DESIGN ANALYSIS

FOR

CASTOR V/21

END DROP IMPACT LIMITER

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REVISION 0

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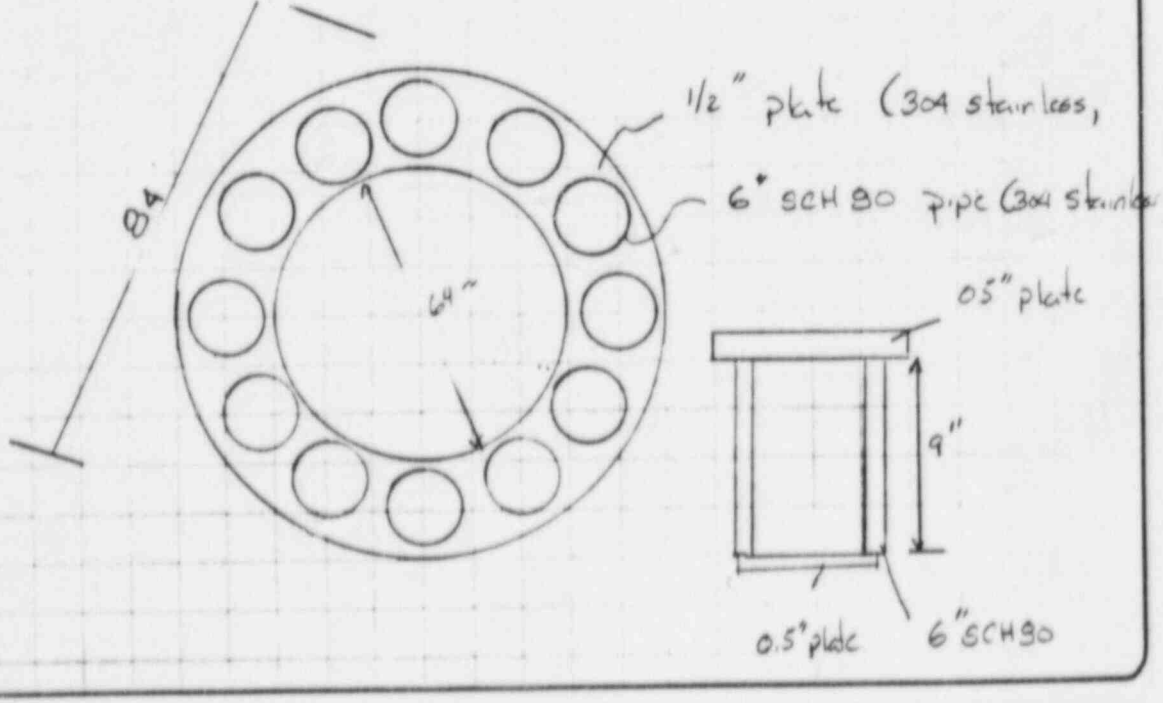
1.0 Scope

This report demostrates the adequacy of the Castor V impact limiter to protect the Castor V cask and its contents form a 6 foot end drop. In addition the corner over C.G. drop is discussed

2.0 Castor V - Impact Limiter Legs - End Drop

A simplified impact analysis is performed on the CASTOR V legs. These legs are designed to protect the Castor V cask and components from a drop of 6'. The maximum acceleration force imposed on the cask for this end drop condition must be less than 50 G's (P. 5-33, Ref 1).

The design of the protection system is shown below



3.0 Material

Plate – SA-240 Type 304

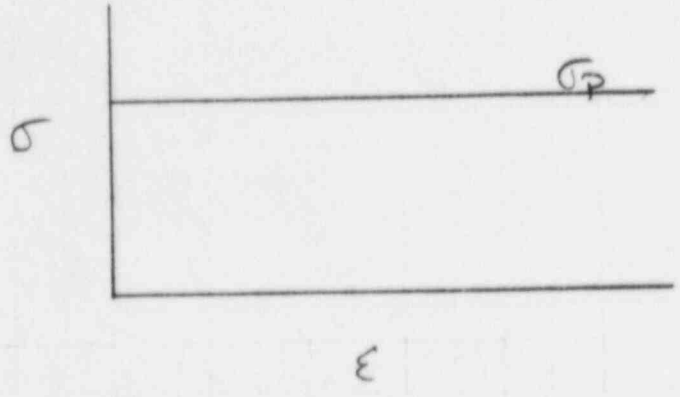
Pipe – SA-312 Type TP 304

The yield strength is 30,000 psi and the ultimate is 75,000 psi (Ref. 2)

4.0 Assumptions

The maximum G load can be obtained by bounding the material behavior with the following assumptions

1) The stress-strain curve is considered perfectly plastic, as shown below:



where σ_p is the plastic flowstress

2) The maximum G' load can be obtained with the largest value of σ_p expected

3) The maximum displacement can be obtained with the minimum value of σ_p expected

4) The Cask and storage Mat are unyielding and donot absorb any energy. The impact limiter absorbs all the energy.

The yield strength times the area of one 6"-SCH80 pipe is

$$F_y = (30{,}000)(94) = 252{,}000 \text{ lbs}$$

The ultimate strength times the area of on 6"-SCH80 is

$$F_u = (75{,}000)(94) = 630{,}000 \text{ lbs.}$$

These loads are plotted on Figure 1, which also shows the load deflection curve for 6"-SCH80 carbon steel pipe. This data was obtained from tests on scale specimens, and the load includes a 30 percent increase to account for dynamic effects. This data is

obtained from Chem-Nuclear System 3-55 transportation cask SAR (Ref. 3), and it is used for the design its impact limiter.

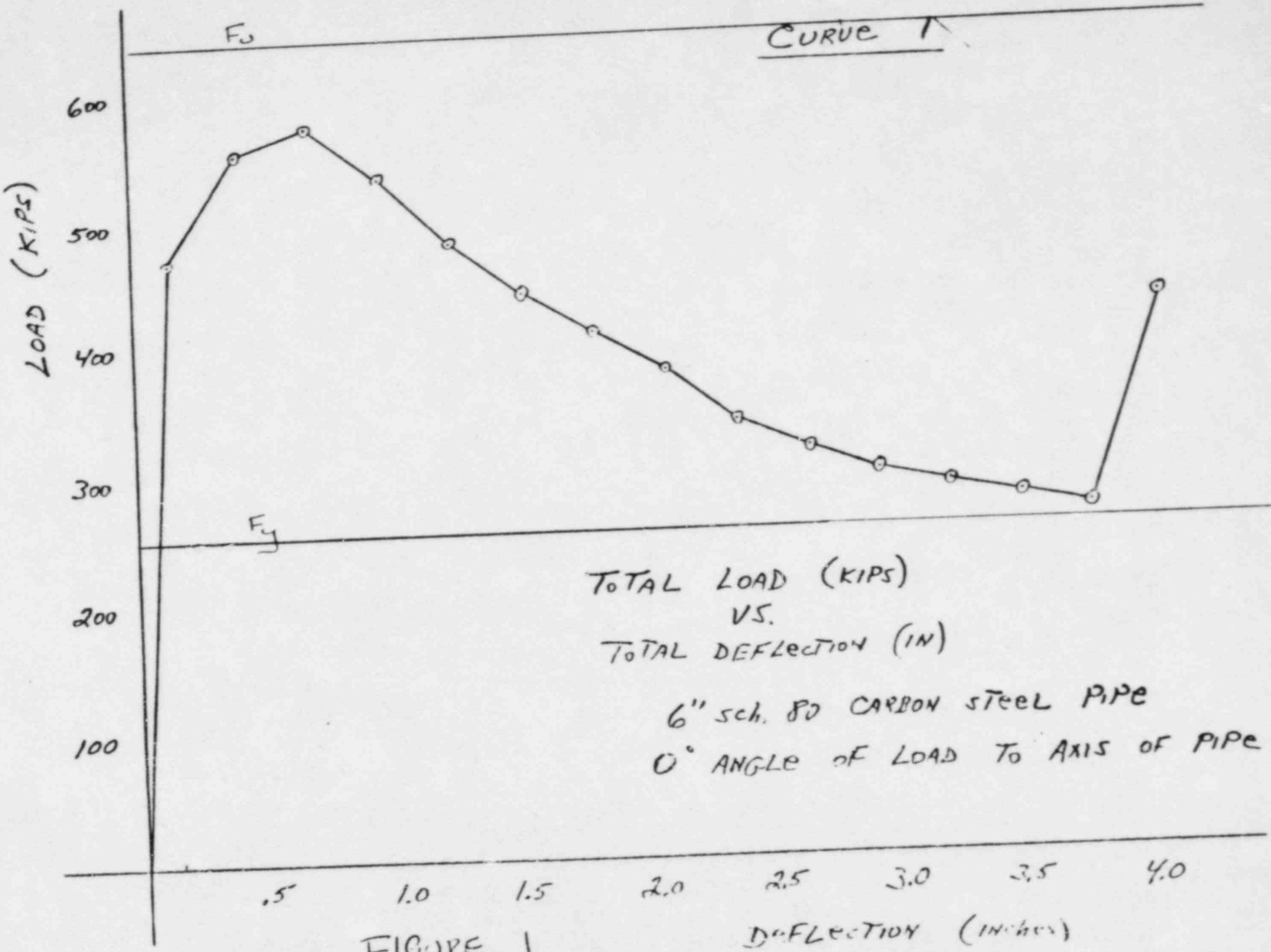


FIGURE 1

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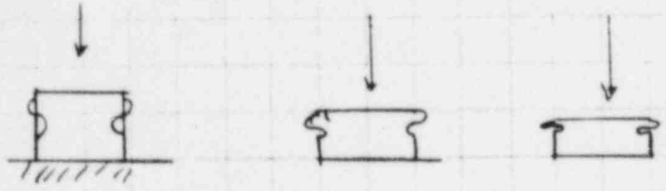
5.0 Maximum G load Calculation

$A_{pipe} = 8.4\ in^2$ 6" SCH 80

12 pipes $A_{TOTAL} = 100.8\ in^2$

The specified minimum yield strength for the pipe is 30,000 psi. The dynamic yield is probably in the vicinity of 40,000 psi. To be absolutely conservative, the ultimate strength of 75,000 psi is used to estimate maximum G load Actually, the pipe is expected to locally buckle at a stress above yield, and stiffen itself as the wall collapses onto itself, as shown below.



$F_{max} = (75,000)(100.9) = 7,560,000$ lbs

in terms of G's on the cask (The cask weight is 233,200 lbs)

$$G = \frac{7,560,000}{233,200} = 32.4 \text{ G's}$$

The maximum G load of 32.4 G's is well below the limit of 50 G's use in the analysis of the cask (Ref 1)

60 The maximum Deflection

The maximum deflection can be conservatively estimated by assuming a lower bound on σ_p, the plastic flow stress.

The Total Energy absorbed is

$$E_T = 233{,}200\,(6\times12) = 16{,}790{,}400.\ \text{lb-in}$$

$$E_{AB} = \int_0^D F\,dx = F\Delta$$

$$F = (30{,}000)(100^{\#}) = 3{,}024{,}000\ \text{lbs.}$$

$$\Delta = \frac{16{,}790{,}400}{3{,}024{,}000} = 5.6\ \text{inches}$$

The average strain is $\frac{\Delta}{L_0} = \frac{5.6}{95} = 5.9\%$

Compression test of scale models of 6" sch 80 pipe (Reference 3) show that these pipes can absorb energy at average strains ($\frac{\Delta}{L}$) up to approximately 65%

7.0 Tip Over Over Corner over C.G. Drop

To keep the tip-over case less severe than the side drop, the C.G of the cask after the corner over C.G drop must be less than 5'-2". This equates to no more than a 2" vertical increase in the height of the cask over the surface of the mat, as shown in Figure 2.

During a drop or to one pipe, this pipe would easily crush so that it would be below the 2" limit. Even a drop from only 12" would crush the pipe more than 5.5" The energy of a 12" drop is

$$E = 233{,}200\,(12) = 2.79 \times 10^6 \text{ lb-in}$$

From Figure 3 the deflection of the pipe is greater than 5.5" Figure 3 is obtained from scale model test of 6"-sch 80 pipes approximately 6.5" long and loaded at an angle of 22.5°. This data

is obtained from Reference (3) and use for the design of impact limiter of a transportation cask. The deflection of this pipe would be expected to be ever larger, since the angle is 240° and the length of the pipe is slightly larger. In addition, it is conservatly assumed the impact limiter is rigidly attached to the cask.

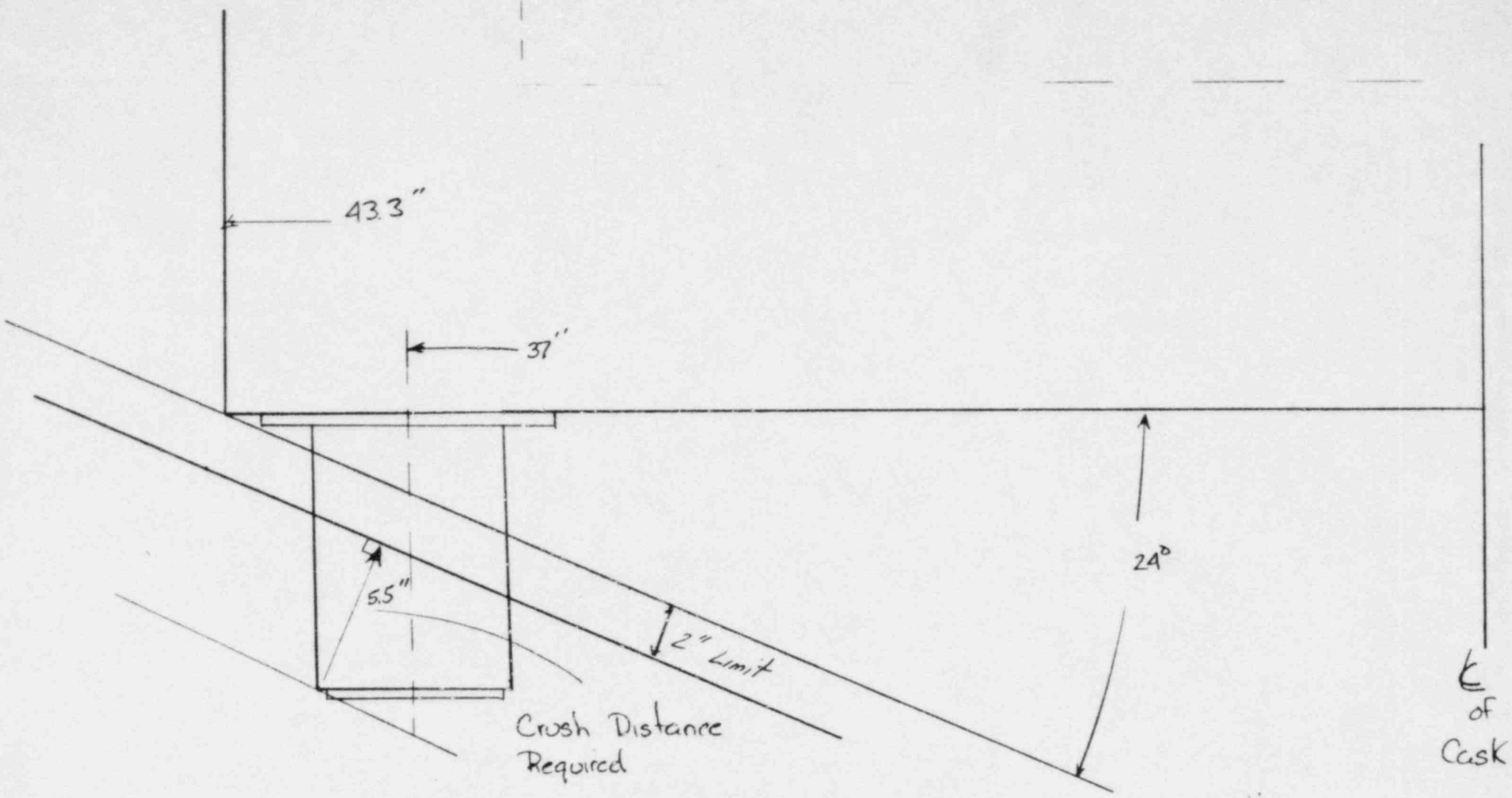


Figure 2 — Crush Distance Required

TOTAL ABSORBED ENERGY (IN. lbs.)
VS.
TOTAL DEFLECTION (IN)

6" Sch 80 CARBON STEEL PIPE
22½° ANGLE OF LOAD TO AXIS OF PIPE

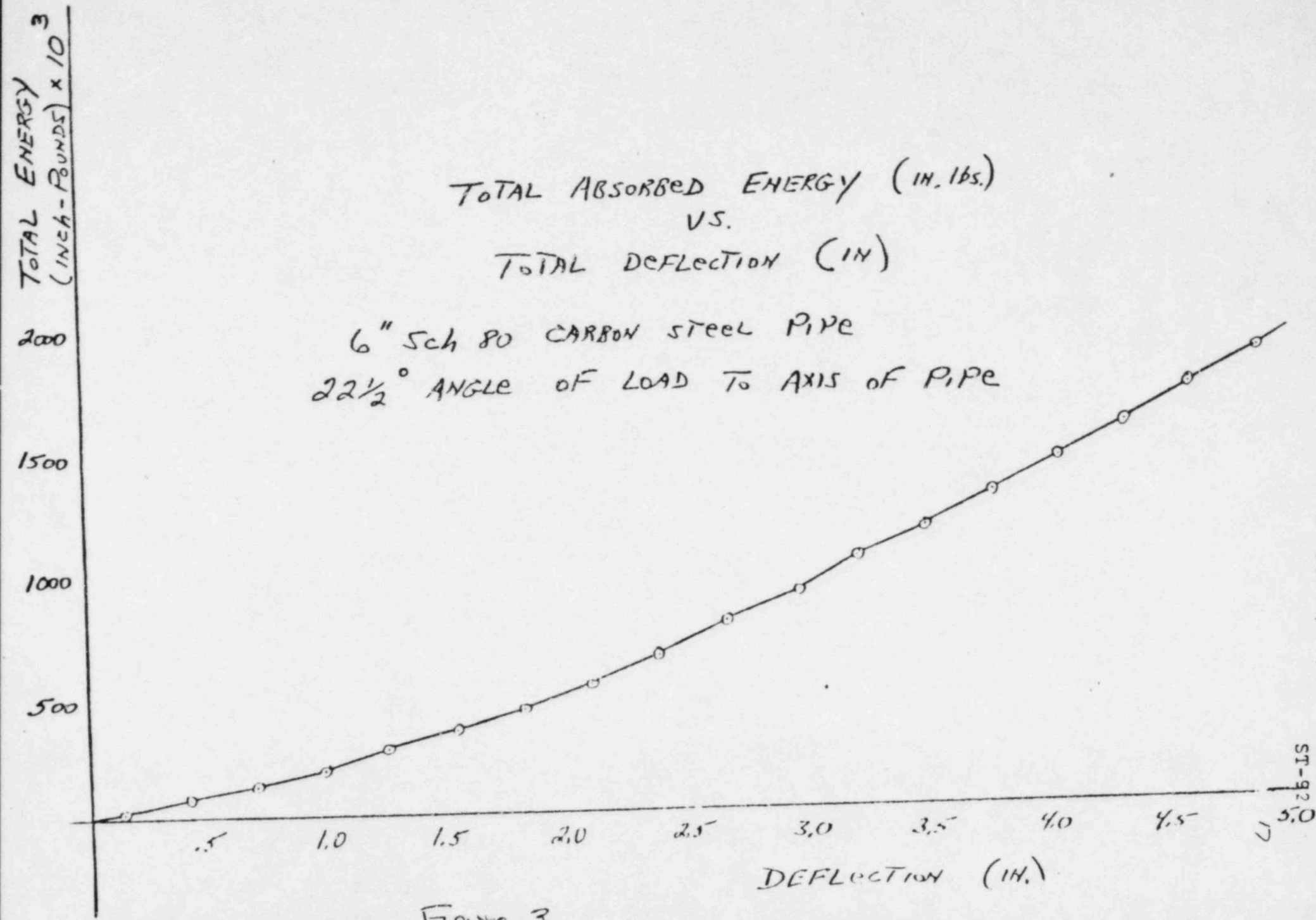


FIGURE 3

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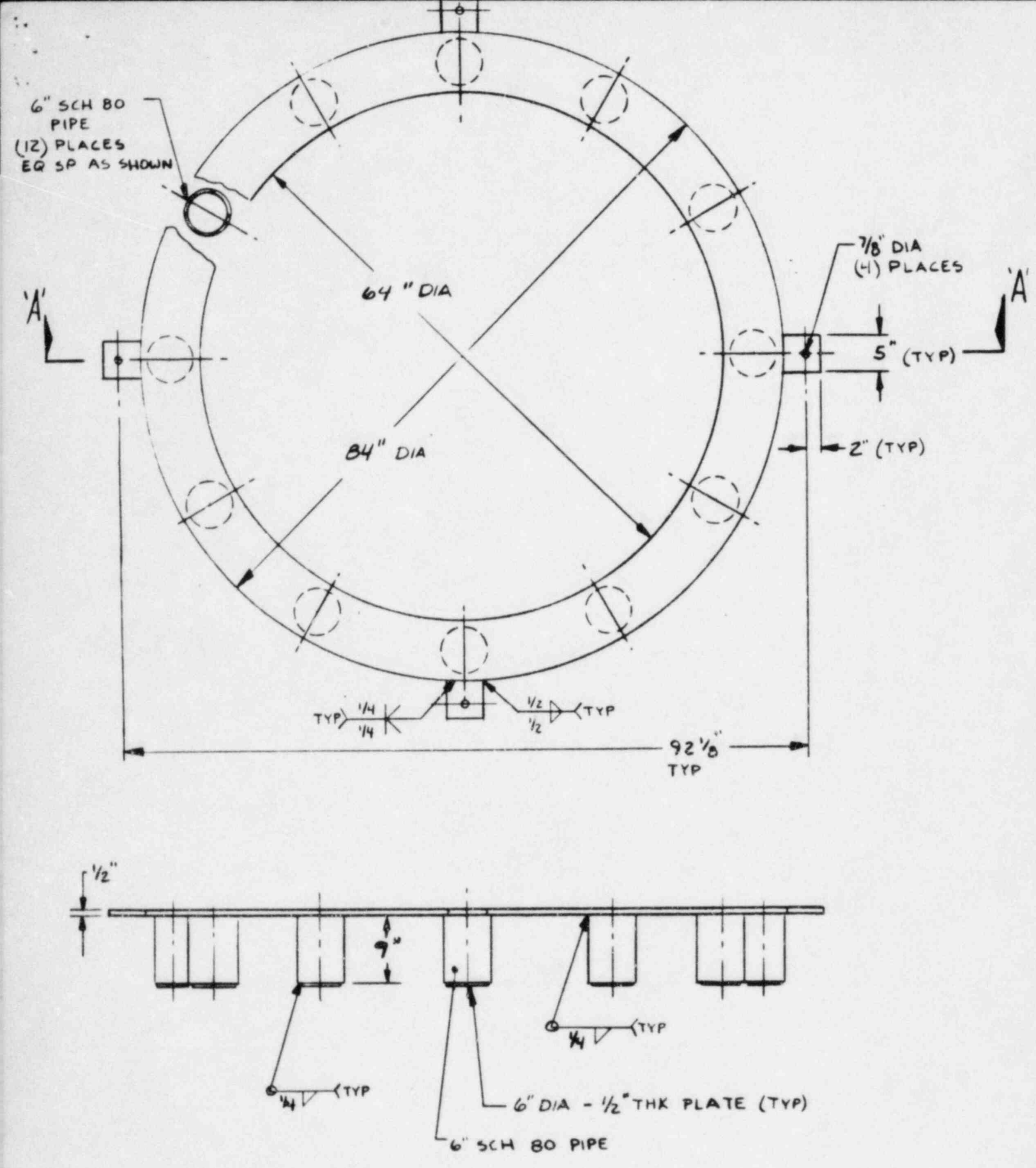
8.0 References

1.0 Chem-Nuclear Systems, Inc', "ASME code Stress Report for the Castor Vb/2 Spent Fuel Storage Cask", Rev 0 January 1985

2.0 ASME, ASME BPVC, Section II

3.0 Chem-Nuclear Systems, Inc, "Procedures, License and Safety Analysis Report for Chem-Nuclear Systems, Inc, CNS-3-55, Type B Radwaste Shipping Cask, USA/5305/B( ) F



Reference Design for CASTOR V/21 End Drop Impact Limiter.