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CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.
INDIAN POINT NUCLEAR GENERATING UNIT NO. 3

FOURTH SUPPLEMENT TO:
PRELIMINARY SAFETY ANALYSIS REPORT

DOCKETED USAEC OCT 31 1968 REGULATORY MAIL SECTION DOCKET CLERK

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PREFACE

Supplement 4 to the Indian Point Nuclear Generating Unit No. 3 Preliminary Safety Analysis Report consists of page changes for Supplement 1 and Supplement 2 along with the responses to the remaining questions from the the AEC letter of July 16, 1968 on Structural Design Information.

The new pages for Supplements 1 and 2 should be inserted into the text according to Item and page number for Supplement 1 and Questions and page number for Supplement 2. The pages that are superceded should be removed from the text.

Insert here Tab entitled: RESPONSES TO AEC LETTER
JULY 16, 1968
STRUCTURAL DESIGN INFORMATION

QUESTION 1.1

Provide complete lists of:

(a) Class II Structures and systems:

(b) Combined structures (i.e., having elements of more than one class)

(c) Any Class I items housed in, adjacent to, or supported by, Class II or III structures.

ANSWER

(a)
1. Pressurizer relief tank
2. Sampling system
3. Spent fuel pit cooling loop
4. Primary make-up water tank
5. Primary make-up water tank pumps
6. These chemical and volume control system items -
    a. Batching tanks
    b. Monitor tanks
    c. Monitor tank pumps
    d. Excess letdown heat exchanter
    e. Surge tank
    f. Surge tank drain pumps
    g. Evaporator condensate demineralizers
    h. Deborating demineralizers
    i. Concentrates holding tank
    j. Holding tank transfer pumps
7. All secondary plant controls not listed as Class I.

(b) The fuel storage building is a combined structure. The spent fuel pit is a Class I structure, and the superstructure is a Class III structure.

(c) There are no other Class I items housed in adjacent to or supported by Class II or III structures.

QUESTION 1.2

Describe the protection to be provided any Class I equipment not in, or supported by, Class I structures.

ANSWER

There is no Class I equipment not in or supported by Class I structures.

QUESTION 1.3

State how the earthquake loads will be established for equipment in 1.2 above.

ANSWER

There is no Class I equipment not in or supported by Class I structures.

QUESTION 1.4

Describe the design methods used for the combined structures in 1.1 (b) above.

ANSWER

The superstructure and concrete substructure not related to the spent fuel pit are designed for normal live and dead loads using working stress design and for 30#/ft^2 wind load using stresses 33-1/3% higher than allowable stresses. The loads and reactions from the superstructure including earthquake loads are transmitted to the top of the spent fuel pit and are included in the design of the spent fuel pit. In addition, the spent fuel pit is designed for the hypothetical and design earthquake and the stress levels associated with these earthquakes.

QUESTION 1.5

In addition to the containment building crane, which is listed as a Class I item, information is requested as to the design of the other facility cranes to insure that they cannot be dislodged during an earthquake or otherwise cause damage which might impair safe shutdown and containment.

ANSWER

There are no other cranes which can be dislodged during an earthquake or otherwise cause damage which might impair safe shutdown and containment.

QUESTION 2.1(1)

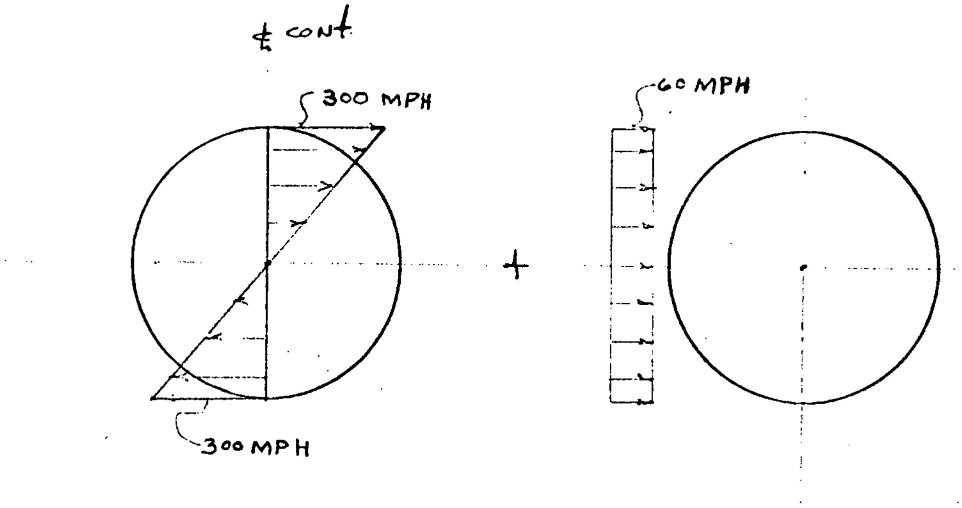
With respect to the design criteria for the tornado, indicate the design wind loading and pressure drop considered, and the basis for their selection.

ANSWER

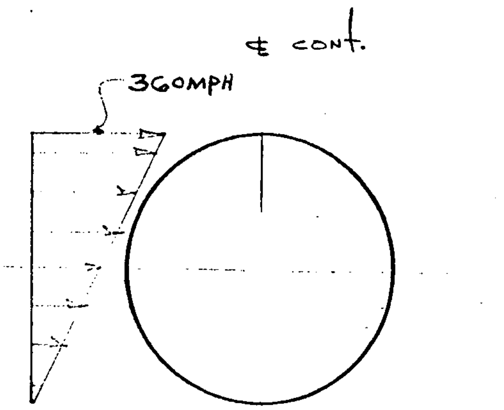
The wind load will be considered for three tornado conditions. One includes a tangential velocity of 300 mph and a translational velocity of 60 mph. This load superposition depicts a tornado condition where the funnel coincides with the center of the containment. Load pressure distribution patterns that will result due to various locations of the funnel will be considered. The structure will be designed for a triangular and a rectangular wind distribution of 360 mph.

A pressure drop of 3 psi in 3 seconds will be used for the containment structural design.

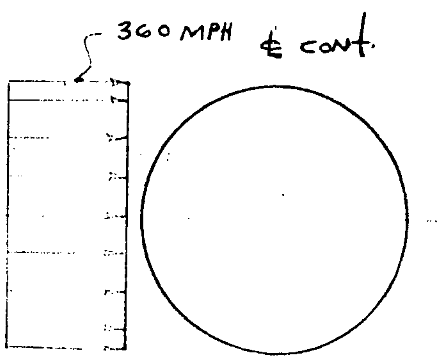
The above wind loading and pressure drop design criteria are consistent with the generally accepted tornado design criteria utilized on nuclear power plants in the eastern United States. The basis of the criteria is further discussed in Item 6 of the First Supplement to Indian Point Nuclear Generating Unit No. 3 PSAR.



CASE I



CASE II



CASE III

FIGURE 2.1(1)-1

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QUESTION 2.1(2)

With respect to the design criteria for the tornado, identify the equipment which will be designed to withstand these loadings.

ANSWER

All of the equipment necessary to be protected from tornado loadings is contained within structures designed to withstand the tornado loadings. These structures are discussed in Item 6 or Supplement 1 to Unit No. 3 PSAR.

The equipment or systems located within these structures include the following:

Primary Auxiliary Building

1) Safety Injection Pumps
2) Residual Heat Removal Pumps
3) Component Cooling System
4) Waste Disposal System (except for Waste Holdup Tank in Waste Holdup Tank Pit and Reactor Coolant Drain Tank and Pumps in the Containment).
5) Chemical and Volume Control System (except for Excess Letdown and Regenerative Heat Exchangers inside the Containment and Holdup Tanks in the Waste Holdup Tank Pit).
6) Refueling Waste Purification Pump
7) Sampling System
8) Auxiliary Building Ventilation System
9) Containment Spray Pumps
10) Spray Additive Tanks
11) Pressurization Air Receivers

Control Room

1) Instrumentation Readouts and Controls
2) Control Room Ventilation System

3) Batteries and Battery Chargers

4) Instrumentation Air System

Containment

1) Reactor Vessel, Core, Instrumentation, and Controls

2) Primary Coolant System (including Pressurizer and Pressurizer Relief Tank)

3) Steam Generators

4) Residual Heat Removal Heat Exchangers

5) Reactor Coolant Drain Tank and Pumps

6) Excess Letdown and Regenerative Heat Exchangers

7) Accumulators

8) Recirculation Pumps

9) Containment Air Recirculation Cooling and Filtration System

The Seismic Water Pump Motors are inherently capable of withstanding the tornado loadings and therefore no protective structure is provided for these pumps. However, the service water valve pits will be protected by a tornado proof structure.

QUESTION 2.1(3)

With respect to the design criteria for the tornado, discuss the ability of the plant components and systems to withstand tornado-originated missiles.

ANSWER

All plant components necessary to be protected from the tornado originated missiles are contained within structures designed to withstand tornado originated missiles. The design basis tornado missiles and the structures are discussed in Item 6 of Supplement 1 to the Unit No. 3 PSAR. The specific plant components and systems which can withstand tornado missiles are the same as the equipment and systems listed in the answer to Question 2.1(2).

The service water valve pits are protected from tornado originated missiles by a tornado proof structure. The redundancy of the service water pumps is discussed in Item 6 of Supplement 1 to the Unit No. 3 PSAR.

QUESTION 2.2

List the spectrum of other external missiles that the containment will be designed to withstand and the procedures to be used in checking the containment design to withstand such missile hazards.

ANSWER

The external missiles (apart from tornado generated missiles) considered in the design of the containment structure are those from the turbine.

As was shown in the discussion in Supplement 1 to the PSAR, Item 16 (E-45), these missiles will not penetrate the containment.

QUESTION 2.4(c)

For the containment structure, provide:

The normal operating and transient accident thermal gradients to be used in the design of the containment for the typical winter and summer days.

ANSWER

The temperature distributions through the insulated and the uninsulated portions of the containment wall for operating and accident conditions during limiting summer or winter operation are shown in Figures 2.4(c)-1 through 2.4(c)-4.

NORMAL SUMMER OPERATING CONDITIONS

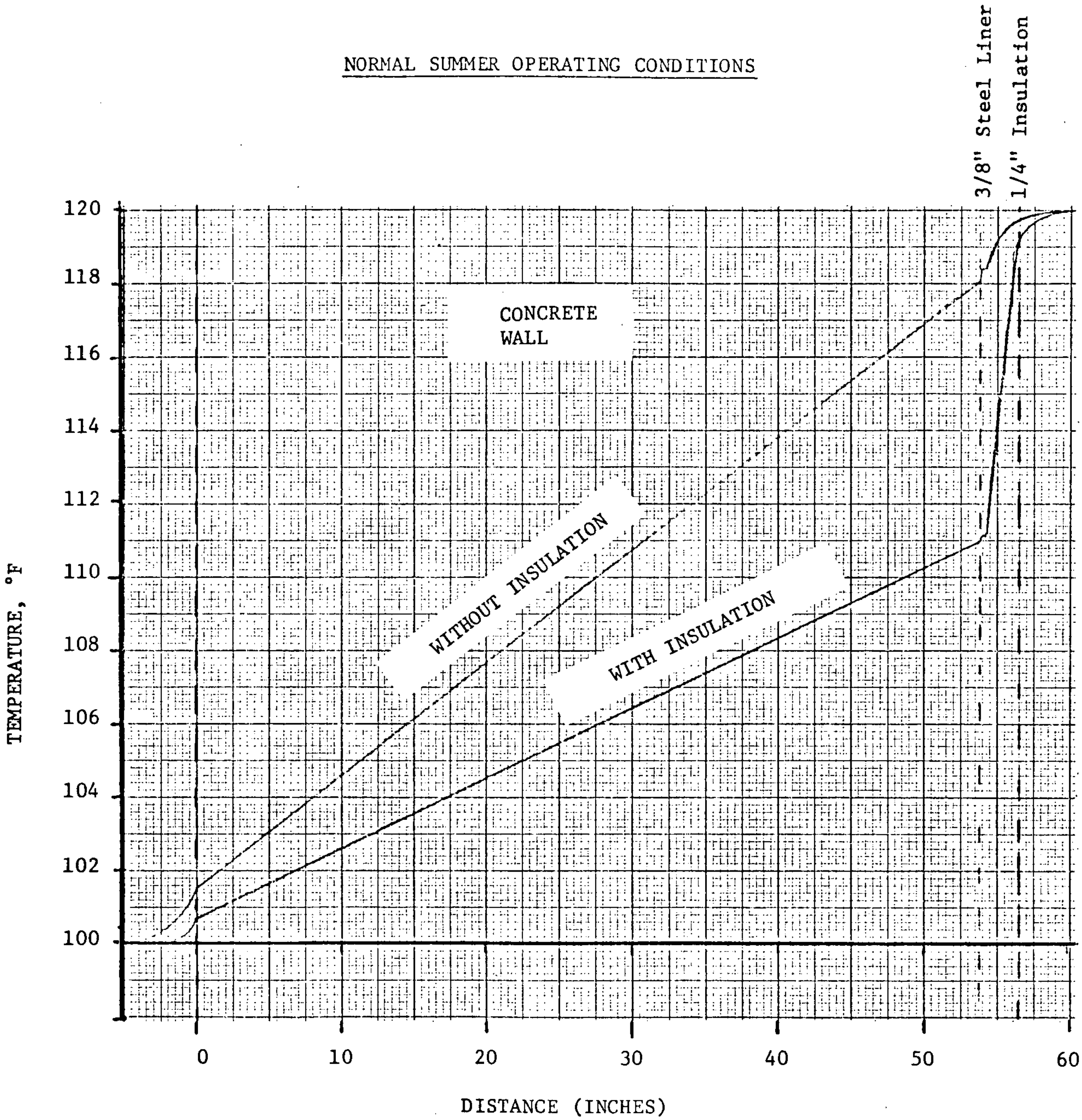

FIGURE 2.4(c)-1
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NORMAL WINTER OPERATING CONDITIONS

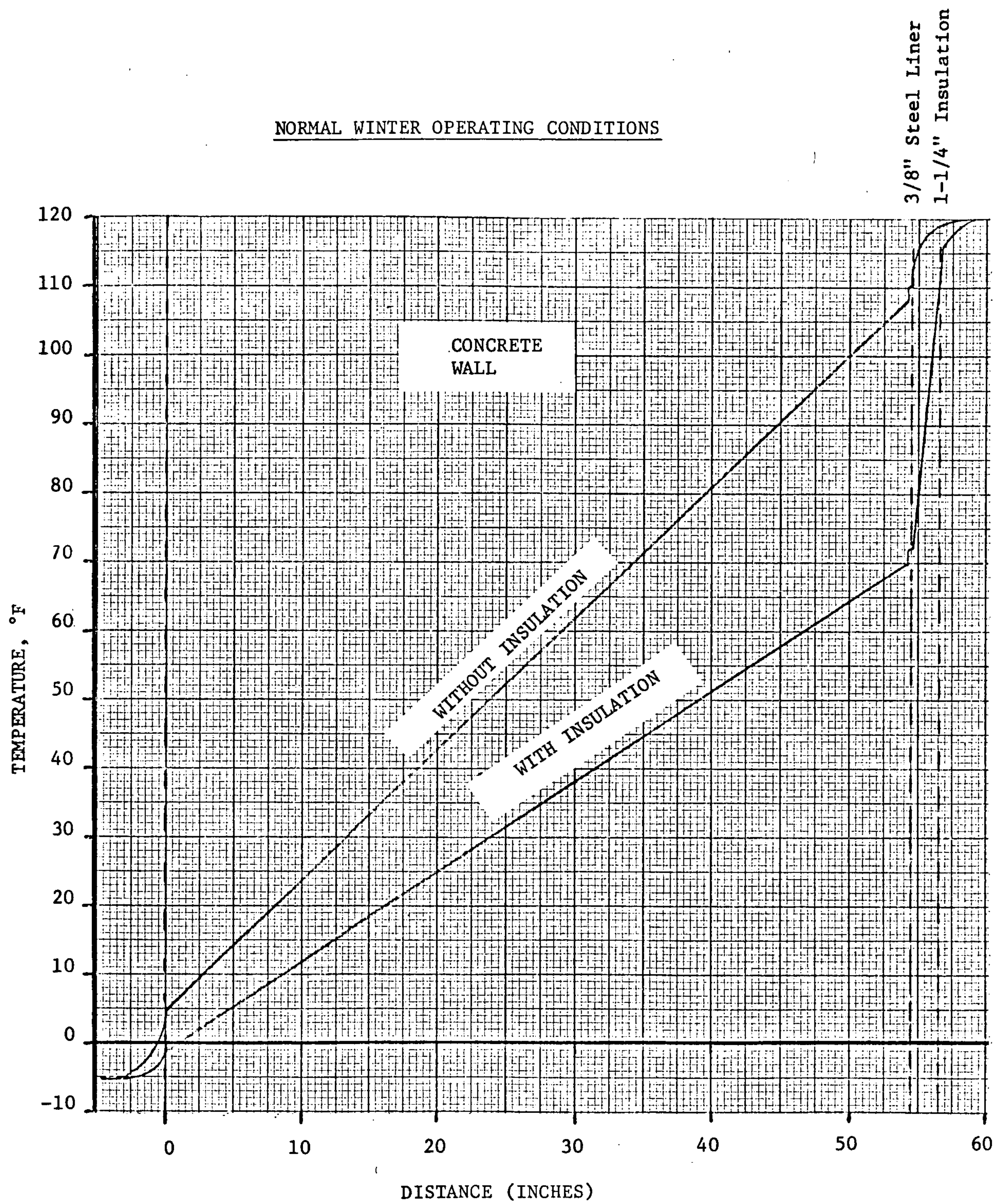

FIGURE 2.4(c)-2
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DESIGN BASIS ACCIDENT CONDITIONS IN WINTER

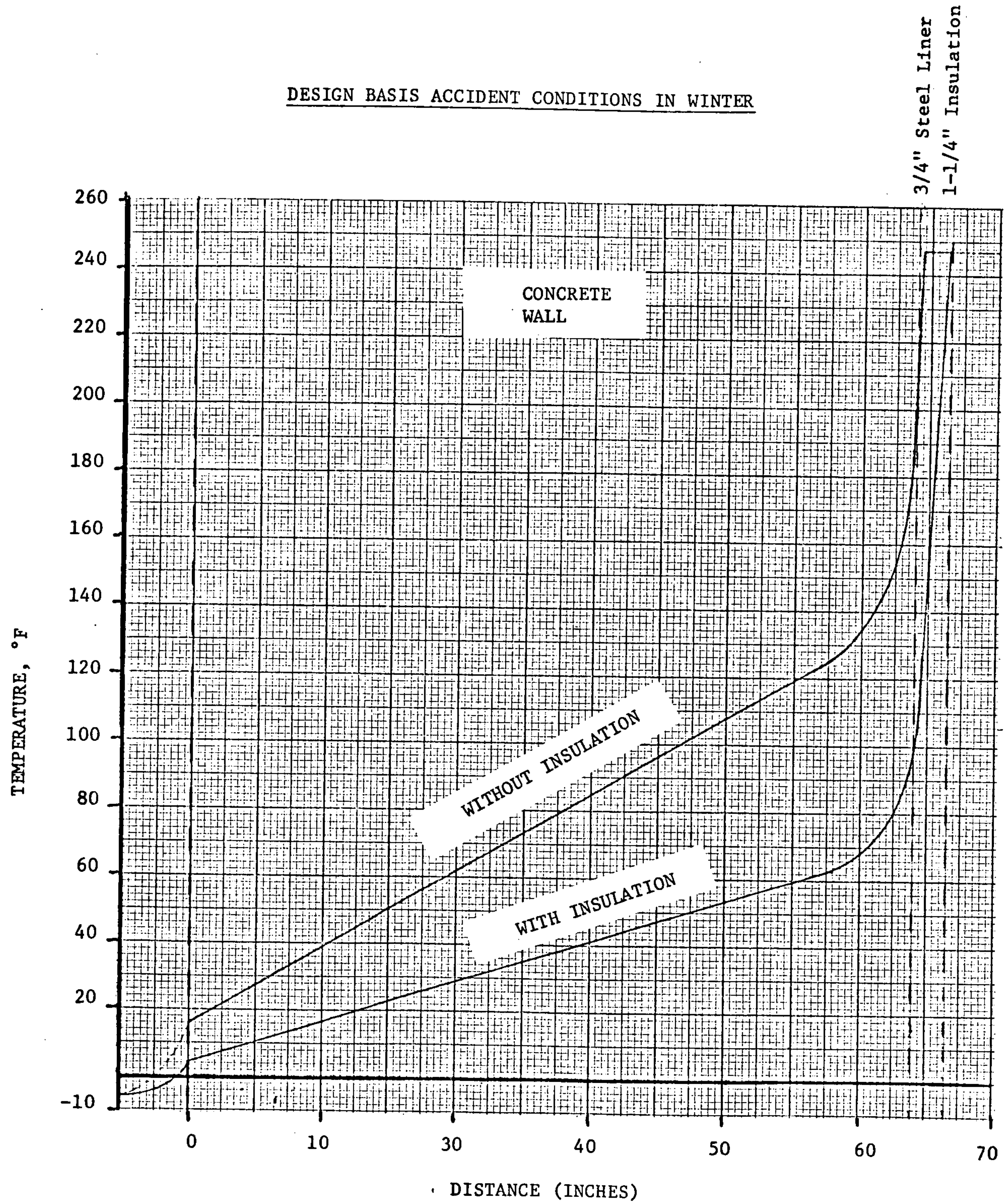

FIGURE 2.4(c)-3
Supplement 4

DESIGN BASIS ACCIDENT CONDITIONS IN SUMMER

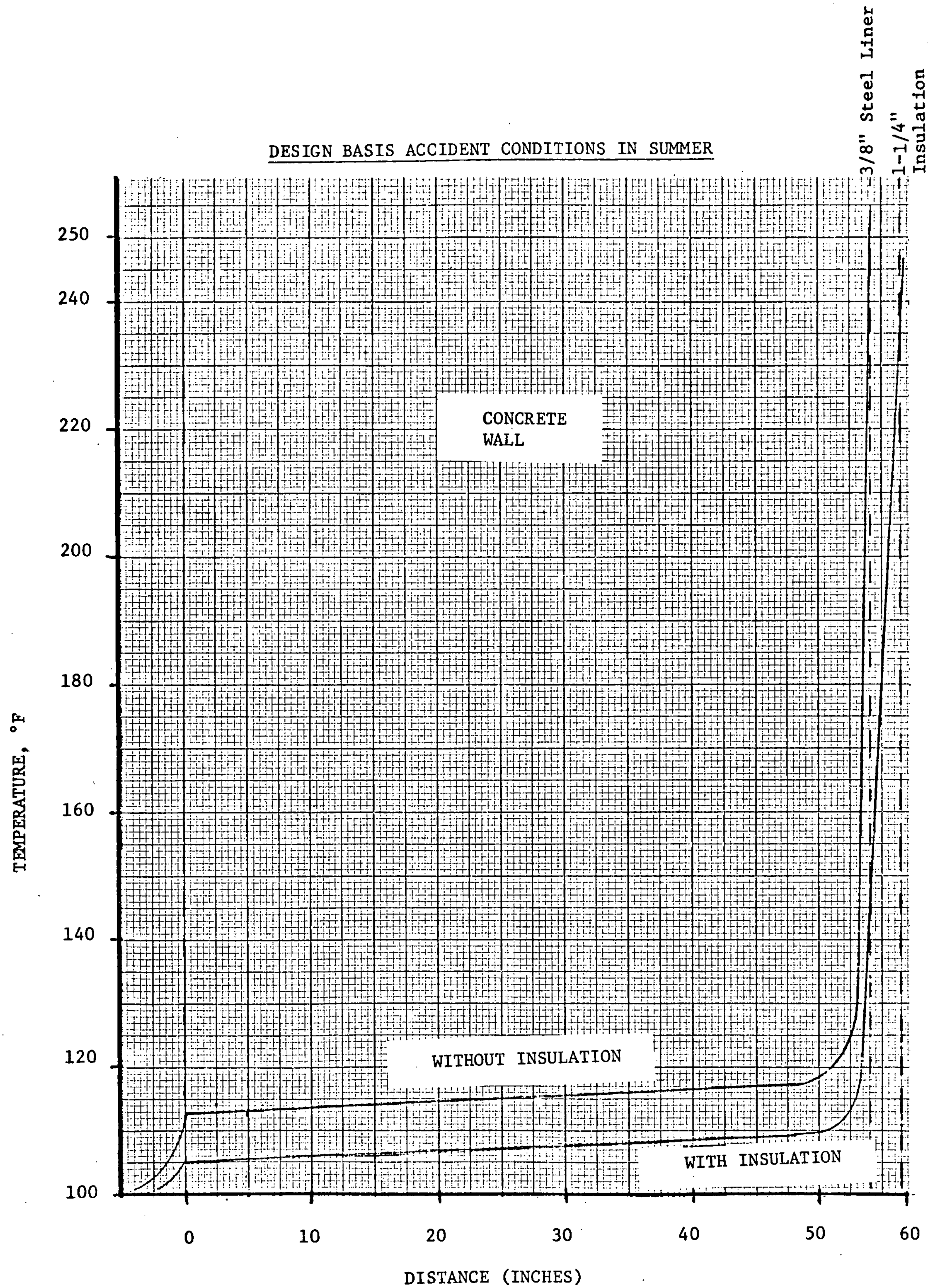

FIGURE 2.4(c)-4
Supplement 4

QUESTION 2.4(d)

For the containment structure, provide:

A description of how torsional loads will be handled.

ANSWER

For case I tornado loading shown in the answer to Question 2.1 (1) a torsional effect is induced into the containment structure.

This torsional effect results from wind striking the containment building at an angle α from the normal.

The torsional force is due to the component of the wind tangential to the surface of the containment building and is equal to:

$$F_t = AC_D\ (q)\ (\text{Sin}\ \alpha)$$

Where A = Surface area of the containment

C_D = 0.5 from A.S.C.E. Paper 3269 - "Transactions of the A.S.C.E. Vol. 126 Part II 1961, p. 1125(coefficient of drag)

$q = 0.002558\ V^2$ (wind pressure)

$\alpha = 45°$

This assumption is conservative in that the actual tangential force would be the result of skin friction and the effects would be negligible.

This component of torsional force is computed from a direct wind loading as based on A.S.C.E. Paper 3269.

Torsional shear is a maximum at the juncture of the walls and base slab and varies to zero at the top of the dome.

The torsional effect can be converted to a shear per lineal foot around the circumference of the containment by distributing the shear over the circumference of the seismic reinforcing.

The seismic bars provide a more than adequate mechanism to withstand this torsional effect. The maximum stress in the bars under this loading is 17 ksi. See Figure 2.4(d)-1.

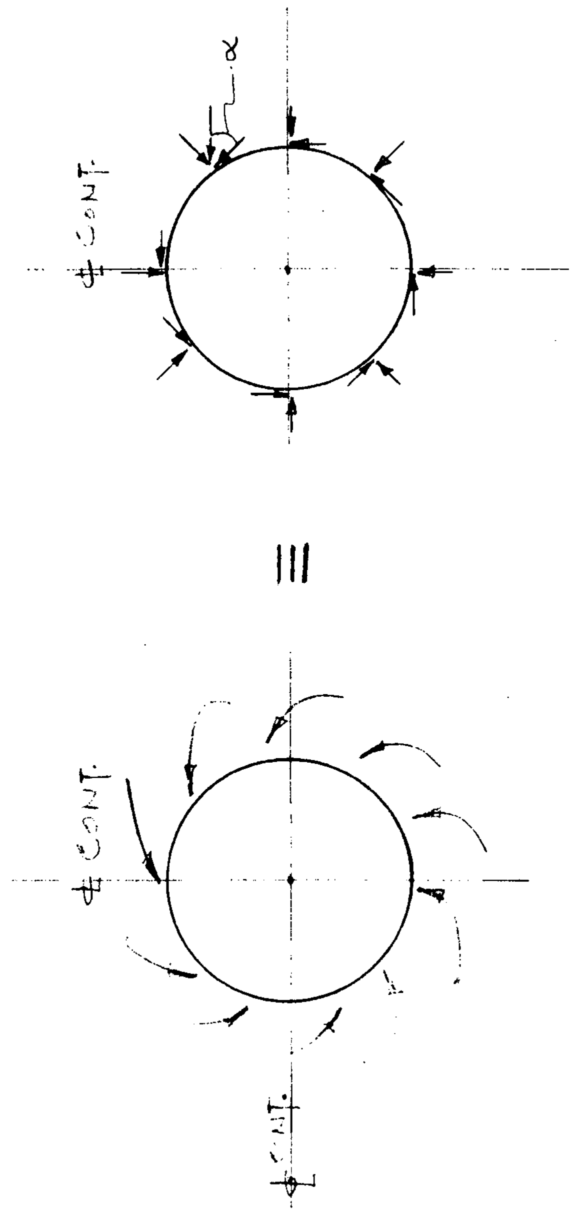

FIGURE 2.4(d)-1
Supplement 4

QUESTION 2.4(f)

For the containment structure, provide:

The values of E_c and μ_c for cracked and uncracked reinforced concrete structure for different elevations and explain their use in the design of the concrete shell and in thermal liner loading computations. Include the effect of shrinkage and creep. State whether the computer program to be used takes into account these variations of E_c and μ_c, and also axisymmetric loads.

ANSWER

The limiting cases in the design of the wall for discontinuity moments and shears were considered. One case looked at an uncracked wall and the other considered a cracked wall with the steel acting as a spring constant. The value of μ_c varied from zero in the cracked case to .14 in the uncracked case. Variations for E_c in the cracked case were discussed in the answer to Question 2.4(e). In the uncracked case variations in E_c will have no effect on the answer since E_c appears in both the numerator and the denominator of the stiffness formulation. For the above variation in E_c and μ_c, the values of discontinuity moment and shear vary by 14% and 7% respectively at the base. These are the maximum deviations of the wall forces since the wall will actually vary from uncracked to cracked with an increase in containment height rather than be cracked or uncracked for the total height.

In the area of thermal stress the entire wall section will be cracked and no variation in E_c or μ_c, need be considered. The liner stresses depend on the strains of the reinforcing steel and are not related to the concrete properties.

Shrinkage and creep effects will be relieved by cracking during the pressure test and will not be included in accident design considerations.

The finite element computer program has the capabilities of taking into account variations in μ_c and E_c and axisymmetric loads. However, it is not necessary to take into account the variations in μ_c and E_c for the reasons stated above.

QUESTION 2.4(g)

For the containment structure; provide:

Provide additional information on the proposed use of the one-third increase in allowable stresses. Use of this increase is not considered in keeping with normal practice, particularly with respect to the D + L + S + T loading. Discuss the problem and provide a criterion that considers biaxial and triaxial loading effects. Justify the values of shear (as a measure of beam strength in diagonal tension) for a structure of this type. Discuss the proposed design criteria in this area, keeping in mind possible biaxial tension stresses, and two dimensional cracking.

ANSWER

A one-third increase in allowable stresses will not be used for the containment structure.

QUESTION 2.4(h)

For the containment structure, provide:

Under incident conditions, concrete may be cracked and the crack pattern may be two-dimensional. Explain how, under this condition, the shears are transferred through the section, and justify the length required to anchor the reinforcing bars.

ANSWER

The arrangement of reinforcing bars in the containment shell is such that a reinforcing bar crosses any potential crack plane. Any cracks resulting from diagonal tension caused by shearing forces will be carried by reinforcing bars which span across the crack. Thus all shears will be carried by the reinforcing bars and none by the concrete.

The reinforcing bars are almost all continuous throughout the containment structure; however, where a bar terminates this is accomplished by means of a 180° hooked bar. In no case are bars simply terminated without providing means for additional anchorage.

QUESTION 2.4(i)

For the containment structure, provide:

The reinforcing steel may be stressed to the yield point. Justify the use of this stress which is larger than the guaranteed minimum yield point of the liner (32,000 psi). Clarify whether, under certain conditions, the liner may be stressed beyond the yield point.

ANSWER

In cases where the loading consists of pressure and no temperature rise the loads are shared proportionately by the liner and the reinforcing steel. The stress level in the liner is below .95 x 32,000 psi.

In areas of discontinuity where the rebar is highly stressed the liner will not act with the wall section since the studs are only capable of transmitting about 10% of the shear before they yield, thus relieving the liner. The liner will remain stressed below .95 x 32,000 psi while the rebar resists most of the discontinuity stresses.

During an accident condition the containment temperature will rise, heating the liner plate and inducing compressive stresses in the liner plate. The resulting combination of this compressive stress and the tensile stress due to the pressure, results in stresses in the liner which are within the yield point (.95 x 32,000 psi) of the plate.

In no case will the liner be stressed beyond the yield point.

QUESTION 2.4(j)

For the containment structure, provide:

Because of cracking of concrete due to shrinkage, to testing, to thermal stresses, and during an accident, the problem of adequate bar anchorage is of special concern. Provide information on how the reinforcing bars are anchored at certain critical points, such as: center of dome, intermediate terminal points of radial bars in the dome, bars provided to take discontinuity stresses, some diagonal bars, etc.

ANSWER

Throughout the dome the meridional reinforcing is continuous. After the springline is reached the bars extend radially toward the center of dome. As the bars reach a 6" spacing which is one-half the required spacing, alternate bars will be dropped off by means of reinforcing splice plates. The splice piece consists of a plate with two Cadweld sleeves welded on the incoming side and one sleeve welded on the outgoing side. Thus, the number of bars present is halved and the spacing is increased to the required 12".

This is repeated until the top of the dome is approached where a three layered grid pattern will be used to maintain the continuity of the rebar. The bars in the grid pattern will be Cadwelded to the same type reinforcing splice plates described above but the Cadweld sleeve will be beveled to obtain the desired direction of the grid.

At the base in the area of high discontinuity stresses additional #18S bars will be provided. At the point where they are no longer needed they will be Cadwelded to a #11 bar which will be terminated with a 180° hook.

All seismic bars will be terminated in a 180° hook. In no case will an #18S bar be terminated in this way since the minimum 180° hook could not be provided in a 4'-6" thick wall.

Radial shear reinforcing stirrups will be terminated by hooking around vertical bars.

QUESTION 2.8(a)

With respect to liner design, describe:

Types and combinations of loading considered with regard to liner buckling and the safety factors provided. Include the influence of large tangential strains due to cracks in the concrete under the load combination that includes accident and earthquake loads.

ANSWER

The buckling of liner plate has been investigated with respect to normal operation, proof testing and accident conditions. The loads involved will be pressure, thermal, dead, and seismic. Under the worst loading condition $(C = 1.0D \pm 0.05D + 1.5\ P + 1.0\ (T + TL)\ )$ the liner stress reaches 30.4 ksi in the 1/2" plate, the critical buckling stress is 38.4 ksi, for the 3/8" plate the stress is 26.4 ksi and the critical buckling is 38.1 ksi, therefore providing a factor of safety against the possibility of the occurrence of elastic buckling.

For buckling analysis, see Answer to Question 2.8(b).

The largest anticipated crack is 1/16 of an inch. Cracks of this magnitude would have negligible effect on the liner.

QUESTION 2.8(b)

With respect to liner design, describe:

The geometrical pattern, type, and spacing of liner attachments; and the analytical procedures, boundary conditions, and results with respect to buckling under the loads cited above.

ANSWER

The liner anchorage for the cylinder will be 1/2" diameter bent welding studs. The spacing in the region of the lower 1/2" thick liner plate will be 28" vertical and 24" horizontal. Studs will be spaced at 14" vertical and 24" horizontal in the region of 3/8" thick liner plate. In the dome the liner will be stiffened on the outside by structural tees spaced at a maximum of 5'-0" in each direction with a 1/2" diameter stud in the center of each 5'-0" x 5'-0" panel.

The boundary conditions in the cylinder are determined by assuming a buckling model (shown in Figures 2.8(b)-1 through 2.8(b)-3) in which the studs form the low points and the center of the panels form the high points of a series of peaks and valleys thus forming a set of panels whose edges represent points of inflection. The analytical procedure used is a simply supported plate under biaxial compression. A Mohr's circle analysis is used to find the normal and shear stresses on this simply supported plate. The critical buckling stress is derived considering a plate whose length is equal to 1/2" of the diagonal distance between studs. This critical buckling load is 38.1 k/in^2 for the 3/8" liner and 38.4 k/in^2 for the 1/2" liner, which is higher than the yield strength of the liner, 32 ksi; therefore, the liner plate will begin to yield before the critical buckling stress is reached, and buckling failure does not control the design. Since shear reduces the stability of a plate subjected to compressive stresses, critical shear is considered and it was found that critical buckling is controlled by normal stresses rather than shear stresses. This is determined by considering the magnitude of both the normal and the shear stresses on the panel. The magnitude of the shear is so low that it shows no effect on the previously stated critical buckling stresses.

In the dome the liner will be considered clamped at the stiffeners forming a 5'-0" x 5'-0" grid panel pattern. The center of each panel is fixed by a stud. Assuming points of inflection at the 1/4 point a distance of 1'-3" occurs between points of simple support. The critical buckling load is 58.1 k/in^2 which is also higher than the yield strength of the liner.

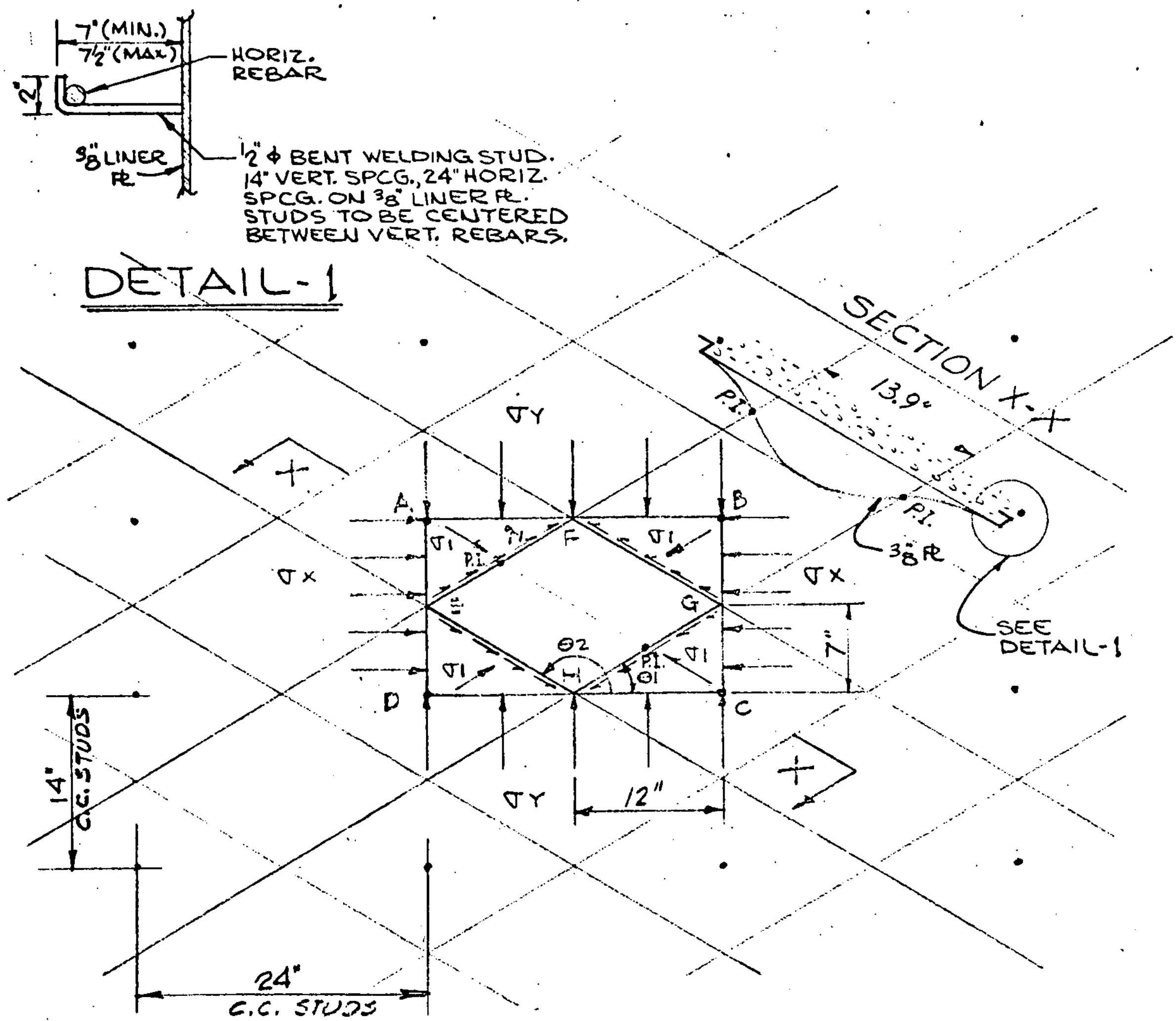

FIGURE 2.8(b)-1

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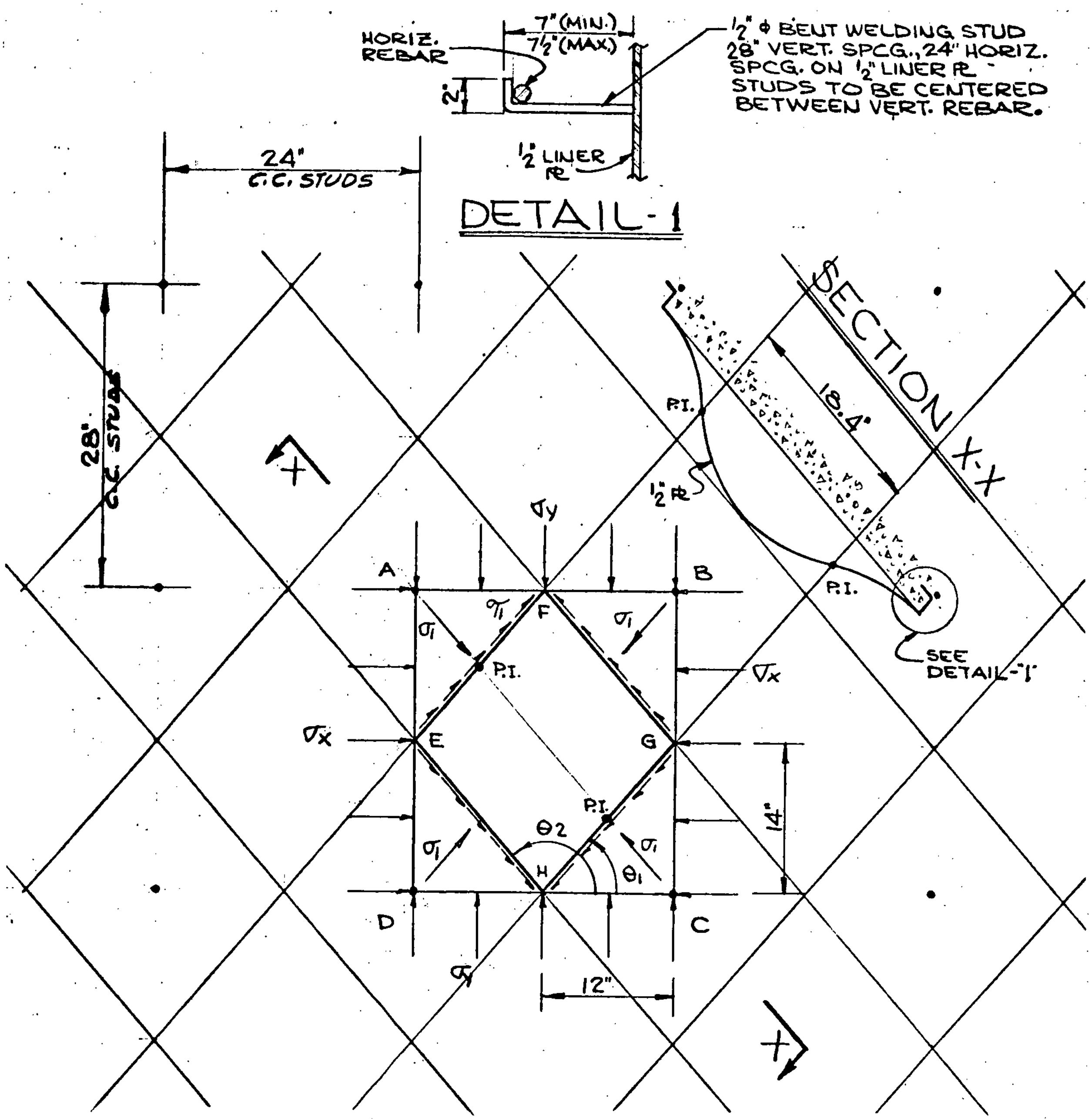

FIGURE 2.8(b)-2

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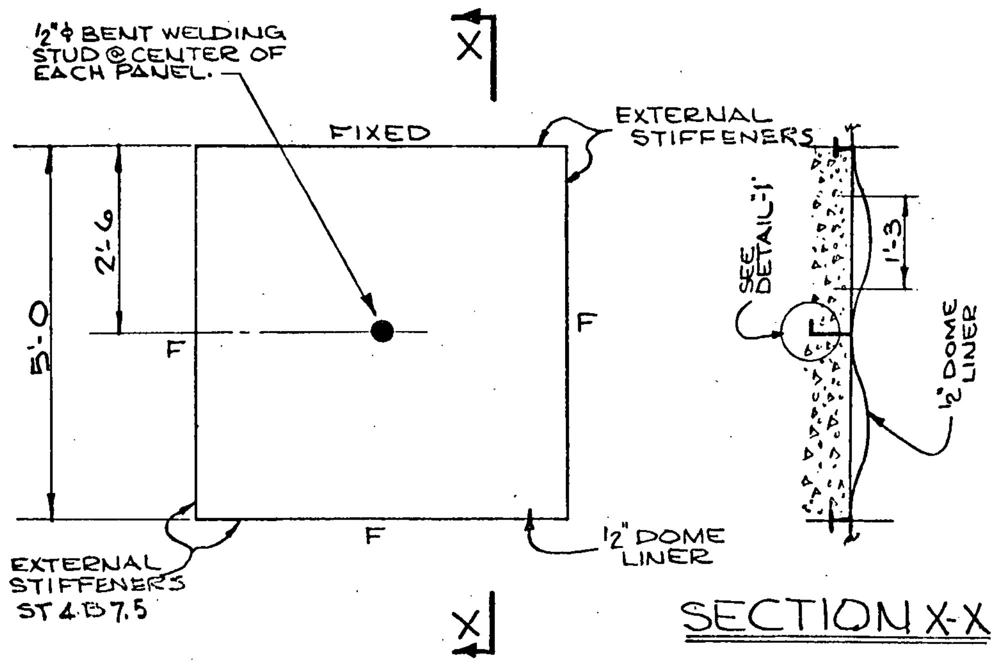
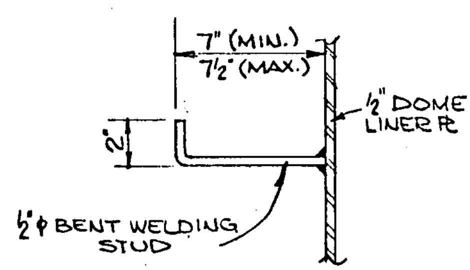




DETAIL 1

FIGURE 2.8(b)-3

Supplement 4

QUESTION 2.8(c)

With respect to liner design, describe:

Tolerances on liner plate thickness and liner yield strength variation and the bases for the selected values.

ANSWER

The liner plates will be ordered to conform with ASTM Specification A-442-66 in regard to thickness tolerances as listed below:

1/4" plate	0.240 in. to 0.276 in.
3/8" plate	0.365 in. to 0.405 in.
1/2" plate	0.490 in. to 0.530 in.

All liner plate material conforms to ASTM A-442 "Standard Specification for Carbon Steel Plates with Improved Transition Properties," Grade 60, and will have a minimum yield strength of 32,000 psi and a minimum tensile strength of 60,000 psi. No upper limit for the yield point of the material is specified.

QUESTION 2.8(d)

With respect to liner design, describe:

The possibility of elastic and inelastic buckling especially at base of the wall. Provide sample calculations showing the influence of all pertinent parameters, such as:

- Variation of plate thickness;
- Variation of yield point of liner steel;
- Influence of Poisson's ratio for steel;
- Erection inaccuracies (local bulges, offsets at seams, wrong anchor location);
- Creep of concrete;
- Shrinkage of concrete;
- Variation of Young's modulus and Poisson's ratio for cracked and uncracked concrete, and as a function of stress level in concrete (elastic and plastic);
- Ground water infiltration, earthquake, temperature loading, etc.

ANSWER

The base of the wall is insulated and therefore not subjected to high temperature rises which cause large liner compressive stresses.

Plate temperature stresses will vary almost inversely with the plate thickness when considering full restraint on the growth of the plate. For the plate with the minimum thickness variation of -3% the temperature stresses will add 6% to the nominal stresses. In the plate with maximum thickness variation of +10%, temperature stresses will decrease nominal stresses by 6-1/2%. In no case will the stress change be sufficient to cause buckling of the liner plate.

It is possible, due to variation inherent in commercially purchased steel, to have an increase of as much as 25% in the yield point of the steel. However, analysis shows that stresses are below the specified minimum for this material.

The design analysis for the liner considers Poisson's Ratio for steel. The inclusion of Poisson's Ratio results in compressive biaxial stress values in the plate higher than what would have been indicated if Poisson's Ratio for the steel had been neglected; and, therefore, results in a more realistic liner design.

Local bulges and plate offsets will be controlled by specification limitations which minimize any effects on liner design considerations.

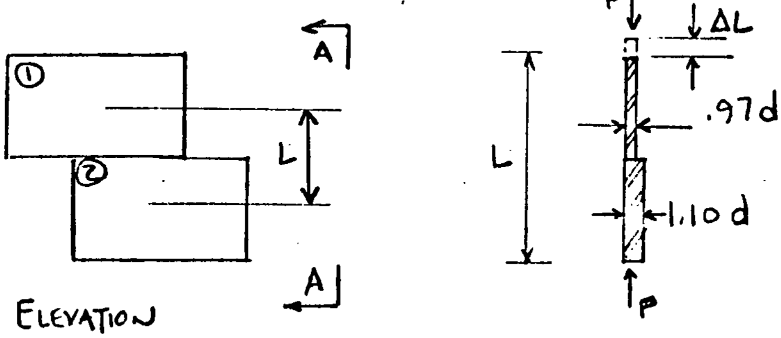
Any creep or shrinkage of the concrete causing compression of the liner will be alleviated during the pressure test when the concrete will be cracked. Therefore, shrinkage or creep are not problems.

In the areas where buckling effects are of concern, the concrete will be cracked due to membrane tensile stresses and the thermal and buckling calculations will be based on Young's Modulus and Poisson's Ratio for steel and variations in concrete properties have no effect.

The answer to Questions 2.3 and 4.4 indicate that ground water infiltration is not a problem for this containment structure. Earthquake and temperature loading variations are part of the normal load evaluation and have been considered in the initial buckling investigation.

STRESS INCREASE IN LINER DUE TO THICKNESS VARIATIONS

PLATE THICKNESS TOLERANCE +10% −3%



AREA FOR 1" STRIP

$A_1 = .97d$

$A_2 = 1.10d$

IF LINER WERE FREE TO EXPAND WITH INCREASE OF ΔT

$\Delta_L = \alpha \Delta T L$ $\qquad$ α: COEF. OF THERMAL EXPANSION

P = FORCE TO COMPRESS PLATES

ASSUME ½ DEFLECTION IN PLATE ① (Δ_1) AND ½ IN PLATE ② (Δ_2)

$$\therefore \quad \Delta_L = \Delta_1 + \Delta_2$$

$$\alpha \Delta T L = \frac{PL}{2A_1 E(1-\nu)} + \frac{PL}{2A_2 E(1-\nu)}$$

$$2\alpha \Delta T E(1-\nu) = \frac{P}{A_1} + \frac{P}{A_2}$$

$$(2\alpha \Delta T E)\left(\frac{A_1 A_2}{A_1 + A_2}\right)(1-\nu) = P$$

$$(2\alpha \Delta T E)(1-\nu)\left(\frac{.97d \cdot 1.10d}{.97d + 1.10d}\right) = P$$

$$P = 1.03d\, E \Delta T \alpha (1-\nu)$$

IF $d_1 = .97d$

$$\underline{\underline{\sigma_1 = 1.06\, E \Delta T \alpha (1-\nu)}}$$

IF $d_2 = 1.10d$

$$\underline{\underline{\sigma_2 = .935\, E \Delta T \alpha (1-\nu)}}$$

QUESTION 2.8(e)

With respect to liner design describe:

The stress and strain limits used for the liner, the bases for these limits, and the extent to which these limits relate to liner leakage.

ANSWER

The liner will be limited to a stress of 95% of yield which is 30.4 ksi and a strain of .00105. Since the loads have a load factor already incorporated into them the 95% serves as a capacity reduction factor which takes into account any deficiencies in workmanship, fabrication, or erection. This limitation is patterned after Part IVB of the ACI-318 Code and is consistent with the design limits of the other containment structural elements.

The minimum elongation in 2 inches for the liner material is 23% assuring a large margin from anticipated strains and thereby limiting liner leakage.

QUESTION 2.8(f)

With respect to liner design, describe:

The type, character, and magnitude of cyclic loads for which the containment liner will be designed. Discuss the pressure/thermal load variations considered and include an evaluation of the number of cycles generated by earthquakes.

ANSWER

The cyclic loads for which the liner will be designed will occur as a result of change from shutdown to operating conditions and proof tests. This would result in approximately 50 cycles.

Daily changes in ambient temperature will not penetrate a significant distance into the concrete shell due to the insulating value of the concrete. Consequently, liner stress variations are minimized.

In the analysis of the liner, a time increment study was used to find the effect of the temperature pressure interaction. For this purpose the entire liner analysis for all loading conditions and at all points shown in Figure 2.8(f)-1 under consideration in the wall was looked at for 0, 2, 5, 10, 20, 50, 100, 400, 800, 1000, 2000, 4000, 6000, 8000, and 10,000 seconds following an accident.

The number of significant load cycles associated with a strong motion earthquake may vary in the range of 25 to 200 cycles depending upon the frequency response of the structure and the degree of structural dampening as well as input motion of the earthquake.

For the liner which acts compositely with the containment shell, cyclic loading in the range of 25 to 50 cycles would be expected.

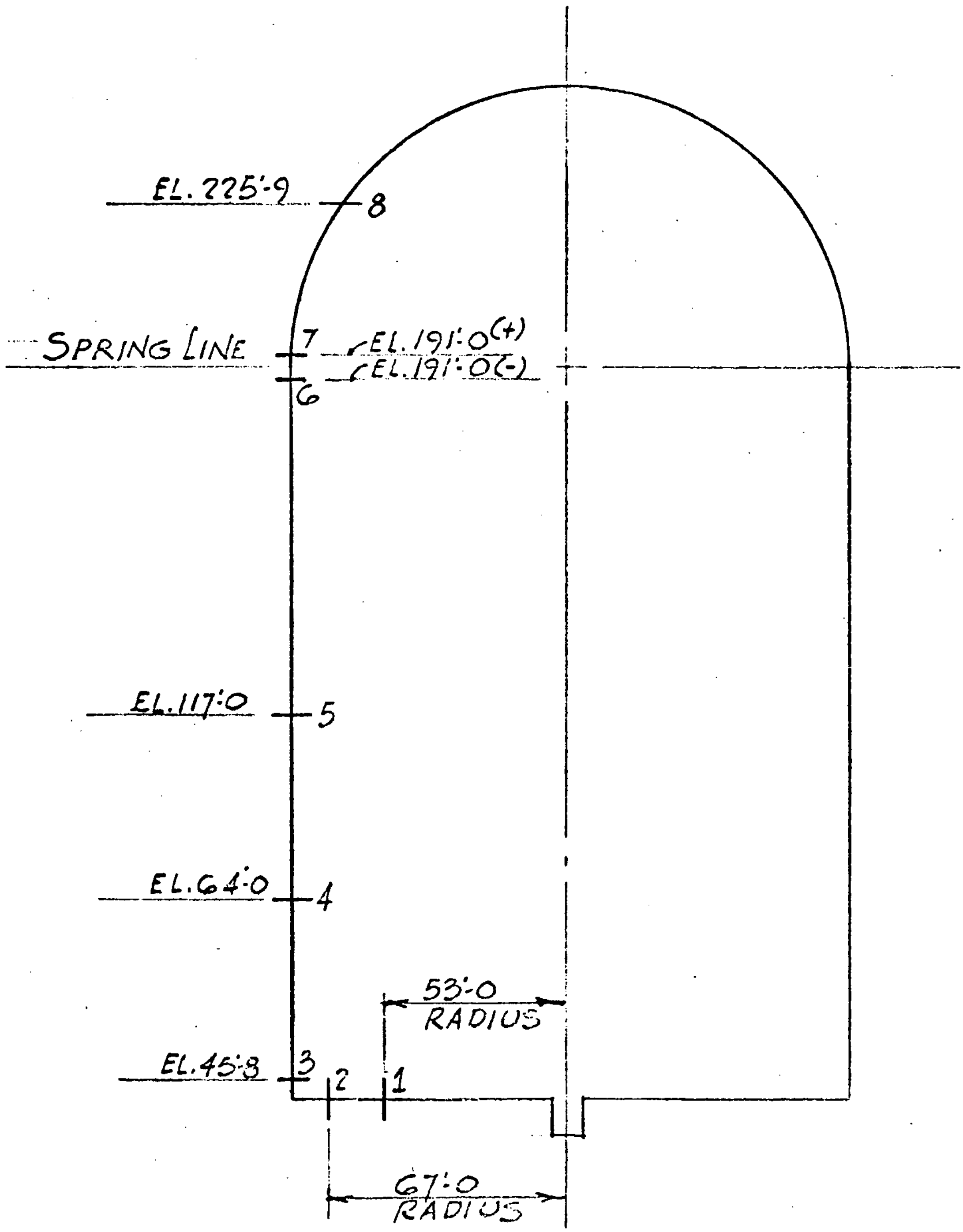


FIGURE 2.8(f)-1

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QUESTION 2.8(g)

With respect to liner design, describe:

How, if the effect of temperature rise on the liner is to be represented by a uniform pressure increase, this approach is justified.

ANSWER

The effect of temperature rise on the liner will not be represented by a uniform pressure increase. Temperature effects are determined by considering consistent deformation of the wall and liner and equilibrium of the forces.

QUESTION 2.8(h)

With respect to liner design, describe:

How variations in liner thickness and yield point are taken care of in the design.

ANSWER

Refer to the answer to Question 2.8(d) of this supplement.

QUESTION 2.8(i)

With respect to liner design, describe:

The plastic strains that the liner material can accommodate without cracking.

ANSWER

The specified minimum elongation of the liner plate material is 23% in 2 inches. Since the liner membrane stresses will never exceed .95 x yield, the liner will never have to accommodate any plastic strains.

QUESTION 2.8(j)

With respect to liner design, describe:

The design approach that will be used where loadings must be transferred through the liner, such as at crane brackets or machinery equipment mounts. Provide typical design details and computations.

ANSWER

There are no significant structural loadings which must be transferred through the liner such as those required for crane brackets or machinery equipment mounts. Miscellaneous spray system piping, instrumentation, conduit, and insulation which are attached to the liner can be supported by the free standing liner without inducing significant stresses in the liner or liner anchorage.

QUESTION 2.8(m)

With respect to liner design, describe:

Describe the procedures for analysis of liner stresses around openings. Also, provide the method of liner design to accommodate these stresses and the related stress limits. Justify the proposed thickening of the liner at penetrations. Discuss the liner anchors at this location.

ANSWER

The liner stress around openings was analyzed by considering the interaction between the liner and the penetration sleeve (See Figure 2.8(m)-1). An expression was written for the unrestrained growth of the liner with the conservative assumption that the liner is stressed to the yield point. The restraint offered by the penetration sleeve was considered by equating the deflection of the penetration sleeve plus the restrained deflection of the liner to the unrestrained growth of the liner. From this equation an expression for the stress in the liner is developed. In no case does this stress approach the stress unit of .95 x 32,000 psi in the liner.

In accordance with the ASME Section VIII Pressure Vessel Code, the cut out area of the liner plate will be replaced by thickening the plate directly around the opening.

The liner stud arrangement and installation method used adjacent to the penetrations will provide sufficient flexibility of the liner at the penetration openings to absorb any expansion forces imposed by the penetration sleeves.

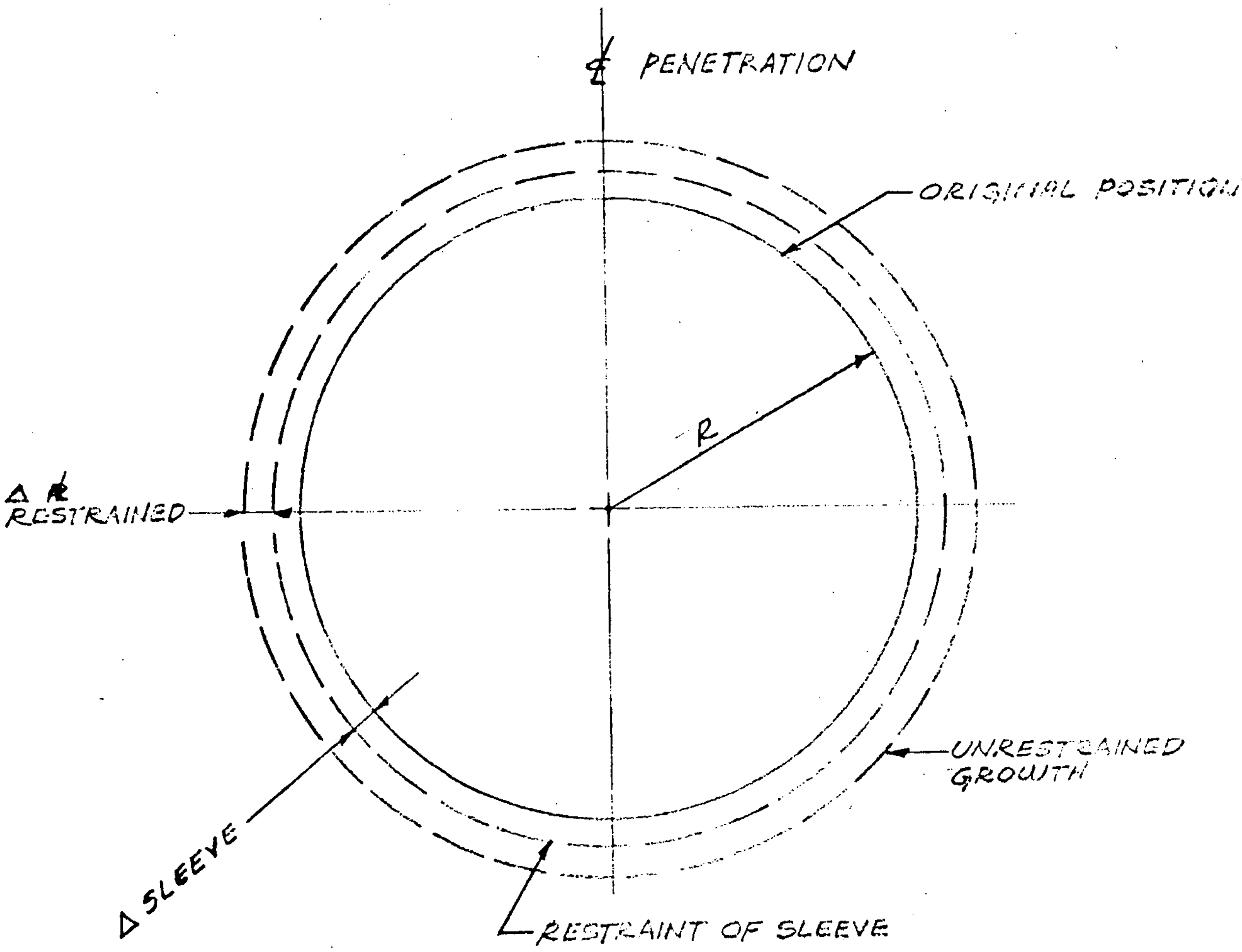


FIGURE 2.8(m)-1

Supplement 4

QUESTION 2.9(a)

For the design of the liner anchorages, describe:

The analytical procedures and techniques to be used in the anchorage design including sample calculations.

ANSWER

The anchor must resist tensile and shearing loads. Tests indicate the lateral load needed to prevent column buckling is 1% of the axial yield load. Conservatively doubling this value to account for uncertain field conditions, a value of 2% will be used*. The total load per plate would be 24 in. x 1/2 in. x 32,000 psi = 384,000 lbs. Therefore, the tensile load per anchor is 384,000 lbs. x .02 = 7,680 lbs. which yields a stress of 7680/.2 = 38,400 psi.

This compares with a yield value of 52,000 psi and a tensile strength of 65,000 psi in the studs. This does not consider the internal pressure which provides further stability against buckling.

The shear load on the anchor will be due to the strain in the liner. Assuming the liner approaches its yield strain of .1%, the anchor deflection would be 28" x .001 = .028". Tests on the stud anchor have shown a maximum deflection of about .1" can be tolerated before failure of the stud.**

* Plastic Design of Steel Frames by Lynn S. Beedle, p. 131, Copyright 1958, second print, 1961.

**Design data - Nelson Concrete Anchor - printed 8/1/61.

QUESTION 2.9(b)

For the design of the liner anchorages, describe:

The failure mode and failure propagation characteristics of anchorages. Discuss the extent to which these characteristics influence leaktightness integrity. Indicate what design provisions will be incorporated to prevent anchorage failures from jeopardizing leaktight integrity.

ANSWER

The anchorages can fail by failure of the studs in shear or tension, by studs pulling out from the concrete or by studs separating from the liner plate. The most likely mode of failure is by tensile failure of the stud. The anchors will be designed so that failure occurs in the anchor rather than the plate, thereby insuring that the leaktight integrity of the containment liner will be maintained. See Supplement 3 of Indian Point Unit No. 2 PSAR and "Design Data - Nelson Concrete Anchor."

If failure should develop, it would be a random stud failure due to poor workmanship during stud attachment. This failure would not impair the liner integrity nor would it cause progressive failure. See answer to Question 2.9(a).

QUESTION 2.9(c)

For the design of the liner anchorages, describe:

How elastic and inelastic buckling of the liner will be considered in the design of the anchors. Discuss the possibility of unbalanced loads acting in one or several anchors and provide a study showing that no chain reaction can occur and that massive buckling of the liner, and mass failure of anchors, is excluded.

ANSWER

The answer to Question 2.9(a) shows that elastic and inelastic considerations for the liner will be considered in the spacing of the studs.

It is shown in the answer to Question 2.9(a) that at maximum strain in the liner, the studs will not fail. This maximum strain due to an unbalanced load would occur in a panel adjacent to a buckled panel. Since this adjacent stud will not fail, no zipper effect will occur and massive buckling of the liner and mass failure of anchors is not credible.

QUESTION 2.9(d)

For the design of the liner anchorages, describe:

Anchorage and weld sizes and spacings.

ANSWER

Anchors will be 1/2" diameter bent welding studs at a 14" vertical spacing and 24" horizontal spacing in the region of 3/8" liner plate. In the 1/2" thick liner plate region, a 28" vertical and 24" horizontal spacing will be used. The first course of studs will be at El. 44'-7-3/4". Studs will be centered between vertical bars. In the dome 5'-0" x 5'-0" panels will be anchored in the center by studs and by T-bars at the edges.

The 1/2" diameter bent welding studs will be 9" long minimum and 9-1/2" long maximum with a 2" - 90° hook at the end.

An arc stud welding process will be used on all bent welding studs.

QUESTION 2.10(a)

With regard to penetration design, describe:

The design criteria that will be applied to ensure that, under postulated design basis accident conditions, potential resultant torsional, axial, bending, or shear piping loads will not cause a breach of the containment. Include the design criteria intended to prohibit pipe rupture between the penetration and containment isolation valves. Specify the codes that will be used. Provide design details for typical penetrations to illustrate how the criteria will be applied.

ANSWER

To insure that a loss-of-coolant accident does not result in a breach of containment by causing a failure of one or more pipe penetrations through the containment building wall, the following methods will be used:
All auxiliary piping attached to the reactor coolant system which passes through penetrations in the containment building wall must also pass through the circular secondary shield wall approximately fifteen feet inside the building as illustrated in Figure 2.10(a)-1. The total number of pipes in this category is very limited. They will be examined individually and suitable restraints or anchors will be used either at or within the secondary shield wall to prevent a loss of coolant accident or a failure of one of these pipes within the secondary shield wall from causing the failure of the building penetrations through which the pipes pass. In some cases, it is physically impossible for any conceivable movement of the end of these pipes attached to the primary coolant system to be reflected at the building penetration and impose other than ordinary operating loads at these points. In other cases, it may be necessary to design restraints for the pipes at the secondary shield wall to withstand the failure of the pipe within the wall in tension. Some auxiliary pipes attached to the reactor coolant system are attached at points which will not move; for instance, the reactor coolant pump seal water injection pipes and the steam generator blowdown pipes. In general, these will have restraints at the secondary shield wall designed for normal loads plus the reaction forces resulting from the double ended rupture of these pipes within the shield wall.

All containment building piping penetrations will be designed as anchors for the pipes passing through them and will transmit piping loads to the reinforced concrete wall. The anchorage strength will exceed the maximum combined forces imposed by the effects on the piping penetration of dead loads, loads induced from a loss of coolant accident, thermal expansion of the pipe, penetration air pressure, and earthquake loads. The piping penetration will be designed to transmit the above combined loadings to the concrete structure without exceeding the yield strength of penetration steel. Typical penetration details are shown in Figure 2.10(a)-2. Load transfer from the pipe to penetration anchorage will be limited to the actual loads induced or to the ultimate strength capacity of the pipe in bending, shear, axial, or torsional loadings.

All piping penetrating the containment will meet the requirements of the USAS B31.1.0 Power Piping Code. In the case of the main steam and feedwater lines, the supports, inside and outside the containment building to the second isolation valve, will be designed so that a failure of any one of these pipes will not result in breach of containment or the failure of any other main steam or feedwater pipe between the steam generator and the second isolation valve.

The design of all containment building piping penetration sleeves and end plates will be in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII.

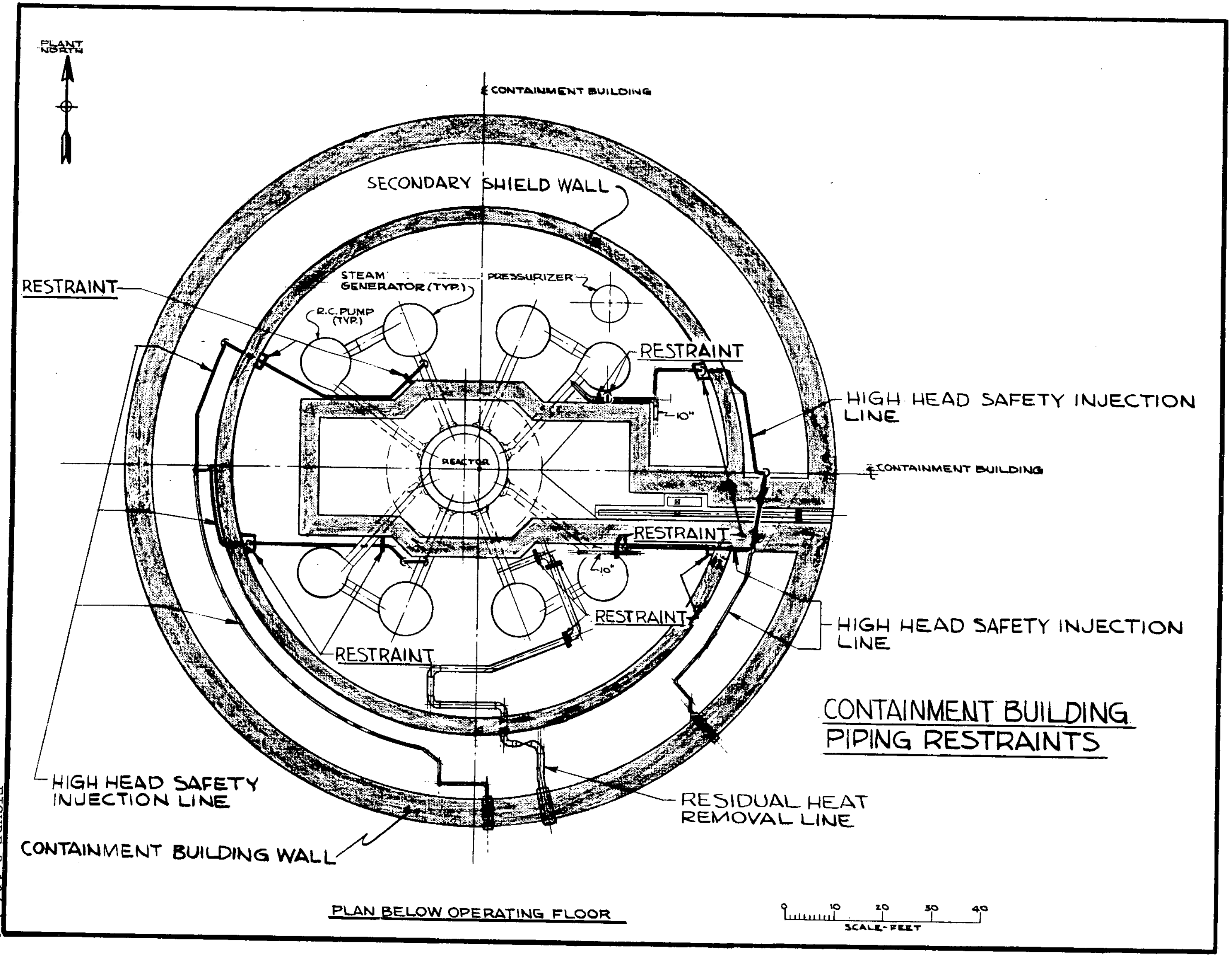
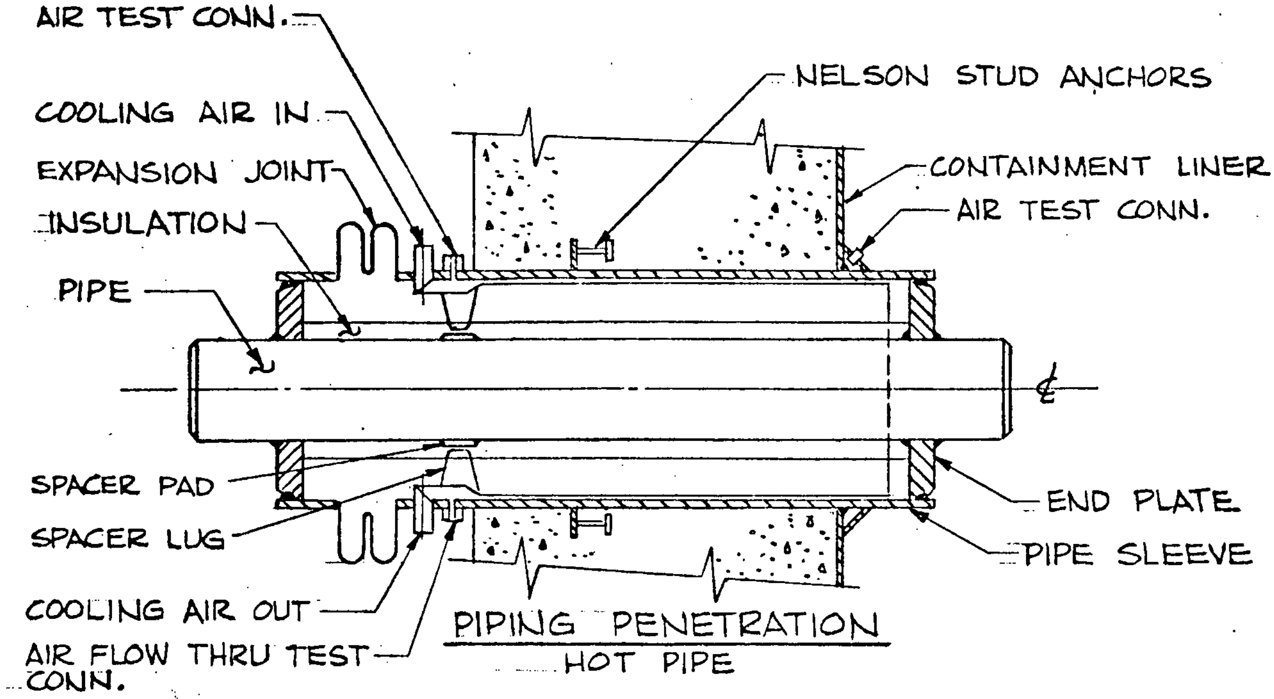
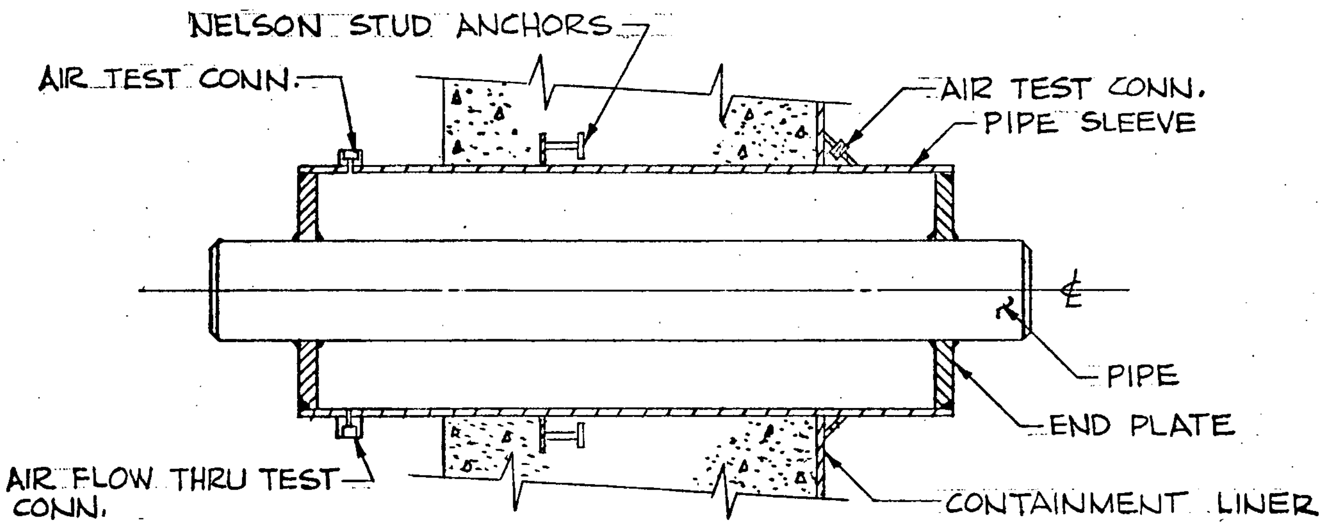


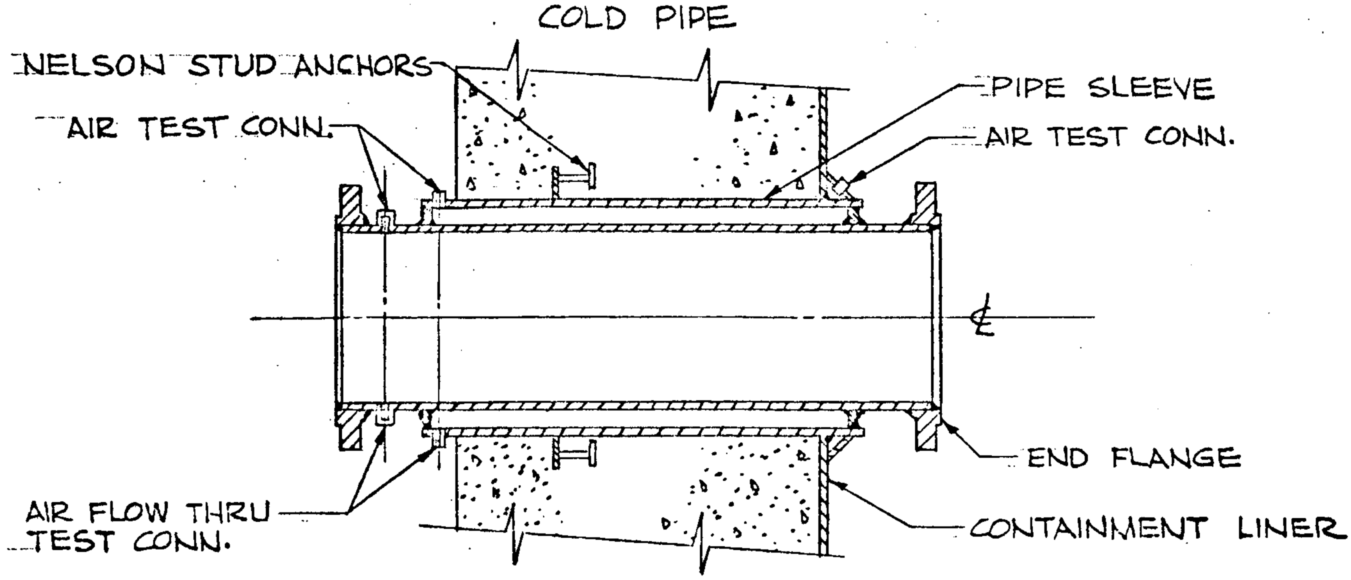
FIGURE 2.10(a)-1
Supplement 4



PIPING PENETRATION
HOT PIPE



PIPING PENETRATION
COLD PIPE



PIPE PENETRATION
PURGE PIPING

FIGURE 2.10(a)-2
Supplement 4

QUESTION 2.10(b)

With regard to penetration design, describe:

The extent to which the penetrations and the applicable surrounding liner regions will be subjected to vibratory loading from equipment attached to the piping systems. Indicate how these loads will be treated in design.

ANSWER

Pipes which penetrate the containment building wall and which are subject to machinery originated vibratory loadings,such as the reactor coolant pumps, will have their supports spaced in such a manner that the natural frequency of the piping system immediately adjacent to the penetrations will be greater than the dominant frequencies of the pump. Pipe line vibration will be checked during preliminary plant operation; and where necessary, vibration dampers will be fitted. This checking and fitting will effectively eliminate vibrating loads as a design consideration.

QUESTION 2.10(c)

With regard to penetration design, describe:

Criteria for concrete thermal protection at penetrations; include the temperature rise to be permitted in the concrete under operation conditions and the time dependent effect that loss of thermal protection would have on the containment's structural and leaktightness characteristics. Indicate the thermal gradients that will be used for design purposes.

ANSWER

All thermally hot pipes penetrating the reinforced concrete wall of the containment building will pass through sleeves approximately 6 inches in diameter larger than the pipe. In the resulting 3 inch annulus, thermal insulation will be applied to the pipe O.D., and a "heat shield" will be provided. The heat shield will be two embossed metal sheets welded and rolled to form a series of passes through which cooling air will flow. The hot penetration heat shield system will be designed to maintain the liner sleeve at or below 150°F.

Loss of cooling for the sleeve is highly improbable. The heat shield has no moving parts, and the cooling air will be at low pressure. There will be redundant blowers to assure that cooling air is not lost for a significant time. The blowers operate off a diesel bus and can be manually started following a blackout. The thermal insulation on the pipe wall will reduce heat flow to the liner sleeve. Operation of the cooling unit can be ascertained by opening the "flow through" connection of the penetration pressurization system on the penetration sleeve and observing the temperature of the cooling air emerging.

In order to lose significant structural properties, concrete must be held at 500°F to 600°F. The hottest penetrations are the main steam lines, which normally operate at a temperature of 507°F. It is tentatively concluded that a temporary loss of cooling to a thermally hot penetration will not result in excessive local concrete temperatures, on the basis that heat will be readily dissipated into the structure and surrounding atmosphere. An analysis will be made, however, to determine the steady state temperatures reached after a temporary loss of penetration cooling.

QUESTION 2.10(d)

With regard to penetration design, describe:

The capability of the penetration design to absorb liner strain without severe distress at the opening.

ANSWER

The liner stress at penetrations has been analyzed as discussed in the answer to Question 2.8(m). This liner stress is imposed on the cylindrical penetration as a circular uniform load acting around the circumference of penetration. The penetration thickness has been chosen to accommodate this load without causing severe distress at the opening.

QUESTION 2.10(e)

With regard to penetration design, describe:

The manner in which axial stresses, hoop stresses, shear stresses, bending stresses (in two directions) and shear stresses due to torsion will be combined in the plastic domain, if the full plastic strength of a pipe with regard to torsion, bending and shear is to be used. State the failure criterion to be used. Indicate how the exterior loads including jet forces will be combined. Give factored loading combinations for all the loads for all types of penetrations considered in the design. Explain how the Standard Code for Pressure Piping-Power Piping, B31.1.0-1967 will be used for these loading cases. Indicate whether factored load combinations will be used with this code.

ANSWER

In the design of the piping penetration sleeves and the piping going through them, maximum total stress in all cases will be limited to a value below the yield stress of the material involved; therefore, no plastic design criteria will be employed. In particular, piping whose failure would result in a loss of coolant accident and the main steam and feedwater pipe penetrations and pipe supports in the Containment Building are designed to prevent the formation of a plastic "hinge" in the pipe should any of these pipes rupture. This will be accomplished by effectively anchoring these pipes at 90° elbows connected to all these pipes adjacent to the penetration both inside and outside the building, and by restraining these pipes along their run inside the building and outside the building to the second stop valve. The anchors and restraints are designed to prevent a breach of containment at the piping penetrations should any of these pipes rupture inside, immediately outside, or within the penetration itself. The penetrations are designed to the strength of the pipe and no further considerations are necessary.

QUESTION 2.10(f)

With regard to penetration,design, describe:

For all penetrations, the criteria that will be used for the bending of reinforcing bars which have to clear the opening. Criteria defining maximum slopes and minimum bending radii to avoid local crushing of concrete should be included.

ANSWER

All reinforcing will be continuous around penetrations. Steps have been taken to insure that no local crushing of concrete will occur. From an article, "Detailing and Placing Reinforcing Bars" by Paul F. Rice from Concrete Construction January 1965, it has been determined that in order to prevent local crushing of the concrete a minimum bend diameter of 31 times the bar diameter is required when the reinforcing is stressed to yield. The angle of bend in the rebar determines the force which will be transmitted to the concrete in the event the bar tries to straighten out due to tension. For this reason most bars will be bent at 10° except at large penetrations including the equipment hatch, personnel lock, main steam and feedwater, and air purge penetrations, where the deviation of the bar from its centerline is too large to permit a 10° bend. In these cases the bars are bent at 30° but a tie back system will be used which will prevent a build-up of forces. To further prevent this build-up (in all cases except the equipment hatch penetration) the line of force will make an angle of one-half of the angle of bend, from a horizontal line from the vertical bars and from a vertical line for the horizontal bars and will be tangent to the outside of the penetration.

At the personnel and equipment hatches a large void will be created since, due to the large offset of the bars from their centerline, it will take the bars longer to return to their centerline after passing the penetration. To prevent any cracking and spalling of concrete and to add lost strength to the cross-section, these voids will be filled with added rebar which will achieve bond by means of mechanical anchorage.

The same precautions mentioned above will be taken with the seismic bars. For further reference see Figure 2.10(f).

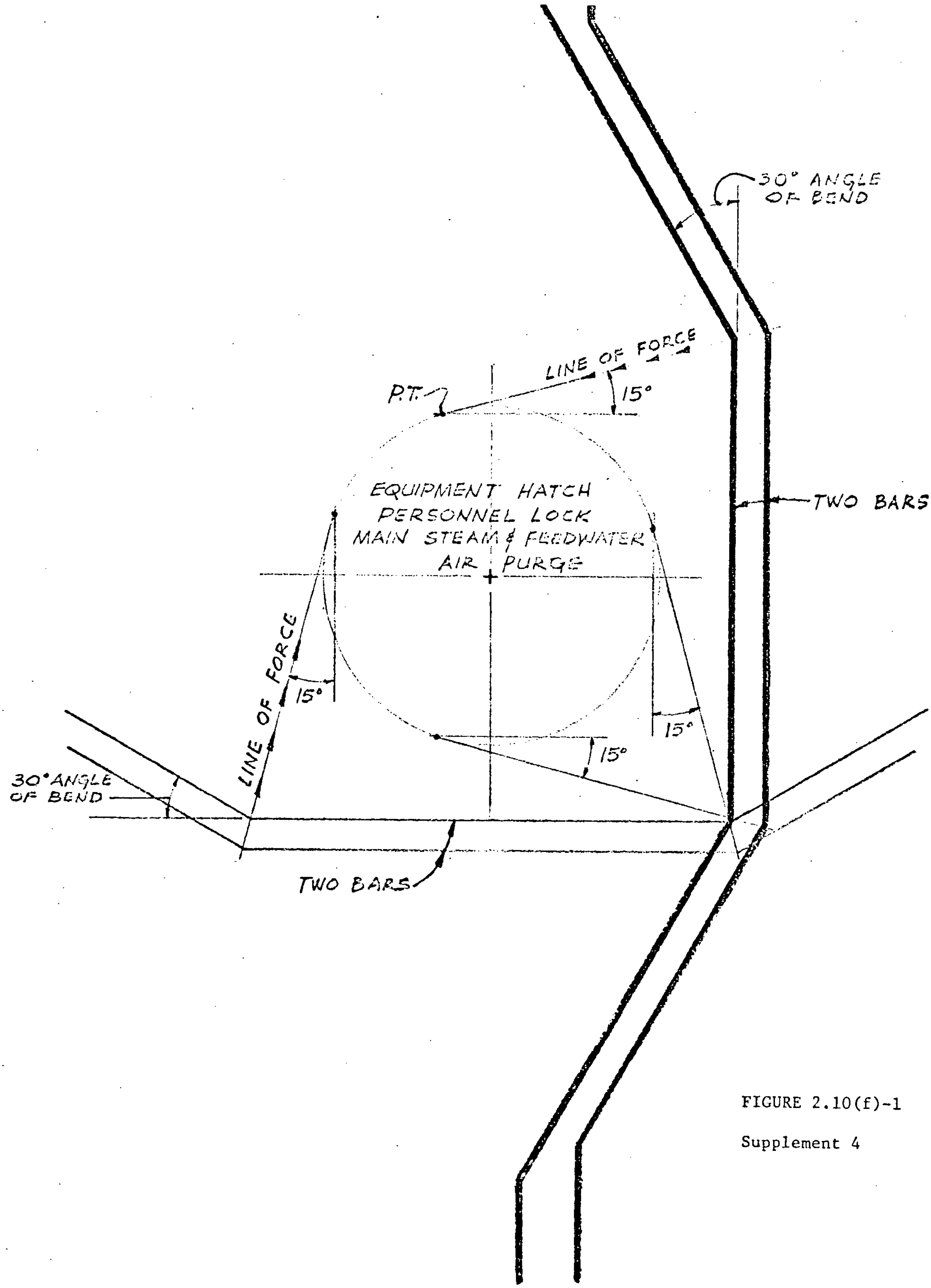


FIGURE 2.10(f)-1

Supplement 4

QUESTION 2.10(g)

With regard to penetration design, describe:

For penetrations between approximately 9 inches and 4 feet in diameter, expalin how normal, shear, bending and torsional stresses will be covered by the reinforcing bars.

ANSWER

For penetrations between 9" and 18", all the reinforcing bars including primary and secondary vertical bars and diagonal bars will be grouped around the penetrations. Due to the continuity of the bars and the relatively small opening size, no special provisions need be made to resist normal, shear and bending stresses. The penetrations will be keyed into the concrete, thus creating an edge loading which will put torsion into the wall. The loads will be small and the rebar will feel little effects from this torsional loading.

For penetrations greater than 18" to 4'-0" the bars will be continuous. Due to the large angle of bend of these bars, a tie back system will be used which will offer additional resisting strength to shear bending and torsional stresses. See Figure 2.11(b)-2 in the answer to Question 2.11(g) for a sketch of this additional reinforcing.

QUESTION 2.11(a)

For large openings, describe:

Criteria with regard to opening sizes that constitute large openings; hence, meriting special design consideration. List the number and indicate the size of the large openings for the containment.

ANSWER

Any opening larger than 4'-0" in diameter constitutes a large opening, hence merits special design consideration.

There are only two large openings in the containment building, the personnel lock opening in the southeast quadrant which is 8'-6" in diameter and the equipment hatch opening in the northeast quadrant which is 16'-0" in diameter.

QUESTION 2.11(b)

For large openings, describe:

The primary, secondary, and thermal loads that will be considered in design of the openings.

ANSWER

The primary and thermal loadings considered in the design will be the same as those indicated in Chapter 5 of the PSAR.

Secondary stresses on the boss around the large openings result from the peripheral forces imposed by the penetration itself. In the cases of the equipment and personnel hatches, the ends distribute the accident pressures as uniform peripheral loading per foot. This loading being eccentric to the centroid of the boss creates a torsional moment per foot of length. This torsional moment produces torsional shears in the rectangular cross section of the boss which must be combined with other shear stresses. Both will be taken by stirrups. In addition, because of the curvature of the ring, an additional moment is created. Reinforcing steel will be placed in the boss to resist this moment.

QUESTION 2.11(c)

For large openings, describe:

The stress analysis procedures that will be used in design.

ANSWER

The stresses in the region of openings are determined by use of a finite element computer porgram.

The vessel as a whole, with square openings substituted for circular is analyzed. The substitution is mainly to facilitate the layout of node points around the opening. The vessel is assumed axisymmetrical and only half of the vessel is taken into consideration in the analysis.

Then a region surrounding the hatch is analyzed by making elements much smaller than those used above, and by using the displacements and rotations of the node points situated around the border lines of the region as boundary conditions. The displacements and rotations of node points which are situated in between the initial node points are obtained by interpolation. Only one quadrant of the opening is taken in the analysis. The thickened wall section around the hatch is idealized into 10 layers of steel and concrete. The arrangement of the node points are shown in Figures 2.11(c)-1 and 2.11(c)-2.

The computer program used to study the general behavior of the structure and to generate boundary conditions was the axisymmetric shell structure program. This computer program developed by Franklin Institute Research Laboratories is designed to handle arbitrarily shaped shells of revolution subjected to axisymmetrical as well as non-axisymmetric loadings. The method of analysis consists of subdividing the shell into elements having continuous meridians with continuous first and second derivatives so that the first and second fundamental forms of the resulting shell elements are continuous throughout the element. By expanding the dependent variables in Fourier series in the circumferential direction, and assigning unspecified functions for the meridional variation, the independent variables are separated and a system of ordinary differential equations results for the dependent variables in terms of the meridional independent variable. Particular and complementary solutions of these ordinary differential equations are then found for each of the elements and each of the circumferential harmonics individually. The matching of the elements is achieved by writing the required boundary conditions.

The idealized section used with the axisymmetric shell structure program consists of five layers whose moment of inertia is equal to that of the actual section. The wall section is considered as cracked with the reinforcing carrying all loads.

Since the axisymmetric shell structure program does not have the capability to analyze the effect of thermal loadings, the finite element program, which is to be used to study the vessel behavior with the penetration effects included is used by simply taking a vertical section of the containment vessel.

The vessel wall is idealized into ten layers of shell with alternate layers of steel and concrete.

The computer program can handle the loads in the form of either surface traction or edge loads or both.

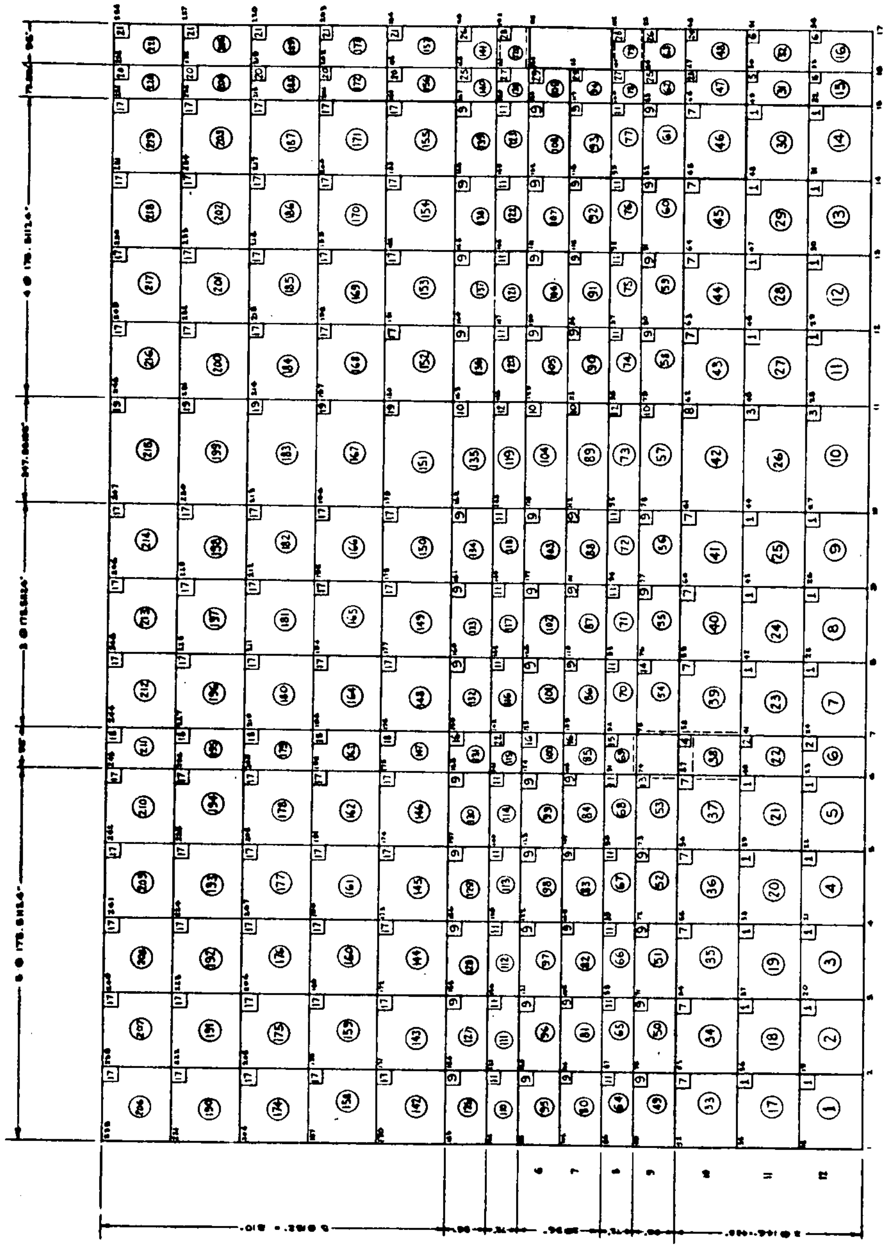


FIGURE 2.11(c)-1
Supplement 4

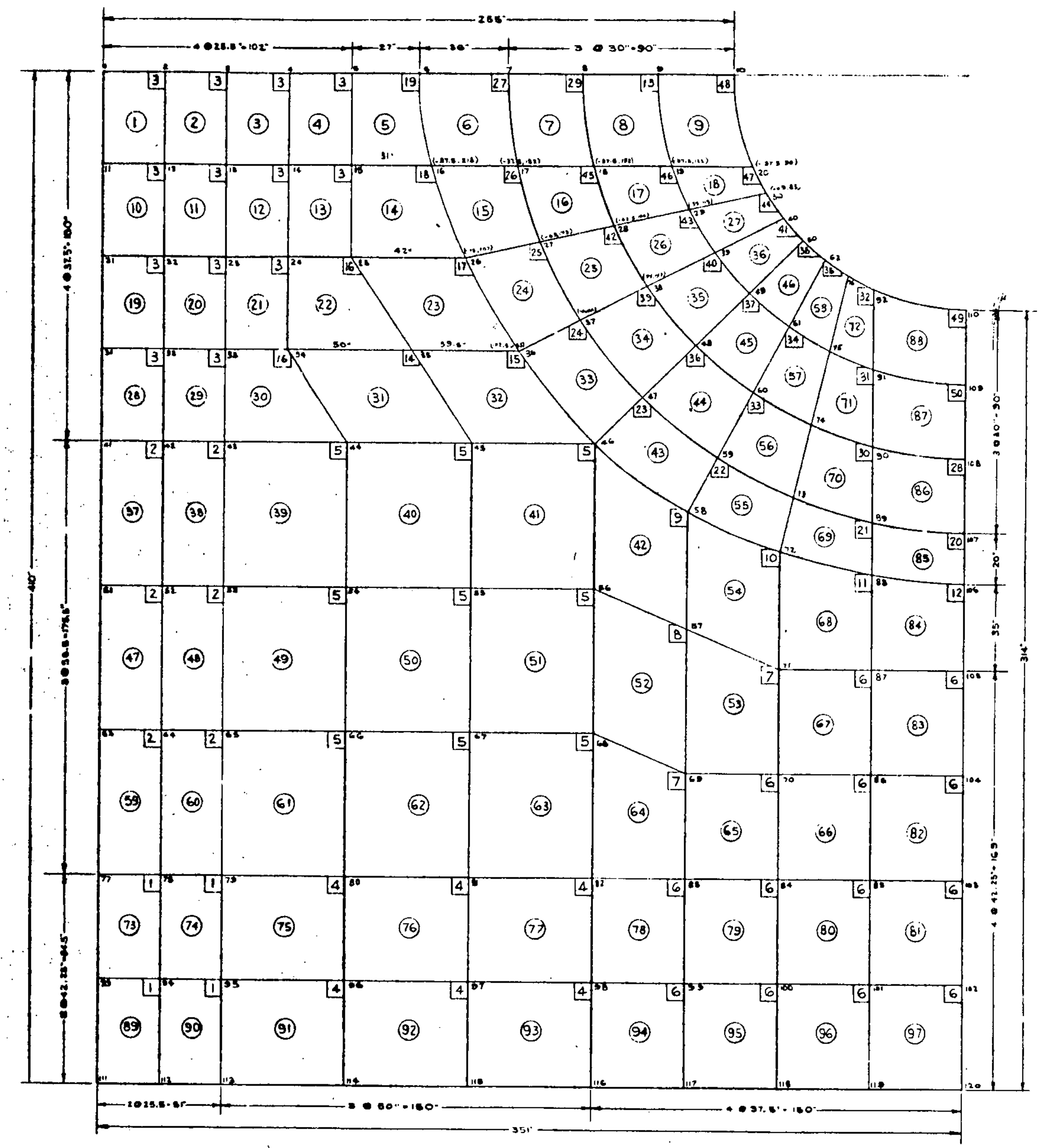


FIGURE 2.11(c)-2
Supplement 4

QUESTION 2.11(d)

For large openings describe:

The method that will be followed for the design (working stress design method, ultimate strength design method, or both). If ultimate strength is used, the factored load combinations should be given together with corresponding capacity reduction factors.

ANSWER

Ultimate strength design method will be used.

The factored load combinations and corresponding capacity reduction factors used will be the same as those discussed in Chapter 5 of the PSAR.

QUESTION 2.11(e)

For large openings, describe:

How the existence of biaxial tension in concrete (cracking) will be taken care of in the design and how the normal and shear stresses due to axial load, two-directional bending, two-directional shear, and torsion will be combined. Also, state the proposed criteria for the design of the thickened part of the wall around the opening (ring girder).

ANSWER

The main vertical and horizontal reinforcing will not terminate at the opening, but will sweep around the opening without interruption, therefore biaxial cracking of the concrete in the vicinity of the opening will not affect the anchorage of these bars. Also the radial stirrups around the opening will be hooked around boss hoops and vertical reinforcing for anchorage.

Any particular cross section of the boss will be subject to axial tension, two directional bending, two directional shear and torsional shear. The bending moments about the two principal axes of the cross section will yield tensile forces on mutually perpendicular planes which will require steel reinforcement so placed to carry these forces. The axial tension is directly additive to these bending tensile forces and must be carried by the same steel and additional bars.

The two-directional shear will be carried by the radial stirrups around the opening. Two legs of the stirrup will carry the shear in one direction and the other two legs will carry the sear normal to the first direction. Torsional shear is carried by all legs of the same stirrups.

For a description of the proposed criteria for the design of the thickened part of the wall around the opening, see the answer to Question 2.11(c) and 2.11(d).

See also the Figures of Question 2.11(g).

QUESTION 2.11(f)

For large openings, describe:

The method to check the design of the thickened stiff part of the shell around large openings and its effect on the shell. Include the manner of considering creep and shrinkage. Comparison with stresses in a circular flat plate would not be convincing, since it eliminates the effect of torsion which is one of the most important effects involved. How will torsional stresses be checked?

ANSWER

The previously mentioned finite element method will be checked by considering the ring girders around the equipment hatch and personnel lock subjected to loading from the internal pressure components, and a shear loading along its inner edge caused by the peripherial reaction of the opening cover.

The bending and axial loads are found by considering a ring loaded in the vertical and horizontal directions in the plane of the boss. An expression is written for the moment in terms of the variable θ. (The central angle of the point under consideration measured from the horizontal centerline). An expression for the strain energy = $\frac{1}{2EI}\int M^2 dr$ is written and set eaual to zero. This equation is integrated and solved for the maximum moment in terms of the load, radius and angle to $\pi/2$ radians from the origin. The moment will be resisted by the continuous hoops around the opening which will be sized to resist the maximum moment.

The shear is found by writing expressions for the horizontal and vertical shears in terms of θ and combining them to form an expression for the total shear. The expression is differentiated, equated to zero and solved for the angle θ at which the maximum shear occurs. Substituting this angle back in the original expression a value for maximum shear is obtained.

The shear loading on the inner edge of the ring in conjunction with the eccentric loading on the ring from the internal pressure plus curvature effects causes out of plane loading on the ring. The out of plane load will be resisted partly by the action of the wall reinforcing bars at the outer edge of the boss due to the rotation of the boss.

Shrinkage and creep effects will be relieved by cracking of the concrete during the pressure test and will not be included in accident design consideration.

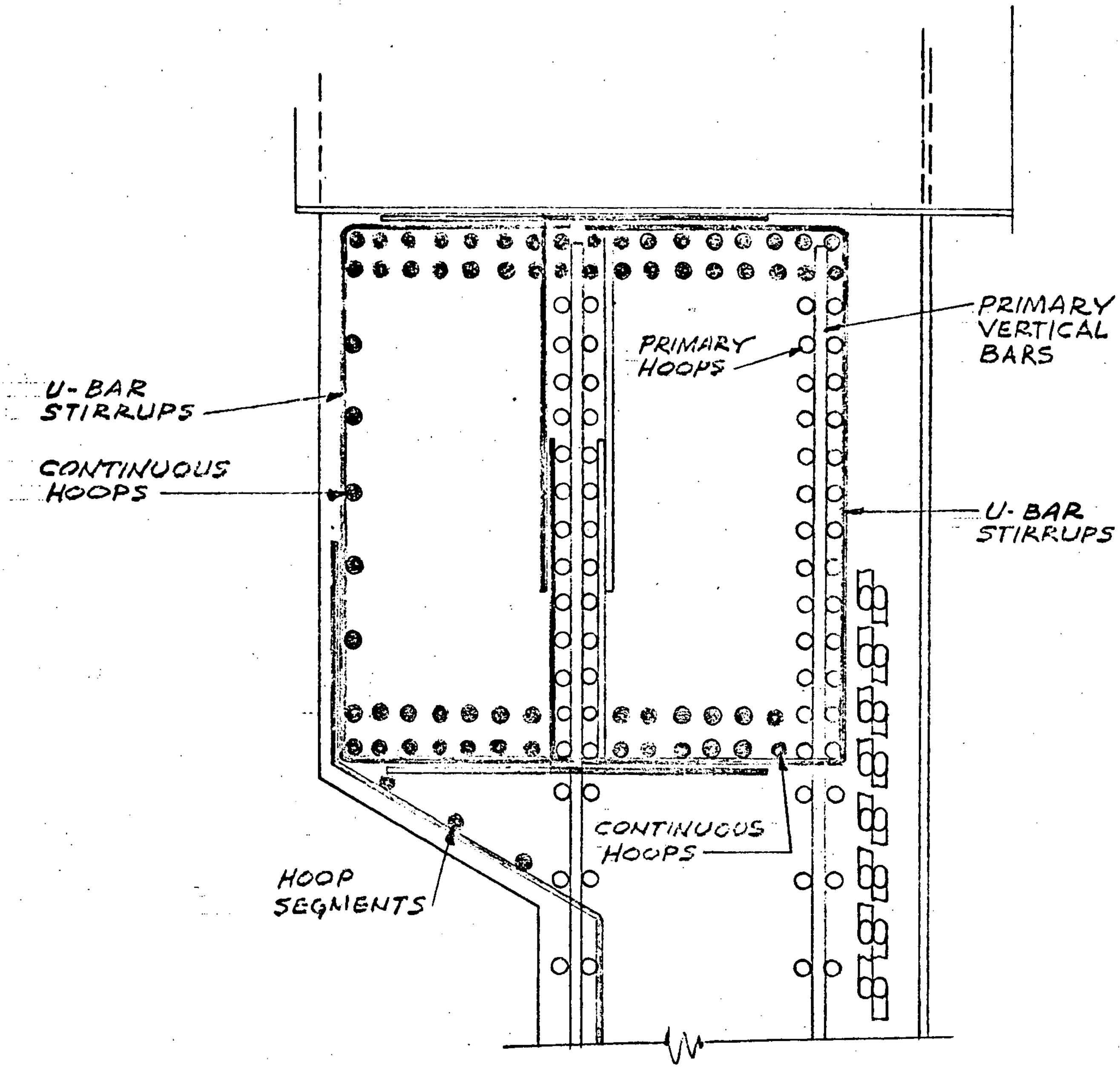
QUESTION 2.11(g)

For large openings, describe:

Additional information on reinforcing patterns that will be used around large openings.

ANSWER

At the large equipment hatch and personnel locks, the wall will be thickened and it will be necessary to add additional reinforcing around the large openings. Continuous hoops will be added around the outside face of the boss. In the transition area from the outside face of boss to the normal outside face of the wall segments of hoops will be used, since the size of the transition varies due to the curvature of the cylindrical wall. Continuous hoops will also be provided through the boss thickness at the inside and outside radii of the boss. These hoops, along with the inside primary vertical bars will be tied together by lapped U-bar stirrups which will be placed radial to the centerline of the penetration. In addition, all bent vertical and hoop bars will be tied back and void spaces due to bending of bars around penetrations will be filled in with additional hooked bars. See Figures 2.11(g)-1 and 2.11(g)-2.



SECTION B-B FROM FIG. 2.11(g)-2

FIGURE 2.11(g)-1
Supplement 4

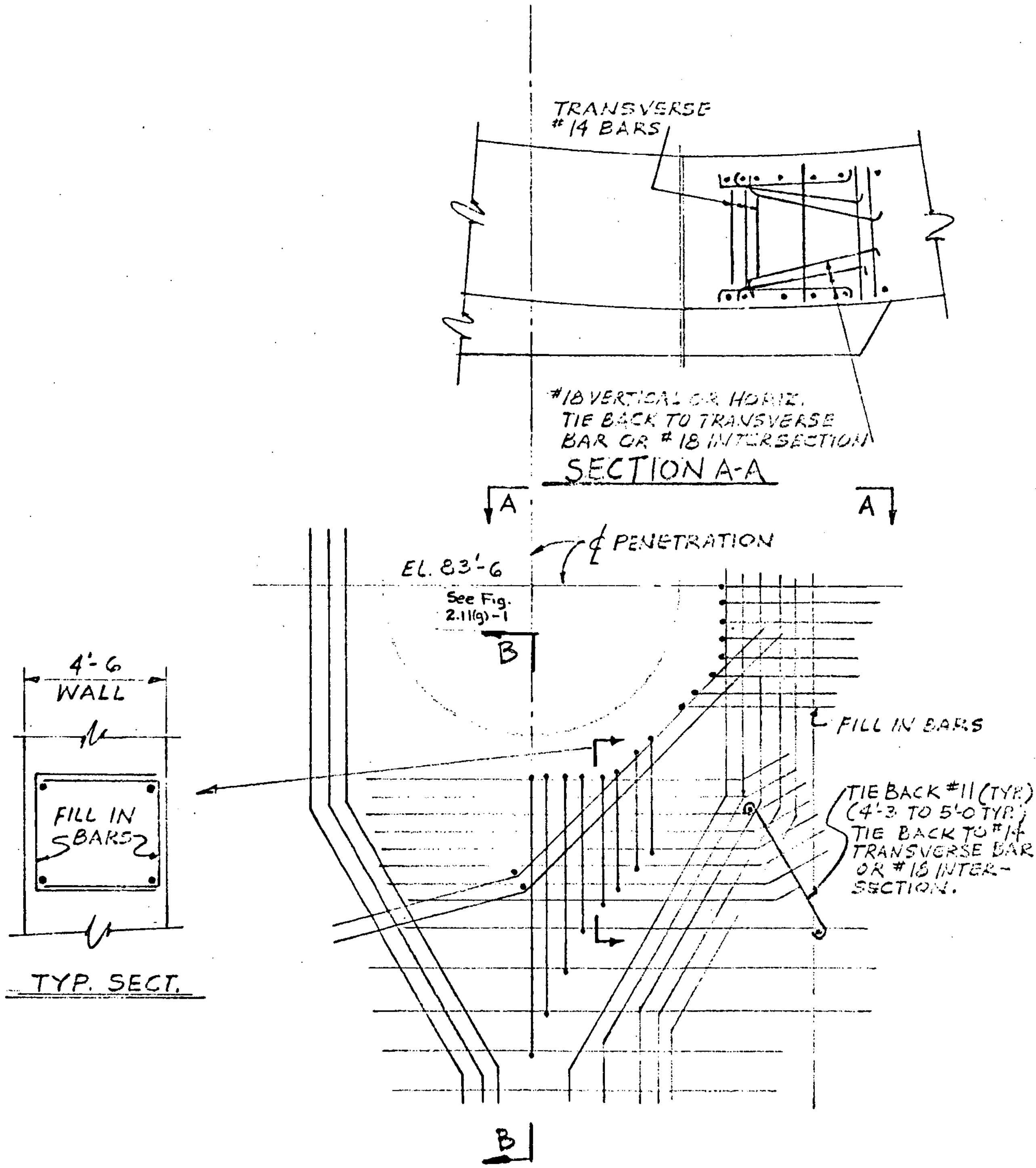


FIGURE 2.11(g)-2

Supplement 4

QUESTION 2.11(h)

For large openings, describe:

The safety factor provided in design at large openings. Sample computations should be provided, listing all the criteria and analyzing the effect of all pertinent factors, such as cracking, etc.

ANSWER

A safety factor will be provided in the design of the large openings due to the factored loads which will be used in the analysis.

The computer analysis will take into account all pertinent factors involved and has been checked by considering an ultimate strength concrete section, with no concrete acting in tension to resist the bending stresses. For a discussion of the methods of design and analysis, see the answers to Questions 2.11(c) and 2.11(e), respectively.

QUESTION 2.12

If insulation is required, present preliminary design information, including proposed design requirements and performance specifications to ensure that the necessary insulating qualities will be achieved under accident conditions.

ANSWER

The proposed liner insulation is 1-1/4" thick polyvinylchloride insulation with a thin gauge stainless steel cover.

Design requirements are as follows:

1. The finished product of insulation, cover, and seals shall be able to withstand and meet the following requirements:

   a) Normal operating temperature @ 50% relative humidity...120°F
   b) Under accident conditions with outside ambient temperature ranging from 0°F to 100°F, rise in liner temperature shall not exceed 80°F.
   c) Total radiation exposure (for life of plant)....4 x 10^4 R
   d) Functional in steam and hot water atmosphere (10 hr rating)
   e) Rated non-burning in accordance with ASTM procedure D-1692
   f) A minimum fire rating of 1/2 hr. Flame spread rate of testing shall be done in accordance with ASTM Spec. E-84.
   g) Initial proof test at 54 psig.
   h) Leak tests at 47 psig.

2. Method of supporting lagging from liner shall in no way impair liner by burn-through, or any other means.

3. The insulation system, including joints, shall accommodate a growth of 0.002 in./in. both vertically and horizontally without impairing its function.

4. The manufacturer shall submit test data that insulation panels will perform as required under the specified conditions. These data shall include the accident case initial, intermediate and final temperature values at interface points in the behind the panel.

QUESTION 2.12(a)

If insulation is required, present preliminary design information, including proposed design requirements and performance specifications to ensure that the necessary insulating qualities will be achieved under accident conditions. The presentation should also include:

The specified and tolerable temperature rise in the liner and the design safety factor provided on insulation performance.

ANSWER

The specified and tolerable temperature rise in the liner is 80°F as indicated in the answer to Question 2.12.

QUESTION 2.12(b)

If insulation is required, present preliminary design information, including proposed design requirements and performance specifications to ensure that the necessary insulating qualities will be achieved under accident conditions. The presentation should also include:

Means provided for fastening the insulation to the backing liner, for precluding steam channeling behind the insulation (through the top or joints), and for removing insulation panels.

ANSWER

Insulation panels are secured to the liner by bolting to stainless steel studs attached to the liner. A stainless steel washer with neoprene backing is placed under the stainless steel nut to insure a proper seal.

To preclude steam channeling, the stainless steel cover is returned at each joint and at the penetrations. The return is then sealed with a silicone sealant. See Figure 2.12(b)-1.

Removal of insulation panels is possible by removing the sealant and unbolting the panels.

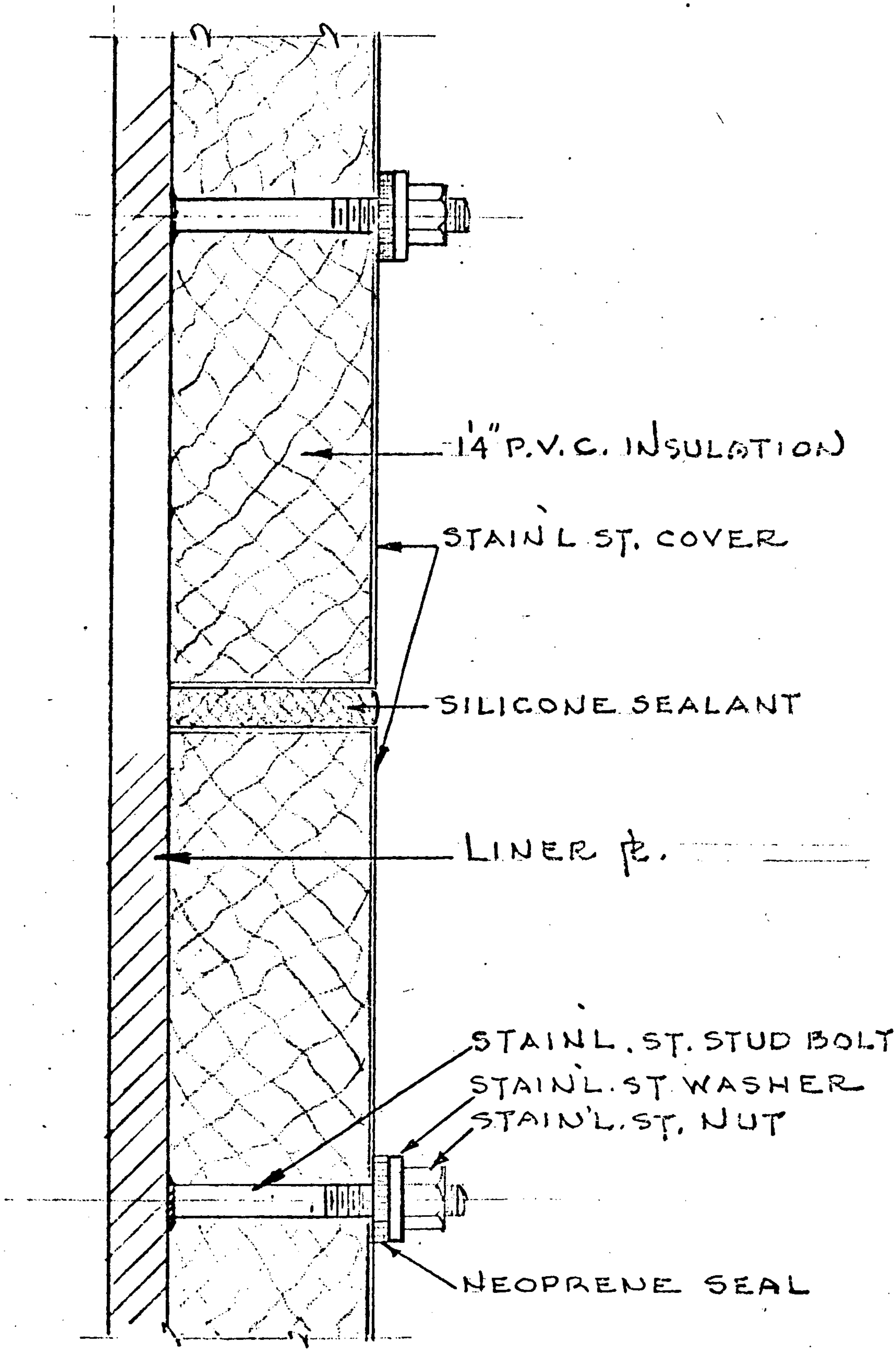


FIGURE 2.12(b)-1
Supplement 4

QUESTION 2.12(c)

If insulation is required, present preliminary design information, including proposed design requirements and performance specifications to ensure that the necessary insulating qualities will be achieved under accident conditions. The presentation should also include:

An analysis of the consequences of one or more insulation panels being displaced from the liner during, or as a consequence of, an accident situation.

ANSWER

The consequence of an insulation panel being displaced from the liner during or as a consequence of an accident is that the exposed liner would tend to expand. The unequal strain between the exposed and unexposed portions of the liner causes a shear load on the liner anchor, and a local yielding in compression of the exposed portion of the liner. As indicated in the answer to Question 2.9(c) the liner anchor stud has the capacity to accommodate much greater strains than would be experienced at yield strain in the liner.

QUESTION 2.12(d)

If insulation is required, present preliminary design information, including proposed design requirements and performance specifications to ensure that the necessary insulating qualities will be achieved under accident conditions. The presentation should also include:

The consideration given to increased conductivity due to humidity and compression during accident pressure transients and precompression from structural and leakage testing.

ANSWER

Because the insulation panels are jacketed with stainless steel and sealed at the joints, the insulation will not be subjected to the moisture and high humidity atmosphere to the containment during an accident.

Manufacturer's tests have indicated that the insulation is capable of withstanding periodic compression at 60 psig at temperatures from 40°F to 120°F and a single compression under accident conditions without any detriment or change to the insulation properties.

QUESTION 2.12(e)

If insulation is required, present preliminary design information, including proposed design requirements and performance specifications to ensure that the necessary insulating qualities will be achieved under accident conditions. The presentation should also include:

An evaluation of the compatibility of the insulation materials and steel liner (chemical reaction, etc.).

ANSWER

The materials in contact with each other are as follows:

The carbon steel liner with an inorganic zinc protective coating is in contact with the polyvinylchloride insulation and the stainless steel and the sealant. These materials do not react with each other.

QUESTION 7.1

Describe the sequence for structural testing.

ANSWER

The containment shall be pressurized to 18, 36, 47, and 54 psig. At each of these levels the pressure shall be maintained and stabilized for a minimum of one hour while gross deformations are determined and visual inspections performed.

The containment pressure will then be reduced to 47 psig and held for a minimum of 24 hours for the integrated leak rate test. During this time, selected areas will be visually inspected for crack spacing and widths.

QUESTION 7.2(a)

Describe the instrumentation program for structural testing. Include: Identification of structural, and liner areas to be instrumented.

ANSWER

The containment will be visually inspected for crack pattern and spacing and optical measurements will be made to determine deformation behavior of the containment. These results will be correlated with the results obtained from the structural test behavior of Unit No. 2 as the test proceed to ensure structural behavior of Unit No. 3 is comparible to the successful testing of Unit No. 2.

QUESTION 7.2(b)

Describe the instrumentation program for structural testing. Include: Purpose, type, expected accuracy, and redundancy of instrumentation.

ANSWER

Instrumentation will consist of high power optical theodolite capable of measurement of movement of ± 0.01 in and mechanical feeler gages used to measure crack width with ± 0.002 in. accuracy.

QUESTION 7.2(c)

Describe the instrumentation program for structural testing. Include: The range of strains and deformations expected.

ANSWER

The range of strains and deformations expected vary from 0 to the following expected maximums:

	In.
Vertical elongation (top of mat to top of dome)	1.5
Increase in Diameter	2.0
Crack Width	1/16
Uniform Strain	.002 in/in.

QUESTION 7.2(d)

Describe the instrumentation program for structural testing.
Include: The protective measures that will be taken to insure instrument performance during structural testing, considering the interval between instrument installation and its use.

ANSWER

Instrumentation intended to be used during structural tests is not subject to deterioration prior to or during test and therefore requires no protective measures.

QUESTION 7.3

Derive a relationship between two test pressures and the actual pressures they represent, showing the validity of the test pressures. Use one test pressure for design basis accident along, the other for earthquake plus accident.

ANSWER

The 1.15P test pressure is selected on the basis of attaining a maximum test pressure without causing any structural damage to any portion of the structure. Since in testing there is no rise in containment temperature as would exist in the case of the maximum credible accident, the liner will be stressed to higher tensile levels. This would represent a more severe leakage condition than during an accident. The maximum computed tensile stress in the liner for the test condition is 30,000 psi. Under accident conditions the liner is primarily in compression with local areas of minimal tensile stress.

QUESTION 7.3(a)

Derive a relationship between two test pressures and the actual pressures they represent, showing the validity of the test pressures. Use one test pressure for design basis accident alone, the other for earthquake plus accident. Include the following:

Thermal stresses at large openings: evaluation of temperature gradients, stress computations for concrete and reinforcing steel, methods of combining stresses due to normal, tangential, bending, and torsional load, assumptions on cracking, stresses in stirrups, etc.

ANSWER

Since the containment will not be subject to accident temperatures during the test, no direct correlation between test and accident conditions can be made in evaluating thermal stresses at large openings.

For assumptions on cracking, stresses in stirrups, methods of combining stresses due to normal tangential, bending, and torional loads see the answers to Questions 2.11(a) - (h).

QUESTION 7.3(b)

Derive a relationship between two test pressures and the actual pressures they represent, showing the validity of the test pressures. Use one test pressure for design basis accident alone, the other for earthquake plus accident. Include the following:

Influence of shrinkage.

ANSWER

No relationship will be required to exist between the test pressure and the actual pressures they represent because shrinkage and creep considerations are eliminated during testing due to the cracking in the concrete.

QUESTION 7.3(c)

Derive a relationship between two test pressures and the actual pressures they represent, showing the validity of the test pressures. Use one test pressure for design basis accident alone, the other for earthquake plus accident. Include the following:

Creep.

ANSWER

See answer to Question 7.3(b).

QUESTION 7.3(d)

Derive a relationship between two test pressures and the actual pressures they represent, showing the validity of the test pressures. Use one test pressure for design basis accident alone, the other for earthquake plus accident. Include the following:

Influence of liner elastic and plastic deformations.

ANSWER

There will be no liner plastic deformations since yield in the liner is never exceeded.

The elastic liner deformations during the test pressure will be from tensile stresses while during an accident loading they will be from compressive stresses, therefore, a relationship between them cannot be derived.

QUESTION 7.3(e)

Derive a relationship between two test pressures and the actual pressures they represent, showing the validity of the test pressures. Use one test pressure for design basis accident alone, the other for earthquake plus accident. Include the following:

Liner stresses before cracking of concrete occurs.

ANSWER

Assuming a concrete tensile strength of 350 psi and a modular ratio of 9, the liner stress at concrete cracking is equal to 350 x 9 = 3150 psi.

Under accident conditions the concrete is already cracked from the structural testing and will have no relation to the liner stress.

QUESTION 7.3(f)

Derive a relationship between two test pressures and the actual pressures they represent, showing the validity of the test pressures. Use one test pressure for design basis accident alone, the other for earthquake plus accident. Include the following:

Influence of transient thermal gradients.

ANSWER

The primary effect of transient thermal gradients during the pressure test will be to alter the initial stress condition in the liner from 0 stress to a maximum of about 8 ksi in compression. Since the liner during the test is in tension, this condition would result in a possible variation of 8 ksi in the liner stress under test pressure.

The temperature correlation between accident and test is so small that such a correlation cannot be considered.

QUESTION 7.4

Describe the surveillance capabilities provided by the containment design with reference to both periodic inspection of the steel liner and periodic structural testing of the containment. If the leak rate testing is intended to be performed at reduced pressure, provide an evaluation of the minimum level of such tests that would also serve to verify continued structural integrity. Consider in the evaluation structural response and surveillance instrumentation requirements.

ANSWER

The insulation attached to the steel liner is designed so that sections can be removed for inspection of the liner. There is nothing in the design of the containment which precludes the performance of containment structural tests at design pressure during the life of the plant. However, no degradation of structural integrity of the containment is expected and therefore no structural testing of the containment beyond initial proof testing is contemplated. Leak rate testing is not intended to verify containment structural integrity.