Cleveland Electric Illuminating Company
Perry Nuclear Power Plant Units 1 & 2
Ultimate Structural Capacity
of
Mark III Containments

FINAL REPORT

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1.0 INTRODUCTION

The ultimate internal presure capacity of the Perry Nuclear Power Plant Units 1 and 2 Mark III Containments has been evaluated using the results of published buckling and yield analyses of 2:1 ellipsoidal shells, existing stress analyses of the containment vessel, and supplemental linear and non-linear analyses as required to establish the ultimate capacity. The containment vessel design is described in the FSAR, Section 3.8.2. The actual material strengths of the ASME-SA-516, Grade 70 steel have been used to determine the mean, lower bound, and upper bound values of the material yield strength and ultimate strength. Local regions of the containment vessel, equipment hatch and personnel air locks, and the main steam penetrations have been evaluated for static loads. The ability of the containment vessels to resist a suddenly applied dynamic pressure has also been evaluated.

In response to a USNRC Structural Engineering Branch question, the containment vessel, including penetrations, has also been evaluated according to the requirements of the ASME Boiler and Pressure Vessel Code, (ASME Code) Division 1, Subarticle NE-3220, Service Level C Limits. The load combination of dead load and internal pressure of 45.0 psig is used with these ASME code requirements.

The Service Level D Limits of Subsection NE were also used to calculate a more realistic ultimate capacity, i.e., the maximum pressure inside containment, which does not create stresses above the Level D limits. These additional analyses are presented in Section 6.0 of this report.

2.0 CONCLUSIONS

The capacity of the general shell to resist statically applied pressure is determined to be 78.0 psig based upon the lower bound vessel strength and 94.0 psig based upon the mean value vessel strength. The initial approach for the evaluation of penetrations was to use a stress concentration approach as presented in Section 4.4.2. As discussed in the Introduction, these calculations have been supplemented using a criteria of 45.0 psig pressure and dead load at ASME Service Level C limits, as well as the calculations of maximum pressure permissible at Service Level D limits. Results are presented, in Section 6.0 for the upper personnel air lock, equipment hatch, and typical penetrations, as well as the general shell.

The dynamic pressure capacity of the general shell has been determined to be 80.0 psig based upon the lower bound vessel strength and 90.0 psig based upon the mean value vessel strength.

3.0 MATERIAL STRENGTH

The containment vessel material strength is evaluated by calculating the mean value and the standard deviation of the yield strength and tensile (ultimate) strength for the ASME-SA-516, Grade 70 steel used for the cylinder and dome areas. The upper and lower bound values of the yield and ultimate strengths are defined as the mean value plus or minus three standard deviations, respectively. The cylinder yield and ultimate strengths are based upon the material certifications for both Unit 1 and Unit 2 containment vessels. The dome yield and ultimate strengths are based upon the material certifications for Unit 1 only, because at the time of this work, test results for the Unit 2 dome plates were not available.

The welding electrodes which have been used for the containment vessel are either ASME-SFA-5.1, E7016 or E7018 covered carbon steel electrodes, SFA-5.17 or SFA-5.23 submerged arc electrodes, SFA-5.18 tungsten inert gas rods, or SFA-5.18 or SFA-5.20 gas metal arc electrode wire for carbon steel welding. All of the above welding materials have a minimum specified yield strength of 60.0 KSI, a minimum specified tensile strength of 72.0 KSI, and a minimum specified elongation in 2 inches of 22% (Reference 1).

A summary of the vessel plate material properties and the weld material properties is provided in Table 1. The lower bound vessel plate material strengths are the controlling properties since the weld strengths are greater. The mean value vessel plate material strengths are used as the controlling properties even though the plate ultimate strength is greater than the minimum specified ultimate strength for the weld. This is acceptable because the weld properties are expected to have a variation similar to that obtained for the plate material; consequently, the actual mean tensile strength of the weld material would be expected to meet or exceed the 77.2 KSI value for the plates.

All of the following results are based upon the lower bound and mean strength values because the upper bound values given in Table 1 are of no practical use since by definition 99% of the vessel plates would have strengths less than these values.

4.0 CONTAINMENT VESSEL STATIC CAPACITY

4.1 CYLINDER

The containment vessel yield pressures are calculated based upon a detailed model of the vessel for the KSHEL computer program. The model is shown in Figure 1. A unit pressure load case is used to obtain stresses which are factored in order to obtain the yield pressure at a point on the containment vessel.

The initial membrane yield pressure for the cylinder portion of the containment vessel away from discontinuities appears in Table 2. This is the pressure required to produce first membrane yield in the vessel, which for the cylinder occurs simultaneously over a large portion of the cylinder height. The pressure is calculated by use of the maximum shear stress criterion (Tresca) and the distortion energy criterion (von Mises). For comparison, the yield pressures are also shown corresponding to uniaxial yield of the containment vessel in either the circumferential or meridional direction.

The ultimate pressure capacity of the cylinder portion of the containment vessel is shown in Table 3. The ultimate pressure is calculated by considering the circumferential membrane stress reaching the ultimate tensile stress values shown in Table 1.

4.2 DOME

The initial membrane yield pressures are summarized in Table 2 for the dome apex, knuckle, and the spring line. In contrast to the general cylinder region where initial membrane yielding occurs over a large area, first yielding in the dome occurs at a point in the knuckle region 15° above the spring line. The meridional stress at this location is tension while the circumferential stress is compression. The ratio of the circumferential stress to the meridional stress is -1.88.

Table 3 provides a summary of the ultimate pressures for the containment vessel calculated with the tensile strengths of the steel plate. Large deflections of some areas of the containment vessel will occur before these pressures are attained and the deflections will be physically limited by other structures or components.

As shown in Table 2, the knuckle region of the dome is the first area to reach a state of membrane yielding. This fact indicates that the dome is the first area to undergo large deformations; therefore, it should be evaluated for plastic collapse (Reference 2) as a basis for its ultimate pressure.

Two methods are used to define plastic collapse. The first method considers plastic collapse to occur at a pressure which causes the crown deflection to equal twice the yield deflection. The second method considers plastic collapse to occur at a pressure where the slope of a line from the origin to a point with the coordinates of the yield pressure and twice the crown yield deflection intercept the load deflection curve. Both methods are shown on Figure 2. Reference 2 states that the second method always gives plastic collapse pressures which are greater than the pressures from the first method.

The above methods can be applied to the knuckle deflections but the results are not significantly different. The crown deflection method is selected to determine the containment vessel dome plastic collapse pressure.

The plastic collapse pressures for no strain hardening and 5% strain hardening are presented in Table 4. The percentage of strain hardening is defined as the ratio of the slope of the stress-strain curve in the plastic region to the slope in the elastic region.

Due to the fact that the knuckle region of the dome is in a state of meridional tension and circumferential compression, buckling must be investigated. Elastic and elastic-plastic buckling are considered using Reference 3. The elastic buckling pressure is 476 psig. The elastic-plastic buckling pressures are evaluated for zero strain hardening and for 5% strain hardening. The elastic-plastic buckling pressures are summarized in Table 4.

As seen from Table 4, the elastic-plastic buckling pressures are the controlling pressures since the plastic collapse pressures are greater. However, since Reference 3 does not provide an indication of the ellipsoidal shell strains at the buckling pressure, it is not possible to determine precisely if the elastic-plastic buckling pressure with no strain hardening or the elastic-plastic buckling pressure with 5% strain hardening will be the controlling pressure. Therefore, the lower bound elastic-plastic buckling pressure with no strain hardening is considered to be the ultimate pressure capacity of the dome since, according to Reference 3, the shell may fracture where the waves appear.

4.3 SUMMARY OF GENERAL SHELL PRESSURE CAPACITIES

The dome knuckle is the area which controls the capacity of the containment vessel. As seen from the pressure summary below, the knuckle region is the first area to reach yield when using the von Mises yield criterion, at a pressure of 68.0 psig. At this level, the dome apex and cylinder are only at 77% and 71% of their respective yield pressures.

	Initial Membrane Yield Pressure (PSIG)	Buckling Pressure (PSIG)	Plastic Collapse Pressure (PSIG)	Ultimate Pressure (PSIG)
Cylinder	96.2	N/A	N/A	145.7 (LB)
	119.5	N/A	N/A	155.9 (Mean)
Dome Apex	88.4	N/A	N/A	148.4 (LB)
	107.0	N/A	N/A	161.1 (Mean)
Dome Knuckle	68.0	78.0	93.5	114.2 (LB)
	82.4	94.0	116.7	124.1 (Mean)

Since the yielding in the knuckle occurs only at one point along the meridian, the pressure can be increased above 68.0 psig to 78.0 psig, the level at which hoop buckling occurs in the knuckle. At this pressure, waves form periodically around the circumference of the dome. If the strains in this region remain small so that local tearing or fracture does not occur at the buckling pressure, the containment vessel pressure can be increased to the plastic collapse pressure. At this pressure yield circles appear and large deformations ensue in the area around the dome knuckle.

The dome knuckle area also is the first area, disregarding large deformation and instability, to reach the ultimate stress. However, the containment vessel pressure cannot be increased to this pressure because of the large deformations that occur.

Based upon the preceding discussion, the lower bound and mean buckling pressures at 78.0 psig and 94.0 psig are used to evaluate the stresses in the discontinuity regions of the containment vessel.

4.4 DISCONTINUITY REGIONS

4.4.1 Axisymmetric Discontinuities

Tables 5A and 5B provide a summary of extreme fiber stresses at the stiffeners, ring girder, spring line, and at the top of the fix concrete based upon the containment vessel lower bound ultimate pressure of 78.0 psig and the containment vessel mean ultimate pressure of 94.0 psig. The stresses are combined by using the von Mises yield criterion and compared to the yield stresses, where yield occurs when x equals or exceeds $\sigma_0{}^2$. As can be observed from Tables 5A and 5B, there are only two local areas with stresses that exceed the yield stress, the ring girder and the top of the containment fix. The stresses at these locations, which are greater than the yield stress, are local stresses on the inside surface of the containment vessel. The stresses at the same location on the outside surface of the containment vessel are below the yield stress. Therefore, these stresses should not affect the integrity of the containment vessel.

4.4.2 Penetration Regions

The equipment hatch, upper and lower personnel air locks, and the main steam penetration are the three areas investigated for local stresses.

The penetrations were first analyzed by considering the containment vessel cylinder to be a flat plate reinforced with an elastic ring (Reference 4). A uniform membrane stress is applied at the boundaries of the plate. The biaxial stress condition is considered by summing the stresses caused by the circumferential and meridional membrane stresses. The stress at the penetration sleeve-collar or vessel intersection and the collar-vessel intersection is calculated by considering the penetration sleeve or collar to be an elastic ring. A concentrated force equal to the internal pressure multiplied by the area of the penetration sleeve is considered for the personnel air locks and equipment hatch by using the method described in Reference 7. The main steam penetration does not have the concentrated load included since it is anchored in the drywell structure.

The stresses obtained by the procedure described above are utilized with the von Mises yield criterion and the 78.0 psig and 94.0 psig lower bound and mean internal pressures to obtain the stresses to be compared with the vessel yield strength. A summary is presented in Tables 6A and 6B. A sketch of each penetration is shown in Figures 3 through 5.

Tables 6A and 6B show that all of the penetrations have stresses greater than the yield stresses when 78.0 psig or 94.0 psig pressure is applied to the containment vessel. The pressures noted in parentheses are the pressures which cause the initial yielding of the vessel at a point 90° from a horizontal line transverse to and through the center of the penetration which is the point of maximum stress.

In order to determine the extent of the plastic zone around the penetration caused by the 78.0 psig and 94.0 psig pressures, the approximate approach described in Reference 5, International Series of Monographs in Aeronautics and Astronautics, is used. The method calculates the radius from the center of an unreinforced hole in a plate under biaxial stress to the boundary between the plastic and elastic regions. The distances from the edge of the hole to the plastic-elastic boundary for the penetrations, considering the lower bound and mean yield stresses, are summarized as follows:

Main Steam	Upper and Lower Personnel Air Lock	Equipment Hatch
83.5 inches	163.0 inches	407.5 inches (Lower Bound)
68.5 inches	135.0 inches	337.0 inches (Mean)

All of the preceding plastic regions are along the vertical centerline at the top and bottom of each penetration. The plastic zone for each penetration extends to a point located approximately 37° above and below the horizontal for each penetration.

The penetrations can support a pressure higher than the pressure required to cause initial yield around each penetration. As an example, the initial yield pressures indicated in Table 6A and 6B can be increased to approximately 60.0 psig (lower bound) and 75.0 psig (mean) if the plastic zone is limited to a region in the vessel which is one radius from the penetration sleeve.

These increases in pressure beyond their initial yield values are based on the peak stress provisions of paragraph NE-3213.11 of the ASME Boiler and Pressure Vessel Code, Section III, Division 1. Here peak stresses include those stresses that occur as a result of the stress concentration effect around penetrations. These peak stresses are acceptable according to the Code if they do not cause "noticeable distortions" and are "objectionable only as a possible source of a fatigue crack or a brittle fracture". For the pressure load under consideration fatigue does not occur. It is expected that the vessel strains resulting from the one radius yield region around the main steam penetrations (24.5 inches) and personnel air locks (57 inches) would not result in objectionable distortions. However, the distortion associated with yielding of the vessel in a one radius region (120 inches) around the equipment opening is difficult to judge without a more refined analysis of this area.

Additional detailed analyses of the penetrations have been performed. Sections 6.2 and 6.3 of this report provide a summary of detailed finite element analyses of the personnel air locks, equipment hatch , and typical process piping penetrations.

5.0 CONTAINMENT VESSEL DYNAMIC PRESSURE CAPACITY

The dynamic pressure capacity of the containment vessel is determined by considering the pressure-time history to be a suddenly applied triangular load with a duration of 100.0 seconds. The resistance function of the containment vessel is approximated as a bi-linear function as shown in Figure 6. The value R_m, the pressure required to cause the containment vessel membrane stress to reach the yield stress, will vary at different locations on the vessel. The area under the equivalent R_m curve is equal to the area under the pressure-displacement curve at the point of interest on the shell. The construction of the pressure-displacement curve is based on the stress-strain characteristics of the plate material. The ultimate value on the stress-strain curve is assumed to occur at one-half of the material minmum specified ultimate strain. For the ASME SA-516, Grade 70 steel the minimum ultimate strain is a 17% elongation.

The solution on the dynamic problem is based on the elasto-plastic response described in Reference 6 which considers the containment vessel to be a single degree of system.

The elastic response is obtained by solving the following two equations for t_e and yel, the time at which the vessel reaches yield and the velocity of the vessel at yield.

$$Yel = \frac{F_1}{K}(1 - \cos wt_{el}) + \frac{F_1}{Kt_d}\left(\frac{\sin wt_{el}}{w} - t_{el}\right)$$

$$\dot{Y}el = \frac{wF_1}{K}\sin wt_{el} + \frac{F_1}{Kt_d}\cos wt_{el} - \frac{F_1}{Kt_d}$$

Where:

F_1 = applied dynamic force
K = stiffness of the vessel
t_{el} = time of maximum elastic response
w = frequency of the vessel

t_d = duration of the dynamic load

Yel = elastic deflection

$\dot{Y}el$ = velocity of the vessel at yield

The solution to the plastic portion of the containment vessel dynamic response is obtained by solving the following two equations for t_m and y, the time of maximum response and the maximum deflection.

$$0 = (F_1 - R_m)\frac{tm}{M} - \frac{F_1 tm^2}{2t_d M} + \dot{Y}el$$

$$Y = \frac{(F_1 - Rm)tm^2}{2M} - \frac{F_1 tm^3}{6t_d M} + \dot{Y}el\, t_m + Yel$$

Where:

R_m = resistance function

t_m = time of plastic maximum response

M = Mass

Tables 7A and 7B present a summary of the lower bound and mean value deflections and ductility ratios for suddenly applied dynamic pressures at different locations on the containment vessel. As discussed previously, the knuckle controls the allowable pressure capacity. A large increase in the deflections occurs above 65.0 psig for the lower bound and above approximately 75.0 psig for the mean value material strengths at the dome knuckle. Therefore, 65.0 psig and 75.0 psig are considered to be the lower bound and mean value dynamic pressure capacities of the containment vessel. These pressures are conservative because the redistribution of the membrane forces in the knuckle region of the containment vessel is not considered in the analysis.

The penetration areas have a static pressure capacity approximately the same as the general containment vessel and therefore an equivalent dynamic pressure capacity.

The description of the detailed static non-linear analysis of the fuel transfer penetration and the results of the analysis as well as other Level D evaluations is in Section 6.4. This information provides the justification that the penetrations have static pressure capacity and therefore the dynamic pressure capacity approximately equal to that of the general containment vessel.

It is expected that the general containment vessel dynamic pressure capacity could be increased if a more detailed analysis of the vessel were performed to account for the redistribution of the forces which occurs as the vessel yields.

6.0 ADDITIONAL ANALYSES

The United States Nuclear Regulatory Commission, Structural Engineering Branch requested information regarding the containment vessel capacity in question 220.19. The capacity assessment of the steel containment vessel described by this question required that an analysis should provide a reasonable assurance that the integrity of the containment will be maintained during an accident that released hydrogen generated from 75 percent fuel clad metal-water reaction accompanied by either hydrogen burning or the added pressure from post-accident inerting. As a criterion of such an assurance, the analysis should demonstrate that in case of the accident described above, the requirements of the ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subarticle NE-3220, Service Level C Limits are satisfied for the loading condition of pressure and dead load. The code requirements should be satisfied, as a minimum, for a combination of dead load and an internal static pressure of 45.0 psig.

The following sections provide a summary of the results from the evaluation of the containment vessel for dead load and 45.0 psig internal pressure. The results are compared to the requirements of the ASME Code. A more realistic definition of the containment vessel ultimate capacity assessment for the local areas around penetrations is also provided and is based on Service Level D limits.

6.1 CONTAINMENT VESSEL CYLINDER AND DOME

The analysis of the containment vessel utilizes the model presented in Figure 1 and the KSHEL computer program. Table 8 provides a summary of the containment vessel stress intensities at the dome knuckle, spring line, ring girder, stiffeners, and cylinder (away from discontinuities). The cylinder and dome knuckle are the regions of the vessel which are stressed to the greatest percentage of the allowable stress intensity. The allowable stresses summarized in the table are based upon the ASME Code allowable stress intensities using minimum specified yield stresses.

5.2 UPPER PERSONNEL AIR LOCK AND EQUIPMENT HATCH

The analyses of the upper personnel air lock utilized two computer programs; the SUPERB computer program was used to analyze the collar and barrel region of the air lock and the STARDYNE computer program was used to analyze the bulkhead and bulkhead door (Reference 8). Figure 7 is the SUPERB model and Figure 8 is the STARDYNE model. The full model of the collar and barrel region was used in the analysis. Only one-half of the bulkhead and bulkhead door were analyzed due to symmetry.

The analyses of the equipment hatch assembly also utilized two computer programs: the SUPERB computer program was used to analyze the collar and barrel region of the equipment hatch and the ANSYS computer program was used to analyze the shallow spherical cover of the equipment hatch assembly (Reference 9). Figure 9 is the SUPERB model and Figure 10 is the ANSYS model. Because of the symmetry, only one quarter of the collar and barrel region was analyzed. The ANSYS model is axisymmetric.

The stress intensities in the various components of the upper personnel air lock and the equipment hatch produced by dead load and 45.0 psig internal pressure are summarized in Table 9. The allowable stress intensities for Service Level C are also provided in the table. The stress intensity at the junction of the air lock collar and the barrel and the stress intensity at the bulkhead and bulkhead door beam elements for the upper personnel air lock are approximately 90 percent of the Service Level C limits. The stress intensity at the collar of the equipment hatch is approximately 86 percent of the Service Level C Limits.

Since the shallow spherical cover for the equipment hatch is not integral and continuous with the equipment hatch barrel, the deflections at the cover flange and barrel flange must be evaluated at the O-ring locations. The two O-rings are located at nodes 83 and 93 and at nodes 85 and 95 in the ANSYS computer model, Figure 11. The differences in nodal deflections at the pairs of nodes are used to evaluate the separation between the shallow spherical cover and the equipment hatch barrel. The deflections at the O-rings are:

$\Delta i = UY_{93} - UY_{83} = .0656$ inch

$\Delta o = UY_{95} - UY_{85} = .0470$ inch

Based upon an O-ring compression 0.15 inch, sufficient spring-back is available to prevent leakage.

Using the results of Table 9, the maximum permissible internal containment pressure to meet Level C limits can be calculated by factoring up the stresses until the component closest to its allowable stress reaches that allowable stress. Following this approach, the maximum pressure to meet Level C limits for the personnel air lock is 50.2 psig. The controlling stress for this limit is the local membrane stress at the junction of the collar and barrel.

Applying the same procedure to the equipment hatch, the maximum allowable internal containment pressure to enforce the Level C stress limits is 52.6 psig. This maximum allowable pressure is controlled by the local membrane stress in the hatch collar. Utilizing this pressure, the deflections at the O-Rings would be: $\Delta i = 0.0767$ inches and $\Delta o = 0.0549$ inches, which still leaves sufficient spring-back available to prevent leakage based on the precompression of 0.15 inches.

6.3 PENETRATIONS

Penetrations are discussed in four subsections: upper containment penetrations, lower containment penetrations, penetration bellows, and penetration anchor plates. The upper containment penetrations are above the suppression pool region of the containment. The lower containment penetrations are located in the suppression pool and require different analysis techniques because they are located close to the base of the vessel. The bellows form a portion of the containment vessel boundary at those penetrations which are anchored at a structure other than the containment vessel. Anchor plates form a portion of the containment vessel boundary at those penetrations which are anchored into the containment vessel or at spare penetrations which are capped with a flat plate. The following sections discuss the analyses of each area in detail.

6.3.1 Upper Containment Penetrations

The analysis of the process piping penetrations and electrical penetrations utilize the STRAP computer program. The stress output from the original 15.0 psig internal pressure design load case has been factored to the 45.0 psig internal pressure load case. A comparison between the 45.0 psig internal pressure load case and the dead load case indicates that the dead load produces a maximum of 4.7 percent (main steam penetrations) of the stress intensity due to the pressure case. Based upon this comparison, dead load has been neglected for the penetration analyses.

The approach used to evaluate the penetrations involved grouping the penetrations by geometry and then analyzing only representative penetrations in order to reduce the amount of work required. Figure 12 is a sample of the finite element models used to analyze the penetrations. One quarter symmetry is used for these analyses.

Table 10 provides a summary of the penetration actual stress intensities and the allowable stress intensity. All penetrations, except one, satisfy the Service Level C limits of the ASME Code using normal minimum specified yield strength values of the material. Penetration 205, the fuel transfer penetration, is the penetration which does not satisfy the criteria. This penetration exceeds the Service Level C limits of the ASME Code by 11.5 percent; however, these results are based upon the minimum specified material strengths.

Based on material certification data, the minimum yield stress of the ASTM A 516 Grade 70 steel in either the sleeve of P205, or the adjacent shell of the two units is 51.5 ksi in the Unit 2 sleeve. Using this value, the allowable stress is 1.5 Sy, or 77.3 ksi, which is larger than the actual stress of 63.5 ksi.

The highest stressed penetration which is in close proximity to another penetration, and which therefore could be influenced by the stresses in an adjacent penetration, is P414. The centerline of this 44 inch diameter penetration is 84 inches away from P416, a 51 inch diameter penetration. Using an approach outlined in Reference 14, a stress increase factor (k) of 1.19 is calculated. This is the amount by which the stresses in P414 should be increased to account for the stress influence from P416. If this factor is incorporated, the stress intensity for P414 for an internal pressure of 45 psig becomes 1.19 x 43260 psi = 51,479 psi, which is still less than the Level C allowable stress intensity of 57,000 psi. This is the highest stress of any penetration listed in Table 10, except for P205 which has no penetrations in its immediate vicinity.

Also shown in Table 10 is the maximum internal containment pressure which will produce stresses at the highest stressed point in each penetration equal to the Level C stress limits. All except one of these pressures are based on using the minimum specified material properties. The P205 pressure is calculated using properties based on actual material certifications.

6.3.2 Lower Containment Penetrations

The lower containment vessel penetrations are analyzed with the STRAP computer program for the load condition of 45.0 psig internal pressure in addition to the hydrostatic pressure. The dead load has been neglected. The annulus concrete is also neglected for the analyses. Figure 13 is the model which was used for the analysis of the 48 inch diameter penetration. The model used for the analysis of the 32 inch diameter penetration involved the use of insert plates which are shown in Figure 14.

The results for the analyses are summarized below for the maximum stress intensity which occurs on the penetration sleeve at the top of the penetration:

	Actual Stress Intensity (psi)	Allowable Stress Intensity (psi)
32 inch Penetration	15,920	57,000
48 inch Penetration	15,699	57,000

As previously discussed, the annulus concrete has been neglected. This is a conservative assumption, since the stiffness of the concrete would prevent the steel containment vessel and penetration area from being stressed to as great a value as shown above.

Using the values given above, the 32 inch and 48 inch penetrations respectively could be exposed to internal containment pressures of 161.1 psig and 163.4 psig and still have maximum stresses less than the Level C service limits.

6.3.3 Penetration Bellows

Two different geometries of the penetration bellows have been evaluated for a containment vessel internal pressure of 45.0 psig. These two cases were chosen because they are the worst cases of large diameter penetration bellows with thin wall thickness. The systems represented by the two cases are:

P122 (P414 on Unit 2) - Main Steam
P422 (P407 on Unit 2) - RHR and RCIC

The analyses of the penetration bellows are based upon the approach described in Reference 10, with the exception of the buckling evaluations which are based upon equations from either Reference 11 or Reference 12.

Because of the arrangement of the penetration assembly, one of the bellows at each penetration is subjected to external pressure and the other bellows is subjected to internal pressure for penetrations P122 and P422. Table 11 provides a summary of stresses at various points on the bellows for a pressure of 45.0 psig and the ASME Code allowable stress. The stresses summarized are for the internal pressure case. The stresses are negative for the external pressure case.

The bellows are also evaluated for buckling because they can be subjected to external pressure. The factors of safety against buckling for typical penetrations are listed below:

Penetration Number	Bellows FS	Tangent Area FS
P122 (P414 on Unit 2)	12.1	5.3
P422 (P407 on Unit 2)	32.3	5.3

To make an assessment of the maximum static pressure capacity of the containment based on bellows strength, the bellows at penetration P422 (P407 on Unit 2) controls (see Table 11). The static pressure which would bring the highest stressed component to its allowable stress level would be 18,460/13,409 x 45 = 62 psig. This is conservative because it accounts for no increase in the allowable stress used for a normal accident pressure condition of 15 psig. Using the 62 psig pressure, the minimum factor of safety against buckling due to external pressure is an acceptable value of 4.0.

6.3.4 Penetration Anchor Plates

The penetration anchor plates were evaluated for a containment pressure of 45 psig (dead load produces negligible stress) at ASME Section III, Subsection NE Level C Stress Limits.

The anchor plates can be categorized as the following three basic types: single hole, with one process pipe; multi-hole with more than one process pipe; and spare penetrations consisting of flat plates. Not every penetration anchor plate was analyzed. The following criteria were used to select those to be evaluated.

a. The anchor plate which has the largest outside diameter for a group of similar penetration assemblages.

b. The anchor plate which has the smallest thickness for a group of similar penetration assemblages.

c. The plate which has the smallest process pipe diameter for a group of similar penetration assemblages.

The stresses in all anchor plates analyzed for 45 psig loading are within Level C allowable stress limits. The most highly stressed penetrations are P129, P130, P432 and P435 which are all spare penetrations containing no process pipes. Each of these penetrations had stresses in the anchor plates of 41.7 ksi at 45 psig versus the Level C allowable of 54 ksi. The stresses were well within allowable stress limits to the extent that an internal containment static pressure of 58.2 psig is required for them to reach Level C Service Limits.

There is a large increase in anchor plate strength when going to the next strongest anchor plates. The next strongest are penetrations P209 and P303 which each require an internal pressure of 127 psig to produce stresses equal to Level C stress limits.

6.3.5 Level C Stress Limit Summary

In summary, all penetrations, bellows, and anchor plates meet the Level C allowables of Reference 13 for an internal pressure of 45 psig. However, for this to be accomplished, the material certification yield and ultimate strength values for penetration P205 had to be utilized. All other allowables were based on published minimum strength values.

Carrying the evaluation one step further, the components were examined to see what pressure could be applied and still observe the Level C stress limits of Reference 13. For penetration components other than the bellows and anchor plates, the permissible pressure is 50.2 psig based upon the stress in the personnel air lock. For the bellows, the maximum pressure permitted is 62 psig based on penetration P422 (P407 in Unit 2). The penetration anchor plate controlling pressure is 58.2 psig.

6.4 CONTAINMENT ULTIMATE CAPACITY FOR PENETRATION REGIONS CONSIDERING LEVEL D STRESS LIMITS

The penetration region ultimate capacity could more realistically be defined to be the ASME Boiler and Pressure Vessel Code, Division 1, Section III, Subsection NE Level D service limits. Appendix F of Reference 13 which is referenced by Subsection NE for Level D limits further defines Level D limits as "limits which are permitted for combinations of conditions associated with extremely low probability postulated events". Section F-1220 states that the Level D Service Limits "are intended (NCA-1130) to ensure that violation of the pressure retaining boundary will not occur in components or supports which are in compliance with these procedures. These procedures are not intended to ensure safe operability or reoperability of the system either during or following the postulated event". Therefore, considering the nature and probability of the postulated event the Level D limits appear to be a more realistic restriction on stresses.

Adopting this approach, the penetrations were examined to find the maximum pressure possible inside of containment to avoid stressing beyond the Level D limits, based on elastic analysis, any component of the penetrations. Shown in Table 12 is a compilation of the Level D elastic analysis allowables (plastic analysis for P205) and the containment internal pressure which will produce a stress in the highest stressed element equal to the Level D allowables.

Upon examination of this table, the minimum attainable pressure is equal to 58.9 psig for all penetrations (57.4 psig if effects of adjacent penetrations are considered for P414) except P205. This value of 58.9 psig is controlled by the bulkhead door stiffeners in the personnel air lock. To reach this pressure level, it was necessary to utilize the material certification data for the personnel air lock and equipment hatch.

For penetration P205, the Level D allowable stress shown is for inelastic analysis and reflects the use of material certification data. The allowable containment internal pressure given for this penetration is based on an elastic-plastic finite element analysis of this penetration for 60 psig internal pressure factored linearly downward to match the allowable Level D plastic stress allowable in the highest stressed element. The allowable pressure of 55.9 psig for this penetration is conservatively low because the elastic-plastic finite element analysis utilized nominal stress-strain data, not material certification data. Using the higher yield (52 ksi actual versus 38 ksi nominal) of the material as provided by material certification is expected to reduce the computed stress so as to achieve a value of at least 58.9 psig, which is equivalent to the allowable internal pressure capacity of the personnel access airlock, based on Level D allowables.

Using the 58.9 psig personnel air lock controlling pressure, the deflections at the O-Rings on the equipment hatch would be Δ_i = 0.0859 inches and Δ_o = 0.0615 inches. Considering the precompression of 0.15 inches, there is still sufficient spring-back available to prevent leakage.

Considering Level D elastic stress limits for the penetration anchor plates (which is 59.1 ksi versus the Level C allowable of 54 ksi) the permissible internal pressure increases to 63.7 psig. This pressure is controlled by four spare penetrations.

For the bellows, the elastic Service Level D allowable stress is 30,000 psi. Factoring up the bellows' stress in P422 (P407 on Unit 2) in Table 11 which is for 45 psig internal pressure, the maximum allowable internal containment pressure to observe Level D allowables on the highest stressed bellows is 100 psig.

In summary, for the penetration components other than the bellows and anchor plates, the maximum permissible containment pressure so that all stresses would remain within Level D allowable limits is 58.9 psig (57.4 psig if the influence of an adjacent penetration are considered for P414). The controlling component is the upper personnel air lock. The controlling pressure for the bellows is 100 psig and for the anchor plates it is 63.7 psig.

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Table 1

Summary of Material Strengths

Location	Minimum Specified			Lower Bound		Mean		Upper Bound	
	Yield (KSI)	Tensile (KSI)	Min. Elong. in 2 Inch. (8 Inches)	Yield (KSI)	Tensile (KSI)	Yield (KSI)	Tensile (KSI)	Yield (KSI)	Tensile (KSI)
Dome *S_y=2.970KSI *S_{ult}=2.022 KSI	38.0	70.0	21%(17%)	42.4	71.1	51.3	77.2	60.2	83.2
Cylinder *S_y=3.226KSI *S_{ult}=2.797 KSI	38.0	70.0	21%(17%)	40.0	66.5**	49.7	74.9	59.4	83.3
Welds	60.0	72.0	22%	-	-	-	-	-	-

*S - Material property standard deviation

** - 70.0 KSI minimum specified is used for the design.

Table 2

Initial Membrane Yield Pressures (PSIG)

	Tresca		von Mises		Uniaxial	
	Lower Bound	Mean	Lower Bound	Mean	Lower Bound	Mean
Dome						
Apex	88.4	107.0	88.4	107.0	88.4	107.0
Knuckle (105°)	59.8	72.4	68.0	82.4	91.7	111.0
Spring Line	166.7	206.9	170.5	211.6	166.7	206.9
Cylinder						
Circumferential	83.4	103.5	96.2	119.5	83.4	103.5
Meridional					166.7	207.0

Tresca: $|\sigma_1 - \sigma_2| \leq \sigma_o$

$$|\sigma_2 - \sigma_3| \leq \sigma_o$$

$$|\sigma_3 - \sigma_1| \leq \sigma_o$$

von Mises: $(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 \leq 2\sigma_o^2$

Table 3

Ultimate Pressure Capacity Without Considering Plastic Collapse or Buckling (PSIG)
(Membrane Stress)

Location	Lower Bound	Mean
Dome		
Apex	148.4	161.1
Knuckle (105°)	114.2	124.1
Spring Line	298.7	319.6
Cylinder		
Circumferential	145.7	155.9

Table 4

Elastic-Plastic Buckling and Plastic Collapse Pressures (PSIG)

Based On Stresses In Dome

Condition / Yield	Elastic-Plastic Buckling	Elastic-Plastic Buckling (5%)	Plastic Collapse	Plastic Collapse (5%)
Lower Bound 42.4 KSI	78.	88.8	93.5	97.9
Mean 51.3 KSI	94.	107.6	116.7	122.9

Table 5A

Summary of Stresses at Local Areas for 78.0 PSIG
(Lower Bound)

Location	Meridional Stress Inside Surface	Meridional Stress Outside Surface	Circumfer. Stress Inside Surface	Circumfer. Stress Outside Surface	X_i (Inside) $\times 10^8$	X_o (Outside) $\times 10^8$	$\frac{X_i}{\sigma_o^2}$	$\frac{X_o}{\sigma_o^2}$
Stiff. #5	39349.	-1870.	32309.	19944.	13.209	4.386	.83	.27
Stiff. #6	39363.	-1883.	32315.	19941.	13.217	4.387	.83	.27
Ring Girder	40899.	-3420.	29812.	16516.	13.422	3.410	.84	.21
	38075.	-648.	28961.	17344.	11.858	3.125	.74	.20
	50491.	-13065.	28561.	9494.	19.230	3.849	1.20	.24
	52509.	-15030.	29165.	8904.	20.764	4.390	1.30	.27
Spring Line	18258.	19221.	817.	1105.	3.191	3.494	.20	.22
Top of Fix	60508.	-23596.	17015.	-8216.	29.212	4.304	1.83	.27

$$\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2 = X$$

Table 5B

Summary of Stresses at Local Areas for 94.0 PSIG
(Mean)

Location	Meridional Stress Inside Surface	Meridional Stress Outside Surface	Circumfer. Stress Inside Surface	Circumfer. Stress Outside Surface	X_i (Inside) x 10^8	X_o (Outside) x 10^8	$\frac{X_i}{\sigma_o^2}$	$\frac{X_o}{\sigma_o^2}$
Stiff. #5	47421.	-2254.	38937.	24035.	19.185	6.369	.78	.26
Stiff. #6	47437.	-2269.	38943.	24031.	19.195	6.372	.79	.26
Ring Girder	49289.	-4121.	35927.	19904.	19.493	4.952	.79	.20
	45885.	-781.	34901.	20902.	17.221	4.538	.70	.18
	60848.	-15745.	34420.	11412.	27.928	5.578	1.13	.23
	63280.	-18113.	35148.	10730.	30.156	6.376	1.22	.26
Spring Line	22004.	23163.	984.	1332.	4.635	5.074	.19	.21
Top of Fix	72920.	-28436.	20505.	-9901.	42.426	6.251	1.72	.25

$\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2 = X$

Table 6A

Penetration Stresses Due to 78.0 PSIG
(Lower Bound)

Location	Penetration Sleeve-Vessel or Collar Intersection				Collar - Vessel Intersection			
	Tangential Stress	Radial Stress	X x10^8	$\frac{X}{\sigma_o^2}$	Tangential Stress	Radial Stress	X x10^8	$\frac{X}{\sigma_o^2}$
Upper & Lower Personnel Air Lock	45050.	-13043.	27.872	1.74 (59.1 psig)*	66713.	-40852.	88.448	5.53 (33.2 psig)
Equipment Hatch	45220.	- 2287.	21.535	1.35 (67.2 psig)	66713.	-40103.	87.341	5.46 (33.4 psig)
Main Steam Penetration	87364.	-74377.	196.623	12.29 (22.3 psig)	Collar not required			

$\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2 = X$

*Pressures which cause initial membrane yield

Table 6B

Penetration Stresses Due to 94.0 PSIG
(Mean)

Location	Penetration Sleeve-Vessel or Collar Intersection				Collar - Vessel Intersection			
	Tangential Stress	Radial Stress	X x10^8	$\frac{X}{\sigma_o^2}$	Tangential Stress	Radial Stress	X x10^8	$\frac{X}{\sigma_o^2}$
Upper & Lower Personnel Air Lock	54292.	-15718.	40.480	1.64 (73.4 psig)*	80397.	-49232.	128.456	5.20 (41.2 psig)
Equipment Hatch	54496.	- 2756.	31 .276	1.27 (83.5 psig)	80397.	-48329.	126.849	5.14 (41.5 psig)
Main Steam Penetration	105285.	-89635.	285.565	11.56 (27.6 psig)	Collar not required			

$\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2 = X$

*Pressures which cause initial membrane yield

Table 7A

Summary of Containment Vessel Dynamic Pressure Deflections
(Lower Bound)

Pressure (psig)	Knuckle (105°)		Cylinder (radial)		Apex (vertical)	
	Δ(in)	μ	Δ(in)	μ	Δ(in)	μ
45.0	1.15	2.23	-	-	6.12	2.00
55.0	2.04	3.23	1.18	2.04	7.96	2.13
65.0	8.69	11.66	1.56	2.28	11.45	2.59

Table 7B

Summary of Containment Vessel Dynamic Pressure Deflections
(Mean)

Pressure (psig)	Knuckle (105°)		Cylinder (radial)		Apex (vertical)	
	Δ(in)	μ	Δ(in)	μ	Δ(in)	μ
60.0	1.74	2.53	1.26	2.00	8.28	2.03
70.0	3.14	3.91	1.52	2.06	10.52	2.21
80.0	15.60	17.00	2.17	2.43	14.42	2.65

Table 8

Summary of Stress Intensities for Dead Load and 45.0 psig and Allowable Stress Intensities for Service Level C

CONTAINMENT VESSEL

Location	Stress Intensity (psi)	Allowable Stress Intensity* (psi)
Cylinder, away from Discontinuities	$P_m = 21625$	$1.0\ S_y = 38000$
Stiffener #5	$P_L = 15219$	$1.5\ S_y = 57000$
Stiffener #6	$P_L = 15028$	$1.5\ S_y = 57000$
Ring Grider	$P_L = 13442$	$1.5\ S_y = 57000$
Dome Knuckle	$P_L = 31203$	$1.5\ S_y = 57000$

*Based on minimum specified yield stress

Table 9

Summary of Stress Intensities for Dead Load and 45.0 psig and Allowable Stress Intensities for Service Level C

PERSONNEL AIR LOCK AND EQUIPMENT HATCH

Location	Stress Intensity, Maximum Load, or Stress (psi)	Allowable Stress Intensity Load or Stress*
Upper Personnel Air Lock		
Air Lock Collar	$P_L = 27,961$	$1.0\ S_y = 36,000$
Air Lock Barrel	$P_L = 16,407$	$1.0\ S_y = 36,000$
Junction of Air Lock Collar and Barrel	$P_L = 25,971$	$1.5\ S_{mc} = 28,950$
Bulkhead & Bulkhead Door Beam Elements	10,200 (Transverse Shear)	$.6\ S_m = 11,580$
	$P_L + P_b = 48,400$	$1.5\ S_y = 54,000$
Plate Elements	$P_L + P_b = 21,044$	$1.0\ S_y = 36,000$
Sight Glass	$P = 45$	$P_{allow} = 150$ psi
Sight Glass Fillet Weld	$S_v = 500$	9,457
Barrel to Collar Fillet Weld	$S_v = 2,929$	9,457
Equipment Hatch		
Collar	$P_L = 46,222$	$1.5\ S_y = 54,000$
Shallow Spherical Cover	$P_m = 5,400$	$1.0\ S_m = 19,300$
Barrel at Flange	$P_m = 1,800$	$1.0\ S_m = 19,300$
Barrel at Vessel	$P_m = 1,800$	$1.0\ S_y = 36,000$
Junction of Spherical Cover and Cover Flange	$P_L = 5,130$	$1.5\ S_m = 28,950$
Junction of Barrel and Barrel Flange	$P_L = 1,824$	$1.5\ S_m = 28,950$
Barrel Flange	$PL + P_b = 4,784$	$1.5\ S_m = 28,950$
Cover Base Flange	$P_L = 17,950$	$1.5\ S_m = 28,950$
Bolts (Axial)	36,120	$2.0\ S_m = 55,000$
Bolts (Axial + Bending + Shear)	62,965	$3.0\ S_m = 82,500$
Barrel-Collar Fillet Weld	$S_v = 1,957$	9,457

*Based on minimum specified yield stresses

Table 10

Summary of Stress Intensities for 45.0 psig and Allowable Stress Intensities and Maximum Allowable Internal Containment Pressures for Service Level C

PENETRATIONS

Penetration Number	Stress Intensity, P_L for 45 psig Pressure (psi)	Allowable Level C Stress Intensity(3) (psi)	Max. Allowable Internal Pressure (psig)
104	35600	57000	72.1
307	35900	57000	71.4
308	35600	57000	72.1
417	36000	57000	71.3
424	34900	57000	73.5
119	36100	57000	71.1
203	30500	52500	72.1
434	30000	57000	85.5
421(6)	30000	57000	85.5
422(6)	30000	57000	85.5
425	26600	57000	96.4
107	25800	57000	99.4
406	25800	57000	99.4
404	25500	57000	100.6
429	25200	57000	101.8
419(6)	25000	57000	102.6
106	39300	57000	65.3
111	33200	57000	77.3
112	37600	57000	68.2
310	33200	57000	77.3
311	33200	57000	77.3
424(6)	33200	57000	77.3
426(6)	33200	57000	77.3
132	39400	52500	60.0
419	25500	57000	100.6
123	40200	52500	58.8
105	30700	57000	83.6
407	30700	57000	83.6
404(6)	25000	57000	102.6
114	36600	57000	70.1
205	63500	57000 (77,300(1))	54.8(2)
421	41600	57000	61.7
313	38630	52500	61.2
122	38500	57000	66.6
124	37200	57000	69.0
414	43260(4)	57000	59.3(5)

NOTES:

1. Allowable stress based on using material certifications.
2. Based on using material certification data to determine allowable stress.
3. Based on minimum specified material properties unless otherwise indicated.
4. This value increases to 51,479 when considering the effect of adjacent penetration P416.
5. This value reduces to 49.7 when considering the effect of adjacent penetration P416.
6. These penetrations are on Unit 2. All others are on Unit 1.

Table 11

Summary of Penetration Bellows Stresses For 45.0 psig Containment Vessel Internal Pressure

Penetration Number	System	S_1 (psi)	S_2 (psi)	S_3 (psi)	S_4 (psi)	S_{allow} (psi)
P122 (P414)	Main Steam	5,155	6,239	922	9,920	18,460
P422 (P407)	RHR & RCIC	6,490	5,500	1,100	13,409	18,460

S_1 - Bellows tangent circumferential membrane stress

S_2 - Bellows circumferential membrane stress

S_3 - Bellows meridional membrane stress

S_4 - Bellows meridional bending stress

S_{allow}. - ASME Code allowable stress (S_1 through S_4 must each be less than S_{allow}.)

Table 12

Summary of Controlling Level D Stress Limits And Permissible Level D Containment Pressures

Penetration

Penetration	Level D Elastic Allowable Stress Intensity = 1.5 S_f (psi)	Allowable Containment(5) Internal Pressure (psig)
Upper Personnel Air Lock(1)	63300(6)	58.9
Equipment Hatch(2)	82500(7)	59.0
104	62600	79.1
307	62600	78.5
308	62600	79.1
417	62600	78.3
424	62600	80.7
119	62600	78.0
203	53600	79.1
434	62600	93.9
421	62600	93.9
422	62600	93.9
425	62600	105.9
107	62600	109.2
406	62600	109.2
404	62600	110.5
429	62600	111.8
419	62600	112.7
106	62600	71.7
111	62600	84.8
112	62600	74.9
310	62600	84.8
311	62600	84.8
424	62600	84.8
426	62600	84.8
132	53600	61.2

Table 12 (Continued)

Penetration	Level D Allowable Stress Intensity = 1.5 S_f (psi)	Allowable Containment Internal Pressure (psig)
419	62600	110.5
123	53600	60.0
105	62600	91.8
407	62600	91.8
404	62600	112.7
114	62600	77.0
205	52000(3)	55.9(4)
421	62600	67.7
313	53600	62.4
122	62600	73.2
124	62600	75.7
414	65700(6)	68.3(8)
32" Penetration	62600	176.9
48" Penetration	62600	179.4

NOTES:

1. Controlling stress is $P_L + P_b$ in the bulkhead door stiffeners. Level C controlling stress is at the collar and barrel junction.

2. Controlling stress is axial and bending and shear in hatch bolts.

3. This allowable stress is the Level D inelastic allowable stress equal to S_f and is based on material certification data even though the inelastic analysis of this penetration was based on minimum specified material properties.

4. See discussion in Section 6.4 for an explanation of the basis for this value.

5. Based on on elastic analysis unless indicated otherwise.

6. Level D elastic allowable stress based on material certification data.

7. This is the ASME BPV Code Section III Subsection NE Level A allowable. The code does not stipulate allowables for other service levels for bolts.

8. This value becomes 57.4 psig if the effects of an adjacent penetration are considered.

GILBERT ASSOCIATES, INC. ENGINEERS AND CONSULTANTS READING, PENNA.	CLEVELAND ELECTRIC ILLUMINATING CO. PERRY NUCLEAR POWER PLANT UNITS 1 & 2	FILING CODE		
		W.O 044549–	PAGE	
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CALCULATION FOR –		REVIEWER	DATE	

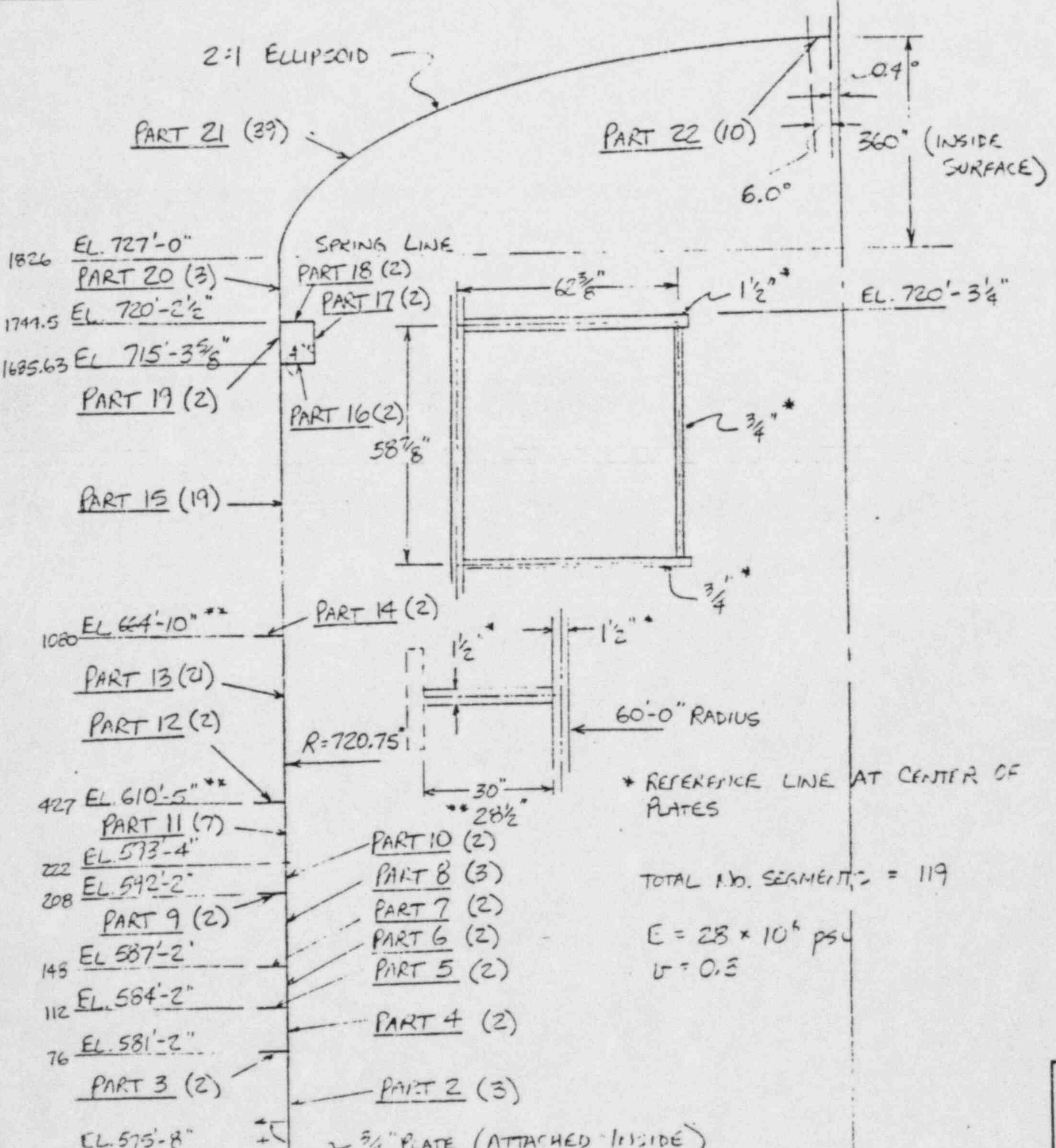
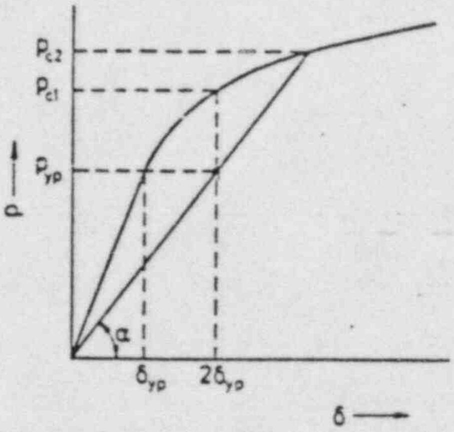


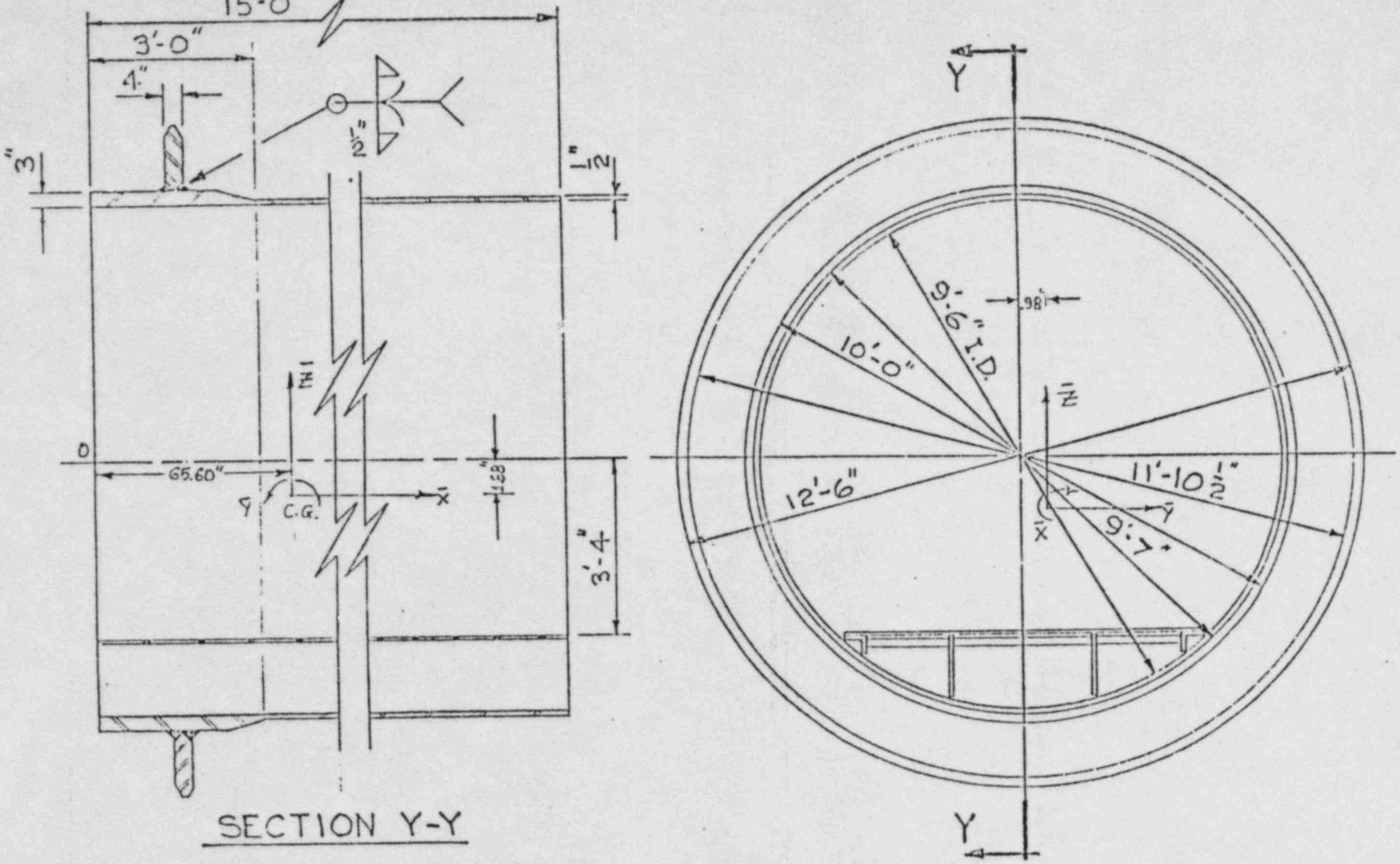
Figure 1

FILING CODE



Definition of plastic collapse pressures p_{c1} and p_{c2} using crown deflection

Figure 2

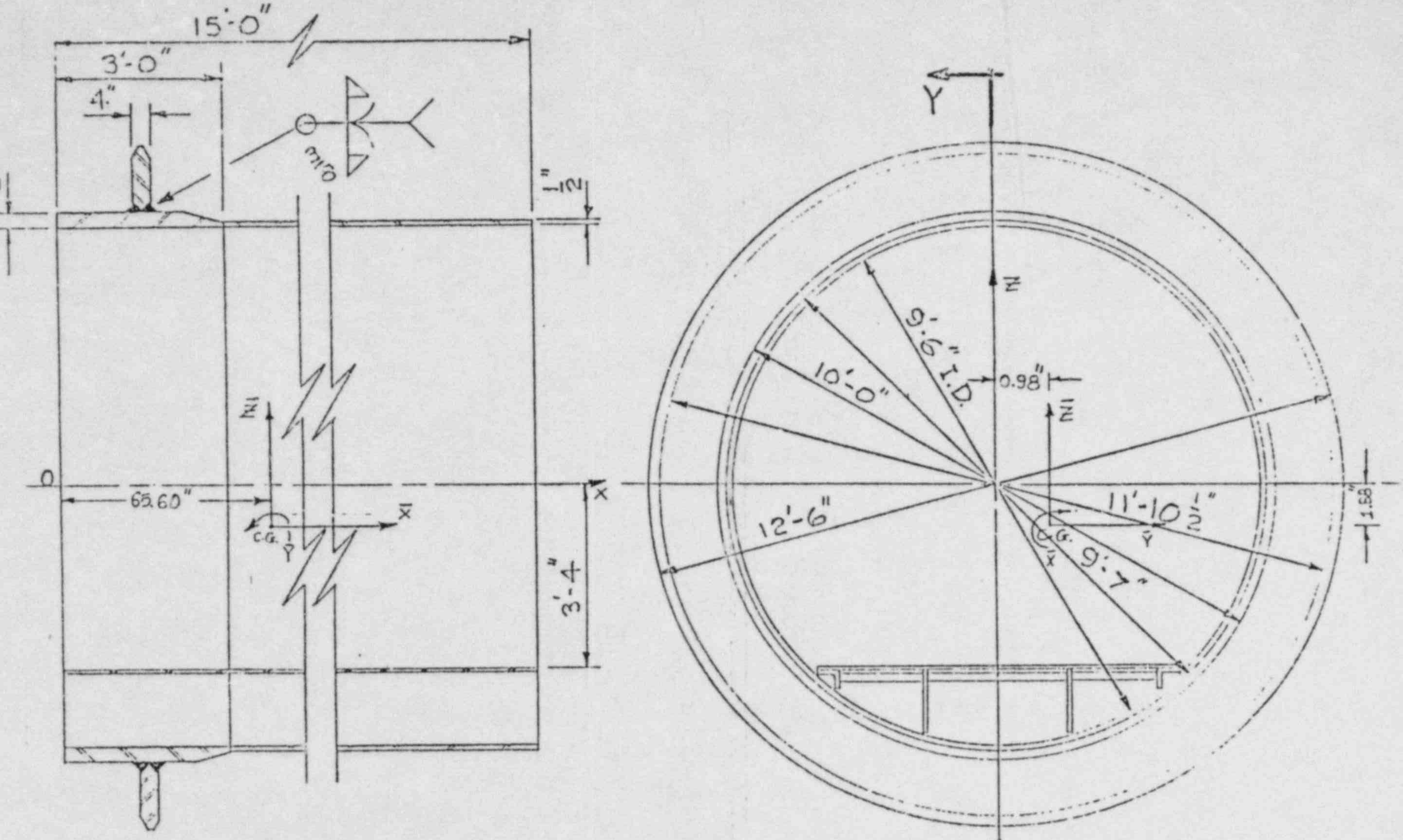


SECTION Y-Y

OVERALL DIMENSIONS OF COLLAR & BARREL

Figure 3A

PERRY NUCLEAR POWER PLANT
UPPER PERSONNEL AIR LOCK
SERIAL NO. 33454

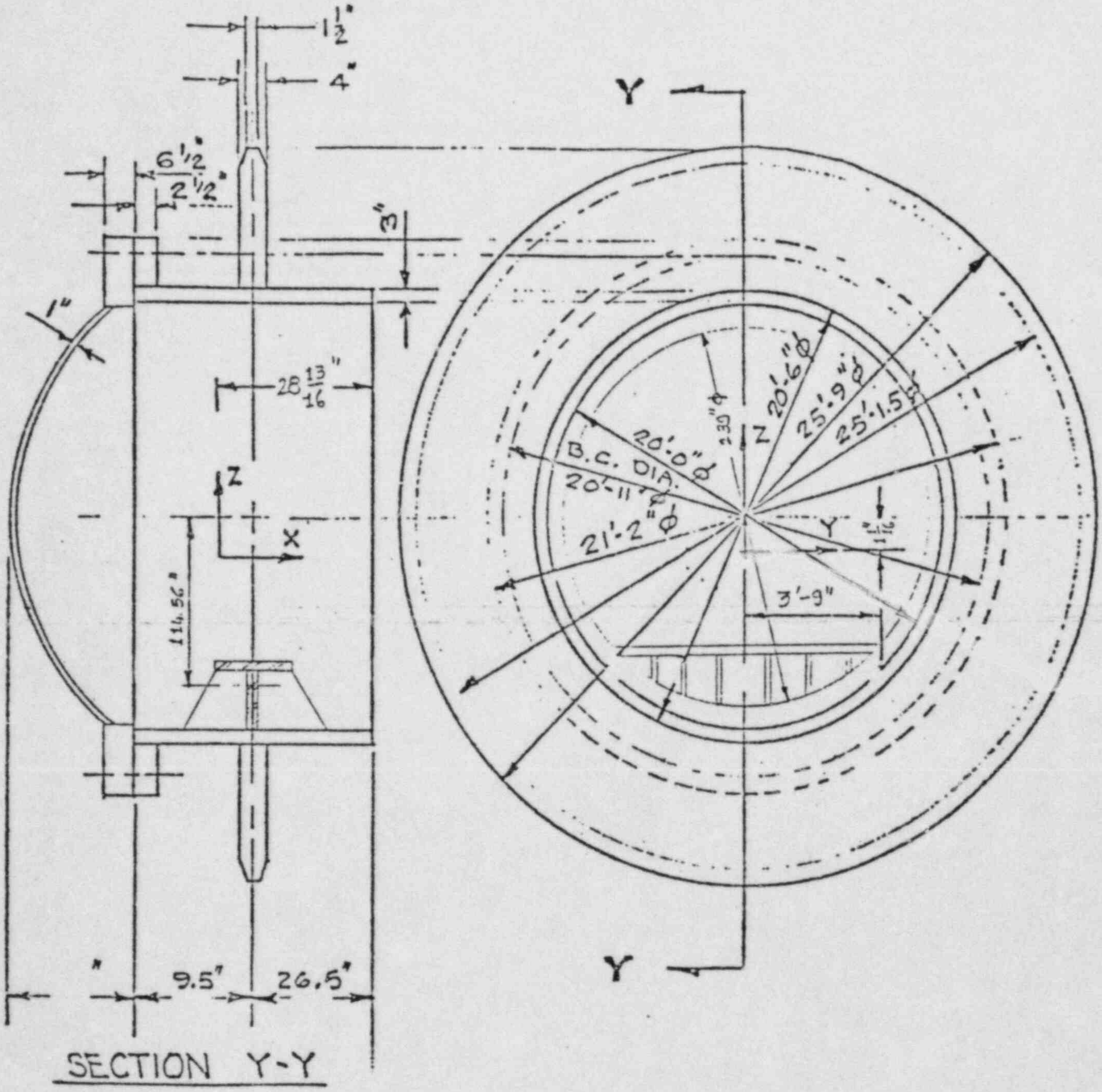


SECTION Y-Y

OVERALL DIMENSIONS OF COLLAR & BARREL

Figure 3B

PERRY NUCLEAR POWER PLANT
LOWER PERSONNEL AIR LOCK
SERIAL NO. 3378



OVERALL DIMENSIONS OF
EQUIPMENT HATCH ASSEMBLY

PERRY NUCLEAR POWER PLANT
20'-0" EQUIPMENT HATCH
SERIAL NO. 33372

Figure 4A

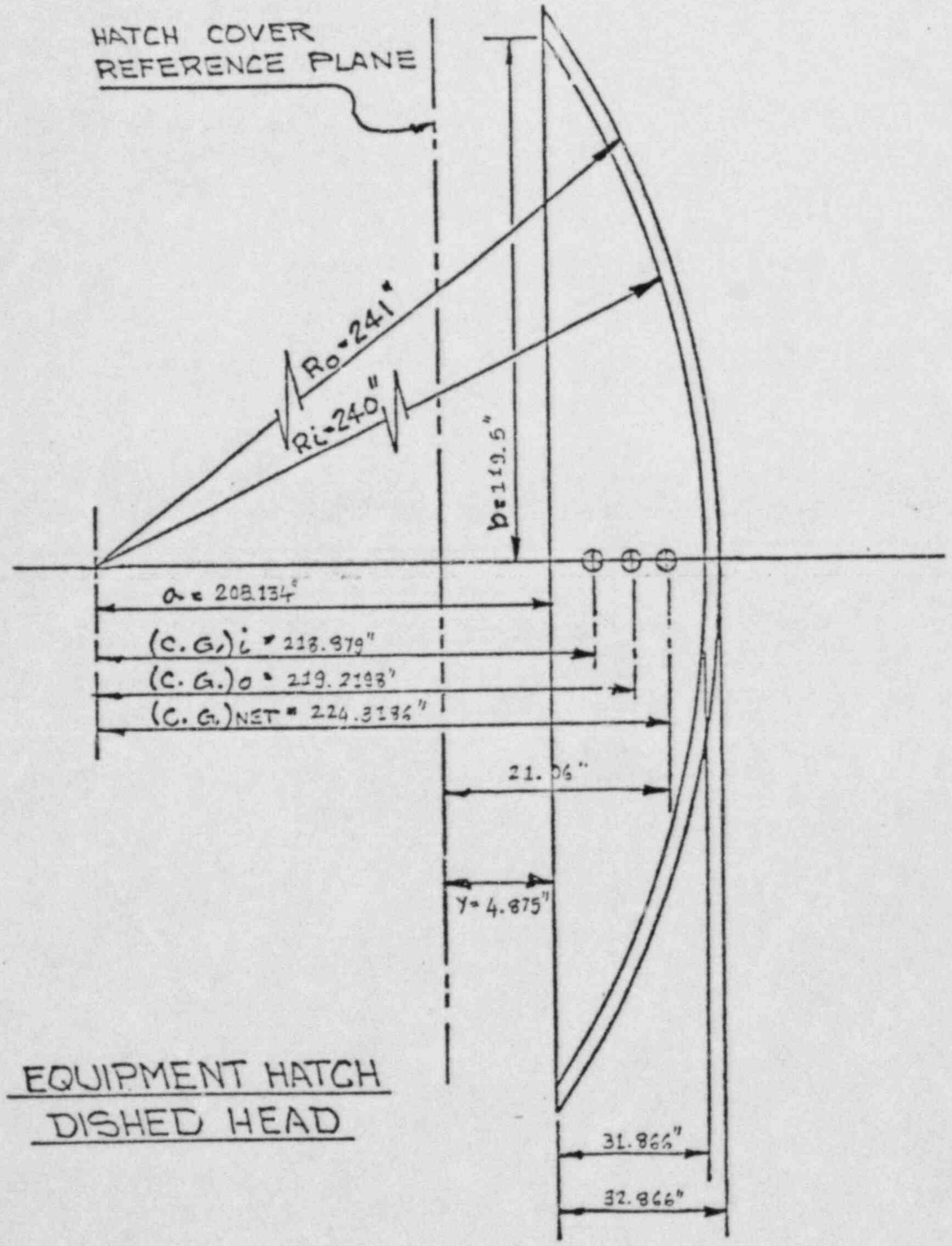


Figure 4B

PERRY NUCLEAR POWER PLANT
20'-0" EQUIPMENT HATCH
SERIAL NO. 33372

MAIN STEAM
PENETRATION

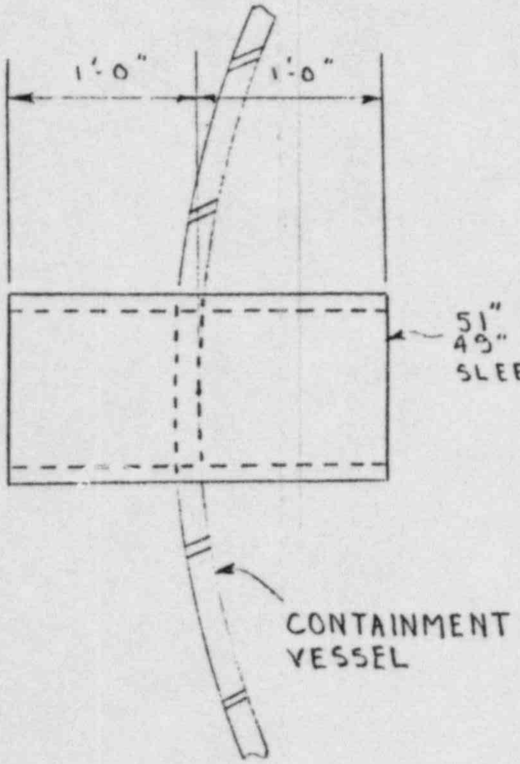


Figure 5

CONTAINMENT VESSEL
RESISTANCE FUNCTION

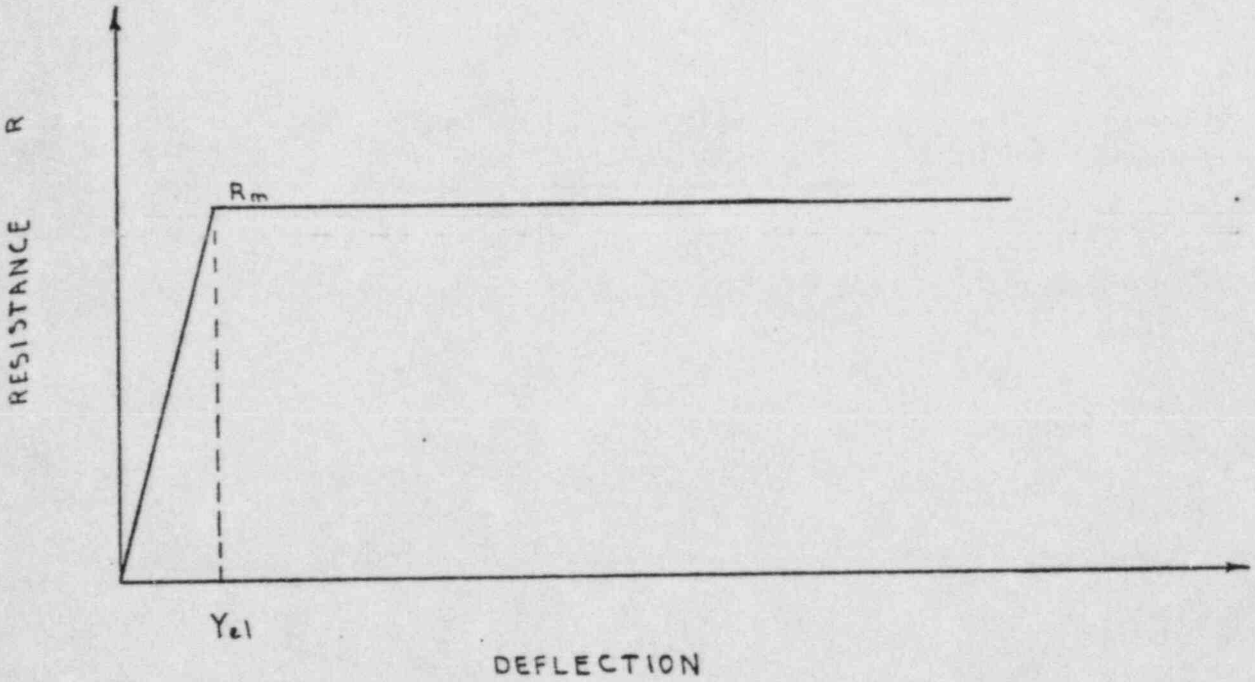
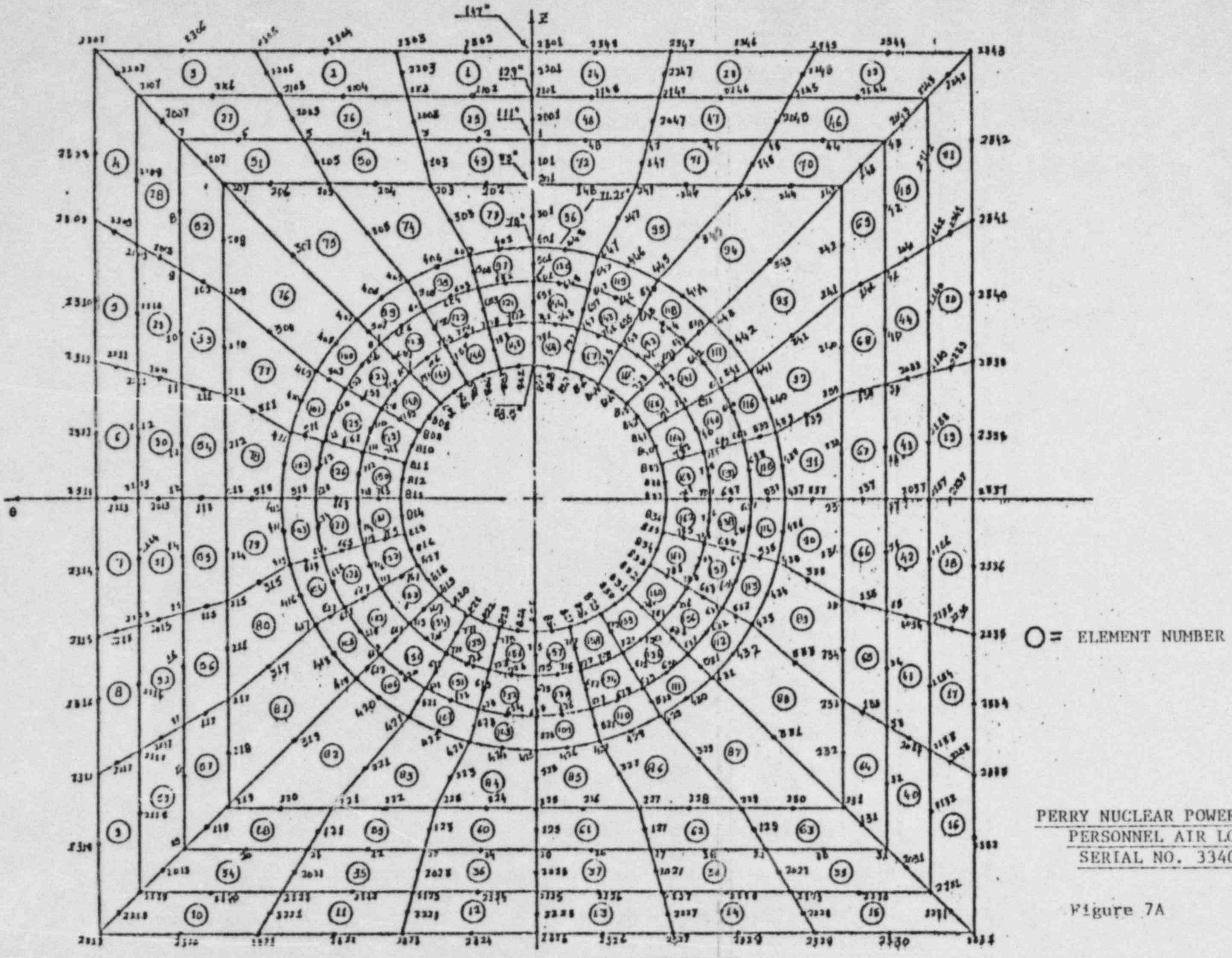


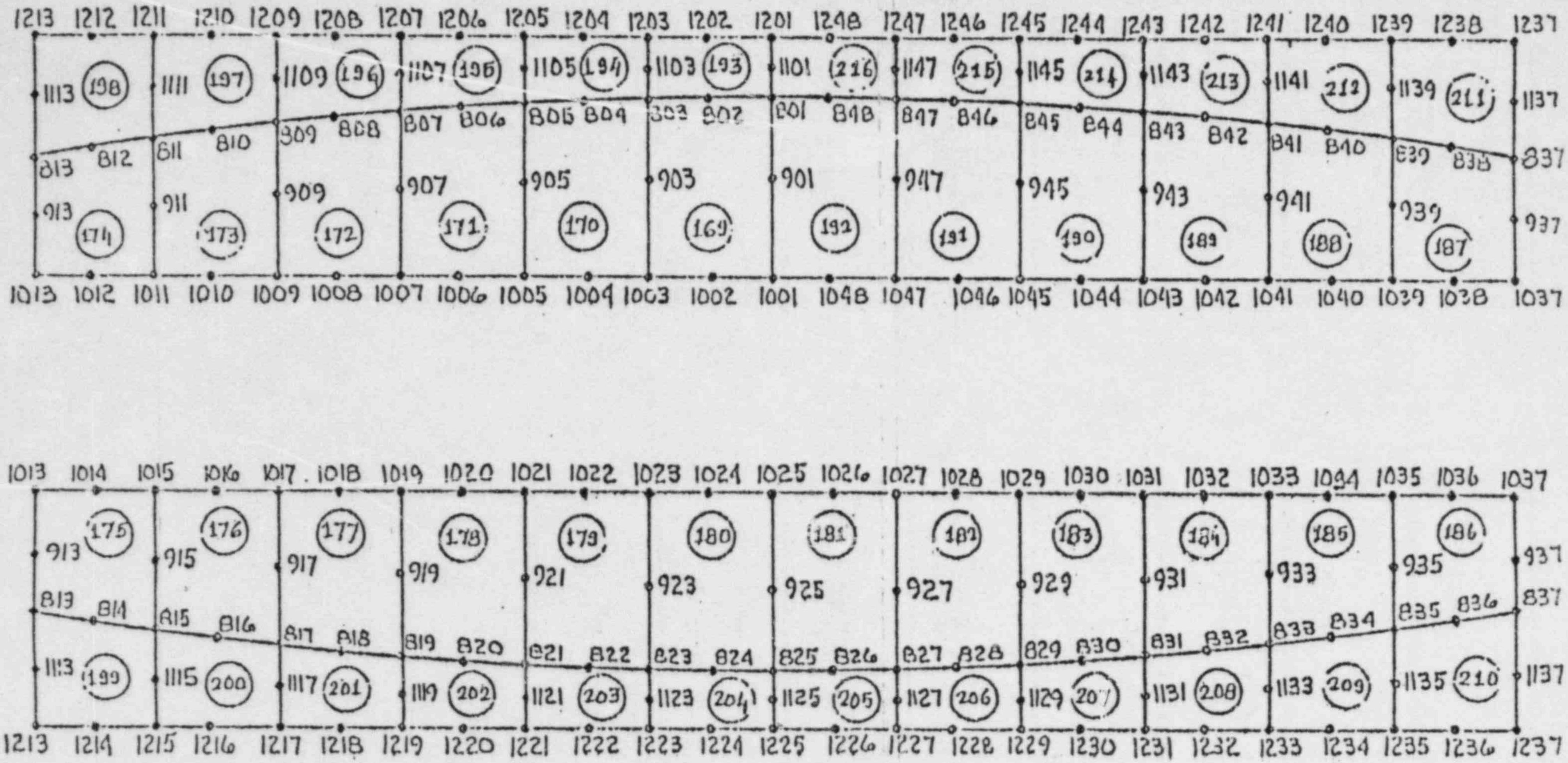
Figure 6



COLLAR AND BARREL
FINITE ELEMENT MODEL (COLLAR)

PERRY NUCLEAR POWER PLANT
PERSONNEL AIR LOCK
SERIAL NO. 33403

Figure 7A

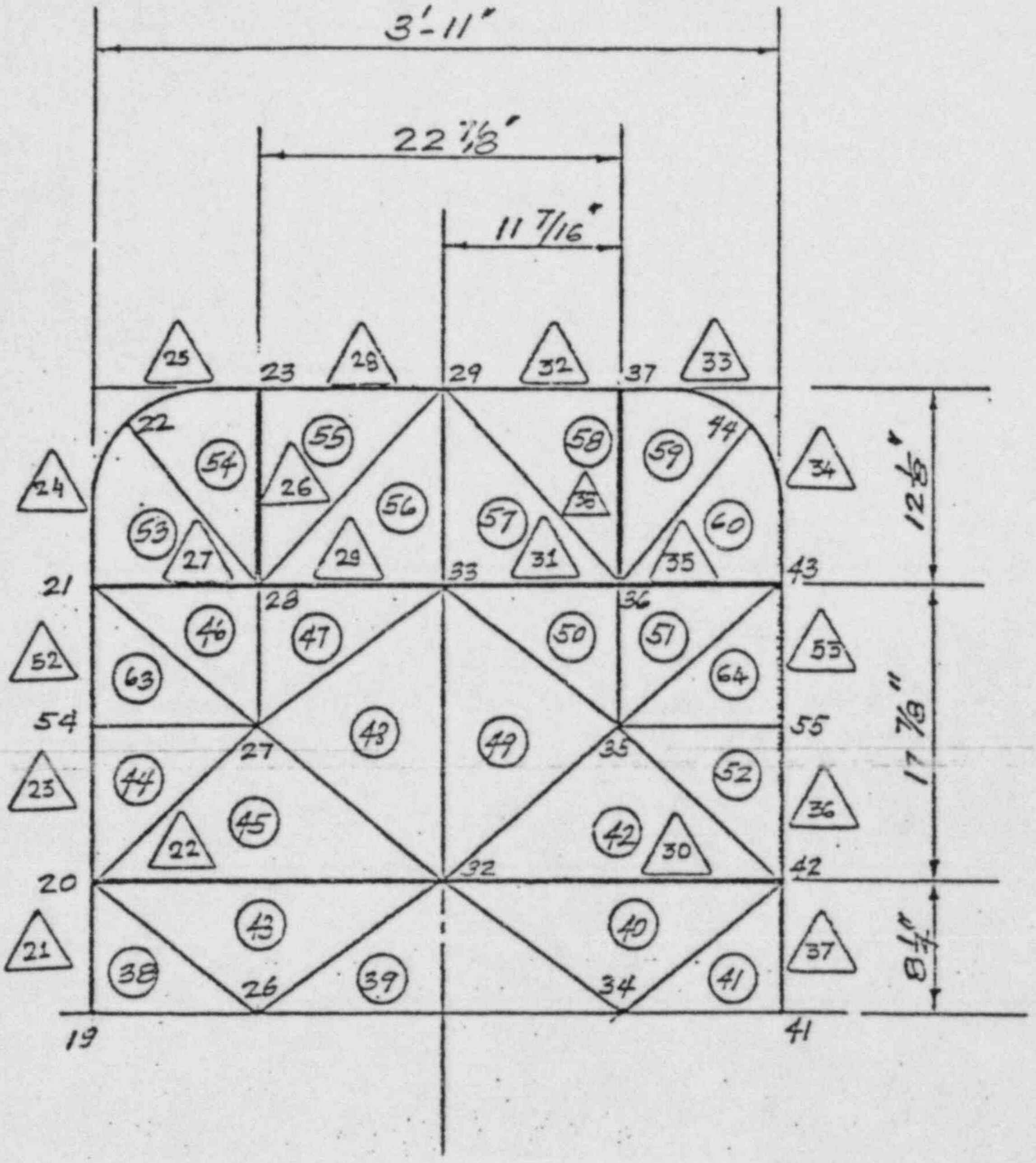


COLLAR AND BARREL
FINITE ELEMENT MODEL (BARREL)

Figure 7B

CIRCLED NUMBERS
ARE ELEMENT NUMBERS

PERRY NUCLEAR POWER PLANT
UPPER PERSONNEL AIR LOCK
SERIAL NO. 33403



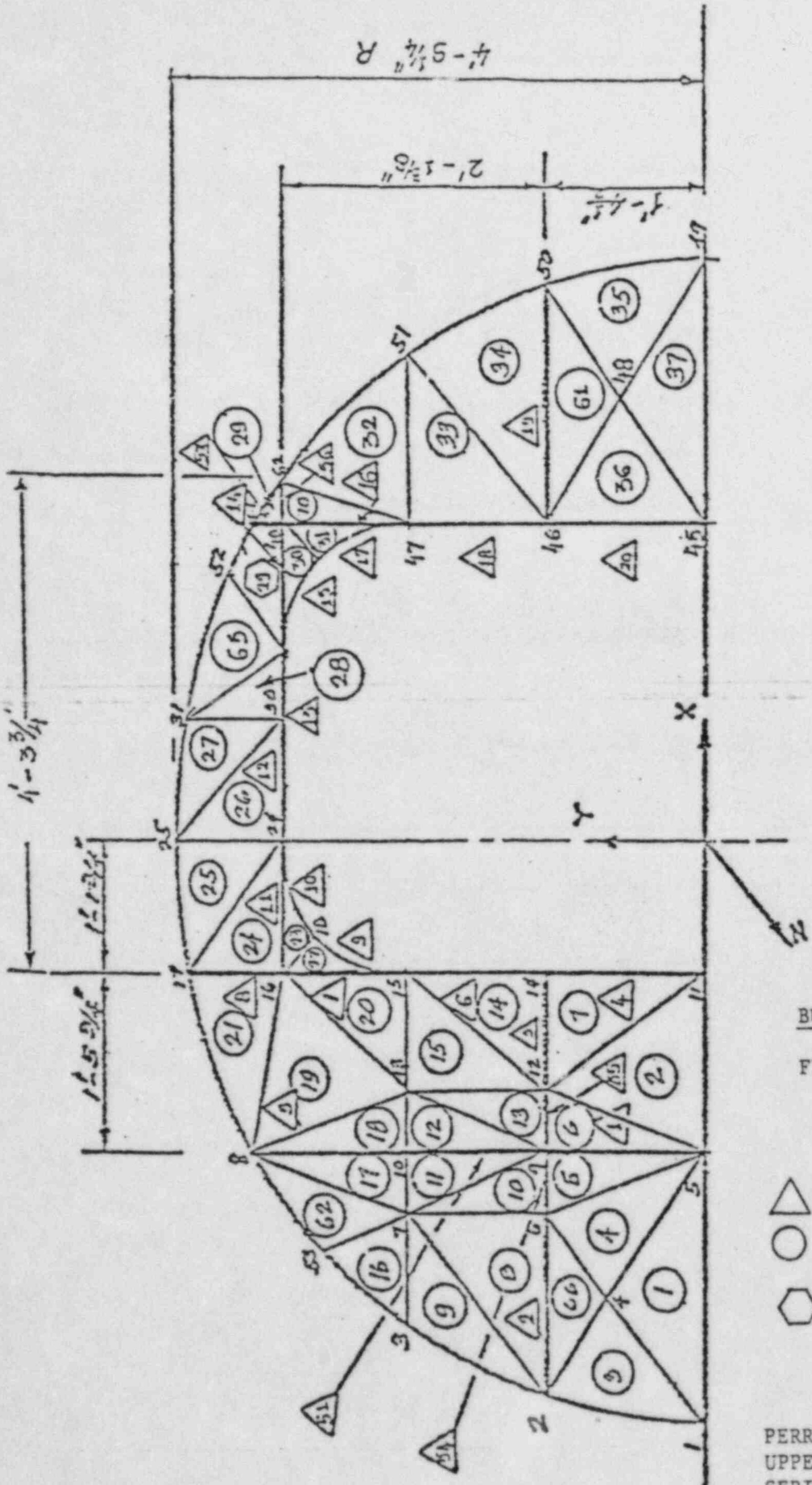
BULKHEAD DOOR
FINITE ELEMENT MODEL

Figure 8A

△ BEAM ELEMENT NO.

○ PLATE ELEMENT NO.

PERRY NUCLEAR POWER PLANT
UPPER PERSONNEL AIR LOCK
SERIAL NO. 33403



BULKHEAD

FINITE ELEMENT MODEL

△ BEAM ELEMENT NO.

○ TRIANGULAR PLATE ELEMENT NO.

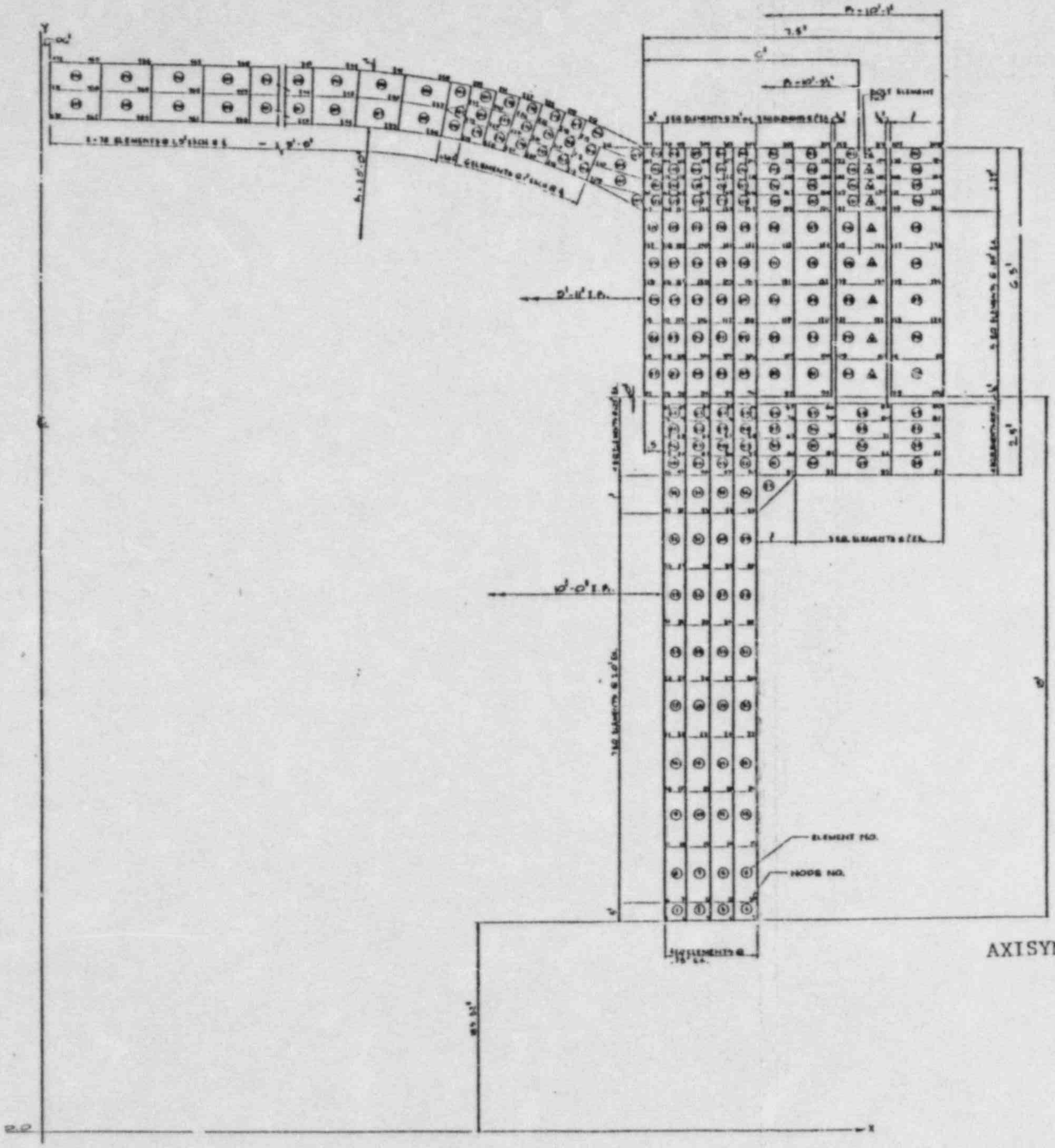
⬡ QUADRILATERAL PLATE ELEMENT NO.

PERRY NUCLEAR POWER PLANT
UPPER PERSONNEL AIR LOCK
SERIAL NO. 33403
Figure 8B

Superb Computer Model of Equipment

Hatch Collar and Barrel

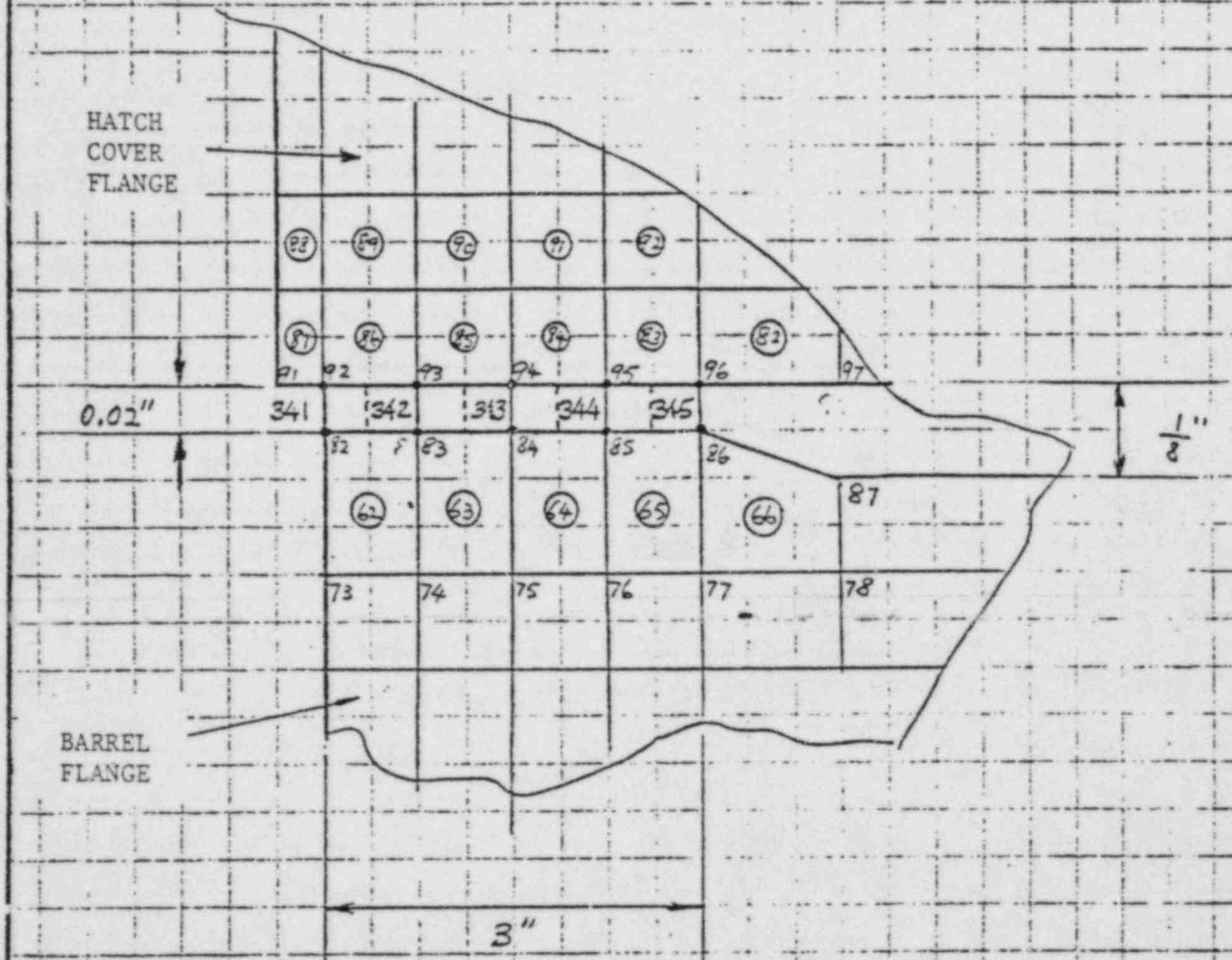
Figure 9



AXISYMMETRIC FINITE ELEMENT MODEL

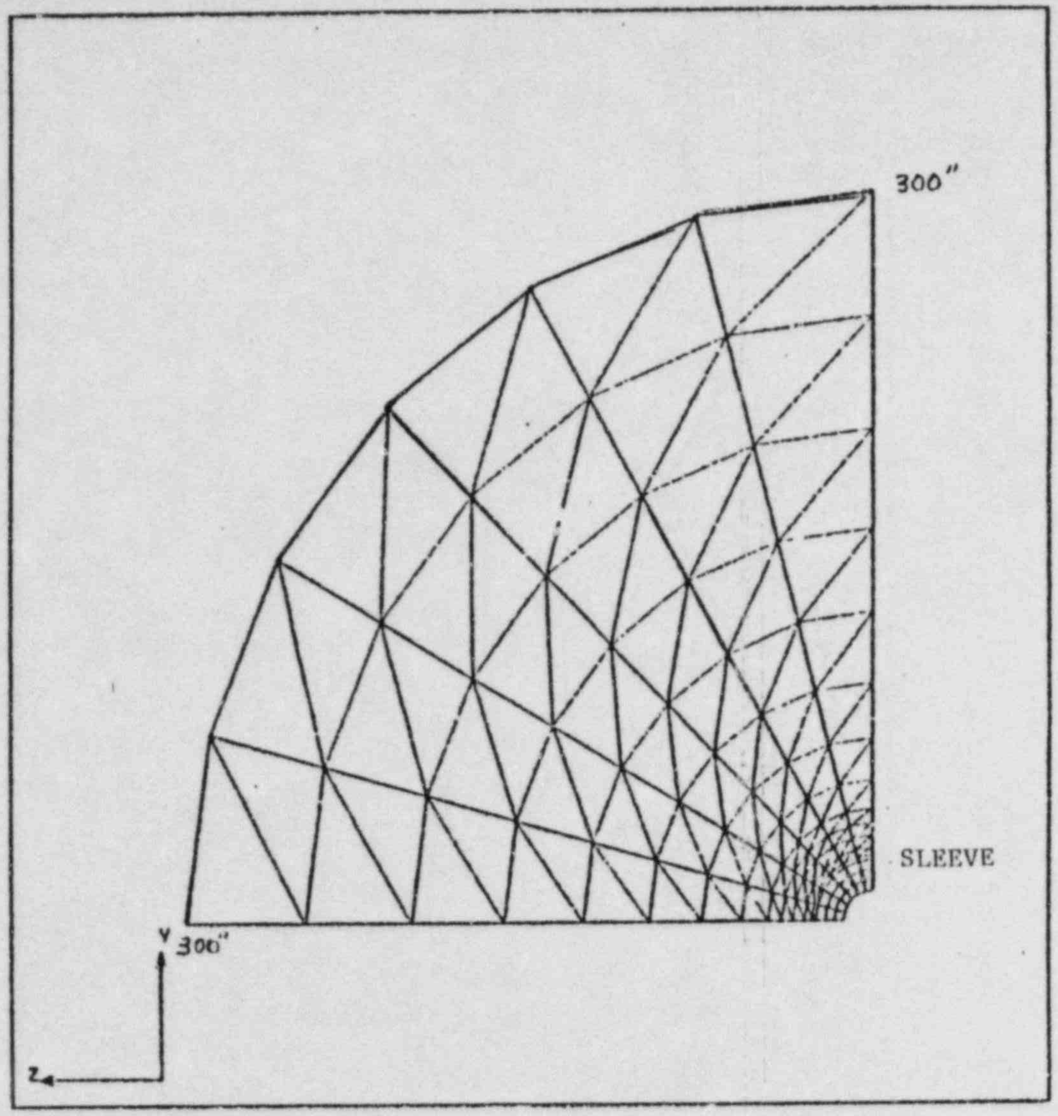
EQUIPMENT HATCH

Figure 10



THE FIVE STAR ELEMENTS
(STIFF 1), 341 to 345

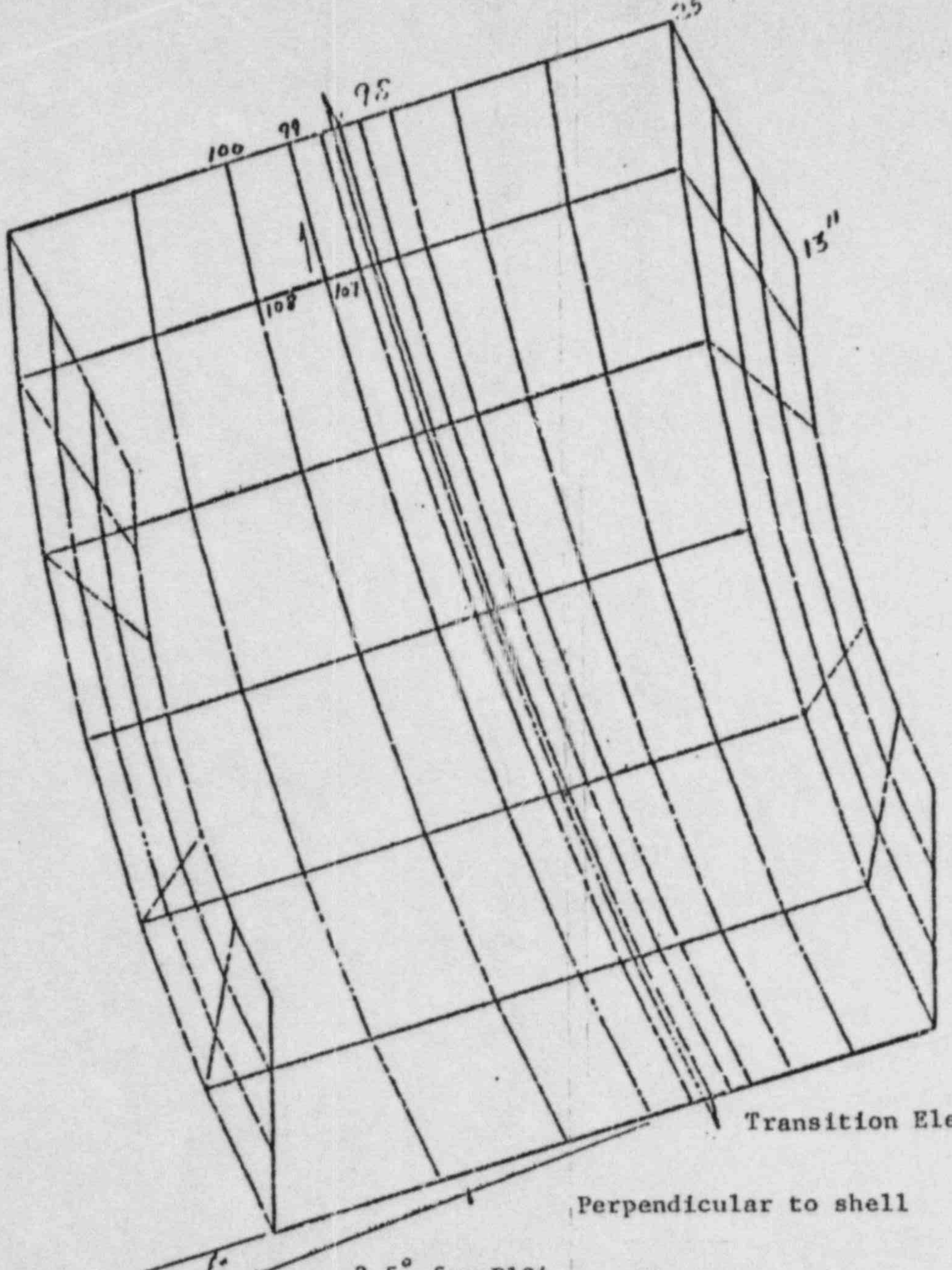
Figure 11



DATA CHECK PENETRATION 122 UNIT 1

JOB 122 SCALE- 1.0/ 76.9

Figure 12a



Transition Element

Perpendicular to shell

3.5° for P124

10.4° for P122

Figure 12b

REFERENCES:

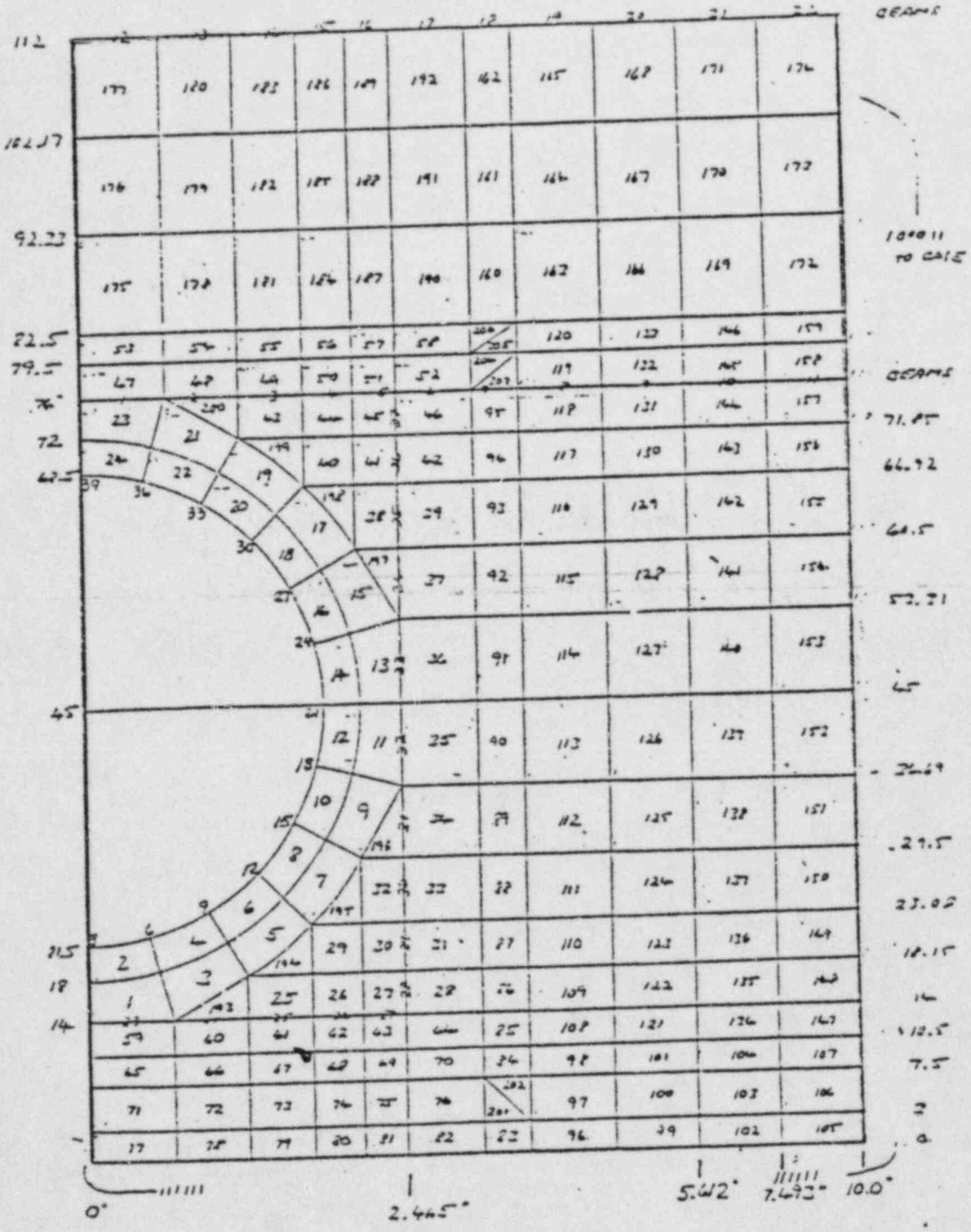


Figure 13a

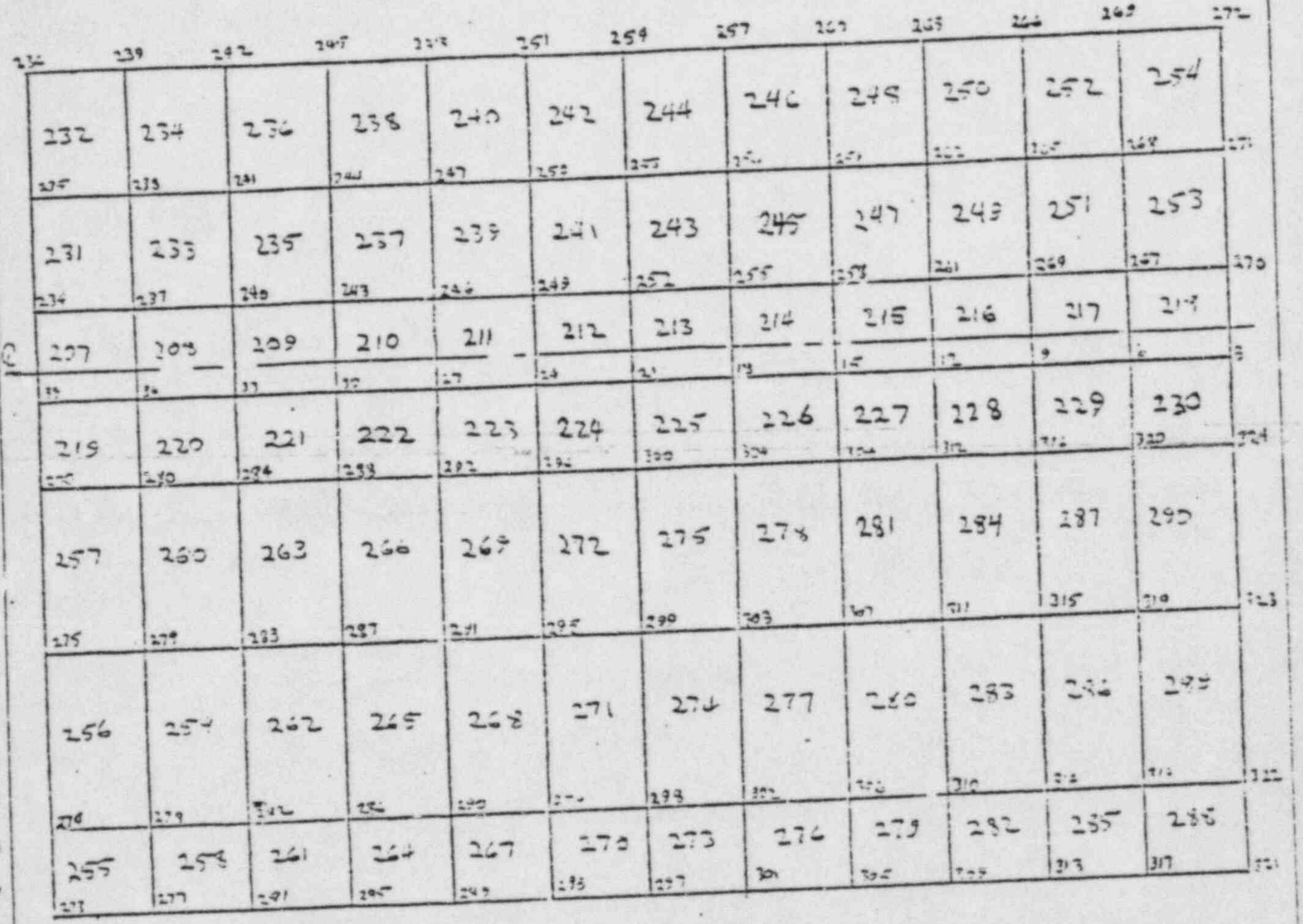
NOTE: FOR 48" PENETRATION SHELL

SUBJECT ULTIMATE CAPACITY ANALYSIS FOR [illegible] PENETRATIONS		J.O.
PREPARED BY J.V.W.	DATE 5/3/8[illegible]	DATE 5/23/8[illegible]
APPROVED BY	DATE / /	FILING CODE
		PAGE 23 OF [illegible]

1-428

REFERENCES:

¼ SLEEVE LAYOUT FOR ~~48"~~ PENETRATION



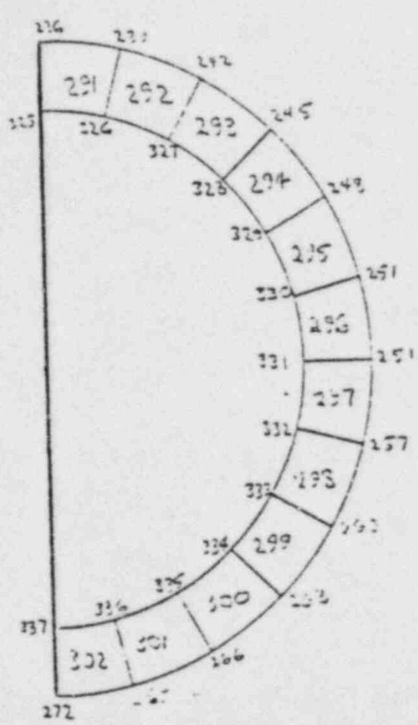
232	234	236	238	240	242	244	246	248	250	252	254
231	233	235	237	239	241	243	245	247	249	251	253
207	208	209	210	211	212	213	214	215	216	217	218
219	220	221	222	223	224	225	226	227	228	229	230
257	260	263	266	269	272	275	278	281	284	287	290
256	254	262	265	268	271	274	277	280	283	286	289
255	258	261	264	267	270	273	276	279	282	255	288

Figure 13b

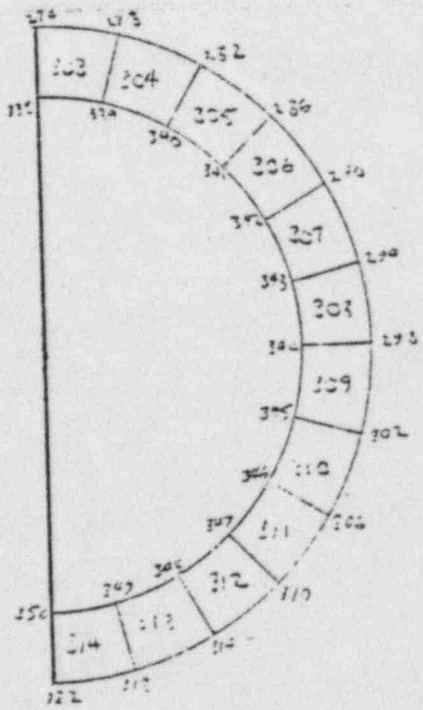
SUBJECT			J.O.
PREPARED BY JMW	DATE 6/3/82	REVIEWED BY	DATE 6/22/82
APPROVED BY	DATE / /	FILING CODE	PAGE 24 OF 32

1-428

REFERENCES:



1½ " Inner Disc Insert



1½ " Outer Disc Insert

Figure 13c

46" PENETRATION

SUBJECT ULTIMATE CAPACITY ANALYSIS FOR LOWER PENETRATIONS			J.O.
PREPARED BY	DATE [illegible]	REVIEWED BY	DATE [illegible]
APPROVED BY	DATE / /	FILING CODE	PAGE [illegible] OF 32

1-428

REFERENCES:

PLATE SURROUNDING PENETRATION ° 32" PENETRATION

RETAIN LOCATIONS FOR NODES
3, 6, 9 . . . 39 . GENERATE
NEW NODES FOR OTHERS
SINCE THEY HAVE
BEEN RENUMBERED

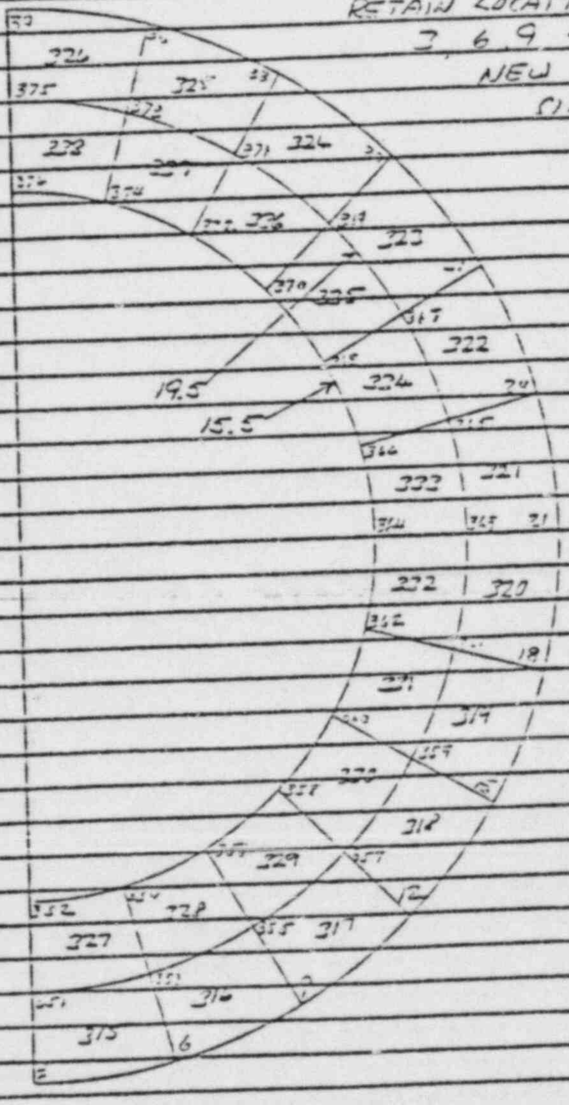


Figure 14

Ultimate Capacity Analysis for
Lower Penetrations