<u>Plate for Vessels</u>

Carbon steel	SA-516, Grade 70 carbon steel plates for pressure vessels for moderate and lower temperature service.
Austenitic stainless steel	SA-240, Type 304.

<u>Forgings</u>

Carbon steel	SA-350, Grade LF1 for welding.
Austenitic stainless steel	SA-182, Grade F304.

The corrosion of the steel containment face in contact with the containment concrete is not a design consideration since portland cement concrete provides good protection to embedded steel. The protective value of the concrete is ascribed to its alkalinity and relatively high electrical resistivity in atmospheric exposure.

ACI Committee 201 Report "Durability of Concrete in Service" identifies three basic conditions as being conducive to the corrosion of steel in concrete [4].

1. The presence of cracks extending from the exposed surface of the concrete to the steel.
2. Corrosion cells arising from electro-potential differences in the concrete itself.
3. Electrolysis by induced currents in the concrete or steel.

With respect to condition (1) the base consists of a 3-foot-thick concrete embedment surrounding all the steel containment. The cracking under the worst of cases is considered minimal. This quantity far surpasses minimum cover recommended by ACI 201-1 in the most corrosive marine environment.

Carbon steel	SFA-5.1, E 70 Classification. Submerged Arc SFA-5.17, EL or EM; Gas metal Arc SFA-5.18, E70-S-1 through E70-S-6; Gas Tungsten Arc SFA-5.18, E70-S-1 through E70-S-6.
Austenitic stainless steel	SFA-5.4 E308 or E309 Classification; SFA-5.9, ER308 or ER309 Classification.

Structural Steel

Plates, bars, and shapes (other than vessel plates)	ASTM A 36.
Plates (leak chase and built-up sections)	SA-516, Grade 70.
Plates (platform walkways and personnel lock floor plate)	Regular quality carbon steel nonskip S400

Gasketing materials, including O-ring seals and flexible membrane seals, shall be of ethylene propylene diene monomer (EPDM) material or other suitable elastomers in continuous rings and with a Shore A durometer hardness of 40-60.

Seals and gasket materials are required to withstand radiation of 10^8 Rads.

3.8.2.6.2 Corrosion Protection

Potential corrosion of the steel containment has been considered at both the embedded bottom liner in conjunction with the concrete, at the inner face in the region of the ice condenser, and at the outer face exposed to the annulus atmosphere.

The conditions which determine corrosion are basically the electro-potential of the materials involved, the presence of oxygen and an electrolyte, temperature and any induced electro-potential from extraneous sources. These have been evaluated in the determination of corrosion.

The containment material is to specification SA-516, Grade 70 being a 1 percent manganese, 0.3 percent silicon low carbon steel, and has interfaces with concrete. Thus no unfavorable electro-potentials exist in the materials.

The climatic conditions for Chattanooga, Tennessee, show an ambient annual temperature range of 0°F to 100°F [3]. The corresponding temperature for the steel containment in the region of the ice condenser are approximately 32°F to 120°F.

Austenitic stainless steel (for personnel lock equalizing valve bonnet, ball, and body)	SA-351, Grade CF8M.

Cold finished steel (for lock and hatch mechanisms)	ASTM A 108, Grades 1018 to 1050 inclusive.
Bar and machine steel (for lock and hatch mechanisms)	ASTM A 576, special quality, carbon content not less than 0.30 percent.
Fasteners	
Carbon steel	SA-320, Grade L7 or L43; SA-193, Grade B7; or SA-194, Grade 2H or 7.
Austenitic stainless steel	SA-193, Grade B8, or SA-194, Grade 8.
Carbon steel (for platform bolts and nuts)	A 307, Grade B.
Welding Electrodes	
Carbon steel (for fittings or couplings)	SA-105, SA-181, Grade II, or SA-234, Grade WPB.
Pipe	
Carbon steel	SA-333, Grade 1 or 6, seamless, or SA-155, Grade KCF70, electric fusion-welded.
Austenitic stainless steel	SA-312, Grade TP316, seamless, SA-358, Class 1, Grade 316, electric fusion-welded.
Carbon steel (for leak chase piping and platform handrail piping)	SA-53 or SA-106.
Castings	
Carbon steel	SA-216, Grade WCB, or SA-352, Grade LCB.
Carbon steel (for lock and hatch mechanisms)	ASTM A 27, Grades 70-36.

The potential for developing corrosion cells was kept to a minimum by limiting the soluble salts and chlorides in the concrete. Further, the continuing corrosion of iron under these conditions requires that the hydrogen deposited at the cathode is freed or combined with oxygen. Since both these mechanisms are prevented by the concrete the corrosion cells are polarized, and the reaction is brought to a standstill.

To preclude the development of induced electric currents and in keeping with good construction practice, all electrical equipment and structures are grounded as determined by the resistivity of the foundation materials for the site. Foundation material resistivity surveys were made and the result considered in the design and determination of the extent of the grounding mat.

The seasonal variation of steel containment temperature in the region of the ice condenser gives rise to a range of relative humidity from 4 percent at 120°F to 45 percent at 32°F. This is based on saturated air leaking from the cooling ducts at a temperature of 10°F and rising to the steel containment temperature at the containment surface.

The annular region exterior to the steel containment is essentially airtight. Only during periods of shutdown during which access doors are open will this seal be broken. In the event of a pipe rupture in the annular region, water would be removed by a drainage system at the base of the annulus.

Any ingress of moisture to the interior steel containment face is prevented by sealing the outer periphery of the ice condenser adjacent to the steel containment, and by the vapor barrier on the inside face of the duct panels at the boundary of the ice bed. In the event of any abnormal ingress of moisture through the seal, the leakage air from the cooling ducts has the capacity to absorb moisture up to the limits of the relative humidities quoted above. In addition, any moisture remaining will have a tendency to migrate to the colder end of the temperature gradient; i.e., for all steel containment temperatures above 10°F, moisture will migrate towards the cooling air ducts, where it will be evaporated as the cooling air increases in temperature in the course of its passage through the ducts.

For steel containment temperatures below 32°F any moisture at the steel containment face will be frozen, this condition pertaining to relative humidities greater than 45 percent, and steel containment temperatures below 10°F when the migration of moisture could take place from the air cooling ducts to the steel containment.

In the event of actuation of the containment spray, water would be applied to the interior surface of the steel containment. Most of the water would be removed by the drainage system and the small amount of moisture remaining would be removed from the steel containment surface by evaporation.

Several references have been established which give corrosion data for the limits of the conditions described above.

For low alloy steels in any industrial atmosphere long-term tests indicate a maximum total corrosion of 0.016 inch in 40 years (based on 14g/ag dm in 18 years [5].

For dry inland conditions which more closely simulate the steel containment conditions the total corrosion for the plant lifetime is approximately 0.010 inch [6] [7]. This is accounted for by the fact that below relative humidities of 65 percent, iron oxide itself forms an adherent film affording good protection to further corrosion [8]. Furthermore, at temperatures below freezing, ion transport in the electrolyte is almost entirely inhibited, obviating the mechanisms of corrosion. This is supported by data for corrosion from Normal Wells - latitude 65°N, where the prolonged winter temperatures and lower annual average reduce the corrosion rate by a factor of 50 as compared with Penn State [9], which is applicable to Watts Bar Nuclear Plant.

It is concluded that the maximum total corrosion for any exposed internal surface of the steel containment in the region of the ice condenser is 0.010 to 0.015 inch over the lifetime of the plant. In general, the corrosion in the region of the ice condenser is expected to be less than in other areas of the containment, which can be readily inspected.

3.8.2.6.3 Protective Coatings

Protective coatings were applied to all exposed steel surfaces of the containment vessel. Surfaces embedded in concrete will not be coated. Coating systems used on the inside of the containment vessel were selected on the basis of their ability to withstand not only normal operating conditions but design basis accident conditions as well. The coating must be able to withstand a DBA without being removed from the surface, so that it will not interfere with emergency pumping and spraying systems. The coating systems were subjected to tests designed to determine their radiation resistance, decontaminability, resistance to decontamination chemicals, and resistance to accident conditions. The accident conditions tests include exposuer to steam and boric acid spray solutions under temperature-time conditions which are more severe than those that would be encountered in a design basis accident.

All exterior vessel shell surfaces and metal surfaces of platforms, floor plate, ladders, walkways, attachments, and accessories located in the annular space surrounding the containment vessel were cleaned in accordance with the requirements of Steel Structures Painting Council Surface Preparation Specification

No. 6, Commercial Blast Cleaning, latest edition. After cleaning and having passed inspection, one complete prime shop coat of Carboline Carbozinc 11 paint (dry film thickness was not less than 2-1/2 mils) was applied in accordance with the manufacturer's instructions.

All interior surfaces of the containment vessel shell and metal surfaces of attachments thereto, except those parts embedded in the base slab and identified as the liner and areas within 2 inches of field-welded joints, were given one prime coat of Carboline Carbozinc 11 within 8 hours after blast cleaning in accordance with Steel Structures Painting Council Surface Preparation Specification No. 10, Near-White Blast Cleaning, latest edition. The primer was topcoated by TVA field forces with an epoxy coating as recommended. The surfaces of the vessel in the annular space were coated with materials selected for the ability to provide protection against atmospheric corrosion.

3.8.2.6.4 Tolerances

The containment vessel as constructed does not exceed the applicable tolerance requirements of the ASME Code for fabrication or erection.

The out-of-roundness tolerance does not exceed 1/2 of 1 percent of the nominal inside diameter.

The deviation from a vertical line of the vertical cylindrical portion adjacent to the ice condensers is limited to $\pm$ 2 inches for the height of the ice condensers.

Threaded studs for attachment of ice condenser outer duct panels do not vary from their theoretical location by more than $\pm$1/4 inch.

Penetrations do not vary from their theoretical location by more than $\pm$1/2 inch.

3.8.2.6.5 Vessel Material Inspection and Test

ASTM standard test procedures were employed for the liner and shell plates to ascertain compliance with ASTM specifications. Certified copies of mill test reports of the chemical and physical properties of the steel were submitted to TVA for approval. Tests for qualifying welding procedures and welders were also submitted for approval. All vessel pressure boundary material was tested (one test for each heat of steel) to determine its Nil Ductility Transition Temperature (NDTT). These tests were conducted to meet the requirements of ASME Boiler and Pressure Vessel Code, Section III, Paragraph NB-2300. The tests were conducted at a maximum temperature of 0°F.

Ultrasonic inspection was required for all pressure boundary plates subjected to tensile forces normal to the plate surface. This inspection was performed in accordance with ASME Boiler and Pressure Vessel Code, Section III, NB-2530.

3.8.2.6.6 Impact Testing

Charpy V-notch impact tests were made of material, weld deposit and the base metal weld heat affected zone employing a test temperature of not more than 30°F below minimum operating temperature. The requirements of the ASME Code, Paragraph NB-2300 were met for all materials under jurisdiction of the code. All weld procedure qualifications for procedures used on the containment vessel shell also meet code requirements for ductility.

3.8.2.6.7 Post-Weld Heat Treatment

Field welded joints did not exceed 1-1/2 inch and therefore the containment vessel as a completed structure did not require field stress relieving. Insert plates at penetration openings did not exceed 1-1/2 inches in thickness and stress relieving was not required by ASME Code before or after they were welded to adjacent plates. Post-weld heat treatment, where required, was performed as required by and in accordance with the ASME Code.

3.8.2.7 Testing

3.8.2.7.1 Bottom Liner Plates Test

Before concrete was placed over the bottom liner, the leak tightness of this liner was verified. All liner plate welds were vacuum box tested for leak tightness. Upon completion of a successful leak test, the welds were covered with channels, and the channels were leak tested by pressurization to 15 psig.

3.8.2.7.2 Vertical Wall and Dome Tests

Welds in the cylinder wall and dome in ASME Code Section III, Categories A and B, were 100 percent radiographed. Welds in Categories C and D were examined by magnetic particle, liquid penetrant, or by ultrasonic methods.

3.8.2.7.3 Soap Bubble Tests

Upon completion of the construction of the containment vessel, a soap bubble test was conducted with the vessel pressurized to 5 psig. Soap solution was applied to all weld seams and gaskets, including both doors of the personnel airlocks.

A second soap bubble inspection test was made at 13.5 psig upon completion of the overpressure test in accordance with the requirements of the ASME Code.

Any leaks detected by soap bubble test which could affect the integrity of the vessel or which could result in excessive leakage during the leakage rate tests were repaired prior to proceeding with the tests.

3.8.2.7.4 <u>Overpressure Tests</u>

After successful completion of the initial soap bubble test, a pneumatic pressure test was made on the containment vessel and each of the personnel airlocks at a pressure of 16.9 psig. Both the inner and the outer doors of the personnel airlocks were tested at this pressure. The test pressure in the containment vessel was maintained for not less than 1 hour.

3.8.2.7.5 <u>Leakage Rate Test</u>

Following the successful completion of the soap bubble and overpressure tests, a leakage rate test at 15 psig pressure was performed on the containment vessel with the personnel airlock inner doors closed.

The contractor performed the leak rate testing by the "Absolute Method," which consists of measuring the temperature, pressure, and humidity of the contained air, and making suitable corrections for changes in temperature and humidity.

Equipment and instruments were calibrated and certified before any pressure tests were initiated.

Continuous hourly readings were taken until it was satisfactorily shown that the total leakage during a consecutive 24 hour period did not exceed 0.1 percent of the total contained weight of air at test pressure at ambient temperature in accordance with the requirements of 10CFR50, Appendix J.

The Contractor and Engineer's representatives reviewed the leakage rate data during the test to determine adequacy of the test, authorize termination, or require continuation of the test.

3.8.2.7.6 <u>Operational Testing</u>

After completion of the airlocks, including all latching mechanisms, interlocks, etc., each airlock was given an operational test consisting of repeated operation of each door and mechanism to determine whether all parts are operating smoothly without binding or other defects. All defects encountered were corrected and retested. The process of testing, correcting defects, and retesting was continued until no defects were detectable.

3.8.2.7.7 Leak Testing Airlocks

The airlocks were pressurized with air to 16.9 psig. All welds and seals were observed for visual signs of distress or noticeable leakage. The airlock pressure was then reduced to 13.5 psig, and a thick soap solution was applied to all welds and seals and observed for bubbles or dry flaking as indications of leaks. All leaks and questionable areas were clearly marked for identification and subsequent repair. During the overpressure testing, the inner door was locked with hold-down devices to prevent upsetting of the seals.

The internal pressure of the airlock was reduced to atmospheric pressure and all leaks repaired after which the airlock was again pressurized to 13.5 psig with air and all areas suspected or known to have leaked during the previous test were retested by above soap bubble technique. This procedure was repeated until no leaks were discernible by this means of testing.

3.8.2.7.8 Penetration Tests

Type B tests were performed on all penetrations with test bellows and/or pressure taps in accordance with the requirements of 10CFR50, Appendix J. See Chapter 6 for imposed leak rates and tests performed on penetrations.

REFERENCES

1. Kalnins, A., "Analysis of Shells of Revolution Subjected to Symmetrical and Non-Symmetrical Loads," Trans. of the ASME Journal of Applied Mechanics, September, 1964, pp. 467-476.

2. Bijlaard, P. P., "Stresses from Radial Loads and External Moments in Cylindrical Pressure Vessels," Welding Journal, 34(12), 1955.

3. American Society of Heating, Refrigeration and Air Conditioning Engineers, Handbook of Fundamentals, 1967.

4. American Concrete Institute Proceedings, Volume 59 Report No. 201, December 1962, H. R., "Durability of Concrete in Service."

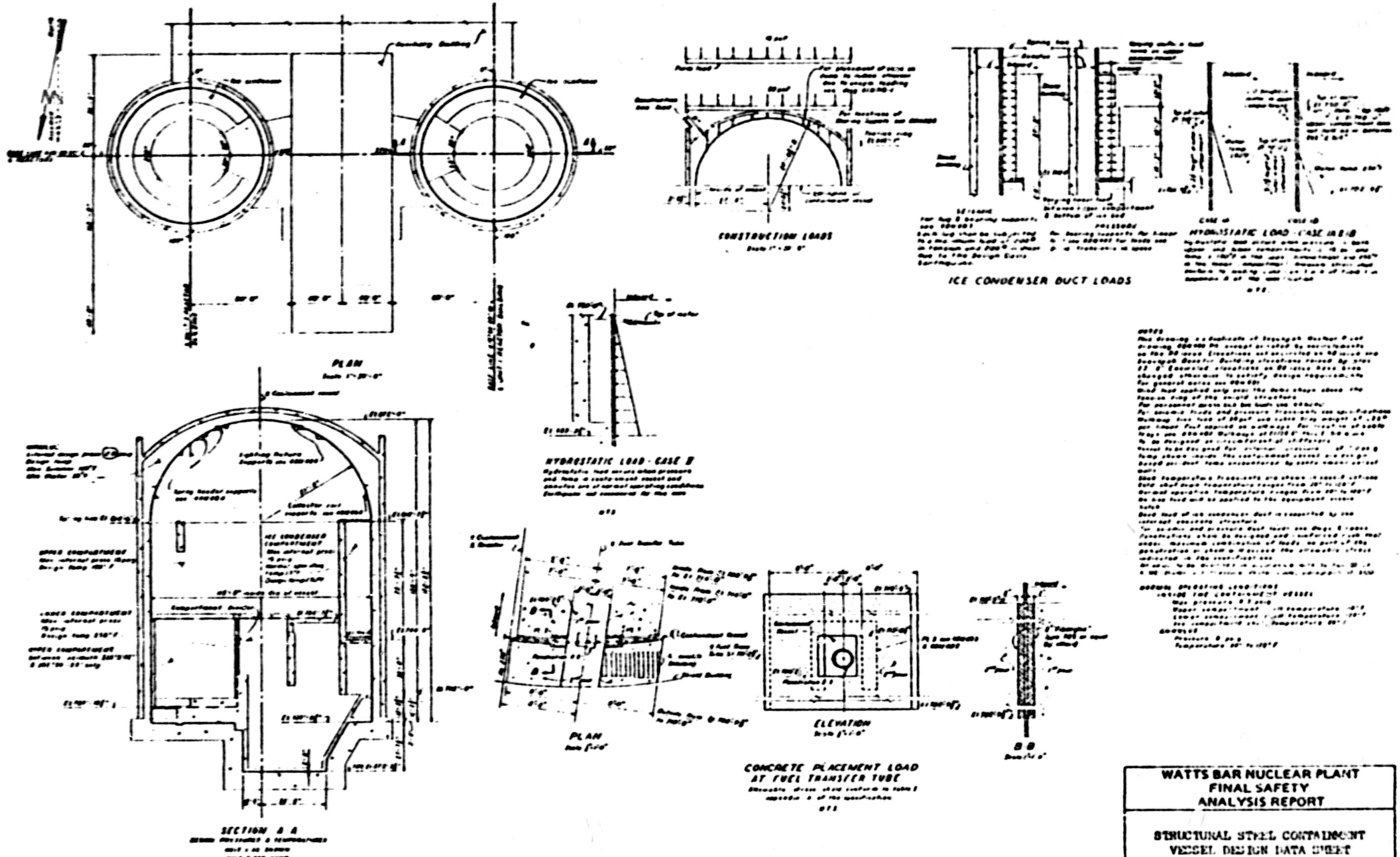
5. "Long Time Atmospheric Corrosion Tests on Low Alloy Steels," Copson, American Society for Testing Materials Proceedings, Volume 60, p 650, 1960.

6. Atmospheric Corrosion Testing of Metals in Canada, Gibbons, E. V.

7. Lauobe, C. P., "Corrosion of Steels in Marine Atmospheres," Trans. Electro Chemical Society, Volume 87, 1945.

8. Vernon, Trans. Faraday Society, 1934.

9. "Corrosiveness of Various Atmospheric Test Sites as Measured by Specimens of Steel and Zinc," Coburn, American Society for Testing Materials Proceedings, 1968.



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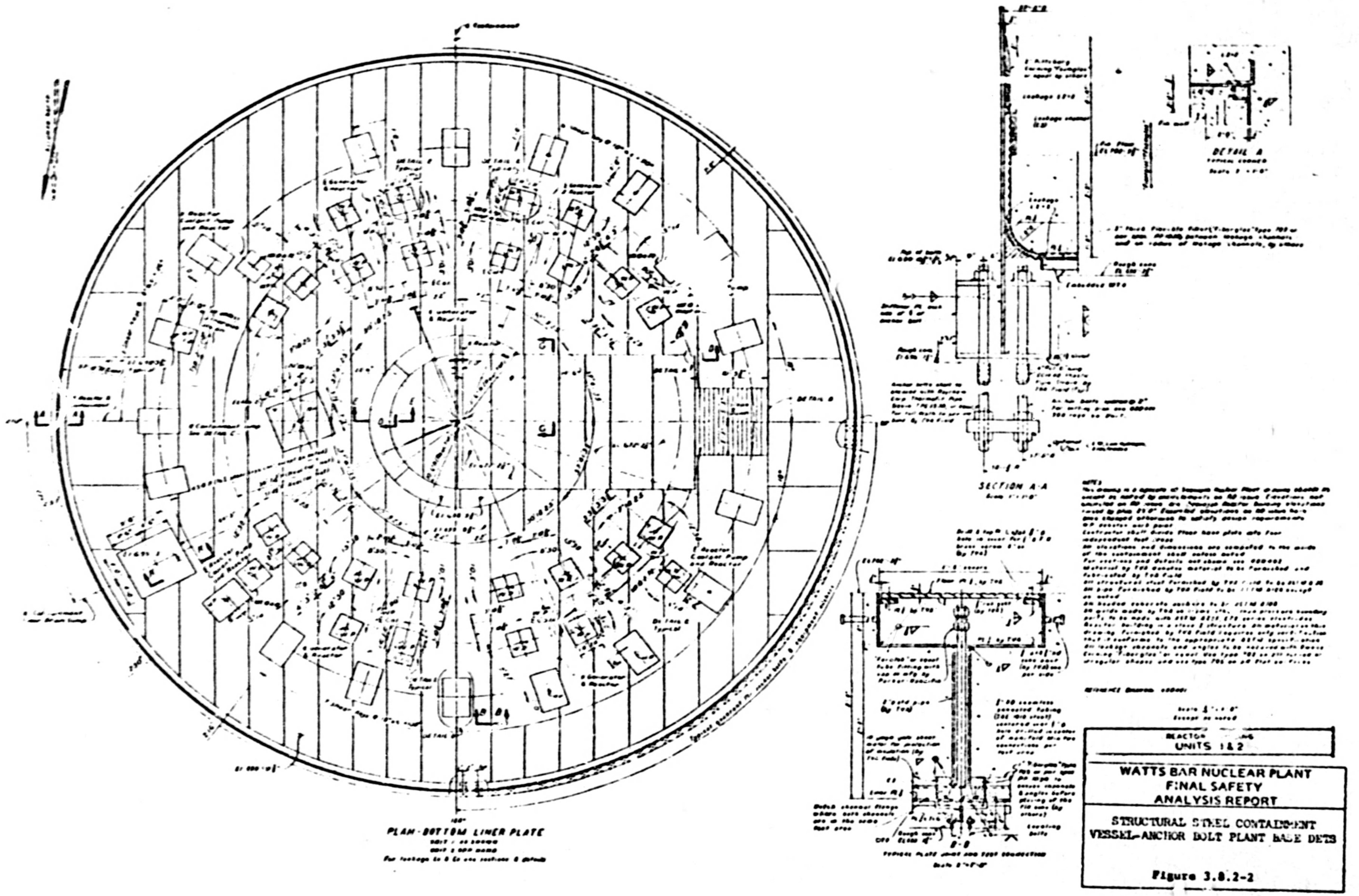
STRUCTURAL STEEL CONTAINMENT VESSEL DESIGN DATA SHEET

Figure 3.8.2-1



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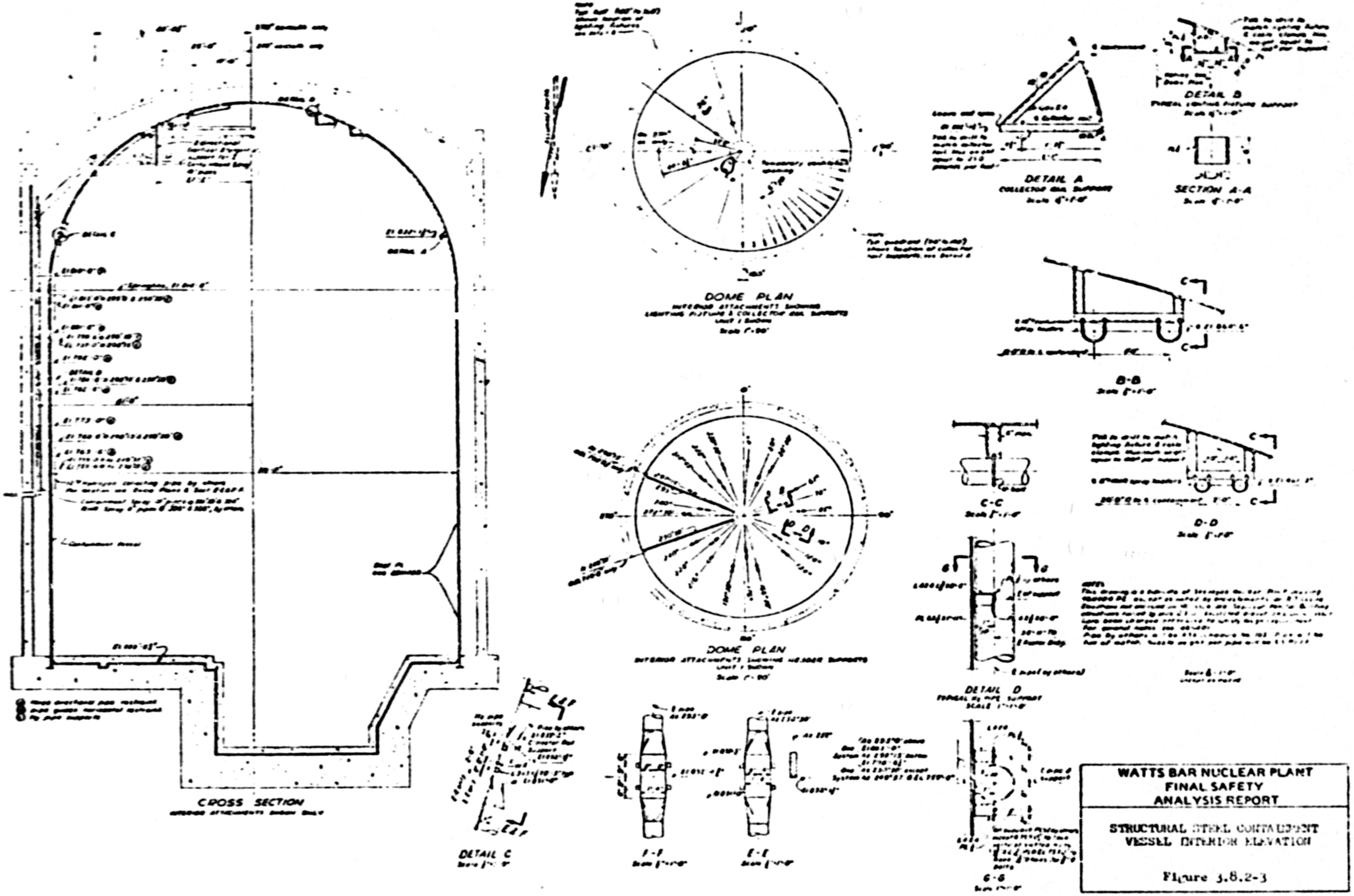
STRUCTURAL STEEL CONTAINMENT VESSEL-ANCHOR BOLT PLANT BASE DETS

Figure 3.8.2-2



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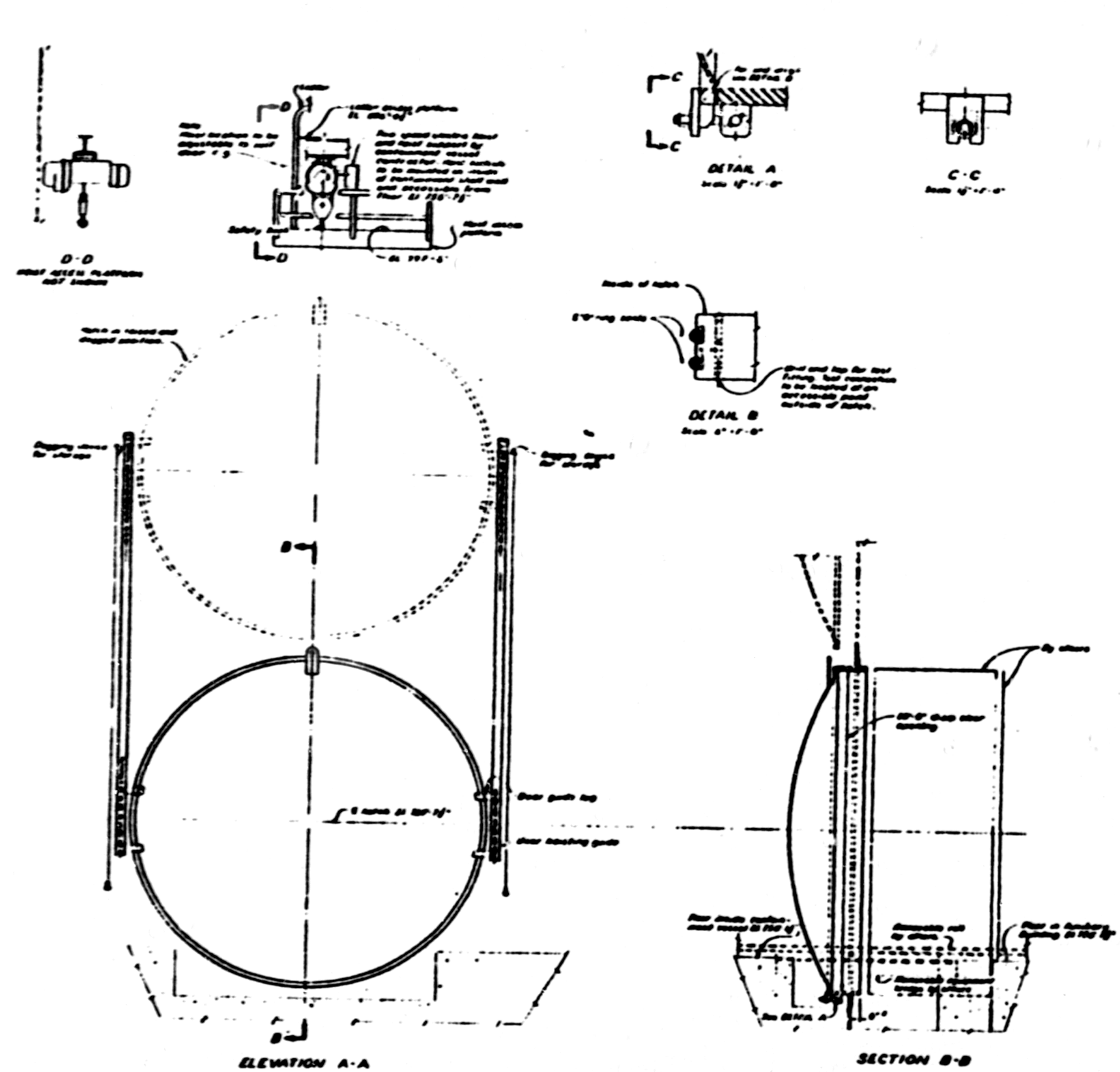
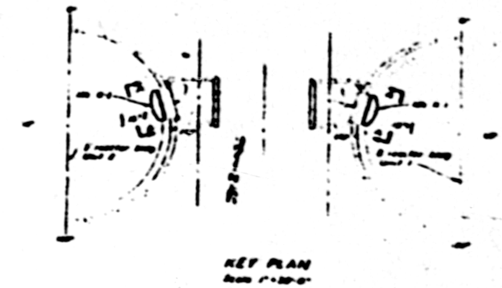
STRUCTURAL STEEL CONTAINMENT
VESSEL INTERIOR ELEVATION

Figure 3.8.2-3





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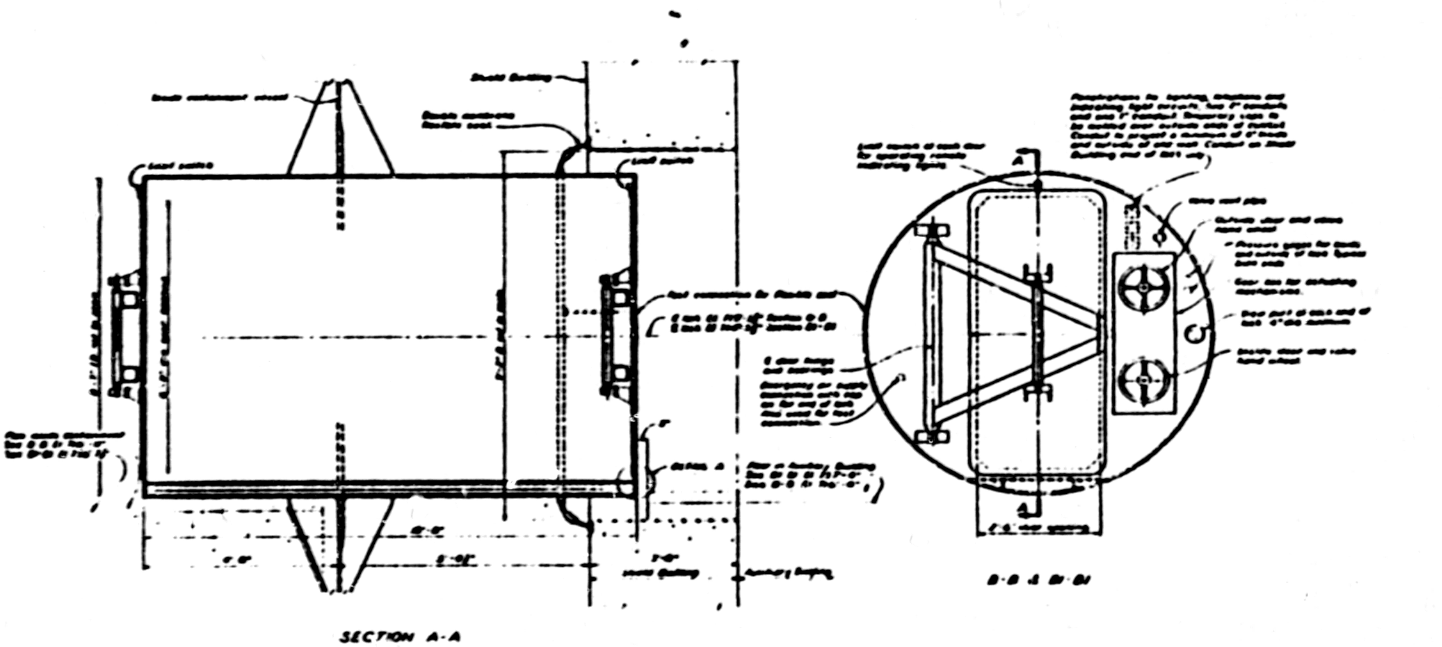
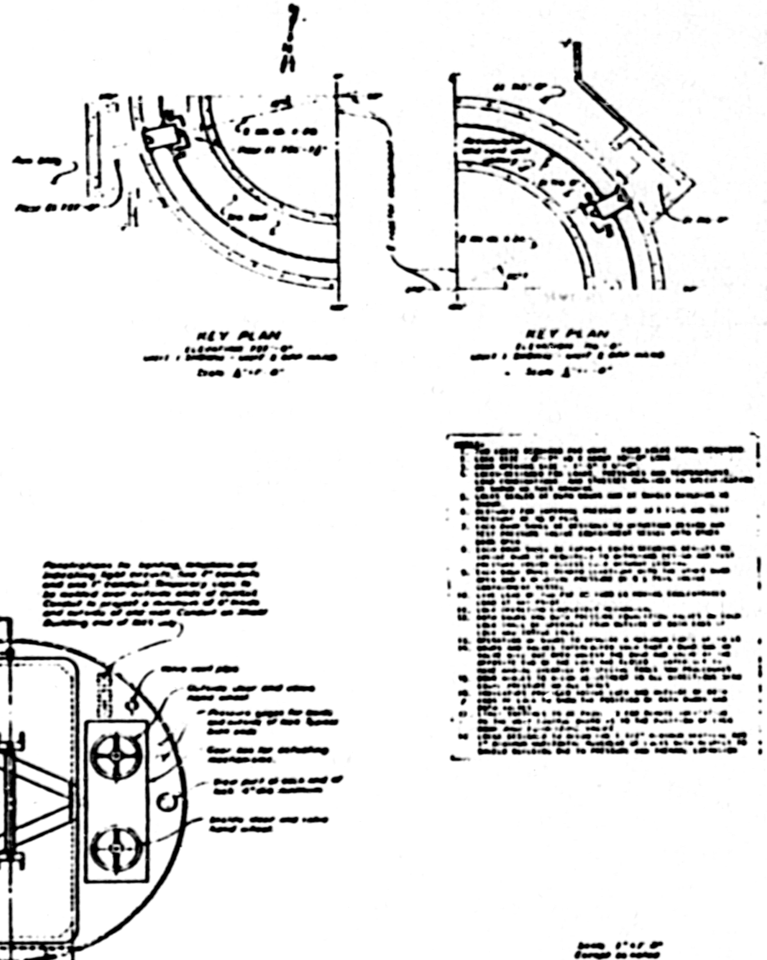
EQUIPMENT ACCESS HATCH
ARRANGEMENT AND DETAILS

Figure 3.8.2-4





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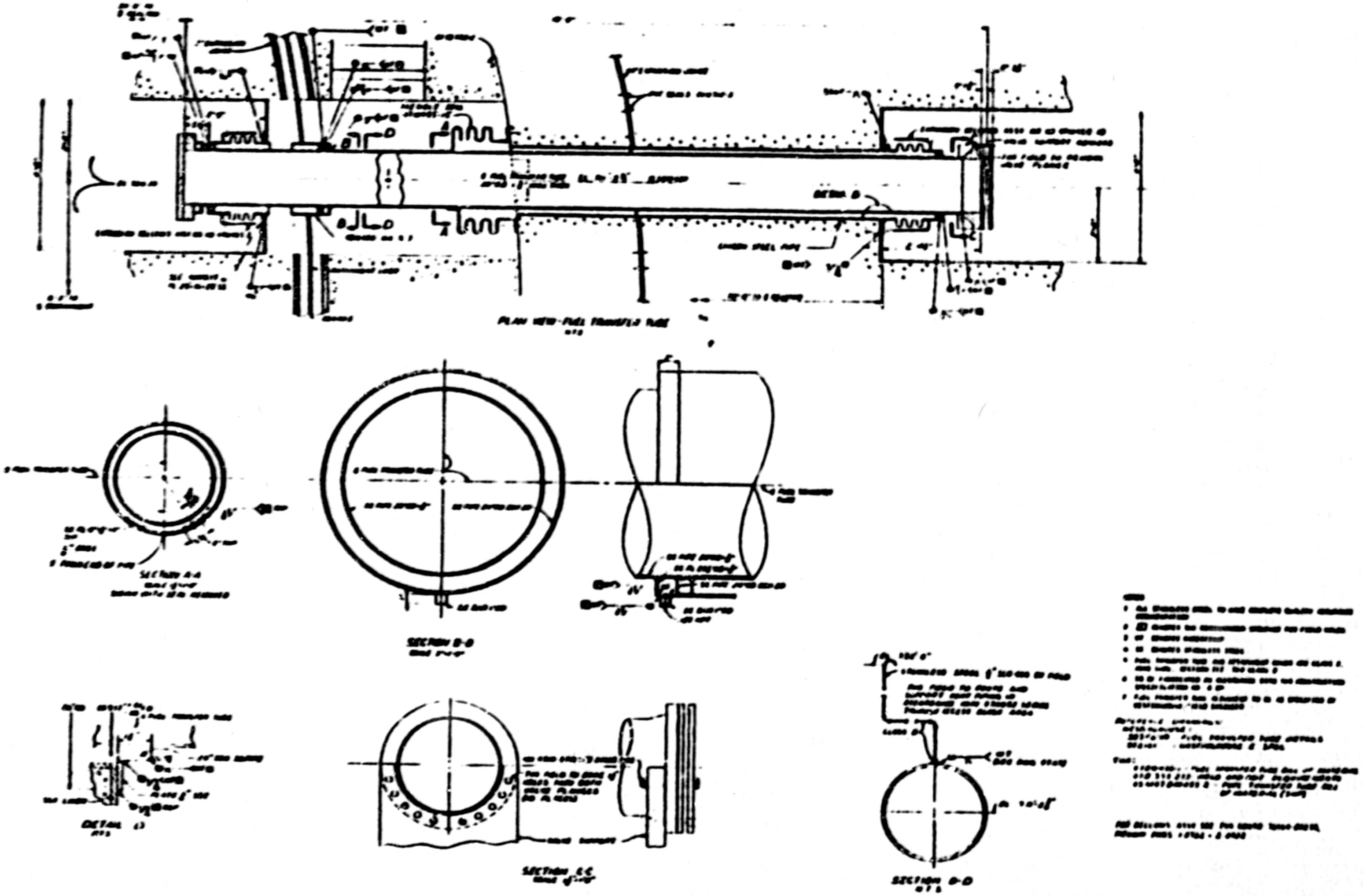
PERSONNEL ACCESS LOCK AND ARRANGEMENT DETAILS

Figure 3.8.2-5



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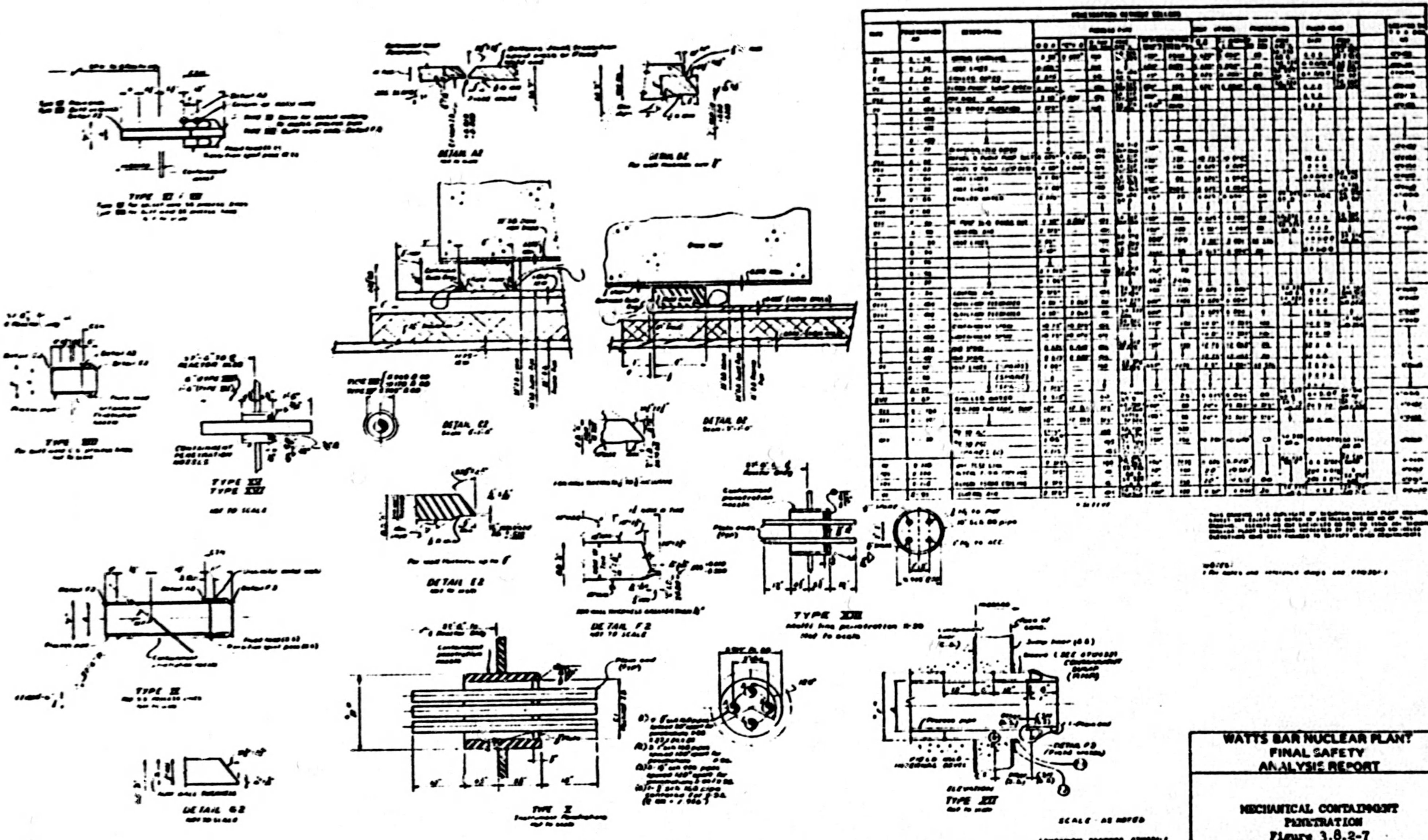
MECHANICAL FUEL TRANSFER
TUBE INSTALLATION
Figure 3.8.2-6



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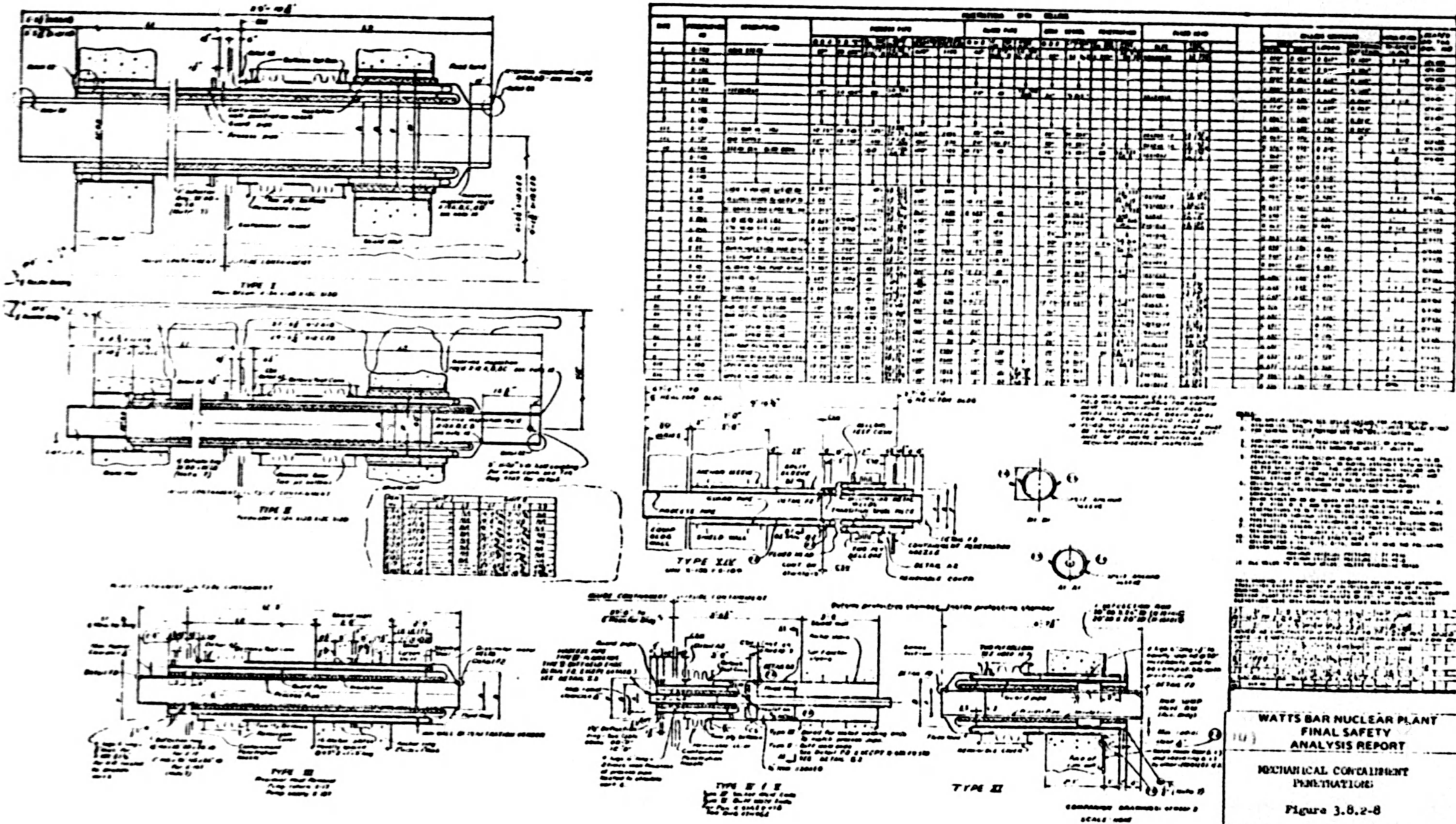
MECHANICAL CONTAINMENT
PENETRATION
Figure 3.8.2-7



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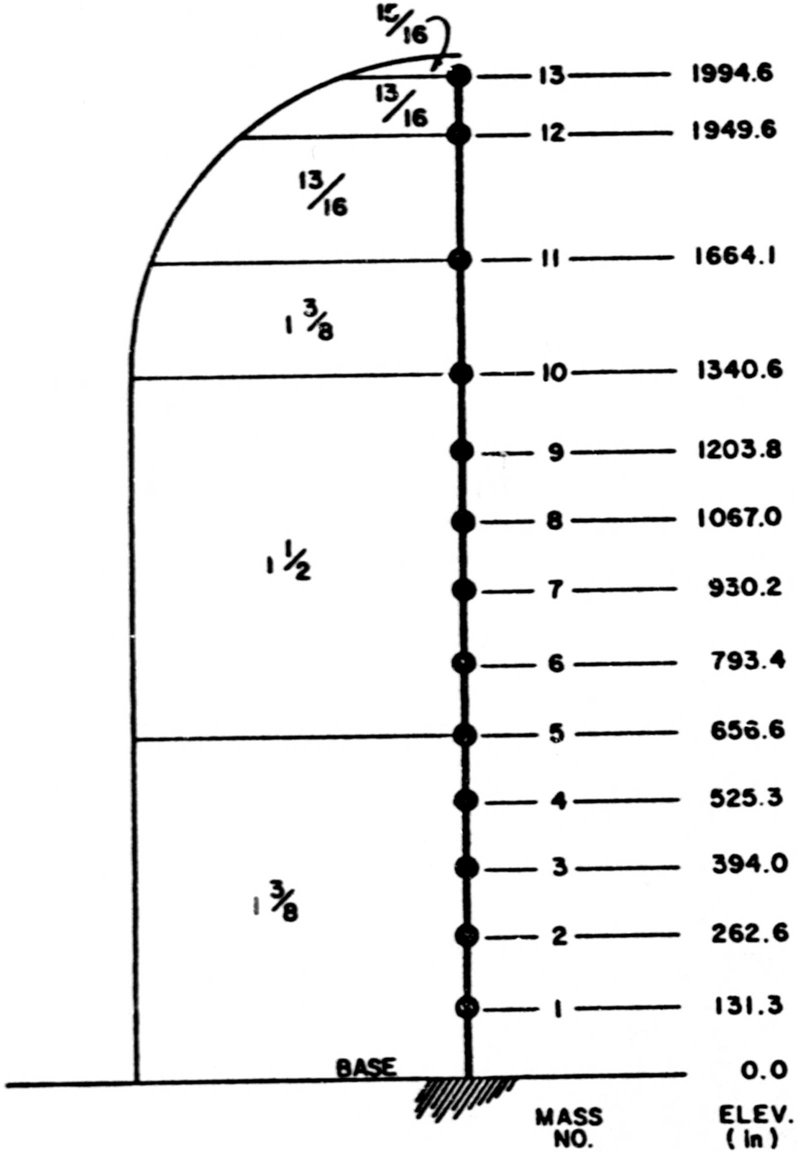
MECHANICAL CONTAINMENT
PENETRATIONS

Figure 3.8.2-8



MASS NO.	I (in^4)	HORIZ A (in^2)	VERT A (in^2)	ELEV. (in)	WEIGHT (k)
1	$.1423 \times 10^{10}$	2981	5967	131.3	271.9
2	$.1423 \times 10^{10}$	2981	5967	262.6	509.5
3	$.1423 \times 10^{10}$	2981	5967	394.0	552.5
4	$.1423 \times 10^{10}$	2981	5967	525.3	425.7
5	$.1423 \times 10^{10}$	2981	5967	656.3	273.6
6	$.1553 \times 10^{10}$	3251	6510	793.4	501.2
7	$.1553 \times 10^{10}$	3251	6510	930.2	305.9
8	$.1553 \times 10^{10}$	3251	6510	1067.0	410.4
9	$.1553 \times 10^{10}$	3251	6510	1203.8	372.4
10	$.1423 \times 10^{10}$	2981	5967	1340.6	315.0
11	$.0578 \times 10^{10}$	1555	3111	1664.1	639.0
12	$.871 \times 10^{8}$	828	1656	1949.6	336.3
13	$.272 \times 10^{8}$	561	1123	1994.6	98.2

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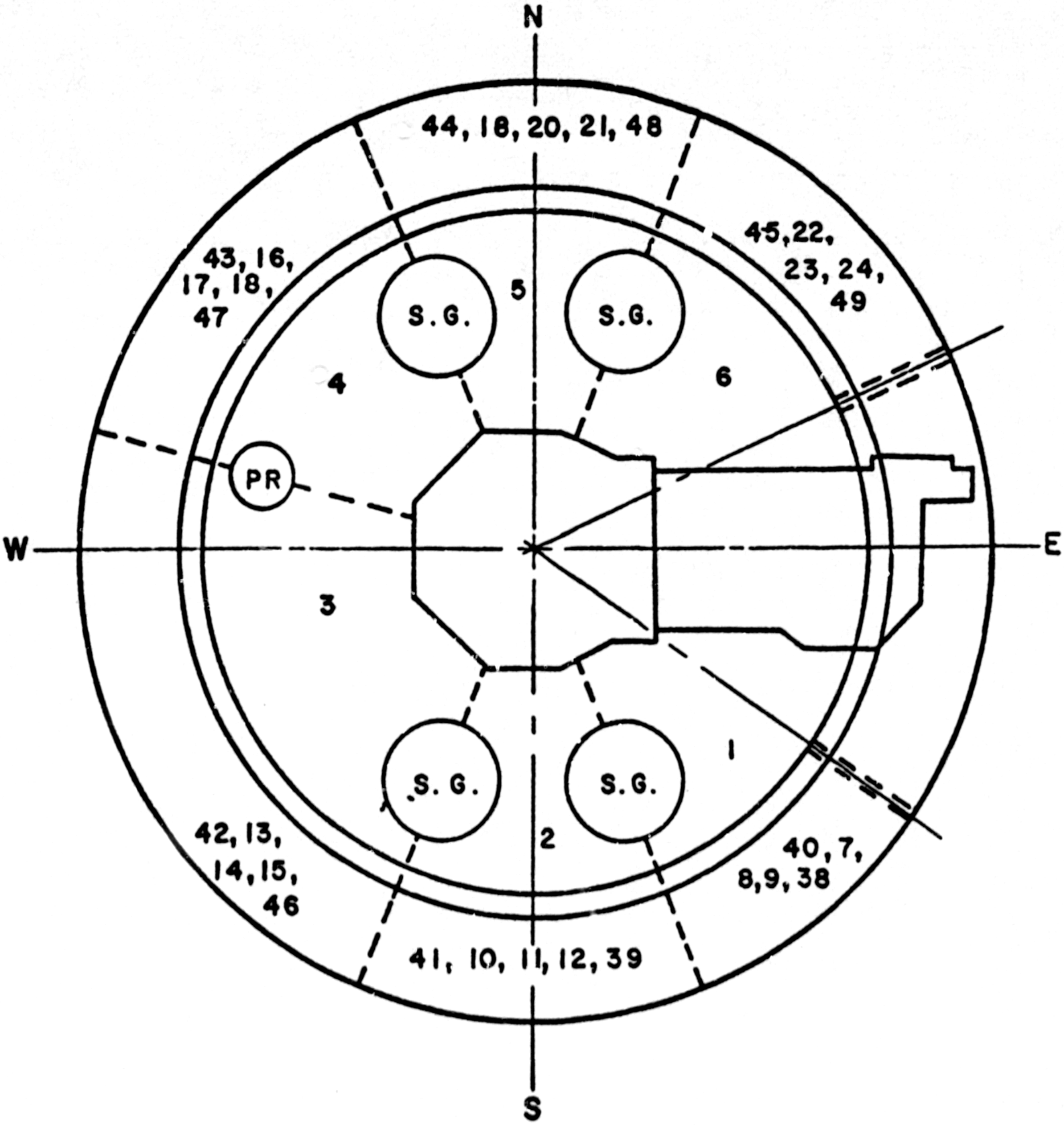
CONTAINMENT VESSEL LUMPED MASS
BEAM MODEL AND PROPERTIES

Figure 3.8.2-9



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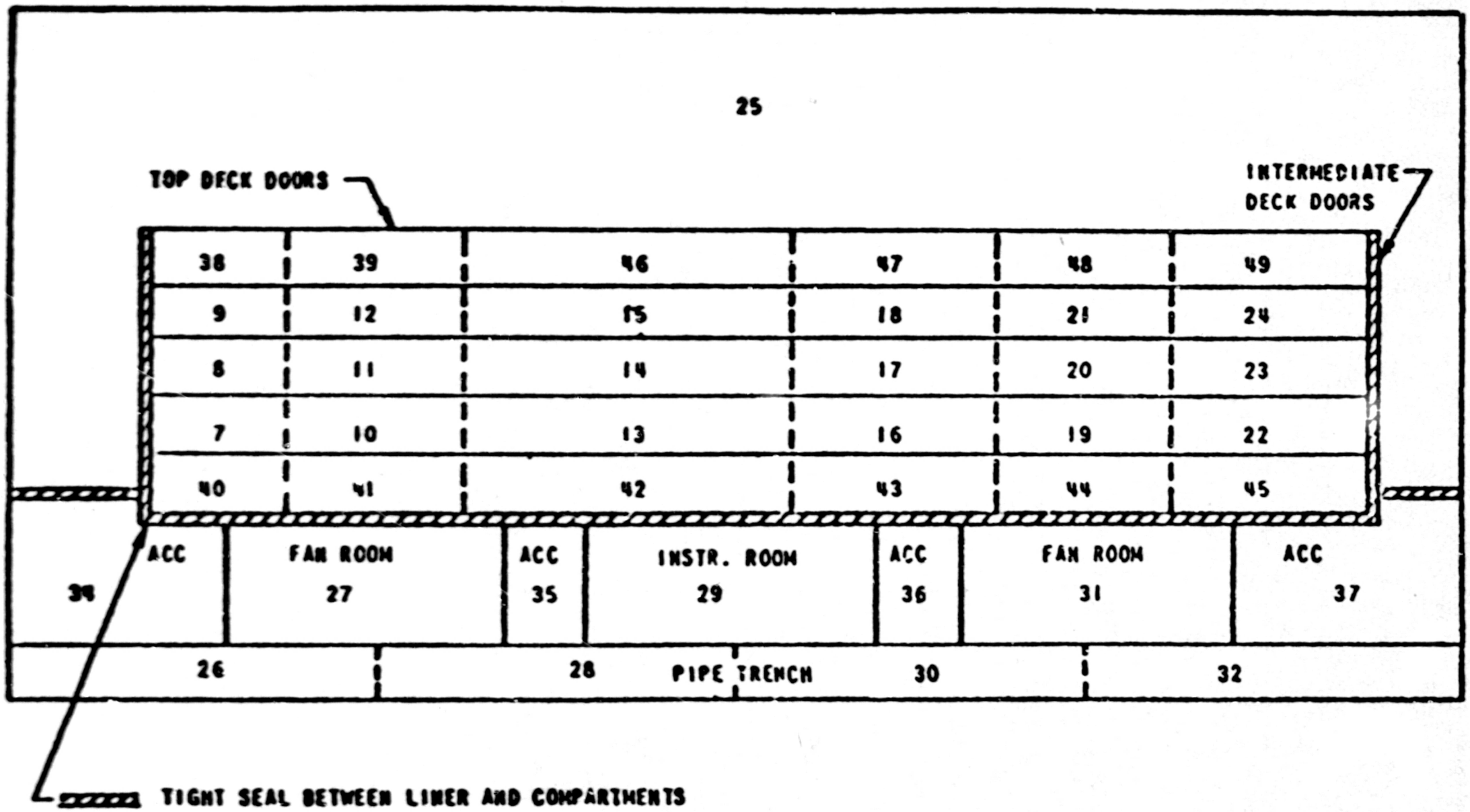
TMD NODAL VOLUMES

Figure 3.8.2-10



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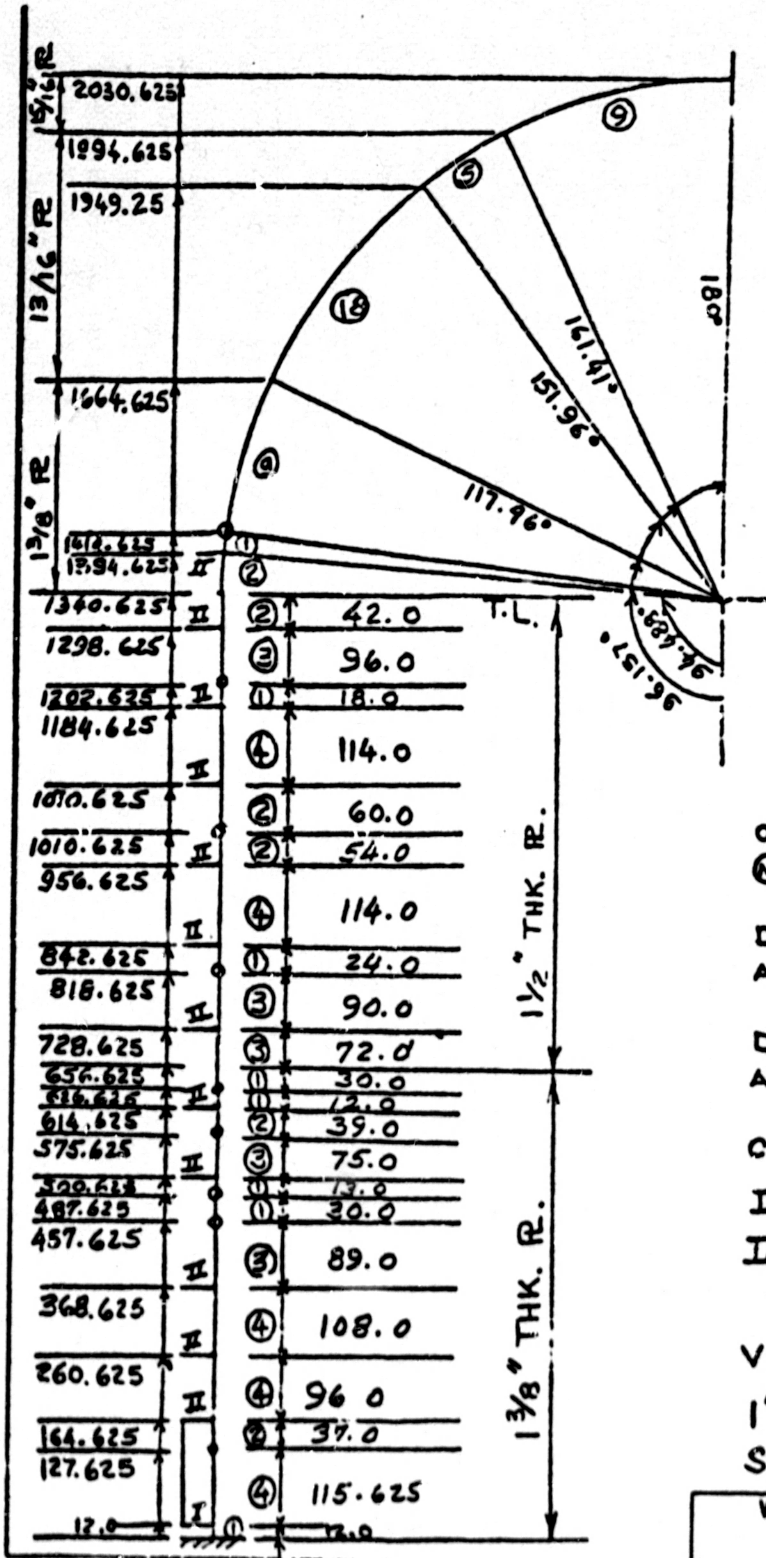
TMD NODAL VOLUMES

Figure 3.8.2-11



o. PRES. CHANGE LOCATIONS

Ⓝ. NUMBER OF SEGMENTS

DIMENSIONS TO THE RIGHT ARE LENGTHS OF EACH PANEL (IN.)

DIMENSIONS TO THE LEFT ARE DISTANCES ABOVE BASE (IN.)

CIRCUMFERENTIAL STIFFENERS

I PL 10" x 1"

II PL 22" x 1 3/8"

VERTICAL STIFFENER

1" x 8" @ 5° SPACING (72 AROUND)

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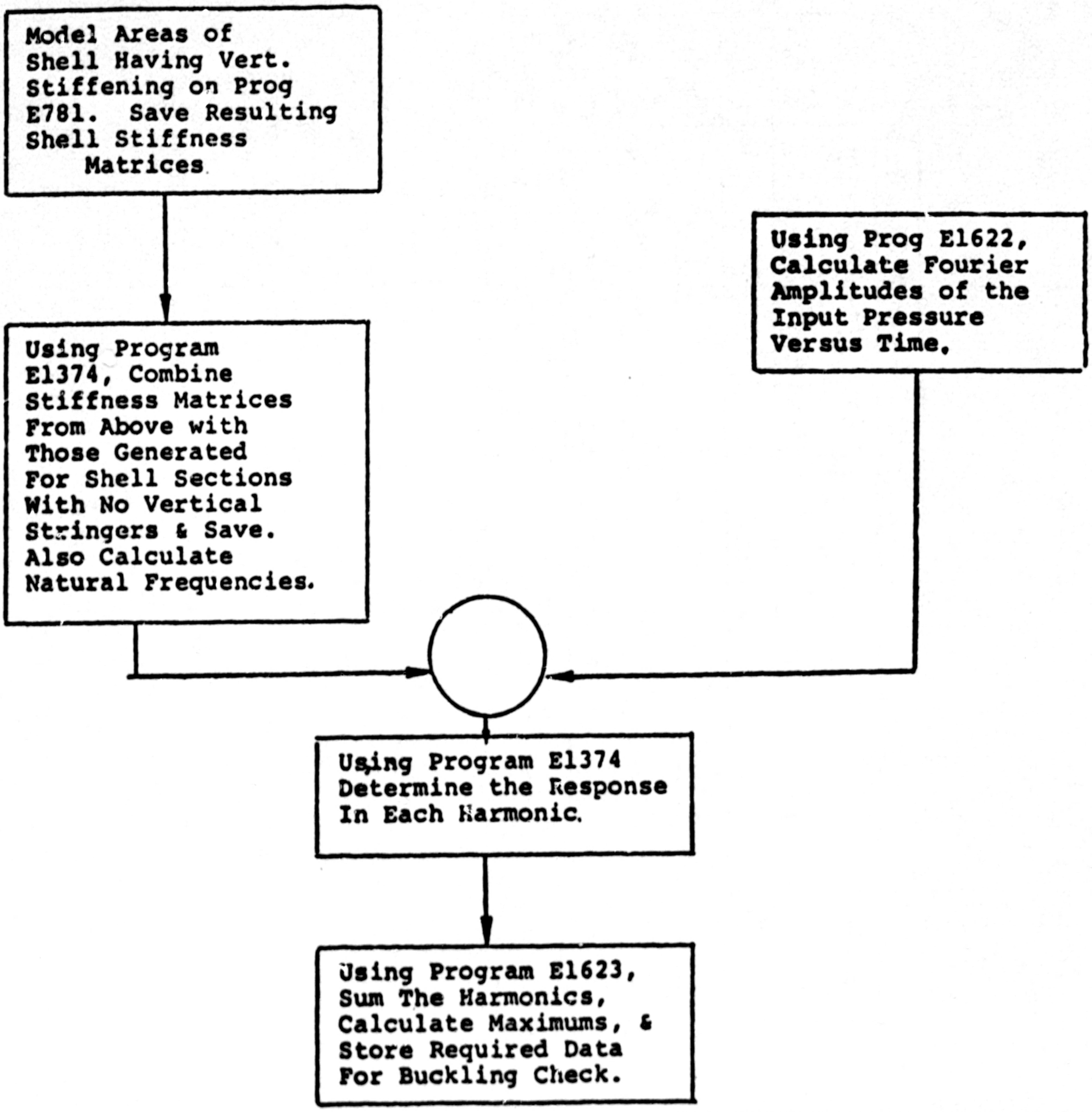
CB&I CONTAINMENT SHELL MODEL

Figure 3.8.2-12



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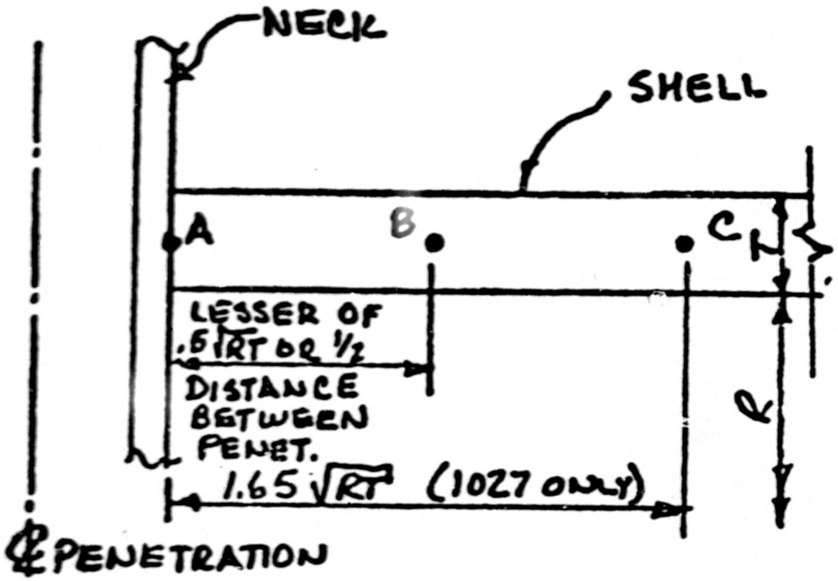
CB&I CONTAINMENT SHELL
ANALYSIS FLOW MODEL
Figure 3.8.2-13



POINT		ASSUMED STRESS CIRCUM CYL	ASSUMED STRESS CIRCUM SPH	ASSUMED STRESS MERID CYL	ASSUMED STRESS MERID SPH	ALLOW STRESS
A	SURFACE	$1\frac{1}{2} S_m$	$1\frac{1}{2} S_m$	$1\frac{1}{2} S_m$	$1\frac{1}{2} S_m$	$3 S_m$
	MEMBRANE	S_m	S_m	S_m	S_m	$1\frac{1}{2} S_m$
B	SURFACE	$1\frac{1}{2} S_m$	$1\frac{1}{2} S_m$	$1\frac{1}{2} S_m$	$1\frac{1}{2} S_m$	$3 S_m$
	MEMBRANE	S_m	S_m	$\frac{1}{2} S_m$	S_m	$1.1 S_m$
C	SURFACE	S_m	S_m	$\frac{1}{2} S_m$	S_m	$3 S_m$
	MEMBRANE	S_m	S_m	$\frac{1}{2} S_m$	S_m	$1.1 S_m$

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STRESS REDUCTION METHOD

Figure 3.8.2-14

Supplement