Perry Nuclear Power Plant Units 1 & 2
Ultimate Structural Capacity
of
Mark III Containments

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1.0 INTRODUCTION

The ultimate internal pressure 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 and existing stress analyses of the containment vessel. 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.

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 present analyses used a stress concentration approach for the evaluation of the upper and lower personnel air locks, equipment hatch, and main steam penetration which controlled the pressure capacity of the vessel. However, these regions could be reinforced to resist the 78.0 psig and 94.0 psig values for the general shell. It is possible that a more refined analysis of these regions as they currently exist, by considering the post yield behavior, would support the general shell capacities.

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 may 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^{o} 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. Eleastic 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 elestic-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, 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	155.9 (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 to reach the ultimate stress. However, the containment vessel pressure cannot be increased to this pressure because of the large deformations that occur at this pressure.

Based upon the preceding discussion, the lower bound and mean buckling pressures of 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 σ_o^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 are analyzed be 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 stress 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.

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 Tables 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 pressures 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 M, 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.

The conclusion of the present evaluation of the penetration regions is that the stresses in these areas control the vessel pressure capacity.

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 minimum 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 $\dot{y}el$, 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.

$$0 = (F_1 - R_m) \frac{t_m}{M} - \frac{F_1 t_m}{M t_d} T + C_1$$

$$Y = (F_1 - R_m) \frac{t_m^2}{2M} - F_1 T \frac{t_m^2}{2 t_d} + C_1 t + C_2$$

Where:

R_m = resistance function

t_m = time of plastic maximum response

M = Mass

T = $t_{el} + t_m$

C_1 = velocity at t_{el}

C_2 = elastic deflection

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. As seen in the table, a large increase in the deflections occurs between 80.0 psig and 90.0 psig for the lower bound and 90.0 psig and 100.0 psig for the mean value material strengths at the dome knuckle. Therefore, 80.0 psig and 90.0 psig are considered to be the lower bound and mean value dynamic pressure capacities of the containment vessel.

The penetration areas have a lower static pressure capacity than the general containment vessel and therefore have a lower dynamic pressure capacity. This dynamic pressure capacity can be increased to the general containment vessel dynamic pressure capacity by providing additional reinforcement around the penetrations and by more detailed analyses of the penetration areas. 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.

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4. Handbook of Formulas for Stress and Strain, William Griffel, Frederick Unger Publishing Company.

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6. Introduction of Structural Dynamics, J.M. Biggs, McGraw-Hill.

7. Local Stresses in Spherical and Cylindrical Shells Due to External Loading, K.R. Wichman, A.G. Hopper, and J.L. Mershon, Welding Research Council Bulletin No. 107.

<u>Summary of Material Strengths</u>

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 1

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

Table 2

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

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

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

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

Ultimate Pressure Capacity (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 3

Elastic-Plastic Buckling and Plastic Collapse Pressures (PSIG)

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 4

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) x 10^8	X_o (Outside) x 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 (Fixed)	60508.	-23596.	17015.	-8216.	29.212	4.304	1.83	.27

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

Table 5A

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) $\times 10^8$	X_o (Outside) $\times 10^8$	$\frac{X_i}{\sigma_o^2}$	$\frac{X_o}{\sigma_o^2}$
Stiff. #5	47421.	-2254.	38937.	24035.	19.185	6.369	.78	.26
Stiff. #6	47437.	-2269.	38943.	[illegible]031.	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 (Fixed)	72920.	-28436.	20505.	-9901.	42.426	6.251	1.72	.25

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

Table 5B

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)	No reinforcement is provided			

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

*Pressures which cause initial membrane yield

Table 6A

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)	No reinforcement is provided			

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

*Pressures which cause initial membrane yield

Table 6B

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
70.0	2.25	2.16	1.47	1.06	9.84	1.22
80.0	4.26	4.09	1.75	1.26	12.40	1.54
90.0	28.59	27.49	2.16	1.56	16.76	2.08

Table 7A

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
80.0	2.63	2.23	1.68	1.07	9.54	1.04
90.0	4.62	3.91	1.96	1.24	13.88	1.52
100.0	17.70	15.00	2.35	1.49	17.96	1.97

Table 7B

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	
STRUCTURE: CONTAINMENT VESSEL		ORIGINATOR: K	DATE: 3/20/81	REV.
CALCULATION FOR		REVIEWER	DATE	

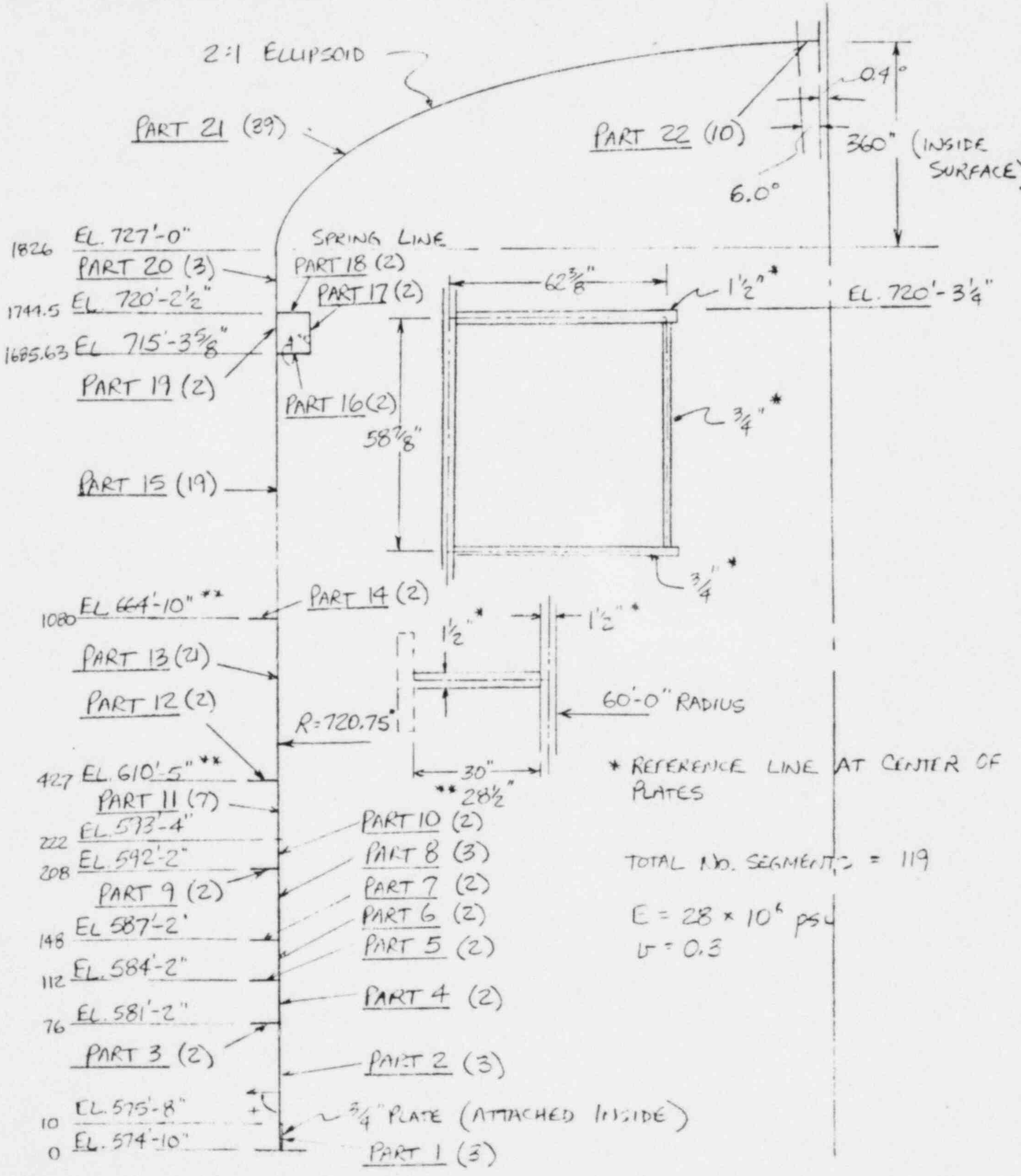
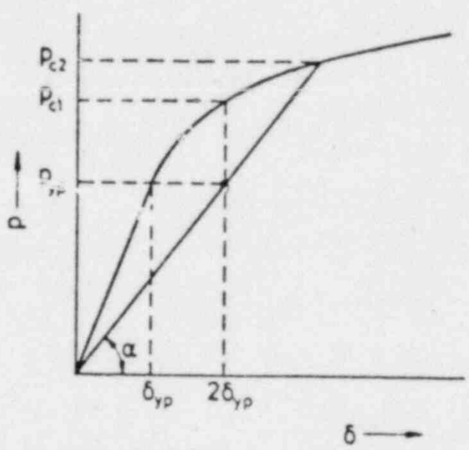


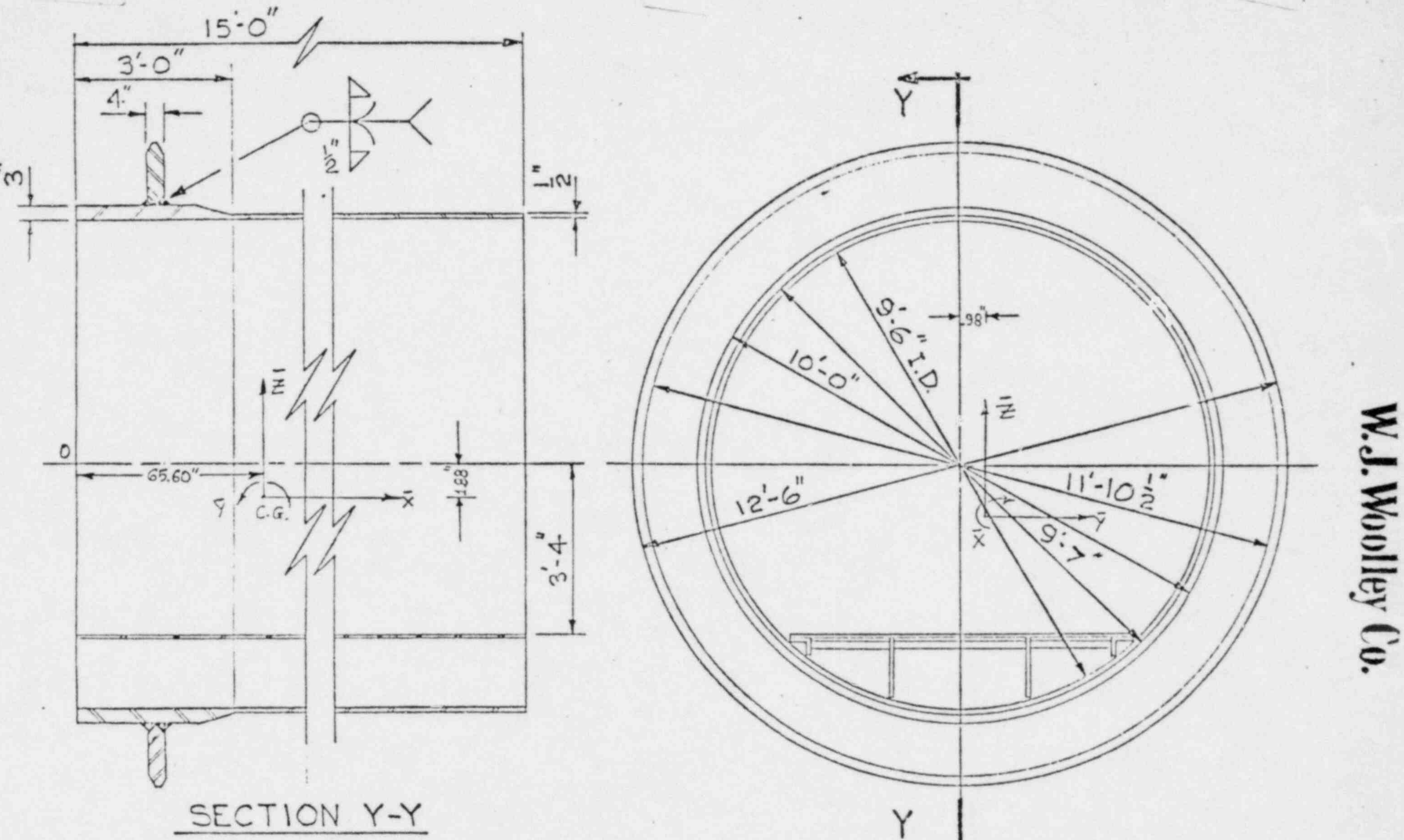
Figure 1

FILING CODE



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

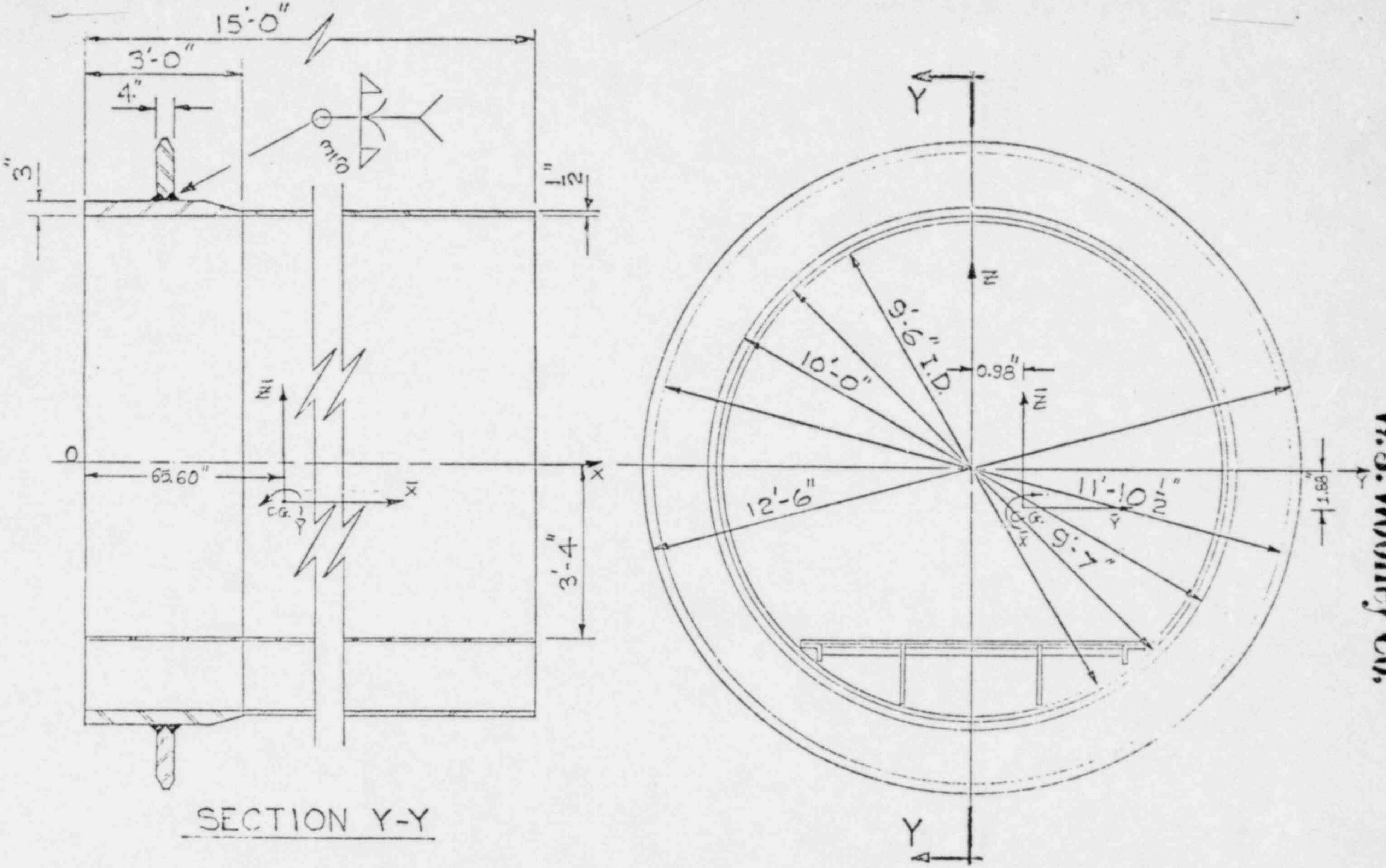
Figure 2



OVERALL DIMENSIONS OF COLLAR & BARREL

Figure 3A

PERRY NUCLEAR POWER PLANT
UPPER PERSONNEL AIR LOCK
SERIAL No 33454

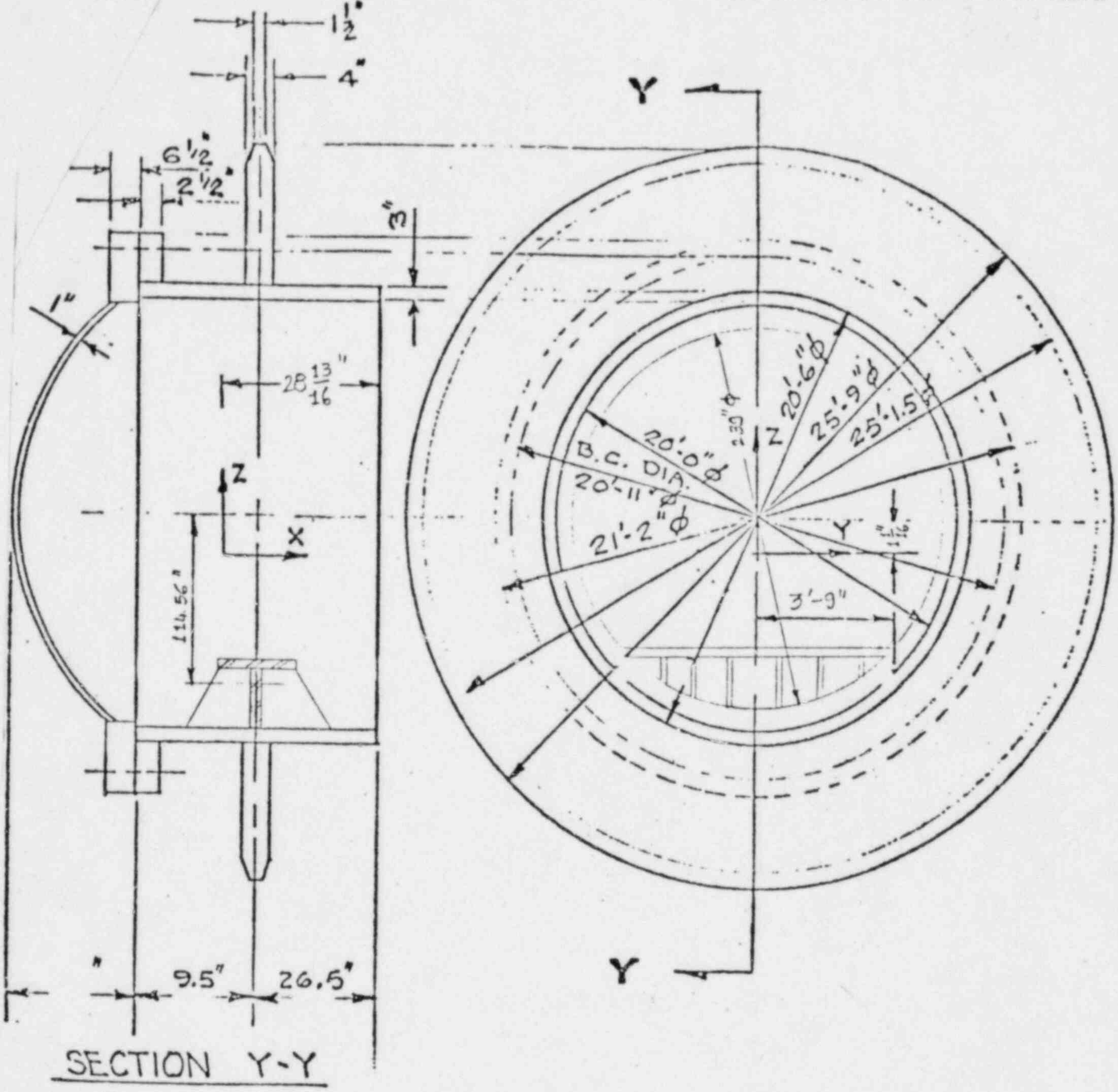


OVERALL DIMENSIONS OF COLLAR & BARREL

Figure 3B

PERRY NUCLEAR POWER PLANT
LOWER PERSONNEL AIR LOCK
SERIAL № 33378

W. J. WOOLLEY COMPANY



OVERALL DIMENSIONS OF EQUIPMENT HATCH ASSEMBLY

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

Figure 4A

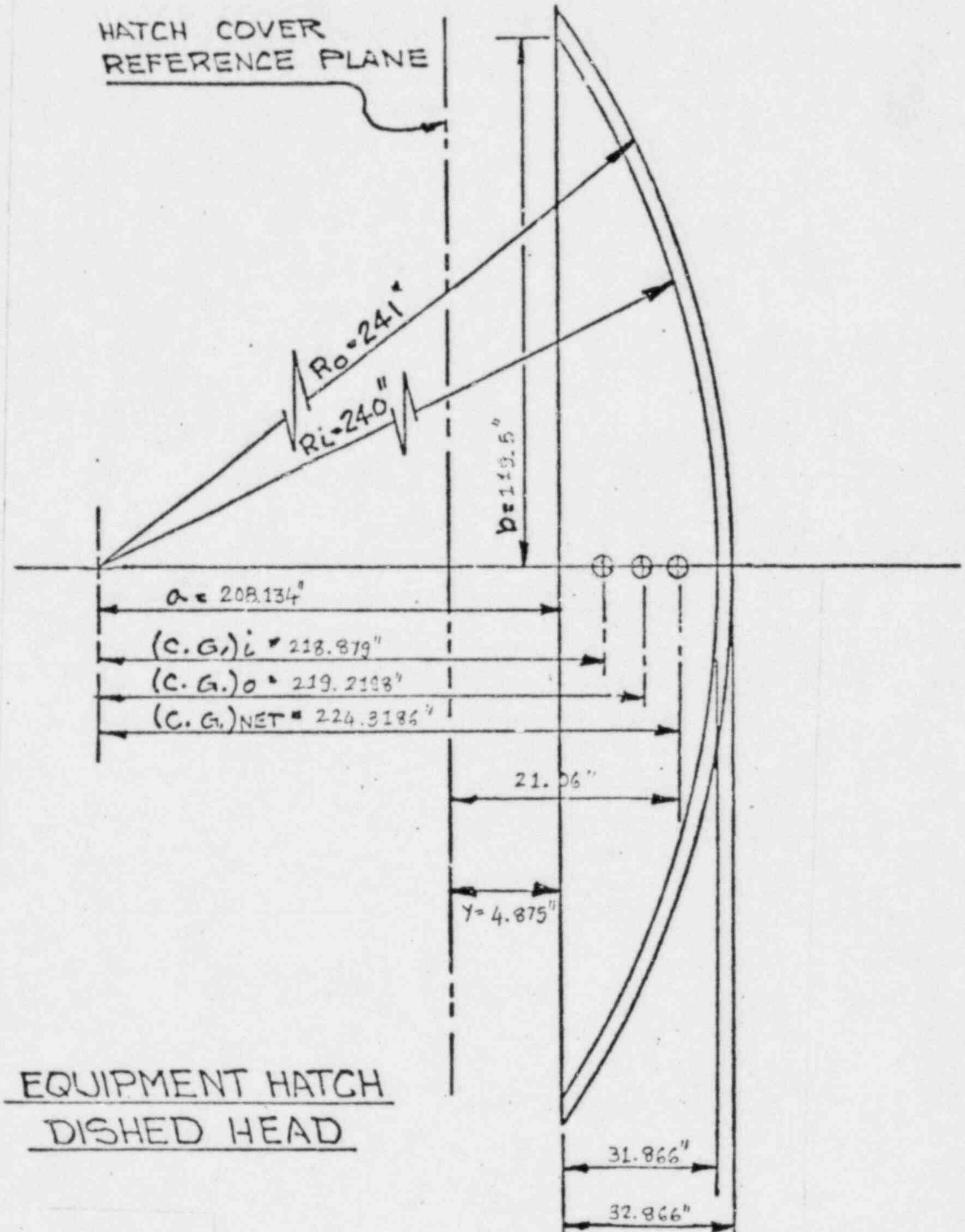


Figure 4B

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

MAIN STEAM PENETRATION

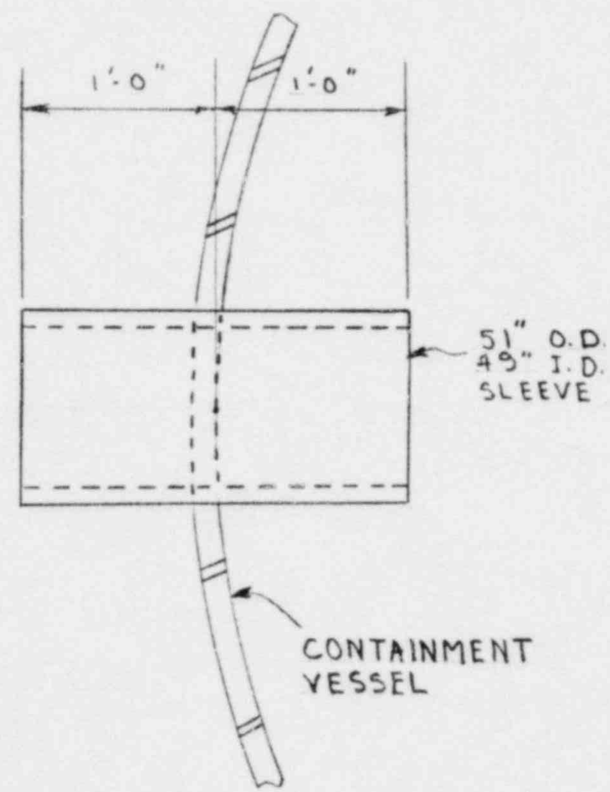


Figure 5

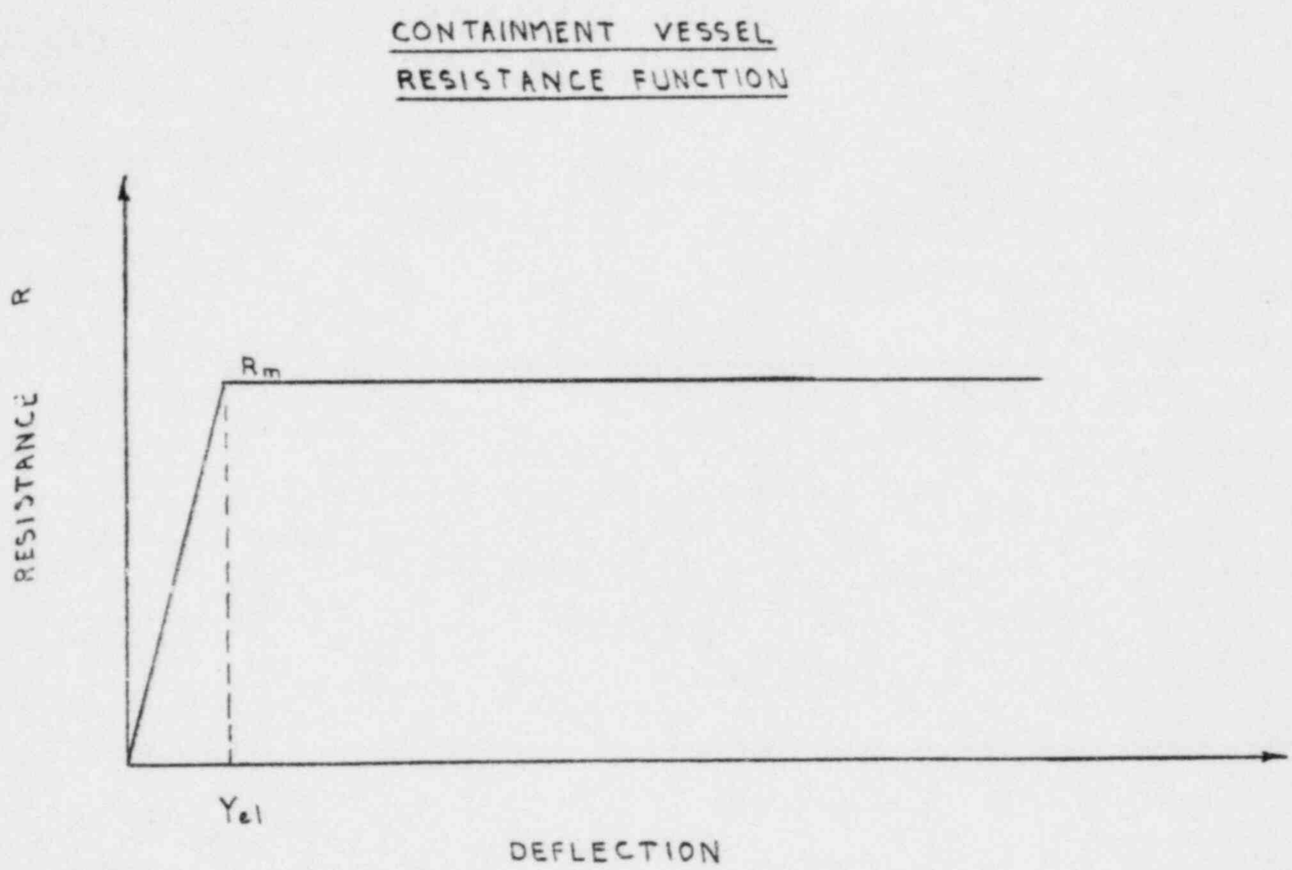

CONTAINMENT VESSEL
RESISTANCE FUNCTION
RESISTANCE R
R_m
Y_{el}
DEFLECTION

Figure 6