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TECHNICAL DIVISION
SAVANNAH RIVER LABORATORY

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M E M O R A N D U M

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HOUSING TUBE HYDRAULIC COLLAPSE

SUMMARY

Hydraulic collapse tests of reactor fuel and target inner housings at SRL show correlation within 5% of Sturm's[1] formula for the collapse of thin-walled cylinders. The test series verified the calculational method for determining housing wall thickness in order to meet safe operating design limits.

A collapse pressure differential of 250 psi is recommended for future inner housing designs. A numerical coefficient derived from Sturm's formula can be applied to the range of inner housing sizes used at SRP to arrive at a wall thickness to meet this criterion.

BACKGROUND AND DISCUSSION

Calculations were made using Sturm's formula for collapse of *thin-walled cylinders:*

$$W_c = KE\left(\frac{t}{D}\right)^3$$

[1] R. G. Sturm, "A Study of the Collapsing Pressure of Thin-Walled Cylinders," University of Illinios Exp. Sta., Bull, No. 12, 1941.

The collapsing pressure, W_c, was defined as the modulus of elasticity of the material, E; thickness of the tube wall, t; and outside diameter of the cylinder, D; and dimensionless coefficient, K. The factor K depends upon the L/D (tube length to diameter) and the D/t (tube outer diameter to wall thickness) rations, as shown in Figure 1.

SRP housing tube sizes range from about 1.5 to 4.25-inches OD yielding D/t ratios of 40-60, and L/D ratios of >12 to 24; therefore collapse coefficient, K, as shown in Figure 1 becomes 2.2.

The calculations were made assuming nominal dimensions and the results are summarized in Table I.

The Effects of Temperature

SRP inner housings will fail below the elastic limit of the material due to instability, therefore, the effect of temperature on the material does not warrant a modification of E as suggested by Sturm. Figure 2 shows variation in modulus of elasticity with temperature for 6063-T833 aluminum. At 100°C a reduction in E, and collapse pressure, from the value at 24°C is only 2%.

Although the effects of creep for the 6063-T833 aluminum are not known, Alcoa Research Lab data on 6063-T6 show good creep resistance at reactor operating temperatures. Figure 3 shows the relation of temperature and stress to give 0.5% creep strain in 10,000 hours. Hoop stress in the inner housings designed for 250 psi collapse is shown to be well below the yield stress. In the region of actual operating pressures and temperatures, the yield stress is at least a factor of 10 greater than the hoop stress.

In-reactor temperature has not been a significant factor in the design of target and fuel inner housings. Toward the bottom of the assembly the inner housing temperature increases with increasing coolant temperature (110°C maximum) and coolant pressure decreases resulting in a pressure differential of <10 psi acting on the inner housing. Collapse, when it occurs, begins at the upper end where the pressure differential is highest. The temperature contribution over the range is a second order effect and is in the opposite direction.

Hydraulic Testing

Hydraulic collapse tests were performed on inner housing extrusions used in reactor component designs because inner housing extrusions used at SRP depart from thin-wall cylinders used in other hydraulic collapse studies, e.g., they are manufactured in port hole extrusion dies and have external, axial ribs.

Results of the collapse tests compared well with the calculational method (see Table II). However, variations in diameters and wall thicknesses due to manufacturing tolerances can result in collapse pressure varying up to ±50 psi.

Test Method

Test Specimen

Sixteen specimens were prepared consisting of four each of four types of inner housing tube extrusions, Figure 4. End plugs were welded in both ends of the test pieces. A pipe thread in one end accommodated a quick-disconnect fitting, Figure 5, for mounting the test piece in the hydraulic test chamber. Measurements of OD, wall thickness, and hardness were made of each piece.

Test Chamber

The hydraulic test chamber, Figure 5, was constructed of 4-1/2" OD, 0.375" wall x 6 feet long Plexiglas* pipe. Plexiglas flanges and stainless steel blind flanges closed the ends of the chamber. Burst pressure of the chamber was calculated at 1500 psi. Maximum tensile or hoop stress at an internal pressure of 300 psi was calculated to be 1500 psi.

Water in the chamber was pressurized with a 4-ton hydraulic hand pump and internal pressure was read on a 1000 psi gage. The inside of the test piece was vented to the atmosphere.

CONCLUSIONS AND RECOMMENDATIONS

Test results show that the calculational method is adequate for the design of inner housing extrusions. A W_c of Δ250 psi is recommended for future designs to prevent in-reactor collapse. Even with allowable variations in manufacture all designs will withstand a maximum plenum pressure of 185 psig which occurred in the Cf-I charge.

Since actual operating pressures are well below plenum pressures (Figure 6), the recommended design pressure differential to cause collapse results in a minimum safety factor of 3.4 under 30B operating conditions. However, most designs have a collapse safety factor of 5 or greater. All existing inner housing designs, with the exception of the 30C and 30D, meet or exceed the 250 psi criterion. Based on calculated operating pressures these designs have a collapse safety factor of 2.8 and 3.5 respectively. MK-53 with 0.050-inch wall is no longer used. This design has been replaced with an inner housing having a 0.067-inch wall.

Calculations for future designs are simplified if the relationship of wall thickness to diameter for a W_c of Δ250 psi is plotted as shown in Figure 7. The coefficient 0.02247 times the tube outside diameter will provide an inner housing tube with a wall thickness that will have a collapse pressure of 250 psi.

*Trademark, Rhom and Haas

GBA/jc

TABLE I

$$\text{Collapse Pressure } W_c = KE\left(\frac{t}{D}\right)^3$$

Inner Housing	D (OD)	t (Wall)	ID	Calculated* Collapse Pressure
Mark 16	1.378"	.050"	1.278"	1056
Mark 30B	2.250"	.060"	2.130"	413
Mark 14	1.880"	.050"	1.780"	412
Mark 18	2.016"	.050"	1.916"	336
Mark 50A	2.130"	.050"	2.030"	284
Mark 52	2.400"	.050"	2.300"	199
** Mark 30C	2.616"	.050"	2.516"	154
** Mark 30D	2.800"	.050"	2.700"	125
** Mark 53	2.982"	.050"	2.882	104
** Mark 53 (.067" Wall)	2.982	.067	2.848	250

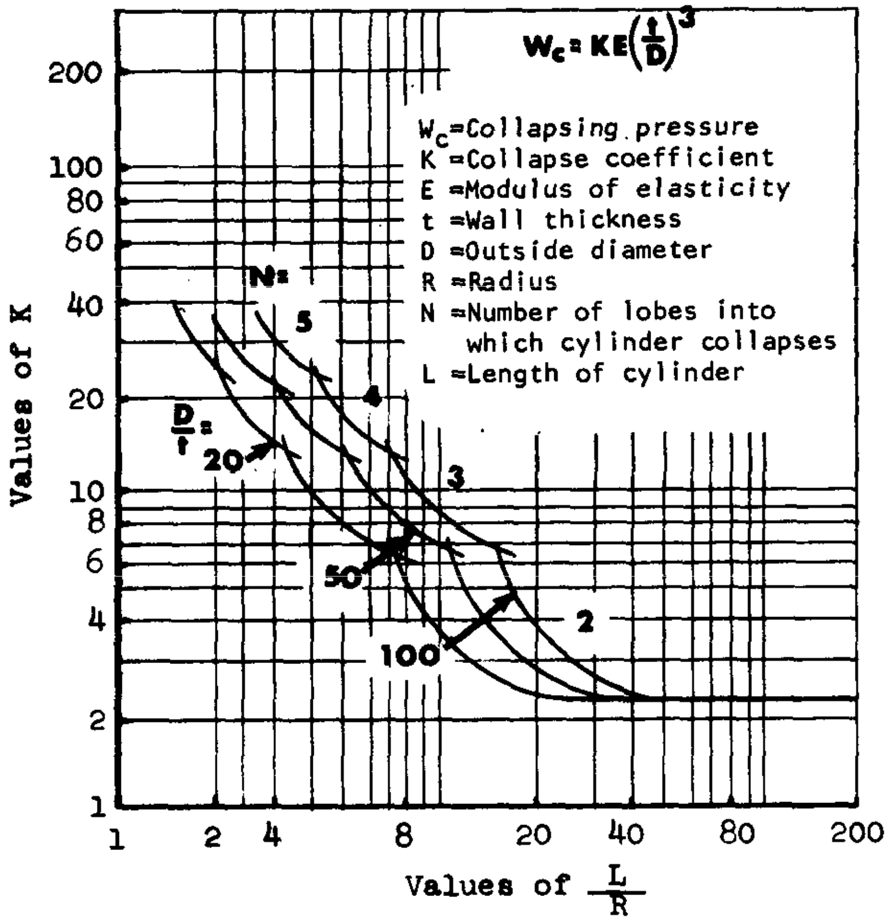
*Based on nominal dimensions.
**Selected for collapse tests.

TABLE II

HYDRAULIC COLLAPSE TEST RESULTS

Mark No.	Nom. Dim.	Actual Dim.	Calculated* Collapse, p.s.i.	Actual Collapse, p.s.i.
53 (.050" wall)	2.982" OD .050" wall	2.975-2.982" .050 - .052"	104	108-110
53 (.067" wall)	2.982" OD .067" wall	2.980-2.985" .066-.068"	250	250-260
30 D	2.800" OD .050" wall	2.795-2.798" .051-0.053"	148	140-145
30C	2.616" OD .050" wall	2.613-2.616" .052-.054"	191	190

*Based on measured dimensions.



After Sturm

FIGURE 1 - COLLAPSE COEFFICIENTS; ROUND CYLINDER WITH PRESSURE ON SIDES AND ENDS
$\mu = 0.30$

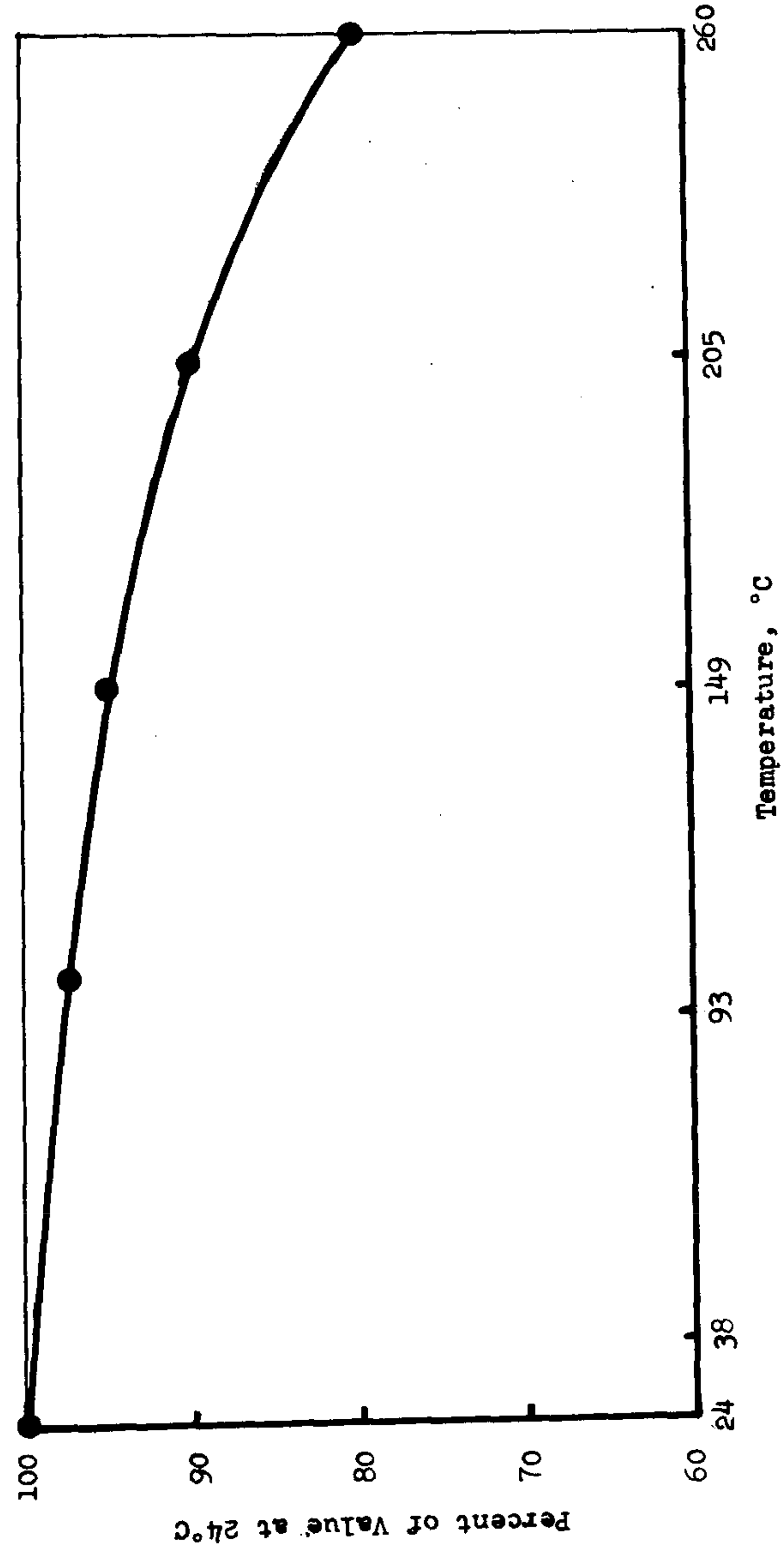


FIGURE 2 - VARIATION OF MODULUS OF ELASTICITY E WITH TEMPERATURE FOR 6063-T833 Al (from Alcoa Research Lab Data)

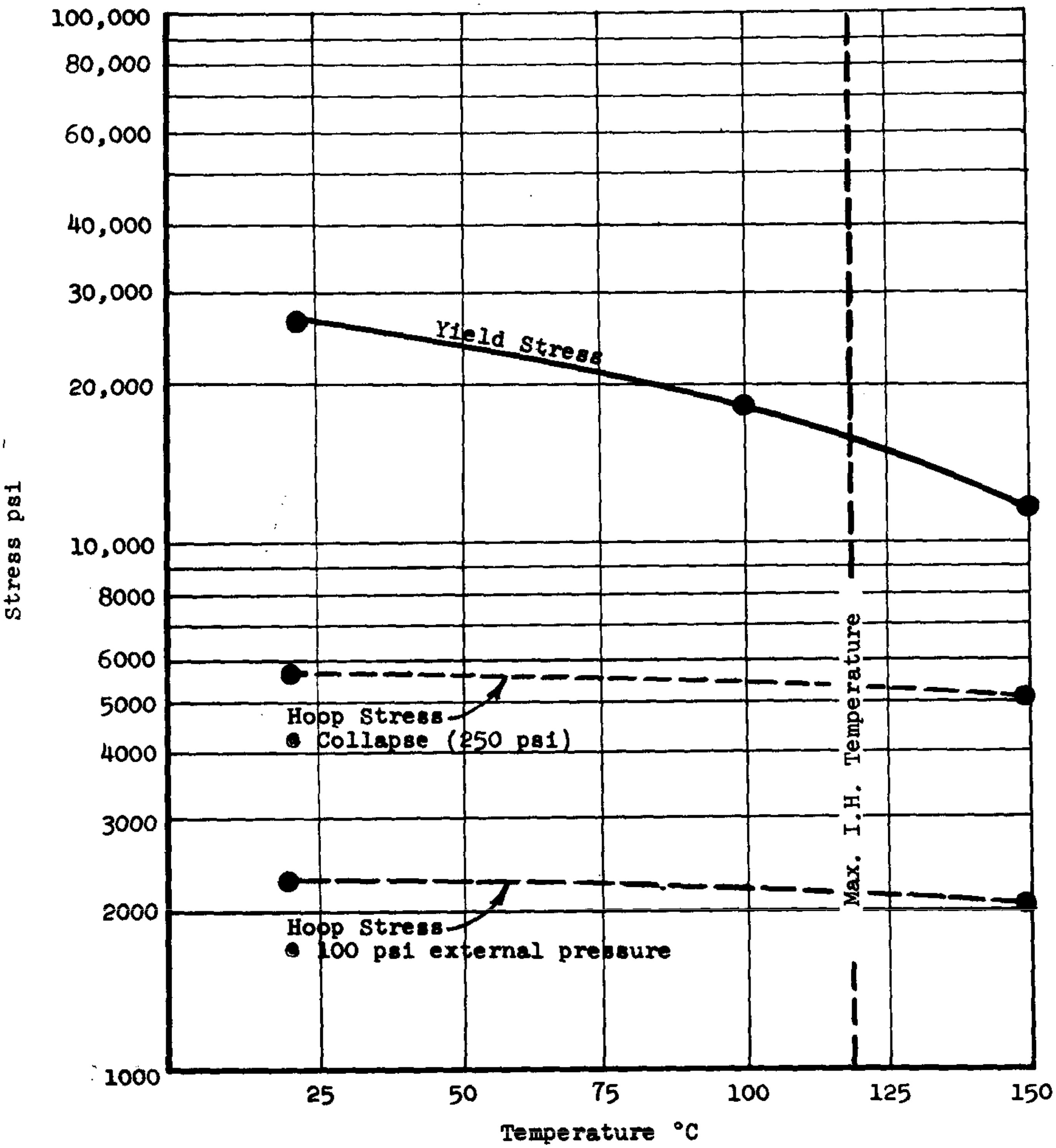


FIGURE 3 - TEMPERATURE - STRESS RELATION FOR 6063-T6 Al TO GIVE 0.5% CREEP STRAIN IN 10,000 HOURS (Alcoa Research Lab Data)

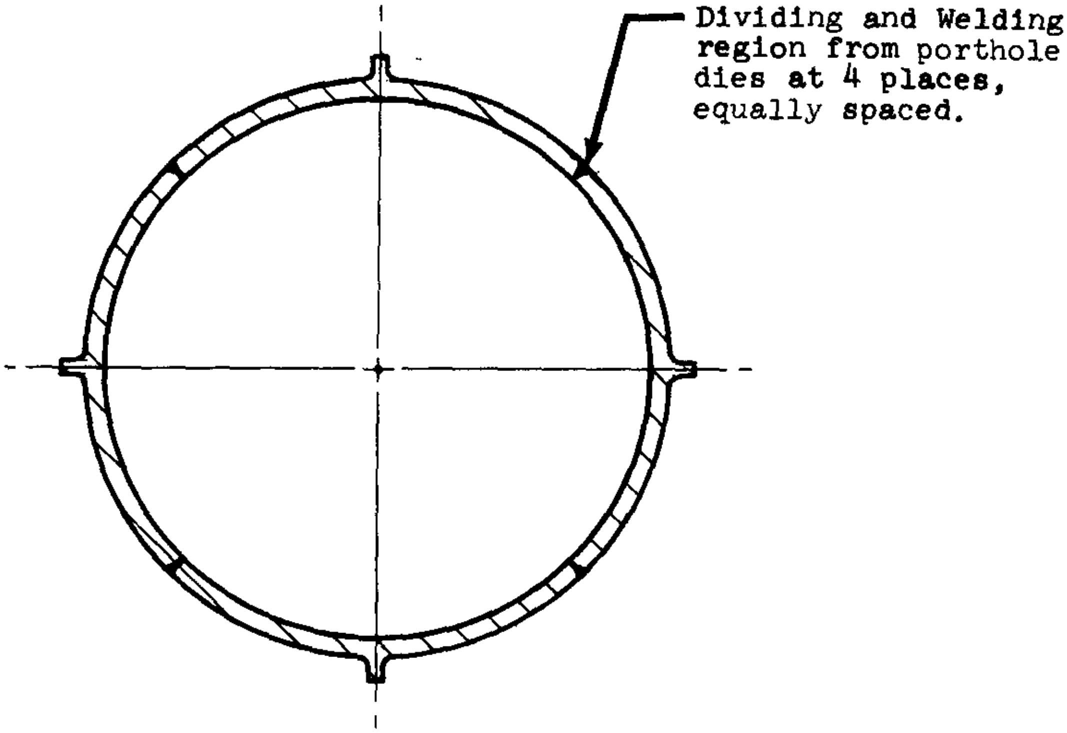


FIGURE 4 - TYPICAL CROSS SECTION OF INNER HOUSING TUBE
Matl: 6063 Aluminum

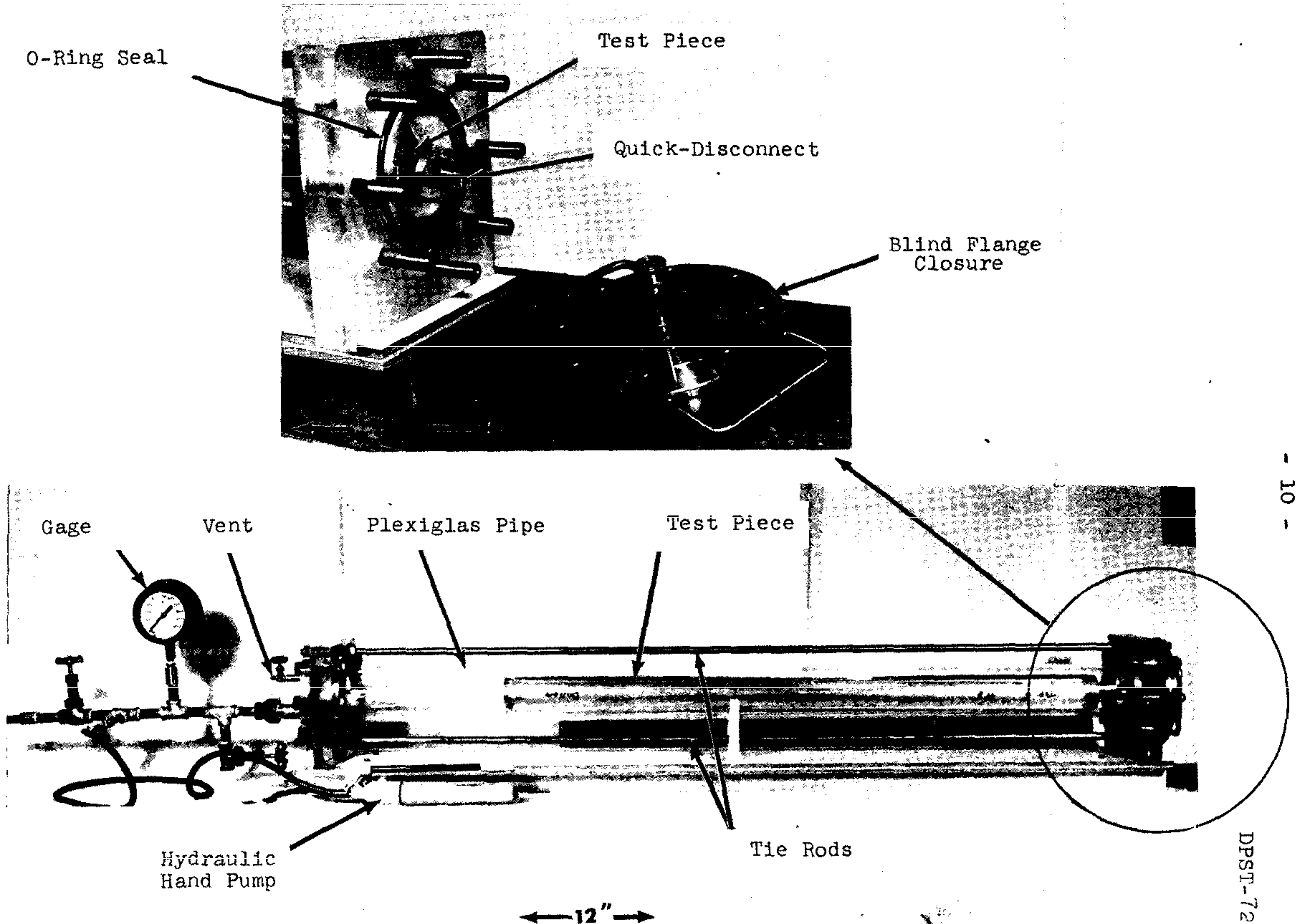


FIGURE 5 - HYDRAULIC TEST CHAMBER

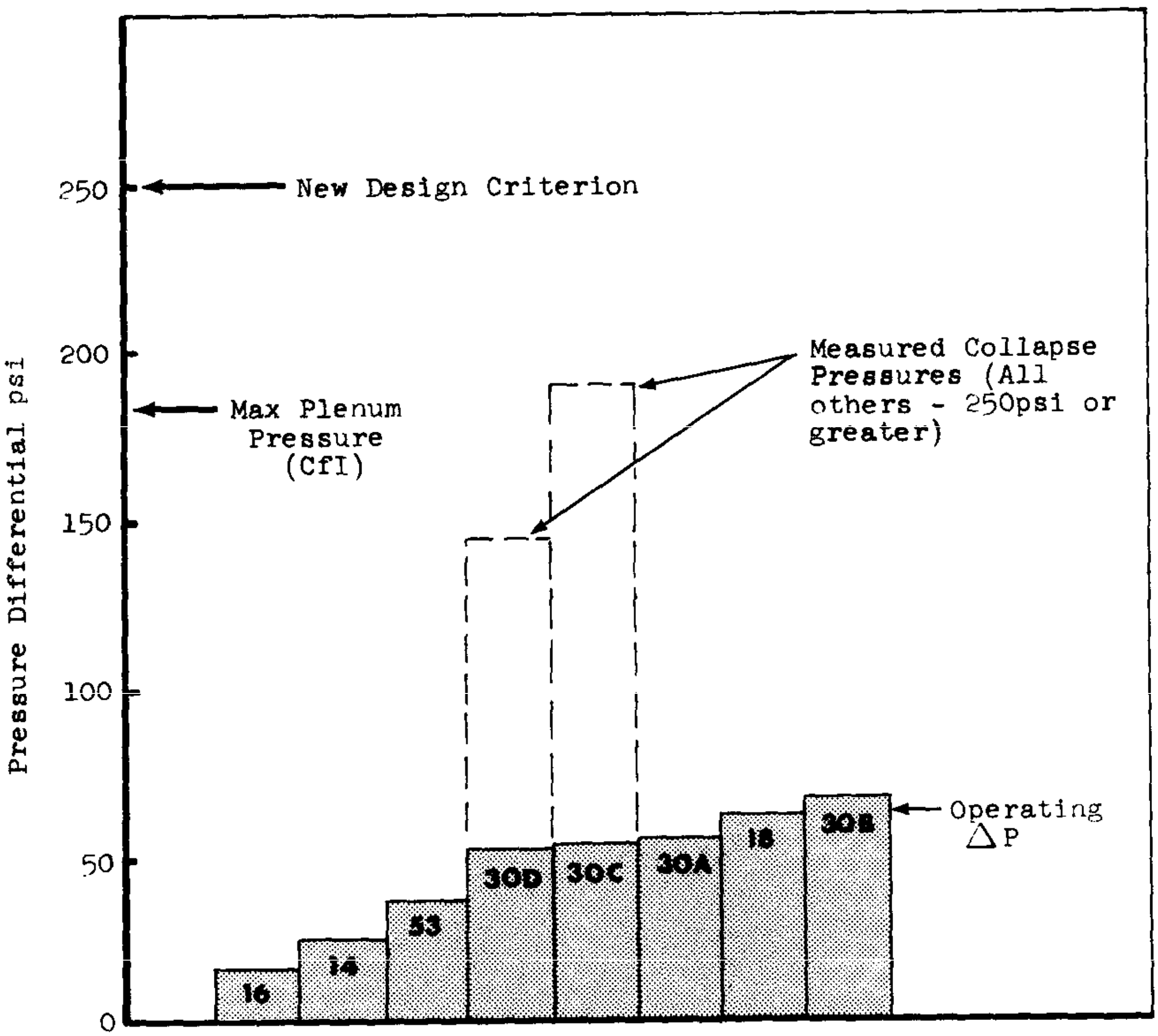


FIGURE 6 - INNER HOUSING OPERATING ΔP's

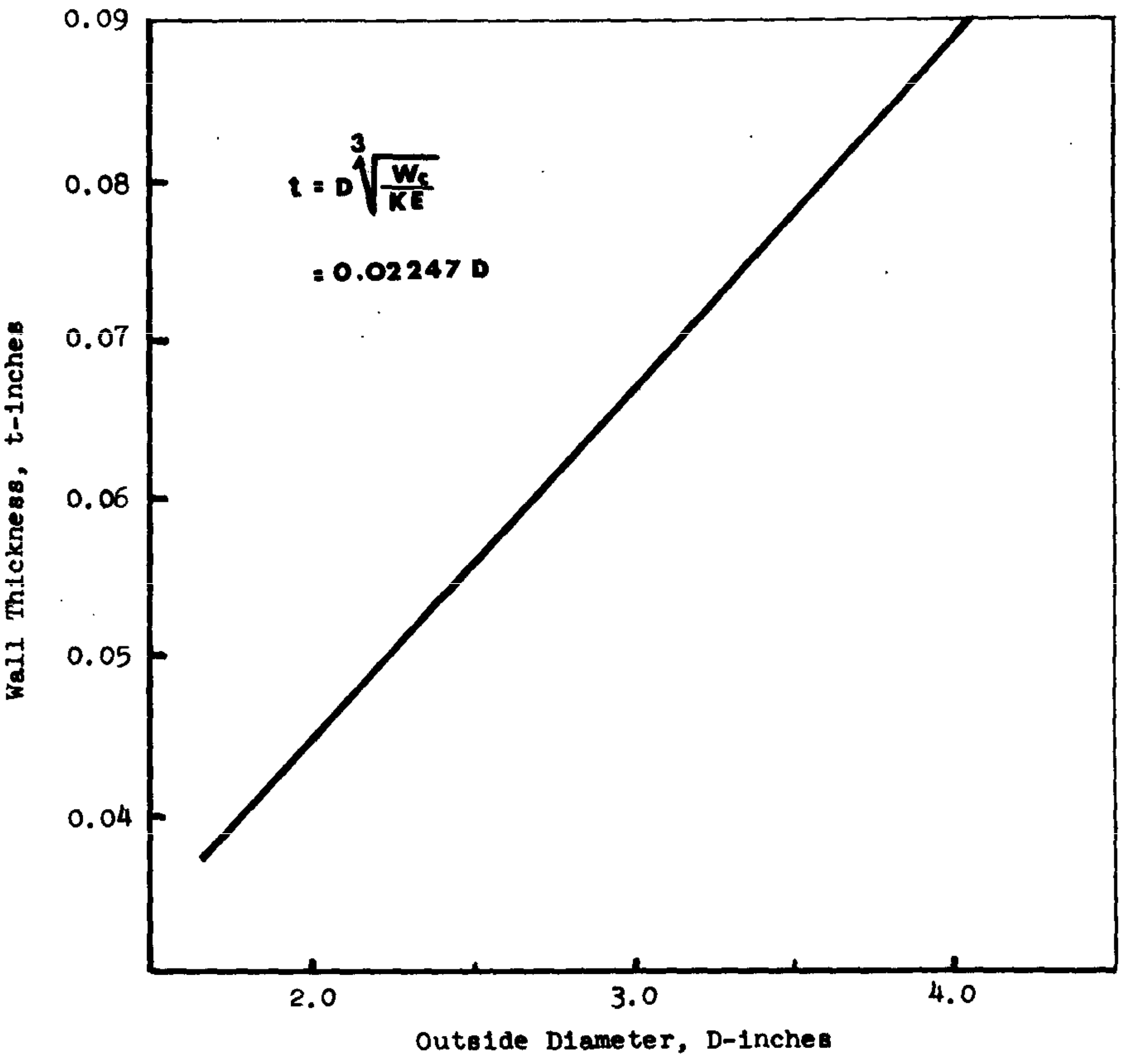


FIGURE 7 - OUTSIDE DIAMETER VS WALL THICKNESS FOR A COLLAPSE PRESSURE OF △250 psi