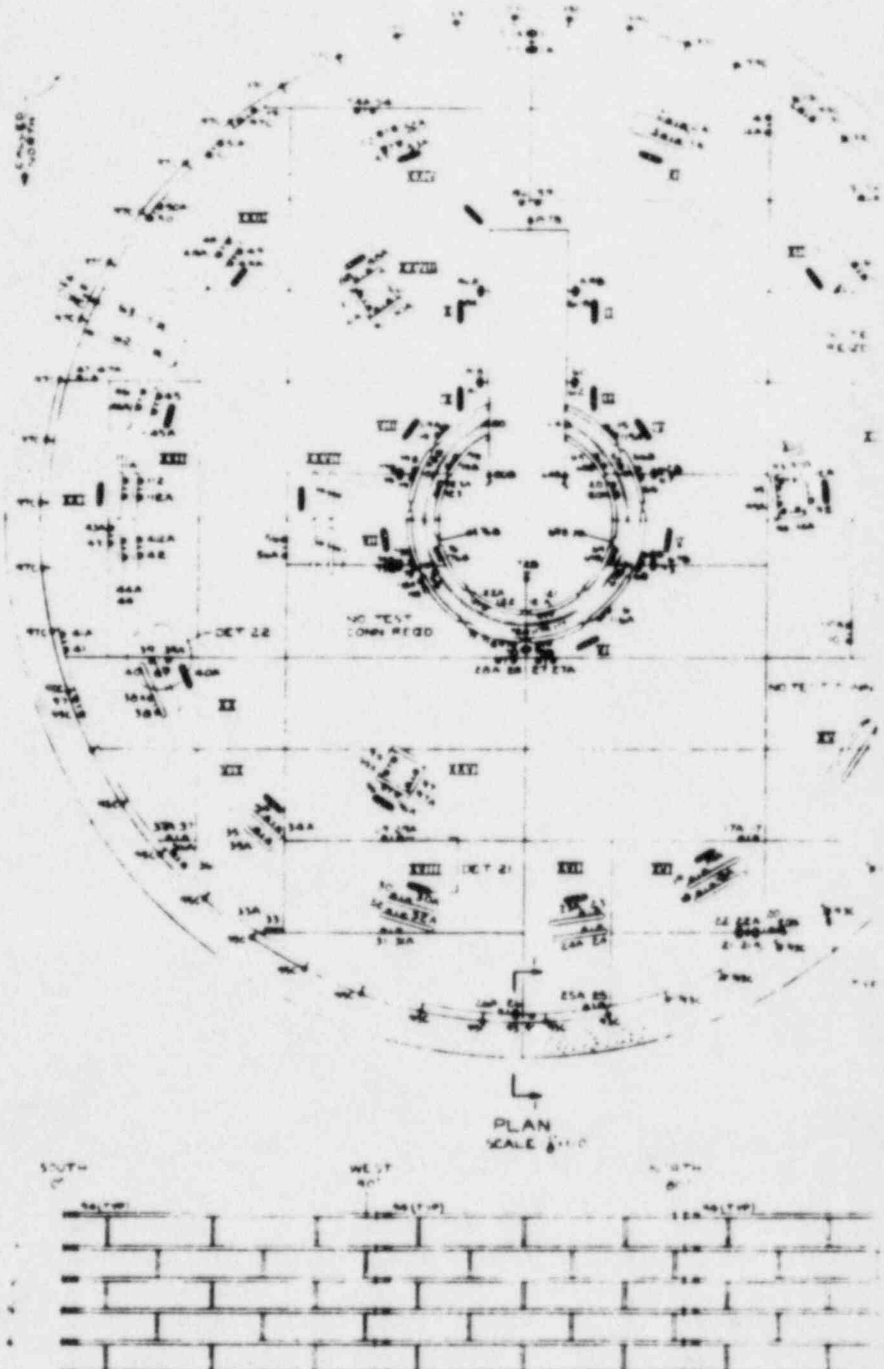
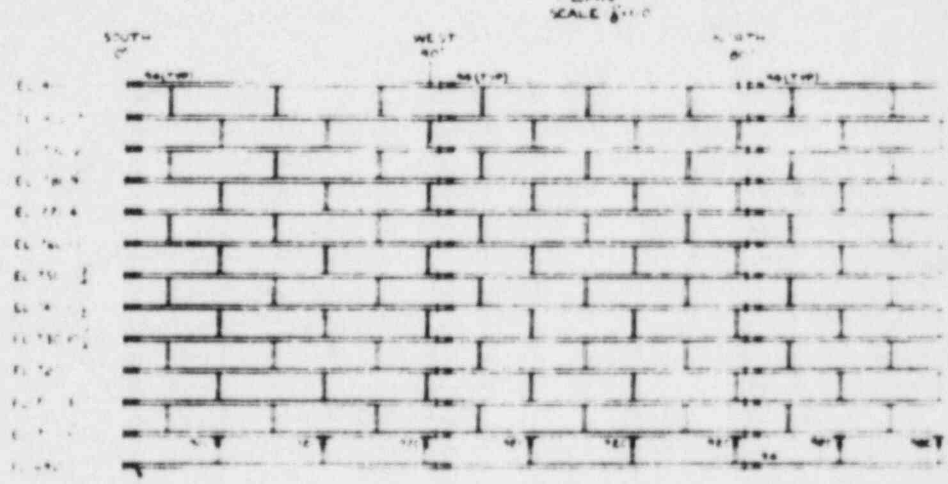
LINER AND TEST CHANNEL
MATERIAL PROPERTIES
BEAVER VALLEY POWER STATION-UNIT NO. 1

CHEMISTRY/PROPERTY	ASTM A-131-GRC	ASTM (SA) A-537-GRB	ASTM (SA) A-516 GR 60
CARBON, MAX, %	0.23	0.24	0.21
MANGANESE, %	0.60-0.90	0.70-1.35	0.60-0.90
PHOSPHORUS, MAX, %	0.04	0.035	0.035
SULFUR, MAX, %	0.05	0.04	0.04
SILICON, %	0.15-0.30	0.15-0.50	0.15-0.30
TENSILE STRENGTH, KSI	58-71	80-100	60-72
YIELD POINT, MIN, KSI	32	60	32
ELONGATION IN 8 IN., MIN, %	21	....	21
ELONGATION IN 2 IN., MIN, %	24	22	25

FIGURE 1-SH 2 OF 2



PLAN



DEVELOPED INSIDE ELEVATION VIEW

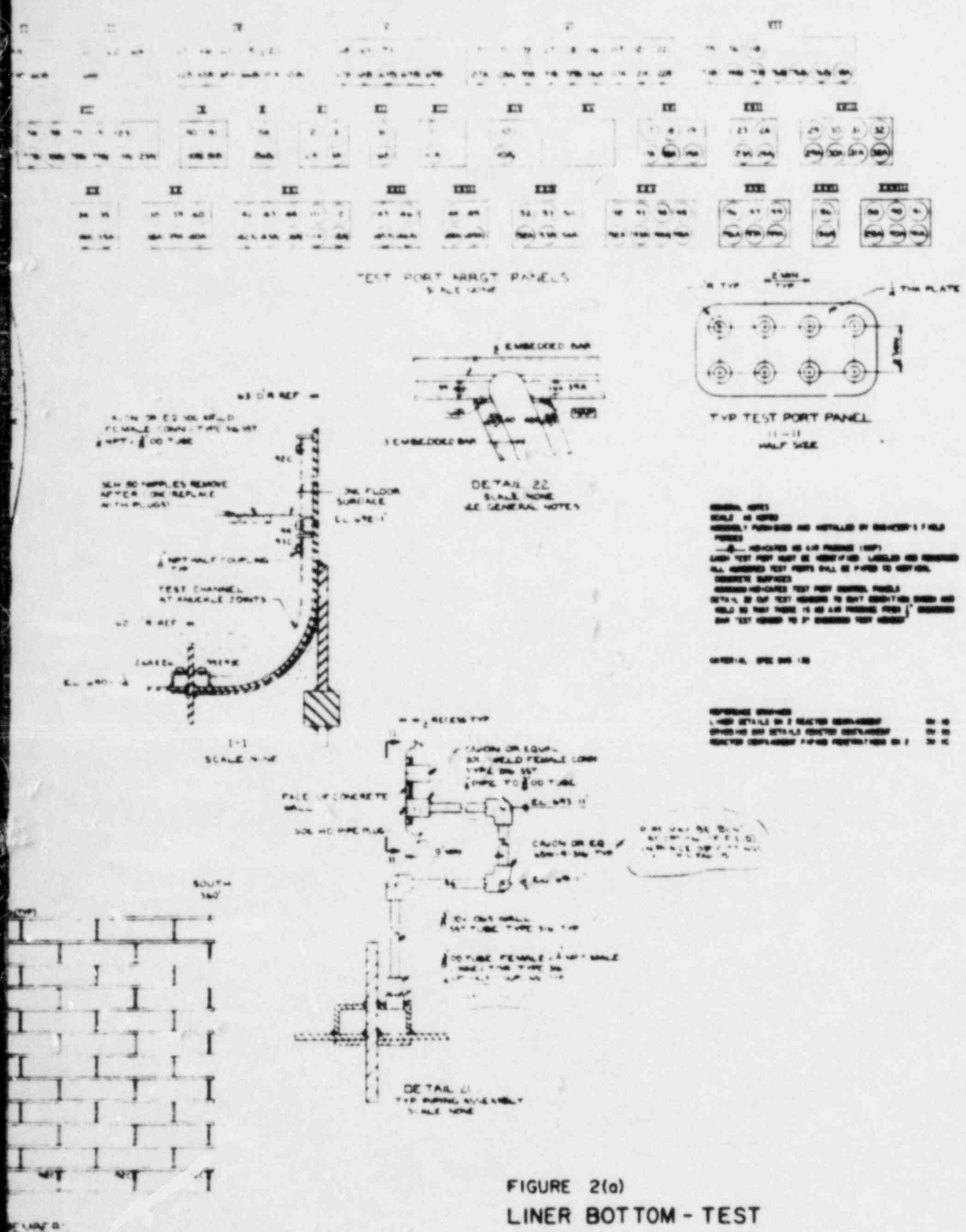


FIGURE 2(a)

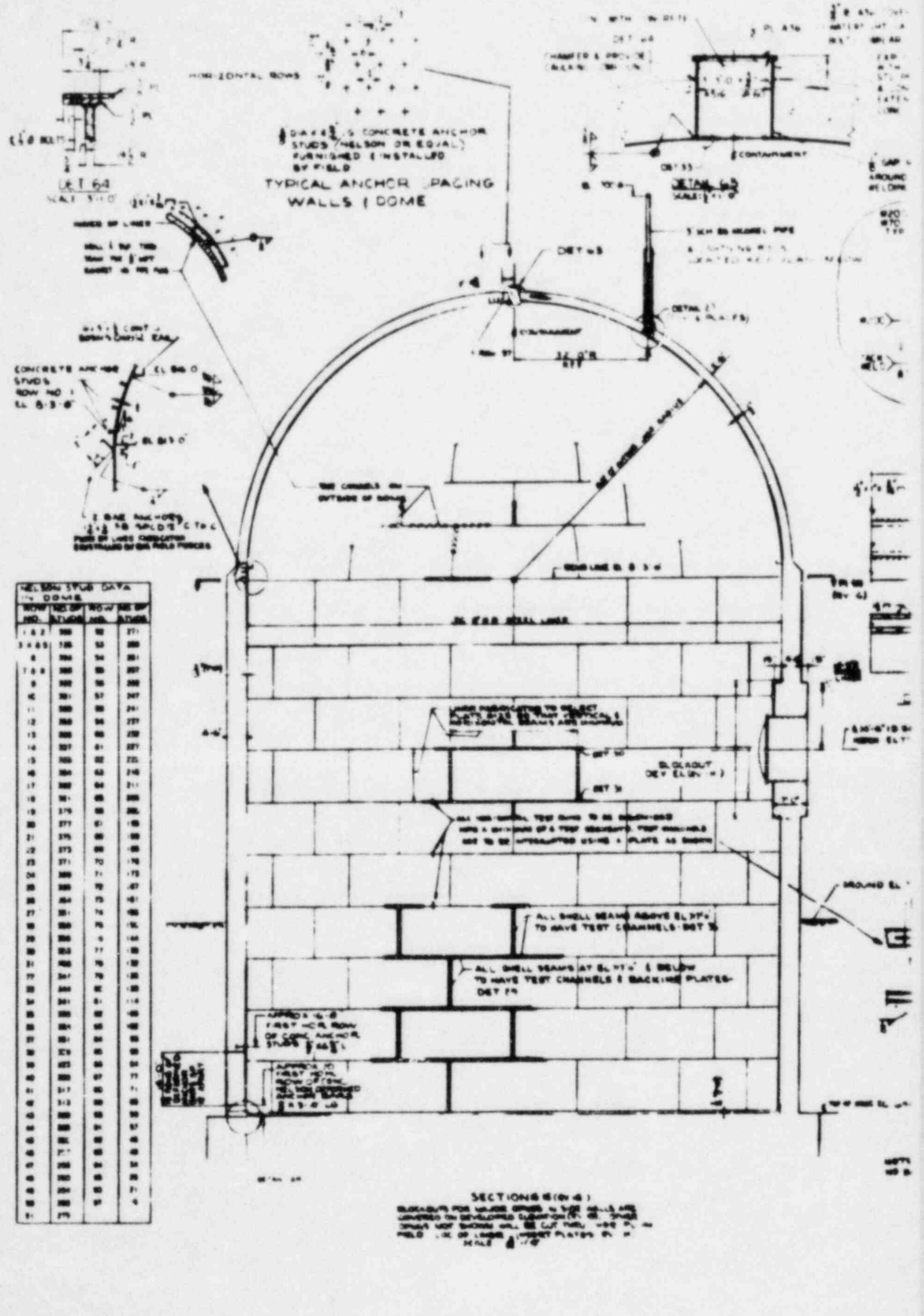
LINER BOTTOM - TEST

CHANNEL ARRANGEMENT

CONTAINMENT

BEAVER VALLEY POWER STATION - UNIT No.1

DUQUESNE LIGHT COMPANY



HORIZONTAL ROWS
CONCRETE ANCHOR STUDS (NELSON OR EQUAL) FURNISHED & INSTALLED BY FIELD
TYPICAL ANCHOR SPACING
WALLS & DOME
DET 64
DETAIL 63
CONTAINMENT
DET 63
CONCRETE ANCHOR STUDS
NELSON STUD DATA IN DOME
ROW NO.
NO. OF STUDS
STEEL LINER
BLOCKOUT DET
ALL SHELL SEAMS ABOVE EL
TO HAVE TEST CHANNELS
ALL SHELL SEAMS AT EL & BELOW
TO HAVE TEST CHANNELS & BACKING PLATES
FIRST HOR. ROW OF CONC. ANCHOR STUDS
SECTION

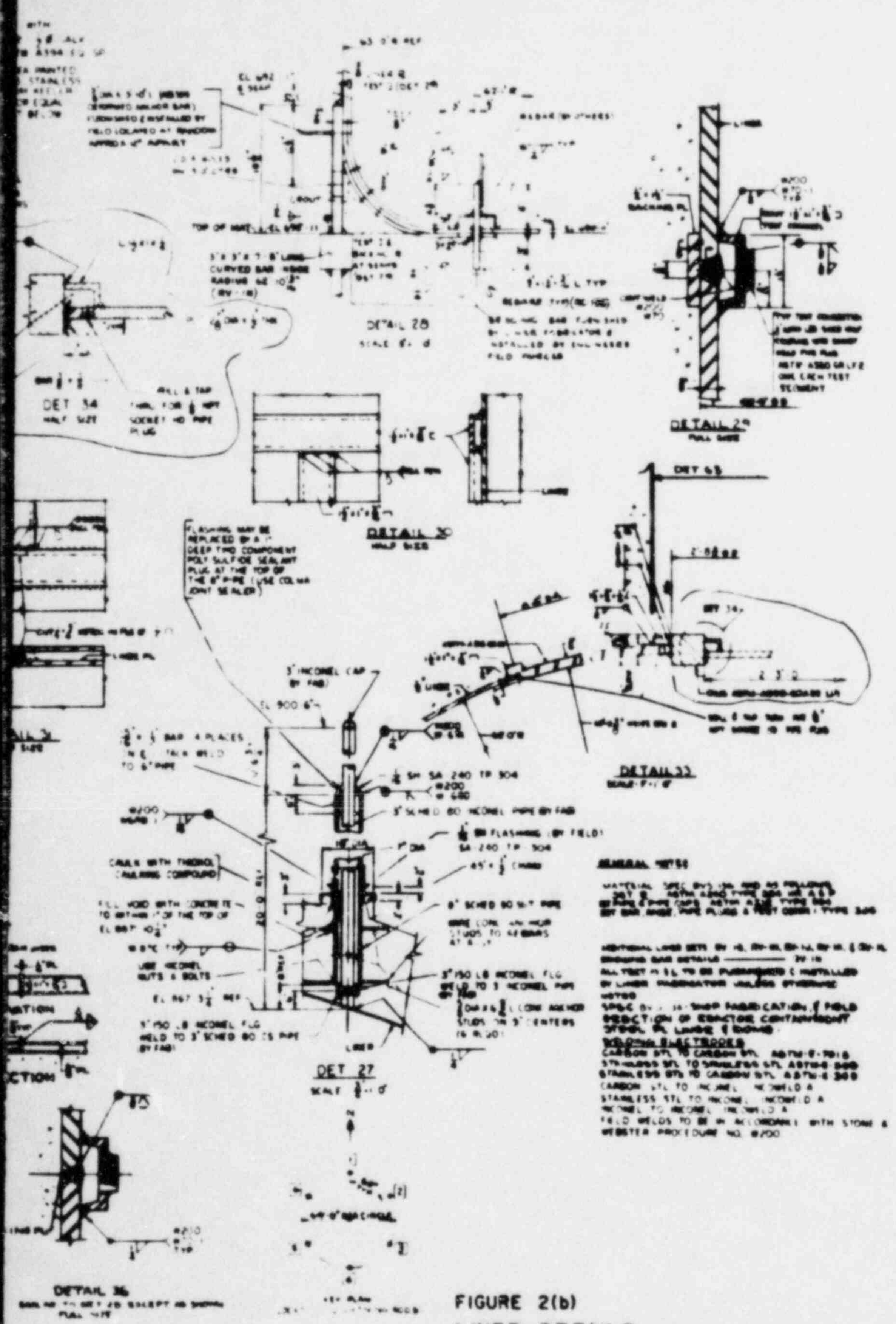


FIGURE 2(b)

LINER DETAILS

CONTAINMENT

BEAVER VALLEY POWER STATION - UNIT No. 1

DUQUESNE LIGHT COMPANY

CONTAINMENT STRUCTURE
BEAVER VALLEY POWER STATION-UNIT NO.1
DUQUESNE LIGHT COMPANY

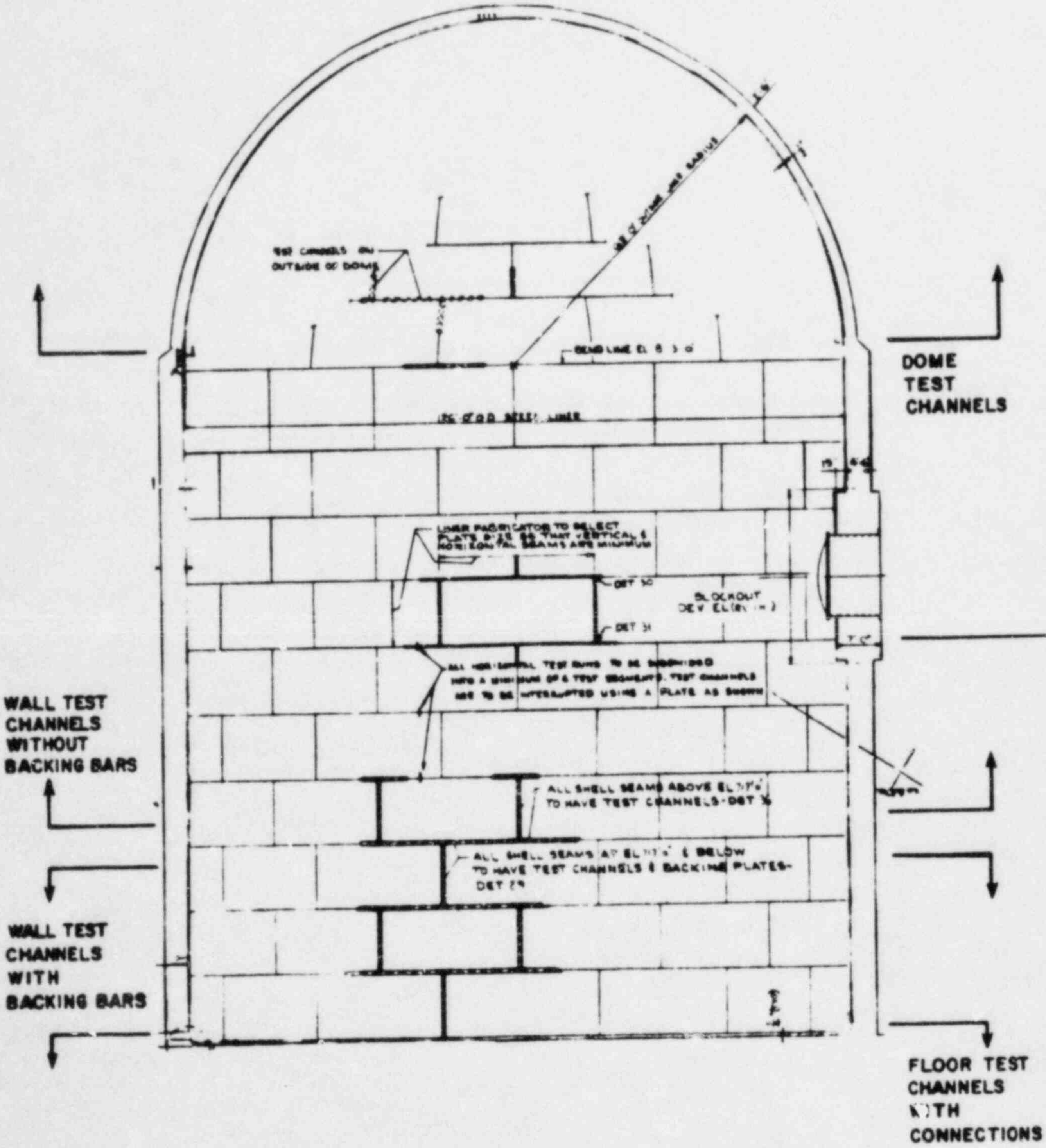
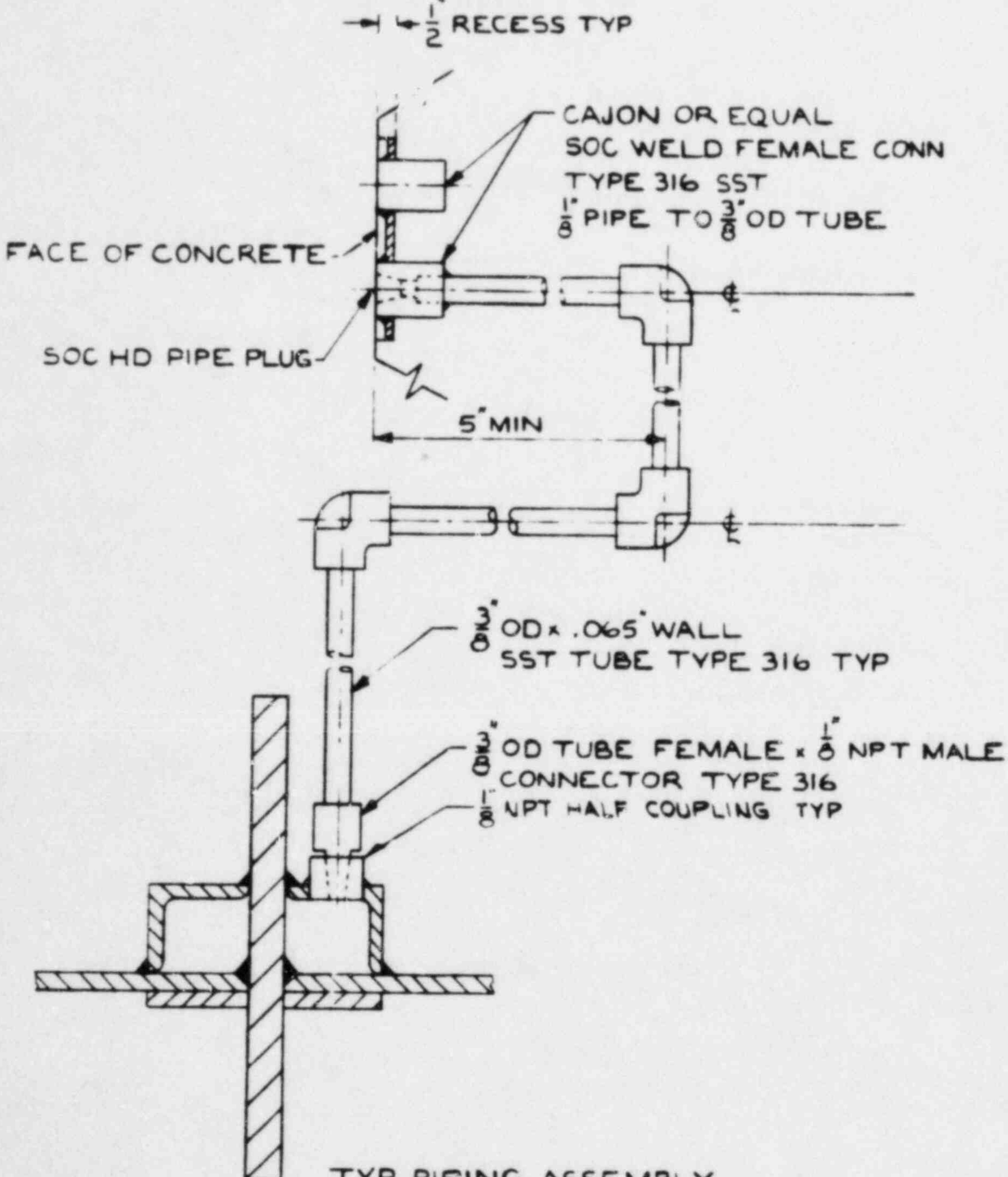


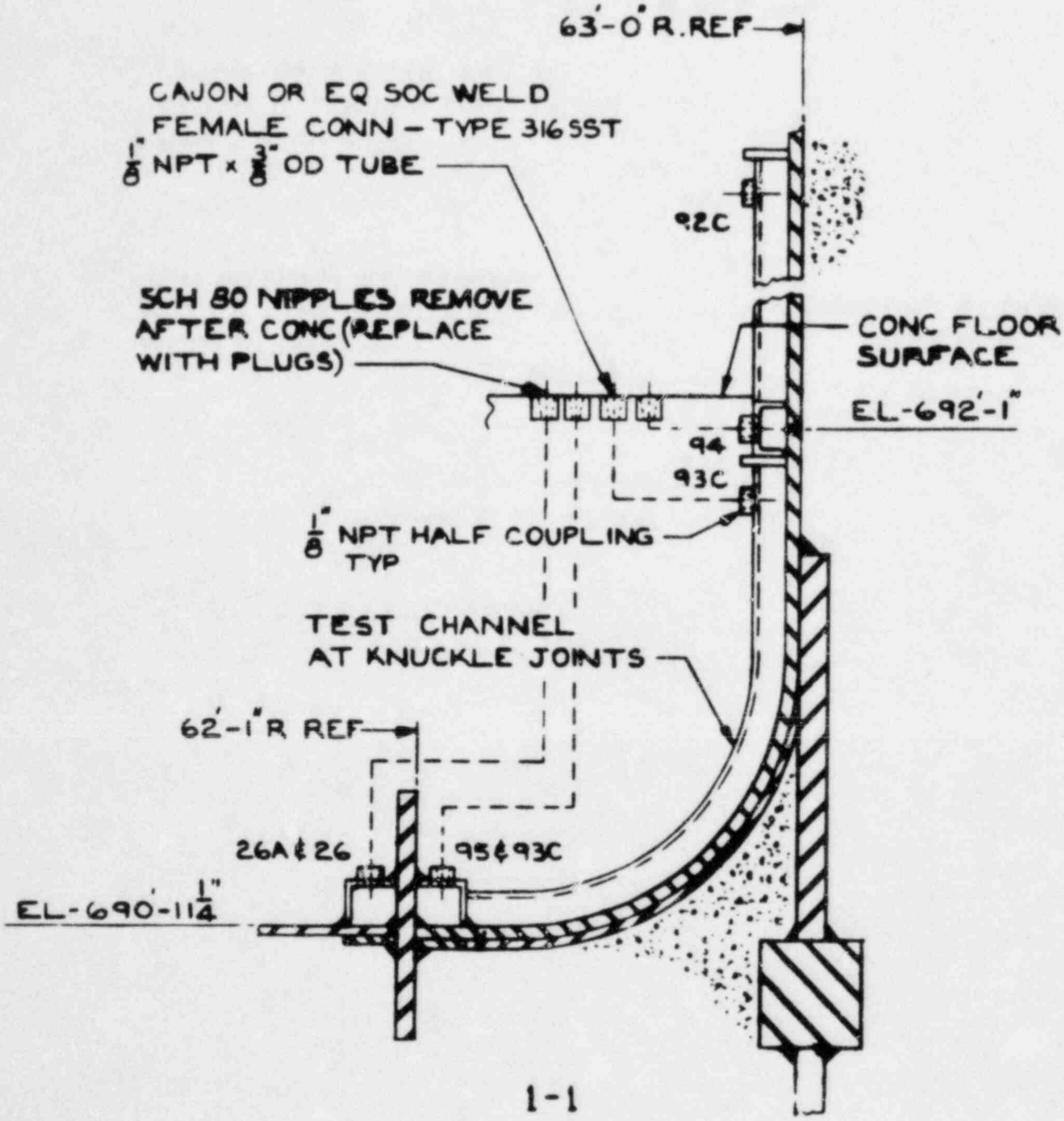
FIGURE 2(c)
LINER ELEVATION DOME



TYP PIPING ASSEMBLY
SCALE: NONE

FIG. 3(a)
SHEET 1 OF 2
TEST CHANNELS-FLOOR DETAILS

CONTAINMENT STRUCTURE
BEAVER VALLEY POWER STATION-UNIT NO. 1
DUQUESNE LIGHT COMPANY

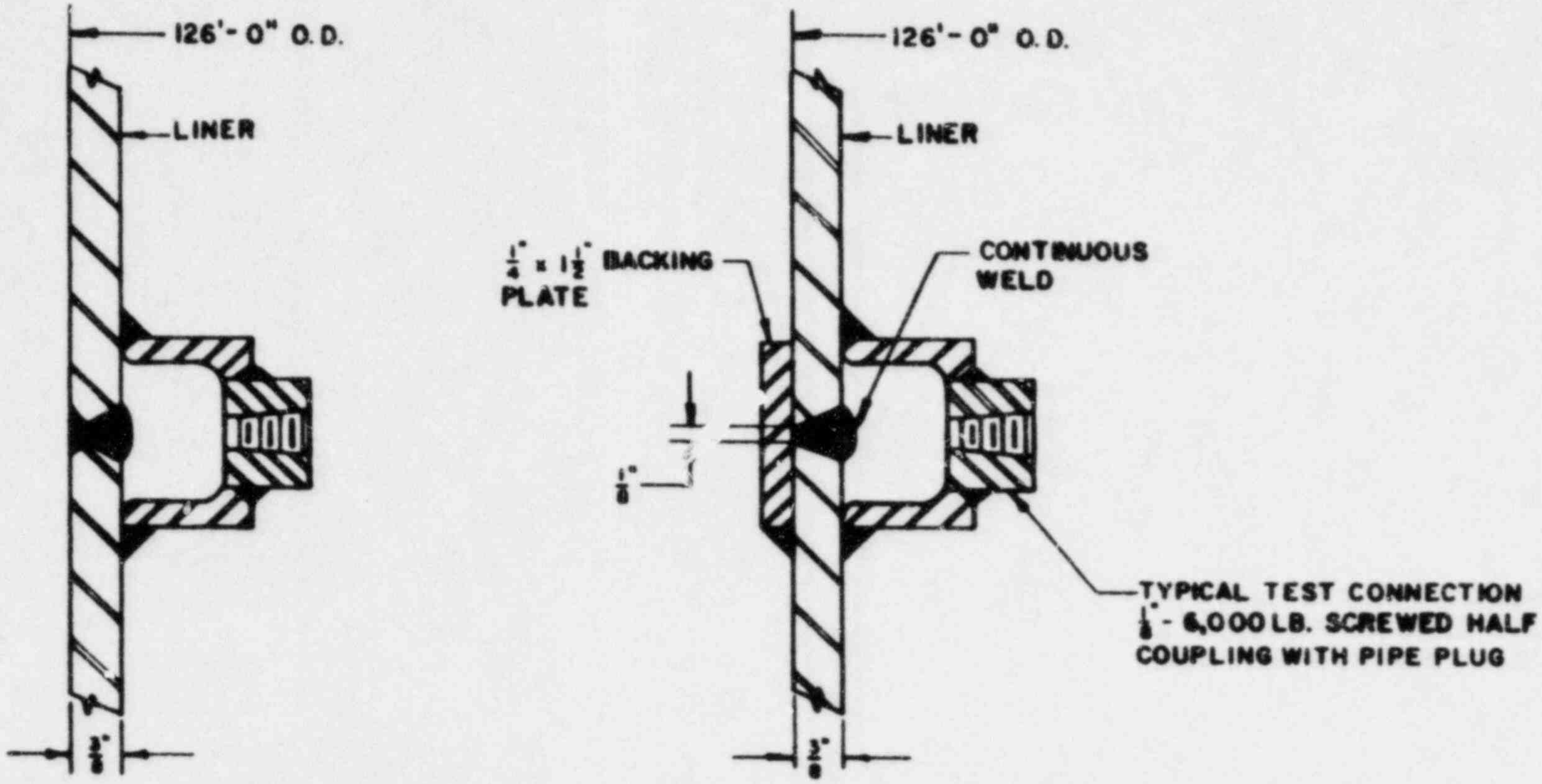


1-1

SCALE: NONE

FIG. 3(a)
SHEET 2 OF 2
TEST CHANNELS-FLOOR DETAILS

CONTAINMENT STRUCTURE
BEAVER VALLEY POWER STATION-UNIT NO. 1
DUQUESNE LIGHT COMPANY

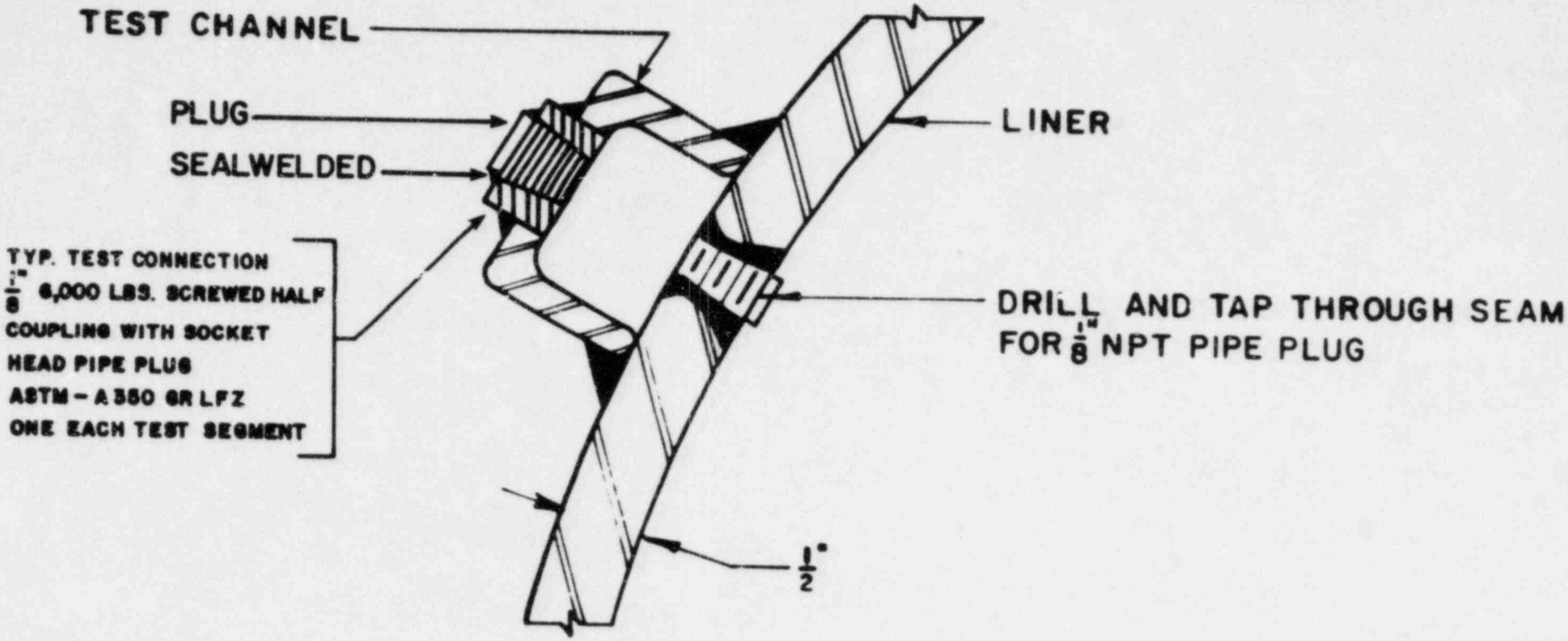


TYPICAL WALL JOINT
WITHOUT BACKING PLATE

TYPICAL WALL JOINT
WITH BACKING PLATE

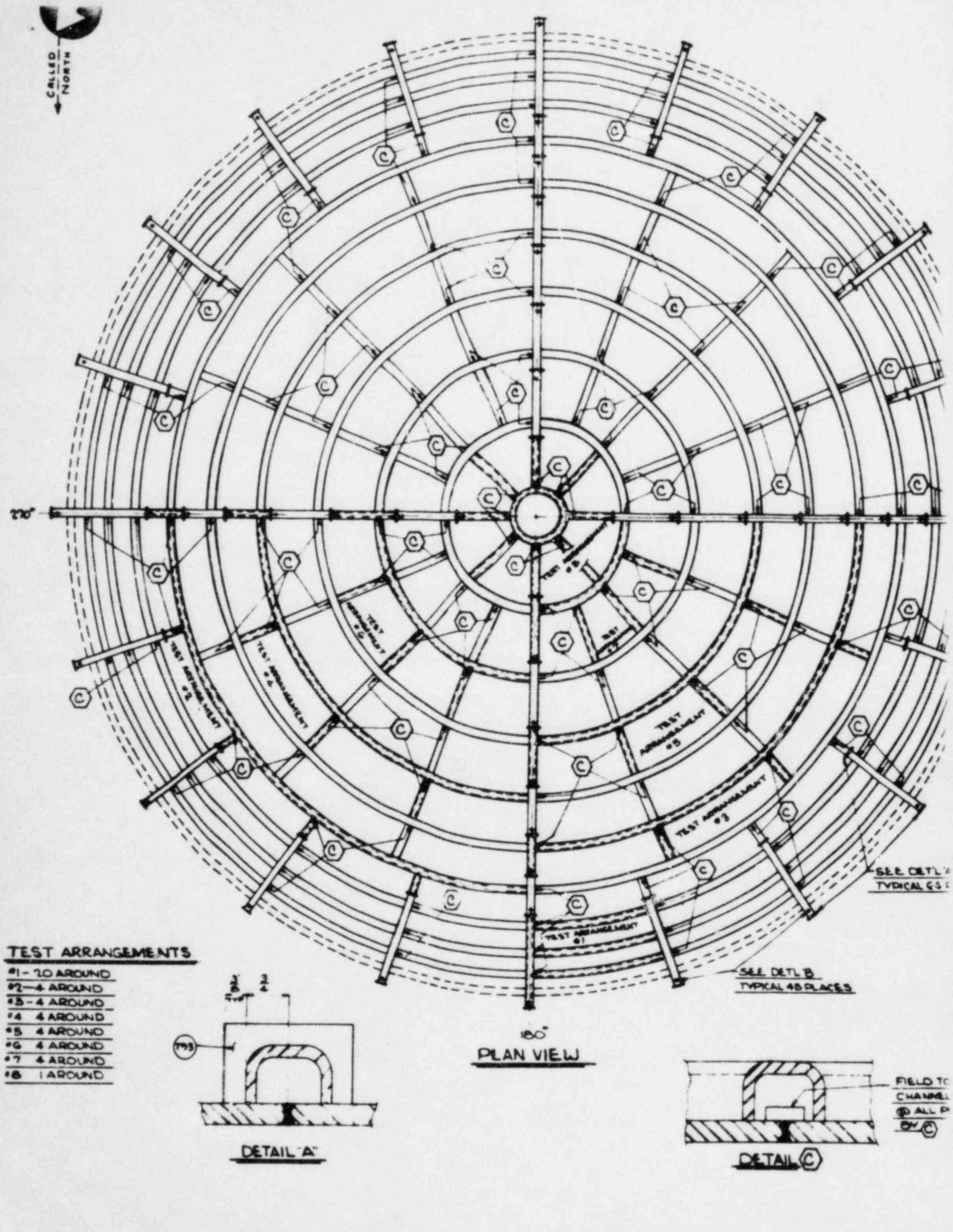
FIG. 3 (b)
TEST CHANNELS-WALL DETAILS

CONTAINMENT STRUCTURE
BEAVER VALLEY POWER STATION-UNIT NO.1
DUQUESNE LIGHT COMPANY



TYPICAL DOME JOINT

FIG. 3(c)
TEST CHANNELS-DOME DETAILS

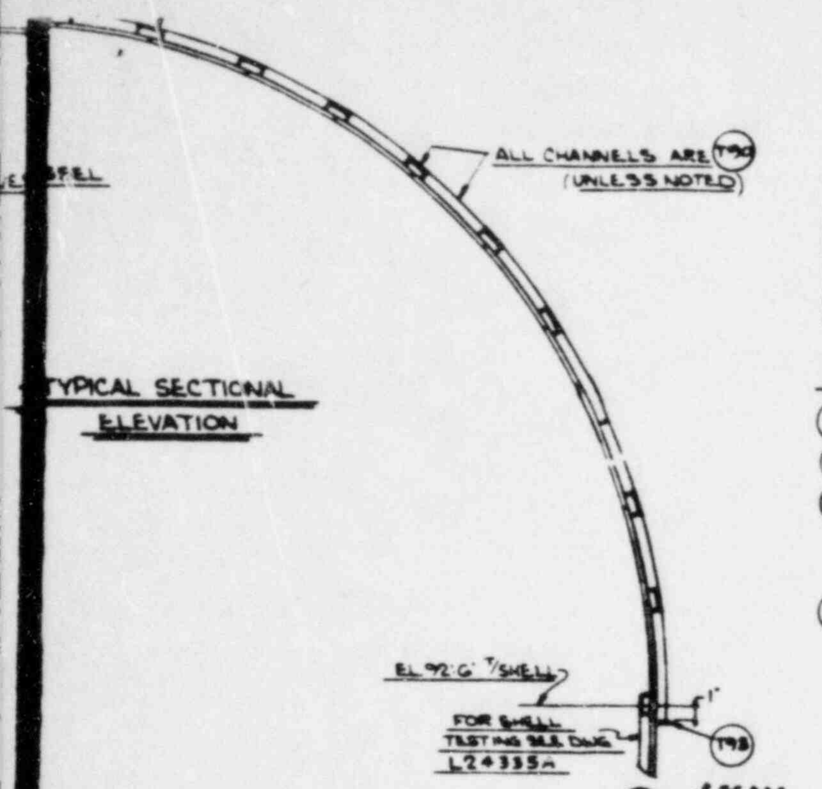


CALLED NORTH
270°
180°
PLAN VIEW
SEE DETL B
TYPICAL 48 PLACES
TEST ARRANGEMENTS
#1 - 20 AROUND
#2 - 4 AROUND
#3 - 4 AROUND
#4 4 AROUND
#5 4 AROUND
#6 4 AROUND
#7 4 AROUND
#8 1 AROUND
DETAIL "A"
DETAIL C

T91	5	CHANNEL (A131GR C) 1½ x 1 x 3/16 x 20-0 LG
		(FORMED TO 12-10½ RAD ON INSIDE TOE THE HARDWAY)
T92	2	CHANNEL A131GR C) 1½ x 1 x 3/16 x 10-6 3/8 LG FIE 2 CHANNEL 20-0 LG AFTER FORMING TO 3-0½ RAD ON INSIDE TOE THE HARDWAY
T93	64	PS 2 x 1 3/16 x 26 (A516 GR 60) + BOTT SCRAP ON DWG L24333A ITEM A43
T94	45	1/8 6000# SCREWED HALF COUPLING (A350 GR LF2)
T95	90	1/8 HOLLOW HEX PLUGS (PARKER PART # 1/8 HHP-S)

GENERAL NOTES:

1. FOR ROOF DETAILS SEE DWGS L24350A L24350A
2. FIELD TEST PER DWGS B30778 TO B30778F INCL.
3. SEC D-D TEST COUPLING IN CHANNEL IS FOR GRAVER'S CONVENIENCE. LEAK TEST SHALL BE PERFORMED ON STRENGTH WELD FROM INSIDE OF CONTAINMENT
4. ALL WELDS CALLED FOR ON THIS DWG ARE TO BE MADE PER PROC #205.



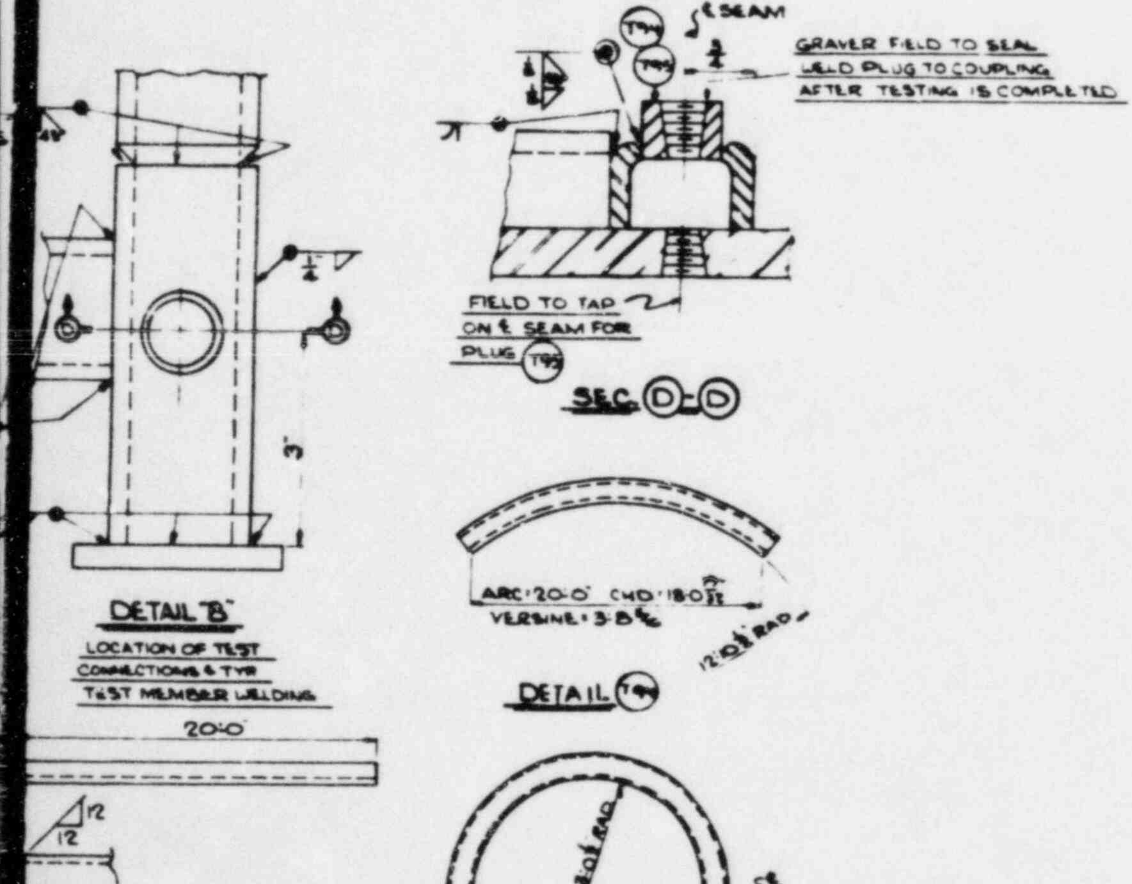


FIGURE 4

ROOF TESTING DETAILS

CONTAINMENT

BEAVER VALLEY POWER STATION-UNIT No.1

DUQUESNE LIGHT COMPANY

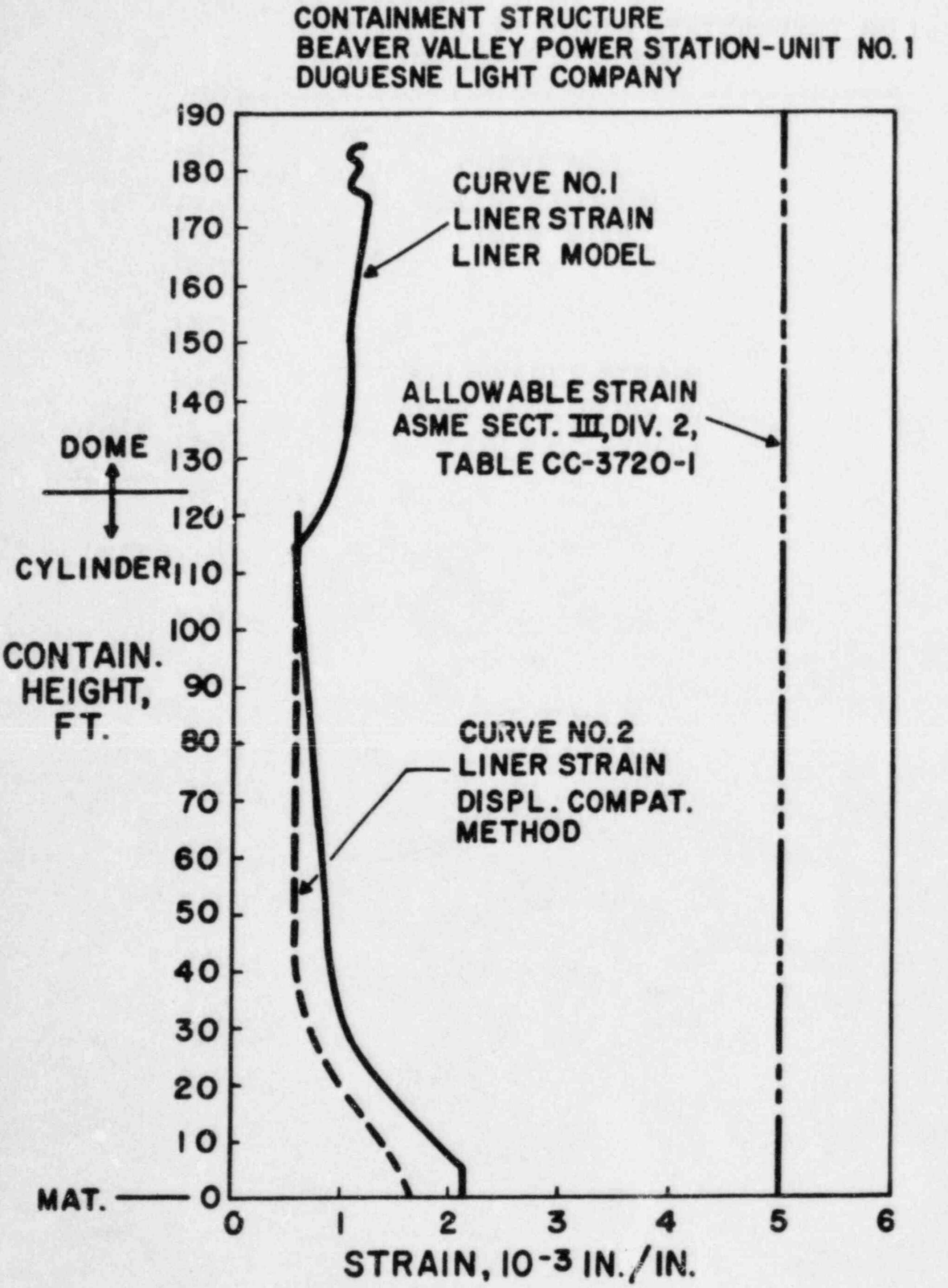


FIGURE 5 CONTAINMENT LINER-STRAIN CURVES

-12,858

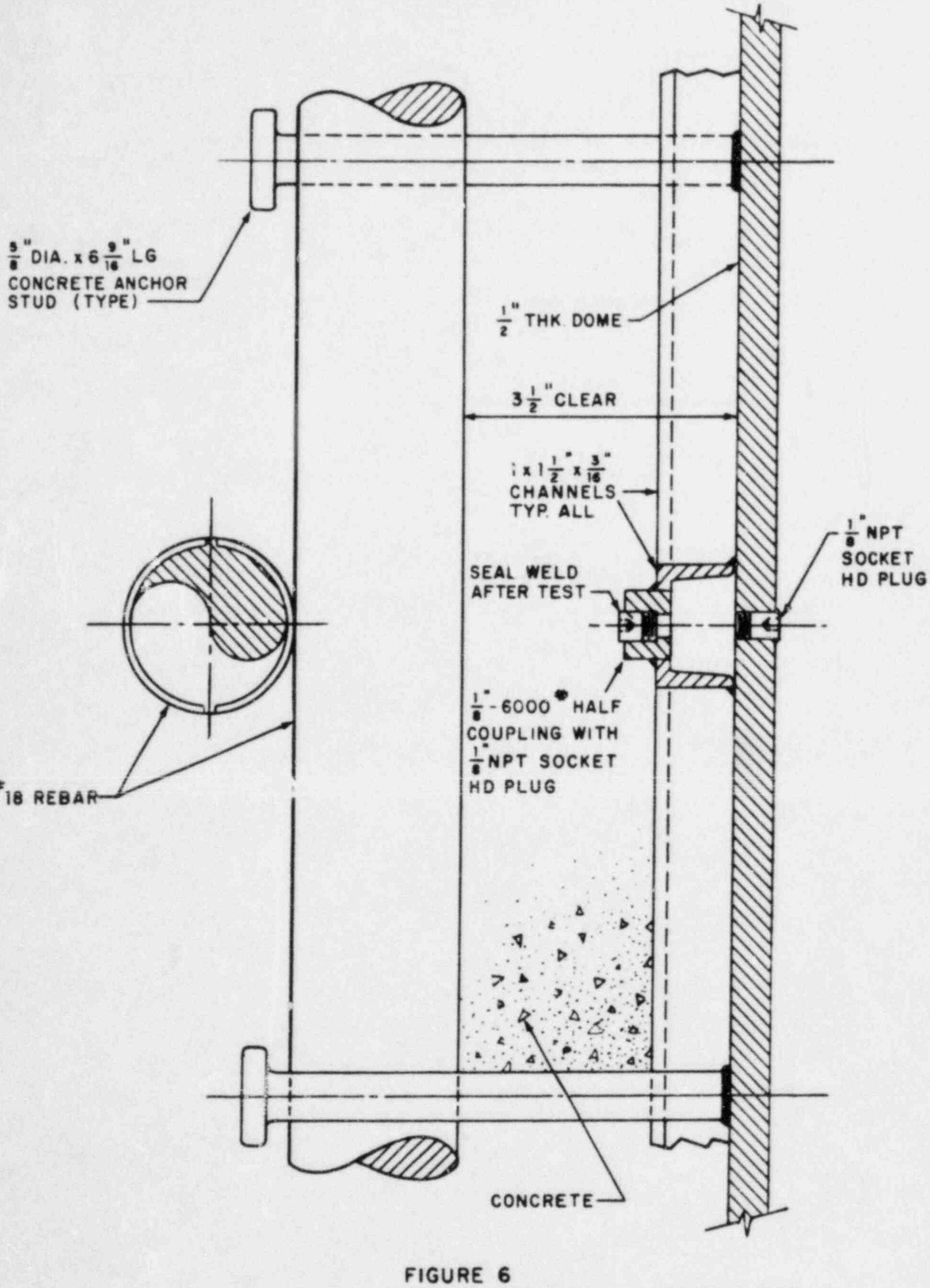


FIGURE 6

DOME - SECTIONAL ELEVATION

CONTAINMENT STRUCTURE
BEAVER VALLEY POWER STATION - UNIT NO. 1
DUQUESNE LIGHT COMPANY

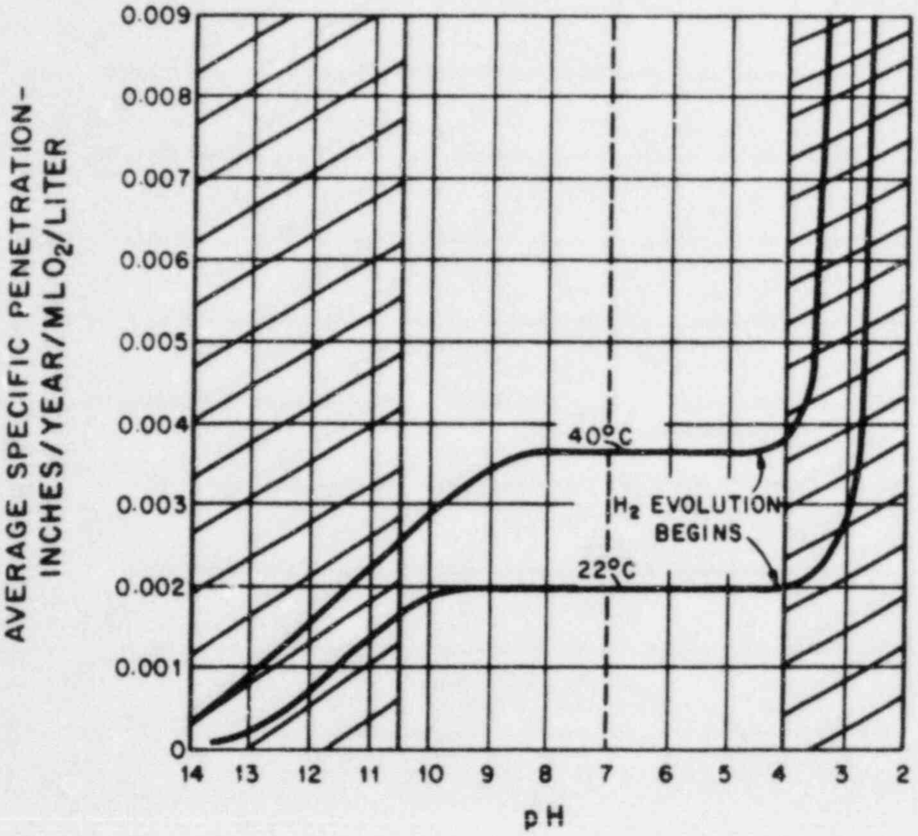


FIGURE 7

EFFECT OF pH ON CORROSION OF MILD STEEL

CONTAINMENT STRUCTURE

BEAVER VALLEY POWER STATION-UNIT NO.1

DUQUESNE LIGHT COMPANY

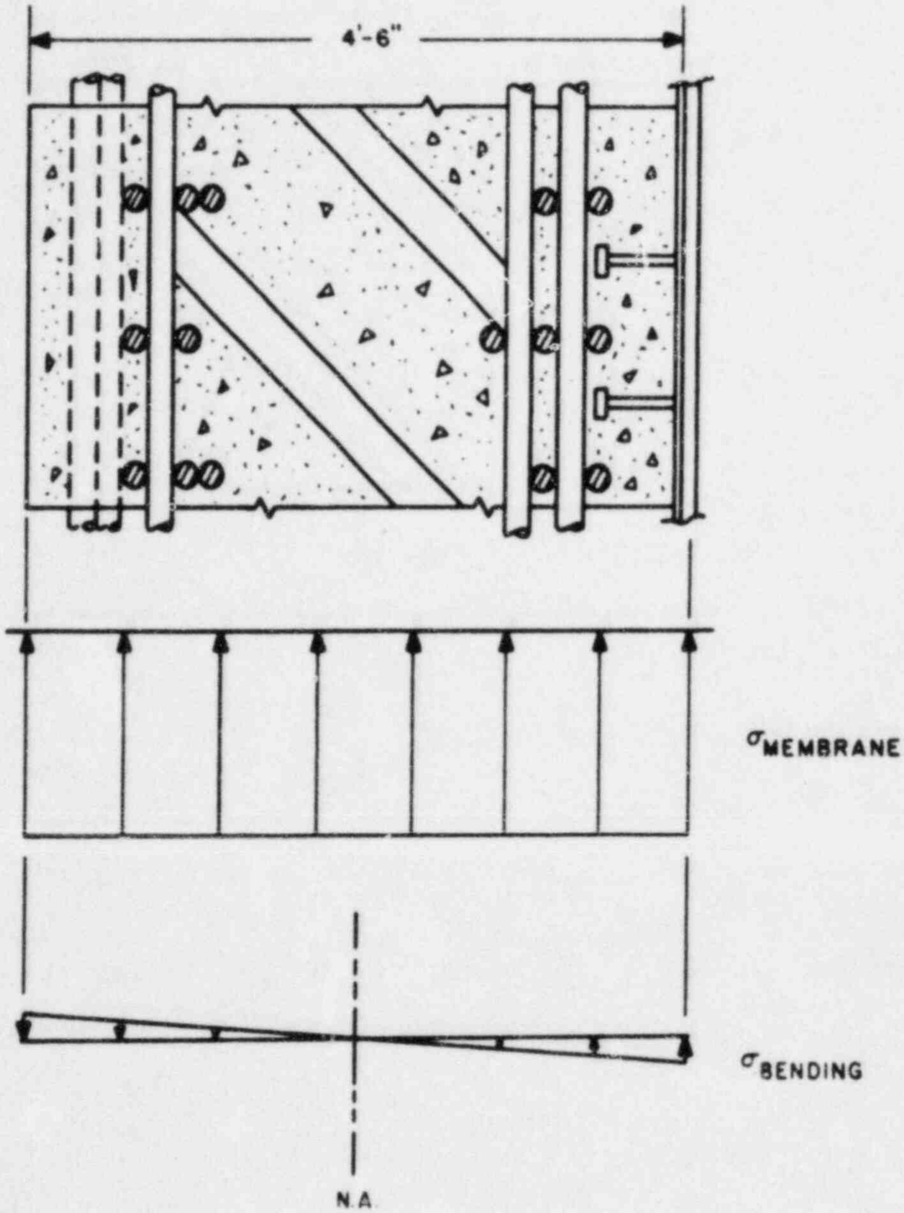
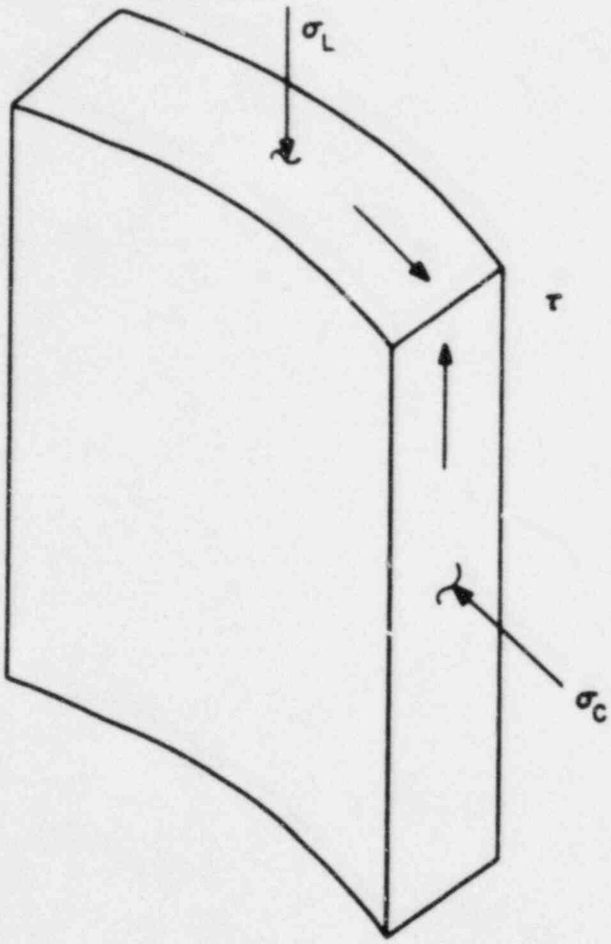


FIGURE 8.1
CONTAINMENT WALL
TYPICAL STRESS DISTRIBUTION
CONTAINMENT STRUCTURE
BEAVER VALLEY POWER STATION-UNIT NO.1
DUQUESNE LIGHT COMPANY



T, SEISMIC SHEAR STRESS, DBE

σ_L & σ_C, LONGITUDINAL & CIRCUMFERENTIAL MEMBRANE AND BENDING STRESSES DUE TO DBA PRESSURE & TEMPERATURE

$$\text{MAX } \sigma = \frac{\sigma_C + \sigma_L}{2} \pm \sqrt{\left(\frac{\sigma_C - \sigma_L}{2}\right)^2 + \tau^2}$$ (MOHR'S CIRCLE EQUATION)

FIGURE 8.2
LINER STRESS COMBINATION
CONTAINMENT STRUCTURE
BEAVER VALLEY POWER STATION-UNIT NO. 1
DUQUESNE LIGHT COMPANY

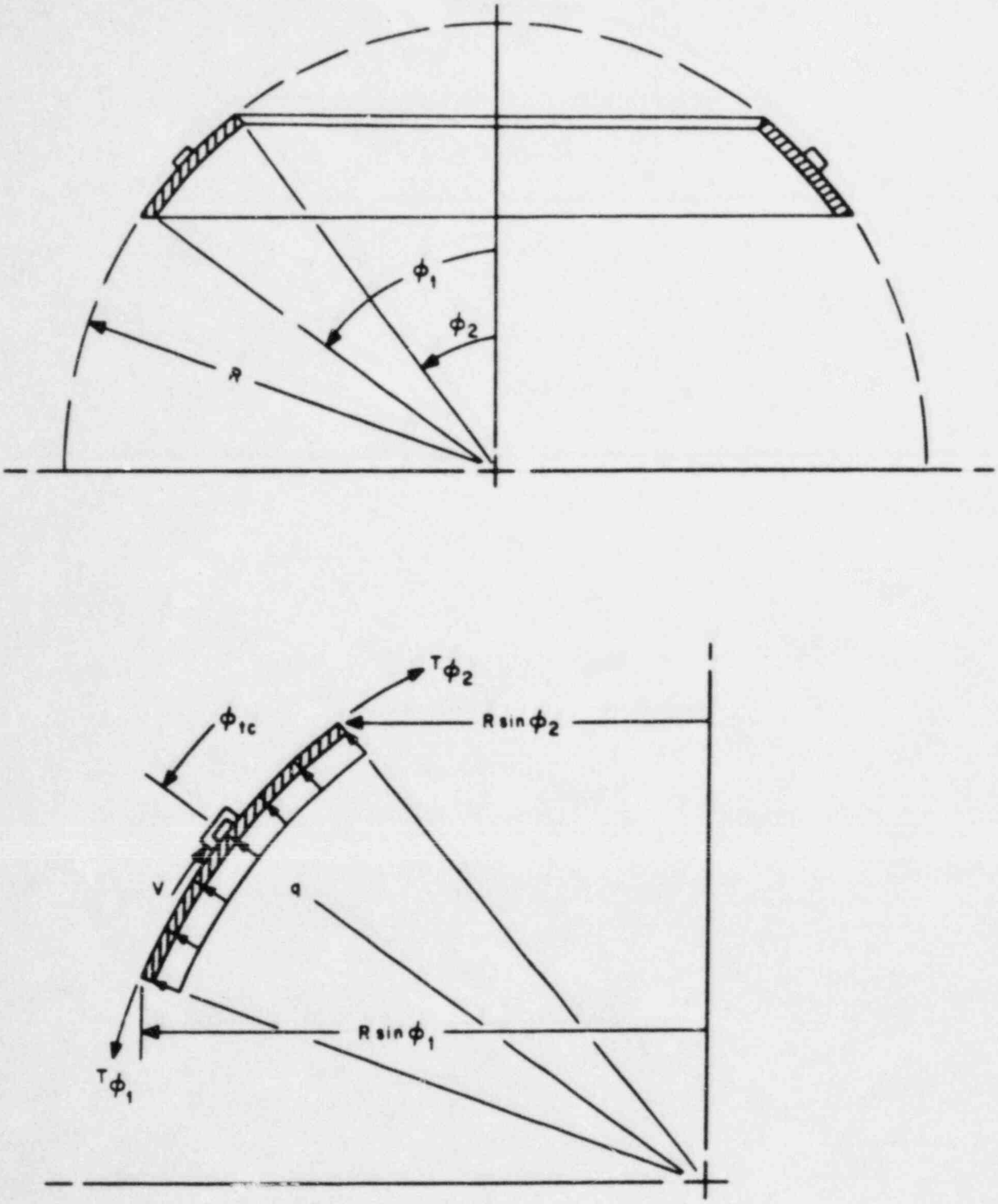


FIGURE 8-3
LINER ELEMENT
CONTAINMENT STRUCTURE
BEAVER VALLEY POWER STATION-UNIT NO.1
DUQUESNE LIGHT COMPANY

FROM VERTICAL EQUILIBRIUM ($\Sigma F_v = 0$),

$$0 = V_v + F_{2_v} - F_{1_v} + F_{q_v}$$

WHERE,

$$F_{1_v} = 2\pi R t \sin^2 \phi_1 \, \sigma_{\phi_1}$$

$$F_{2_v} = 2\pi R t \sin^2 \phi_2 \, \sigma_{\phi_2}$$

$$F_{q_v} = \int_{\phi_1}^{\phi_2} 2\pi R \, (T_\theta + T_\phi) \sin\phi \cos\phi \, d\phi$$

$$V_v = 2\pi R^2 \sin^2 \phi_{TC} V$$

DIVIDING EACH TERM BY $2\pi R$ AND SOLVING FOR V,

$$V = \frac{1}{\sin^2 \phi_{TC}} \left\{ t \sin^2 \phi_1 \, \sigma_{\phi_1} - t \sin^2 \phi_2 \, \sigma_{\phi_2} - \int_{\phi_1}^{\phi_2} (T_\theta + T_\phi) \sin\phi \cos\phi \, d\phi \right\}$$

FIGURE 8.4
STRESS SUMMATION
CONTAINMENT STRUCTURE
BEAVER VALLEY POWER STATION-UNIT NO. 1
DUQUESNE LIGHT COMPANY

DOME TEST CHANNEL WELD STRESSES

TEST CHANNEL LOCATION φ, deg.	TEST CONDITION				DESIGN CONDITION			
	SHEAR FORCE V, lb/in.	WELD STRESS Ksi.	ALLOWABLE STRESS Ksi.*	FACTOR OF SAFETY	SHEAR FORCE V, lb/in.	WELD STRESS Ksi.	ALLOWABLE STRESS Ksi.*	FACTOR OF SAFETY
13.5	265	1.00	21.0	21.0	1513	5.71	31.5	5.52
23.0	2518	9.50	21.0	2.21	5367	20.25	31.5	1.56
31.0	1968	7.43	21.0	2.83	2907	10.97	31.5	2.87
39.0	1005	3.79	21.0	5.54	2203	8.31	31.5	3.79
48.0	784	2.96	21.0	7.09	1746	6.59	31.5	4.78
56.0	906	3.42	21.0	6.14	1890	7.13	31.5	4.42
73.0	472	1.78	21.0	11.8	942	3.55	31.5	8.87
81.0	631	2.38	21.0	8.82	624	2.35	31.5	13.4

*BASED ON ASME III, DIV. 2, CC-3750

FIGURE 8.5
STRESS TABULATION
CONTAINMENT STRUCTURE
BEAVER VALLEY POWER STATION-UNIT NO. 1
DUQUESNE LIGHT COMPANY