Attachment to
Niagara Mohawk Power Corp.
Letter to John F. O'Leary
Dated September 29, 1972

Regulatory File Cy.

Received w/Ltr Dated 9-29-72

NINE MILE POINT, UNIT NO. 1

CASK DROP PROTECTION SYSTEM

SUMMARY

The cask drop protection system being installed in the Nine Mile Point, Unit No. 1 is shown schematically in Figures 1 and 2. This system consists of a circular base plate attached to the bottom of the spent fuel shipping cask and a combination guide structure-dashpot assembly which is permanently installed in the northwest corner of the spent fuel pool. The guide structure guides and restrains the falling cask in the event it is dropped; the guide cylinder and dashpot decelerate the cask to a low terminal velocity to reduce the impact load on the floor of the pool to an acceptable value. The function of the base plate is to act as a piston within the dashpot.

The structural design of the cask drop protection system is based on the worst case hydraulic, vertical and lateral loadings associated with a wide range of postulated cask drop accidents. These include not only straight drops of the cask into the guide cylinder-dashpot assembly, but also a number of postulated cask tipping accidents caused by assumed eccentric breaks of the cask lifting gear or a trunnion failure on one side of the cask. Cask drops into the guide cylinder-dashpot cylinder as well as postulated drops onto the top plate of the guide structure have also been considered.

The analyses presented herein demonstrate that for postulated drops of a 100-ton cask from a height of up to 6 inches over the top of the guide structure, the resulting maximum hydraulic loadings transmitted to the pool floor are less than two times the weight of the cask. For conservatism, this calculation assumed no fluid drag and an orifice discharge coefficient of 1.0 (the maximum value for a perfectly rounded orifice). The maximum impact load occurs when the cask drops onto the top plate of the guide structure from a height of six inches. This load is approximately 4.3 times the cask system weight. These values of pool floor loadings are well within the structural capability of the pool.

DESCRIPTION OF CASK DROP PROTECTION SYSTEM

A. Design Bases

The Nine Mile Point, Unit No. 1 cask drop protection system has been designed to meet the following functional requirements:

Prevent the cask from tipping into the spent fuel pool.

Guide the falling cask into the hydraulic dashpot section of the structure.

Control the attitude of the cask as it falls through the guide structure and dashpot assembly.

Decelerate the cask to a low impact velocity.

Absorb the energy of the cask upon impact.

Limit loads transmitted to the floor of the spent fuel pool to acceptable values.

These requirements are met for both straight and eccentric drops either onto the top plate of the hydraulic guide structure or into the hydraulic guide structure.

The design of the cask drop protection system provides protection against a wide range of different size and weight spent fuel shipping casks. This flexibility is provided by use of the same cask base plate for each cask to be handled over the pool. For conservatism, the analyses presented herein are based on a nominal 100-ton cask fully loaded. Typical dimensions of such a cask and its lifting rig are shown in Figures 3 and 4. The lifting devices to be used will be designed in accordance with the requirements of Title 10, Part 71, "Packaging of Radioactive Material for Transport," of the Code of Federal Regulations as described in 10 CFR 70.31 (C).

B. System Design

The cask drop protection system consists of two main pieces of equipment as described below and shown in Figures 5 and 6.

1. A round aluminum base plate approximately 110 inches in diameter by 2-3/4 inches thick will be attached to the bottom of the spent fuel shipping cask as shown in Figure 5. The plate material is 6061-T6 aluminum alloy. Attachment of this plate to the cask will be performed at the plant site in an area remote from the spent fuel pool. The purpose of the base plate is to act as a piston within the dashpot which is described below.

2. A cylindrical stainless steel guide structure assembly, incorporating a simple hydraulic dashpot effect, is permanently installed in the northwest corner of the spent fuel pool as shown in Figure 6. The guide structure and dashpot assembly shown in Figure 6 consists of (a) an upper guide cylinder which includes a hinged shell section to allow spent fuel to be transferred to the spent fuel cask, and (b) a lower dashpot cylinder into which the fuel cask is lowered to load spent fuel. The hinged shell section, or fuel transfer door, would be closed at all times when lifting or lowering the cask over the spent fuel pool.

   In this design, the required flow area for cask deceleration during a postulated cask drop is provided as annular area between the base plate and the inside diameter of the guide structure and dashpot shells. This design feature essentially isolates the spent fuel and other components in the pool from the flow of displaced water during the postulated cask drop.

   The guide structure and dashpot assembly shown in Figure 6 consist of the following main parts:

   Upper Guide Cylinder - The upper guide cylinder is approximately 23 feet long and has a minimum shell thickness of 0.375 inch. The inside diameter at the top of the guide cylinder is about 130 inches tapering to a diameter of approximately 118 inches at the flanged connection with the dashpot cylinder. The hinged shell section, when open, provides about a 30-inch wide vertical slot to allow for the transfer of fuel into the cask when it is resting on the bottom of the pool floor. The fuel transfer door is provided with a simple and rugged continuous hinge which consists of 2-inch Schedule 160 austenitic stainless steel pipe segments and 1-9/16-inch diameter pins. The latch assembly is similar in design, utilizes the same diameter components and A-286 stainless steel pins. The pins are withdrawn to permit opening the door.

Lower Dashpot Cylinder - The lower dashpot cylinder is approximately 16 feet long and has a nominal 1/2-inch shell thickness. The inside diameter is approximately 118 inches at the flange connection with the upper guide cylinder and tapers to about 110-1/2 inches at the bottom. These diameters in conjunction with the guide cylinder dimensions provide a straight taper from the 130-inch diameter at the top of the guide cylinder to the 110-1/2 inch diameter at the bottom of the dashpot and thus provide a 1/2-inch diametral clearance with the 110-inch diameter base plate at the bottom of the dashpot. These clearances result in low impact velocity for the cask (less than 1 fps).

Top Plate - The top plate of the guide structure assembly is a 2-inch thick stainless steel plate with about a 126-inch diameter opening to allow insertion of the cask into the guide cylinder. The purpose of the top plate is to provide a means for attaching the guide structure-dashpot assembly to the operating floor adjacent to the spent fuel pool. This will be accomplished by fastening the top plate to anchor points in the operating floor adjacent to the northwest corner of the spent fuel pool. This attachment provides the necessary lateral support for the guide structure to ensure that it will not break loose from the pool in the event of a cask drop accident.

Energy Absorption - In addition to the components described above, provision is made to limit loadings transferred to the fuel pool floor due to mechanical impacts of the cask resulting from (a) a postulated cask drop from a height of 6 inches over the guide structure top plate, or (b) bringing the cask to rest on the bottom of the dashpot from an impact velocity of approximately 1 fps (i.e., the terminal velocity provided by the hydraulic dashpot). In the case of the former, energy absorption capability is provided by plastic deformation of stainless steel members between the top plate and the guide cylinder. Energy absorption is provided at the bottom of the dashpot for the relatively light impact of the cask with the floor by plastic deformation of a number of horizontal stainless steel pipe segments welded to the bottom head of the dashpot. These pipes also prevent developing a suction on the dashpot bottom head during normal lifting of the cask from the pool.

Permanent installation of the cask drop protection structure is a relatively straightforward operation. The structure will be brought into the plant in two sections, each of which can be handled by the overhead crane. These sections will be positioned in the northwest corner of the spent fuel pool and bolted together. Shims will be used, as required, between the top plate, guide structure, and dashpot flanges,

to compensate for any nonparallelism between the pool floor and the operating floor level and to permit field positioning of the top of the guide structure to suit the as-built configuration of the pool.

The completed installation will create no interference with the overhead or fuel handling cranes. Protruding structures which could interfere with cask handling operations at the operating floor level have been specifically avoided in order to assure that the guide structure will not contribute to a crane or cask handling accident.

C. Cask Handling Procedures and Controls

The aluminum base plate will be attached to the bottom of the cask in an area remote from the spent fuel storage pool. Suitable means such as brackets will be provided to attach this plate to the cask. As previously noted, different casks can also be used by either modification of the brackets, by the use of additional brackets or other means. To lower the cask into the pool, the cask with its base plate attached will be moved to a position over the center of the guide structure following the path indicated in Figure 7 to assure that if the cask were to be dropped at any point along the path, there would be no tendency for the cask to topple into the spent fuel pool. The transfer path is such that during lateral movement of the cask to the insertion area over the guide cylinder, the center of gravity of the cask is always in a position so that if the cask were to be dropped either (1) there would be no tendency for the cask to tip (i.e., it would be stable on the top plate of the guide structure), or (2) the cask would be tipped in a direction away from the pool (i.e., towards the north or west walls), or (3) the cask would enter the guide cylinder, be decelerated by the hydraulic action of the guide structure and dashpot assembly, and come to rest on the bottom head of the dashpot, as designed. This transfer path was selected as follows:

1. The area within which the cask could be dropped and remain stable on the top plate on a static basis was determined. This stable area is shown as the shaded area in Figure 7. In determining this stable area, credit was taken only for the pool walls and the continuous portion of the guide cylinder shell as support elements (i.e., the 2-inch top plate and the fuel transfer door were neglected).

2. The margin required to accommodate certain dynamic effects such as cask swinging due to stopping the crane when traveling at the maximum possible crane speed, or cask drops from a height of 6 inches above the top plate with lateral velocity equal to the maximum crane speed, was determined and subtracted from the stable area determined in step 1, above. This margin is shown in Figure 7 and is approximately 16 inches wide (corresponding to a maximum crane speed of 60 ft/min.).

3. A practical path within the new stable area was then selected. The acceptable transfer path width of approximately 14 inches for the cask center line assures that no tipping of the cask into the fuel pool will occur if the cask were to be dropped in this area during cask positioning over the pool.

The stable area for the cask center line, the margins required for dynamic effects and the acceptable transfer path are all shown in Figure 7.

During travel along the transfer path shown in Figures 2 and 7, the cask will be lifted about 2 to 3 inches above the top plate of the guide structure. However, the base plate and guide structure assembly have been designed for drops from heights of 6 inches above the guide structure.

Horizontal and vertical cask motion will be positively controlled to assure that the cask center line is restricted to the acceptable transfer path described above and to limit the maximum height of the cask bottom plate to less than 3 inches above the top plate of the guide structure. This will be accomplished by administrative controls and a system of limit and sequence switches which will be installed on the 125-ton overhead crane. The limit and sequence switch system will provide for two modes of control of the crane as follows:

<u>Mode 1</u> - Normal operation, crane can traverse over the entire operating floor.

<u>Mode 2</u> - The crane can traverse only within the acceptable transfer path as shown in Figure 7. In addition, hoist motion is limited such that the height of the cask bottom plate above the guide structure will not exceed 3 inches.

Modes 1 and 2 will be controlled by a key switch. To select Mode 1 or Mode 2, the switch will be turned to the specific mode and the key removed from the switch. The key will be maintained by responsible plant personnel other than the crane operator.

In Mode 2, horizontal crane motion will be restricted by sequence switches and limit switches. The sequence switches are actuated just prior to points in the transfer path where a right angle change in direction of motion is required. Actuation of a sequence switch controls the next direction the crane can be moved in. If the cask center line is moved to any boundary of the transfer path, limit switches will be actuated which stop crane motion. Vertical motion

in Mode 2 will be limited by a limit switch. This vertical limit switch will be set to limit the clearance between the base plate on the cask and the guide structure top plate to 3 inches or less.

Administrative control to assure that the center line of the cask will be aligned with the center line of the required control path will be accomplished by attaching indicators to the crane. When the movable indicators are aligned with the stationary indicators, the center line of the cask will coincide with the center line of the control path. Indicators on the trolley and bridge girders will control the North-South center lines and indicators on the bridge end trucks and building girders will control the East-West center lines.

D. Crane Operation and Testing

All cask handling operations within the reactor building will be performed using the existing 125-ton overhead crane. This crane has been proof tested to 125% of its rated capacity of 125 tons as a part of the post-installation testing and certification of the crane. While no specific cask has been selected as yet for removal of spent fuel, all casks under consideration in the industry at this time have weights well within the rated capacity of this crane. It is normal Station practice to comply with the inspection, testing and maintenance requirements of Chapter 2-2 of USAS B 30.2.0-1967 and the applicable provisions of OSHA 29 CFR 1910.

SAFETY ANALYSES

A. Hydraulic Performance Analyses

The hydraulic design of the guide structure and dashpot assembly is such that in the event of a cask drop accident cask impact velocities and deceleration forces are limited to values which are well within allowable values. Specifically, calculations indicate a maximum impact velocity of a dropped cask of less than one foot per second due to the dashpot action of this system. The calculated floor load during deceleration of the cask in the guide structure and dashpot assembly described herein is less than 2 g's for the 100-ton cask analyzed. The floor loading of 2 g's is well within the capacity of the fuel pool floor. No tight clearances or seals are required; the tightest clearance is the 1/2-inch diametral clearance between the cask bottom plate and the guide cylinder.

The calculational method for hydraulic analysis uses physical parameters (which can be measured) and hydraulic parameters (drag coefficient and orifice discharge coefficient) for which ample experimental data already exist. The motion of the cask during a time interval of interest as it falls through the guide structure and dashpot is accurately described by the following basic equation of motion:

$$S = V_o t + 1/2\ a\ t^2$$

where,

- S = Distance the cask falls during any time interval of interest
- V_o = The velocity of the falling cask at the beginning of the time interval of interest
- t = The duration of the time interval of interest
- a = The net acceleration due to all acting vertical forces on the cask during the time interval of interest

In the above equation of motion, the only independent parameter which is affected by the design of the guide structure and the dashpot is the net acceleration, "a." This parameter consists of the vector sum of accelerations as would be produced by three different effects as follows:

$$a = a_g - a_d - a_p$$

where,

a_g = The acceleration due to gravity

a_d = The deceleration due to drag forces on the cask

a_p = The deceleration due to differential pressure loads on the cask bottom plate which is caused by the pumping action of the falling cask as it forces water out from below the cask bottom plate

The calculation of each of these acceleration effects is summarized below:

1) $a_g = 32.2 \text{ ft/sec}^2$ (constant)

2) $a_d = \dfrac{C_d \rho V^2 A_p}{2w}$

where,

C_d = Drag coefficient

ρ = Water density

V = Velocity of cask

A_p = Area of cask bottom plate

w = Weight of cask

3) $a_p = F_p \times \dfrac{g}{w} = \Delta P \times A_p \times \dfrac{g}{w}$

where,

g = Conversion factor

F_p = Pressure force

ΔP = Pressure differential across the bottom plate of the cask

Next, it is conservatively assumed that the effect of fluid drag forces is small. Therefore, all of the hydraulic performance results summarized in this report are based on a drag coefficient, C_d, of zero.

Accordingly, the ΔP across the cask bottom plate is equal to the pressure drop across the annular flow area between the cask bottom plate and the guide cylinder and dashpot shells. This flow area is shown in Figure 8 as a function of the cask bottom plate position during a postulated cask drop from a height of 6 inches above the guide structure top plate (about 1-1/2 feet above the pool water level). The pressure is defined by the following flow equation:

$$\Delta P = \frac{M^2}{C A_f} \quad \frac{1}{2 g \rho}$$

M = Mass flow of water

C = Orifice discharge coefficient

A_f = Flow area

Finally, the mass flow can be calculated from the vertical motion of the cask:

$$M = A_p \times V \times \rho$$

Thus, the net acceleration and vertical motion of the falling cask are fully determined by the above standard equations.

As can be seen from these equations there are only two parameters which are subject to some degree of variation. Specifically, these are the drag coefficient; C_d, which has been assumed equal to zero and the orifice discharge coefficient C. In the analyses, the orifice discharge coefficient was assumed to vary from a minimum possible value of 0.61 (the value for a square-edged orifice in an infinite plate) to a maximum possible value of 1.0 (the theoretical maximum for a perfectly rounded orifice). The expected value of the orifice discharge coefficient based on the configuration of the cask bottom plate and the dashpot shell is about 0.8.

Results of hydraulic performance calculations are presented in Figures 9 and 10 and summarized in Table 1 for the Nine Mile Point cask drop protection system design. In Figure 9, cask velocity is plotted as a function of depth. Floor loading due to hydraulic pressure versus position of the cask bottom plate is plotted in Figure 10. (The floor loadings plotted in this figure result from the calculated pressure under the cask acting over the area of the guide cylinder or dashpot at the particular depth of the cask bottom plate considered. The corresponding upward force tending to decelerate the cask is somewhat smaller than the floor loading presented in Figure 10 because the area of the cask bottom plate is slightly less than the area of the guide cylinder and dashpot.) As shown in these figures and Table 1, for the nominal discharge coefficient of 0.8 the impact velocity is 0.42 fps and the floor loading is about 1.6 g's (equivalent to approximately 30 psig). Even for extreme values of orifice discharge coefficient the impact velocity of the cask is still significantly less than 1 fps and the floor loading is less than 2 g's, both of which are acceptable.

In addition to the cases discussed above in which the cask orientation is assumed to be vertical (i.e., no significant tipping), calculations have been performed for postulated cask drops with the cask axis tipped the maximum amounts permitted by the guide structure. The impact velocities for this condition are somewhat higher than those shown in Table 1, but are still less than 1 fps for all values of orifice discharge coefficient.

Numerous analyses were performed in which the flow area and its axial distribution were varied by large amounts. The results of these calculations show that the resultant floor loadings are relatively insensitive to the area provided over a wide range. The reason for this is the large diameter of the device. For example, even for differences in total flow area of a factor of 2 greater or smaller than that provided, the maximum hydraulic floor loadings are less than 3 times the weight of the cask.

In summary, the cask drop protection system will decelerate a dropped fuel cask to velocities less than 1 fps while limiting hydraulic floor loadings to values less than twice the weight of the heaviest cask to be used for the complete range of conditions and assumptions considered possible.

B. Cask Drop Accidents Considered

The cask drop protection system is designed to prevent loss of fuel pool integrity in the event a fuel cask weighing up to 100 tons is dropped while the cask is being transported or suspended over the spent fuel pool anywhere along the transfer path shown in Figure 7.

Specifically, the guide structure and dashpot assembly has been designed for the following types of cask drop accidents and loading conditions:

1. Cask Drops Onto Top Plate of Guide Structure -- Cask drops considered are shown in Figure 11 and consist of the following:

   a. Straight Drops - e.g., break in the vertical cable of the overhead crane.

   b. Eccentric Drops - e.g., a lifting trunnion or the lifting yoke fails on one side first and then the other

   c. Tipping - The cask base plate catches the edge of the top plate so that the cask is tipped onto the north or west wall of the spent fuel pool.

   d. Base Plate catches edge of top plate but bending and/or slipping of base plate allows cask to fall into guide structure rather than tip onto the north or west wall.

2. Cask Drops Over or Within Guide Cylinder -- The types of cask drops considered are shown in Figure 12 and consist of the following:

   a. Straight fall within guide cylinder.

   b. Straight fall with cask tipped at the maximum angle of inclination as limited by the guide structure.

   c. Eccentric drop resulting in cask impacting the side of the guide cylinder during its descent.

3. Impact with Floor of Dashpot -- Two cases as shown in Figure 13 were considered as follows:

   a. Cask base plate impacts dashpot floor in horizontal position (cask center line vertical).

   b. Cask impacts dashpot floor with cask tipped at the maximum angle of inclination as limited by the guide structure.

Design loads for the cask drop protection system for each of the conditions considered above are summarized in Table 2. This table also includes the design lateral load (100,000 lbs.) for the connection between the cask drop protection system structure and the operating floor.

The highest calculated lateral load (97,000 lbs.) occurs during the eccentric cask drop (Case 2-C) when the cask impacts the side of the guide structure.

C. Structural Analyses of Cask Drop Protection System

The structural design of the cask drop protection system is based on the following design criteria:

1. Primary stresses due to continuing loads in all main members have been limited to 25,000 psi for 300 series stainless steel and 6061-T6 aluminum. This value is about 50% to 60% of the average 0.2% offset yield strengths of the materials involved and is well below their minimum specified yield strengths. Maximum average shear stresses in the fuel transfer door hinge and latch pins are limited to 2/3 of the shear yield strength (i.e., approximately 40% of the tensile yield strength) of the materials involved.

2. Plastic deformation in local areas of certain components is utilized to absorb dynamic impact energy. In these cases where local plastic deformation is utilized to absorb dynamic energy, the maximum strains are limited to values which are well below the lesser of 50% of the minimum specified elongation of the material or the strain value for which unacceptable deformation would be indicated from a functional standpoint.

The calculated stresses and deflections in the component parts of the cask drop protection system are well within the criteria outlined above for all of the loading conditions considered. The maximum stresses and deflections in the principal parts of the structure are summarized in Table 3. As shown in this table, the calculated stresses are within the allowable stress of 25,000 psi. In addition, bending of the base plate of approximately 4 inches for the loading case where the base plate catches the edge of the top plate (Loading Case 1-d) would not significantly affect the hydraulic performance of the dashpot. Accordingly, it is considered that the structural design of the cask drop protection system is adequate.

D. Structural Analysis of Spent Fuel Pool

1. Loading Conditions -- A dynamic, time-history analysis was used to evaluate the stresses on the spent fuel pool. The following conditions were used in the analysis:

a. Static Loads: Weight of concrete floor and supporting beams; hydrostatic load from water; weight of spent fuel cask drop protection system.

b. Thermal Load: The maximum design temperature of the spent fuel pool water is 125F. The design ambient temperature on the outside of fuel pool walls is 75F. Therefore, the maximum thermal gradient is 50F. In the analysis of thermal stresses, a reduced Young's Modulus for concrete was used. This is in accordance with the Portland Cement Association's publication ST-57 "Circular Concrete Tanks Without Pre-stressing." Accordingly, a value of $E = 1.5 \times 10^6$ psi was used. Also, as shown in Tables 4 and 5 (Case 2.2), a 0F thermal gradient was used and was found to give the maximum stress condition.

c. Impact and Hydraulic Loads from Cask: Both the impact and hydraulic loads were used in the analysis. The largest impact load (cask dropped 6 inches on top of cylinder) produces the greatest stresses.

d. Shrinkage Load: The fuel pool concrete was cast in segments designed to minimize the shrinkage effects in the concrete. The small residual compressive shrinkage forces transmitted to the reinforcement are conservatively neglected in this analysis.

e. Earthquake Load: The probability of an accidental cask drop occuring during an earthquake is extremely low. However, for conservatism, the dead load, live load and hydrostatic load are increased by 30 percent to account for the earthquake condition.

2. Loading Combinations -- The loading conditions described above were combined to determine the maximum values of the stresses in the critical sections of the spent fuel pool structure. At each pool section investigated, critical parameters were varied to insure that the worst condition was found. In Case 1, the end conditions of the floor slab were varied from partially restrained to fully restrained. To investigate the extreme conditions in Cases 2 and 3, the thermal gradient was varied from 0F to 50F. The resulting moments, shears and axial forces are shown in Table 4. The summary of stresses is shown in Table 5.

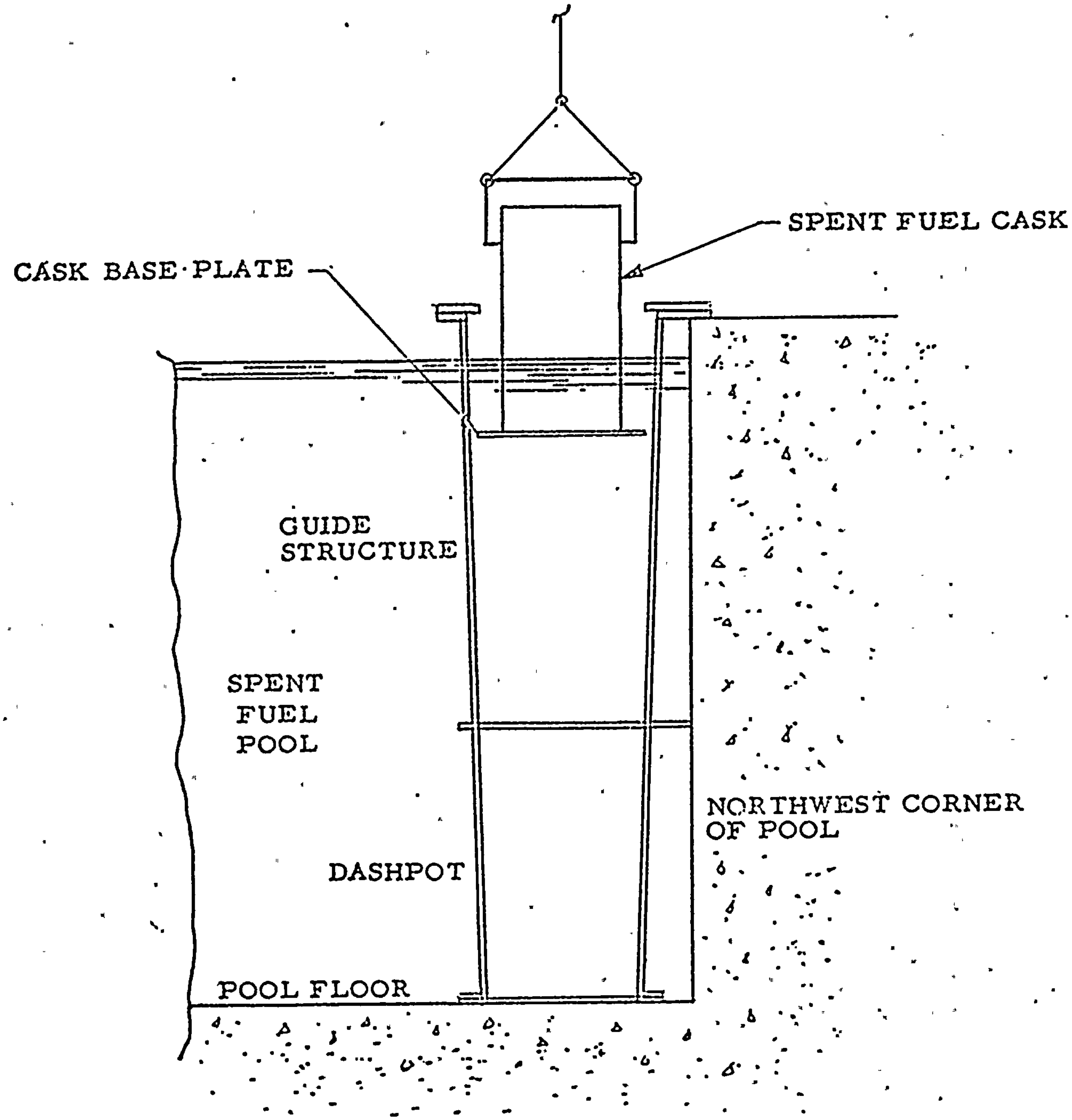
3. Pool Liner -- The maximum tensile stress on the pool liner in the pool corners (location (2-2)-(3-3)) Figure 14, is 14,400 psi. This value is well below the minimum yield stress of 33,000 psi (ASTM-304L). The liner was analyzed for buckling. In the floor liner it was found that the critical buckling stress was higher than

the yield stress of the liner plate. In the wall liner the critical buckling stress is -31,000 psi. Buckling of the liner plate will not occur since the liner stresses as shown in Table 5 are less than the buckling or yield stress. Since all stresses are in the acceptable range, the integrity of the pool liner will be assured.

4. Summary and Conclusions -- The impact forces imposed on the spent fuel pool from the cask drop are considered to be upper bound since the support structural system was assumed to be infinitely rigid. Because the design of the cask drop protection system and the analysis of the fuel pool were carried out in parallel, the preliminary impact loads were increased by 30 percent to insure that the structural analyses were conservative. The final impact loads were slightly less than the preliminary impact loads.

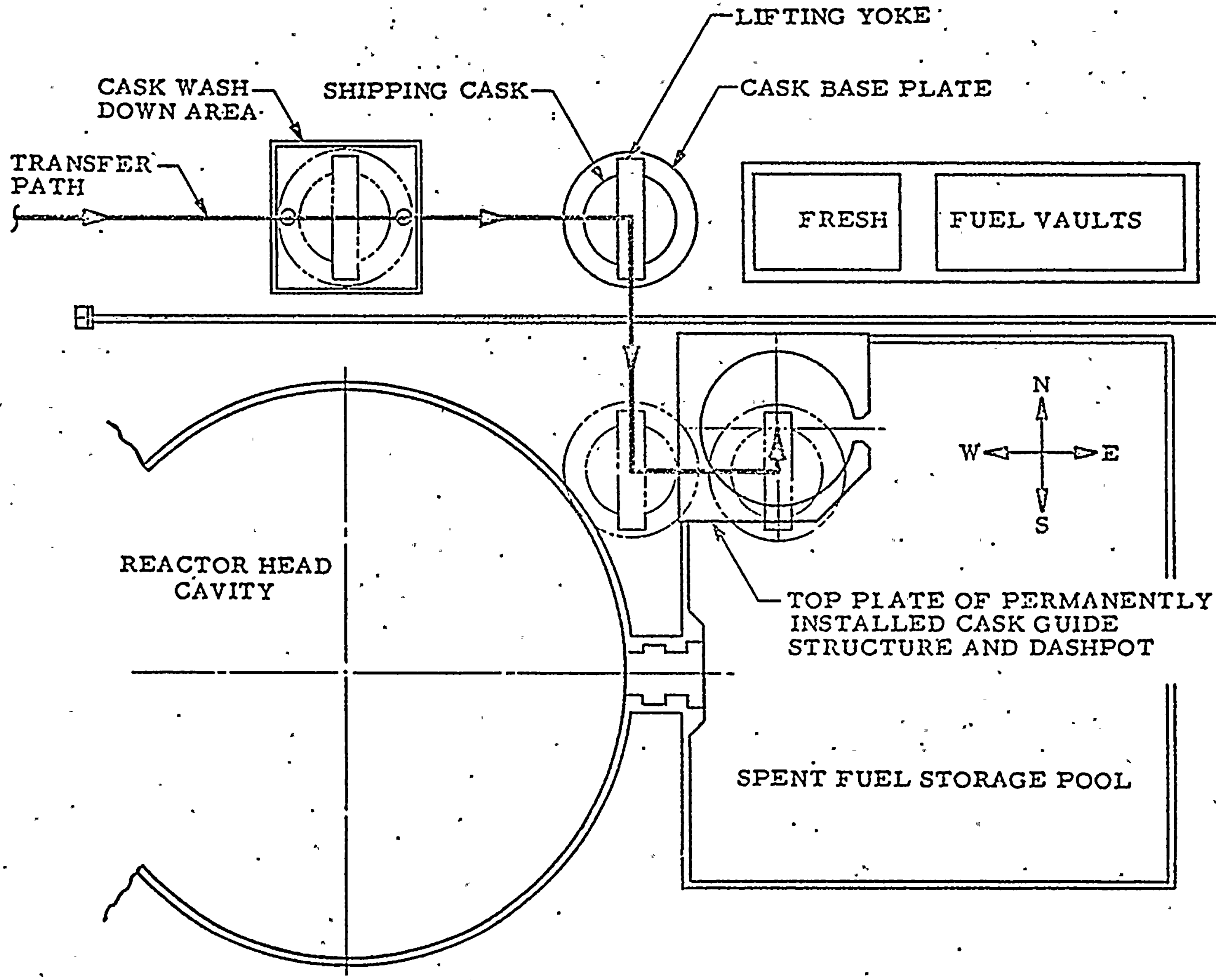
The maximum stress in the reinforcing steel was 41,900 psi (Case 2.2). Since this is a dynamic loading condition and the dynamic yield strength for the reinforcement is approximately 50,000 psi, as described in the Air Force Design Manual, "Principles and Practices for Design of Hardened Structures," by Newmark, et. al., the pool integrity will be maintained.

The maximum concrete punching shear stress was 435 psi. This value is well below the recommended limit of .2 f'_c (f'_c for the fuel pool concrete is 4,000 psi), as described by Newmark, et. al.



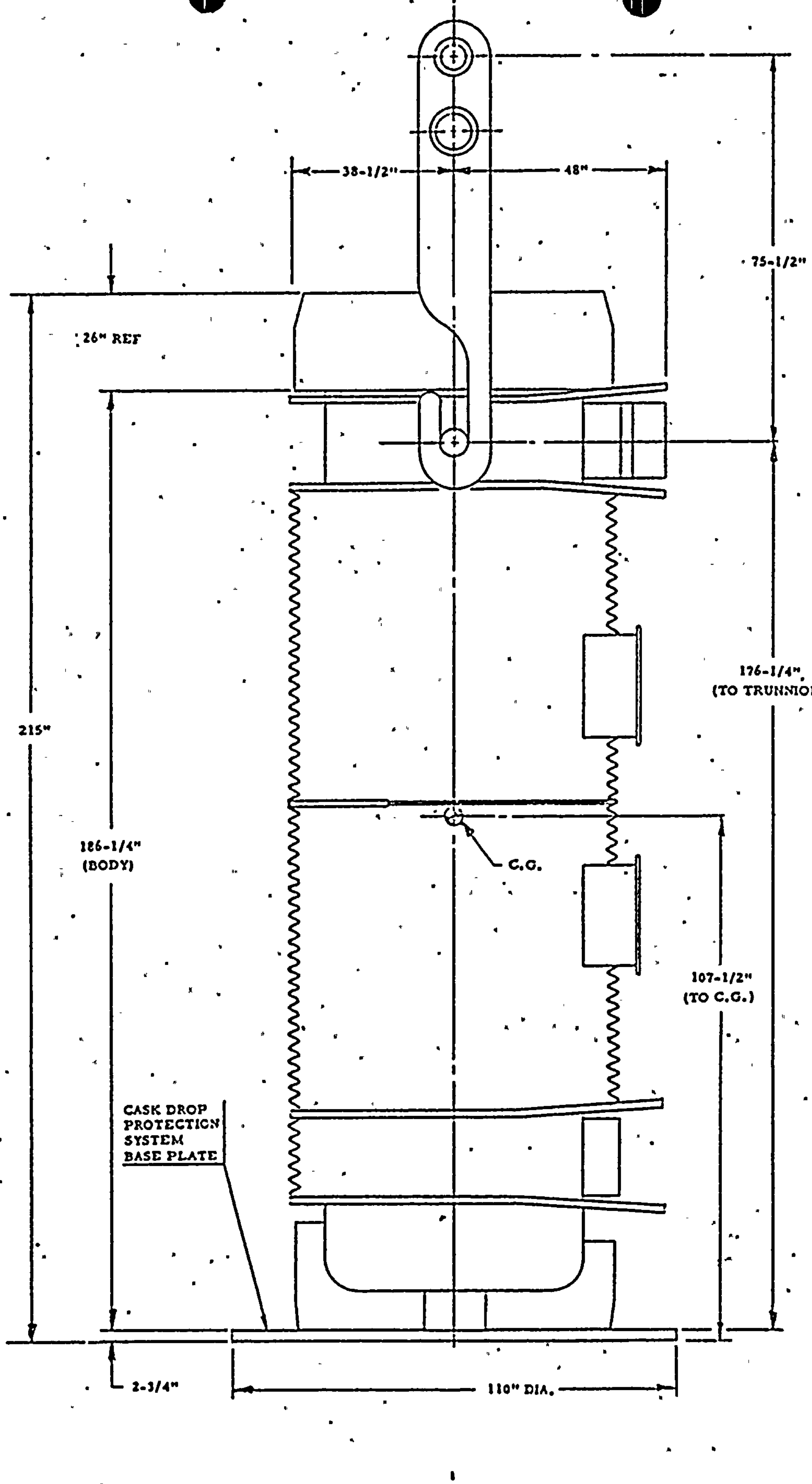
CROSS SECTIONAL VIEW OF CASK DROP PROTECTION SYSTEM

FIGURE 1



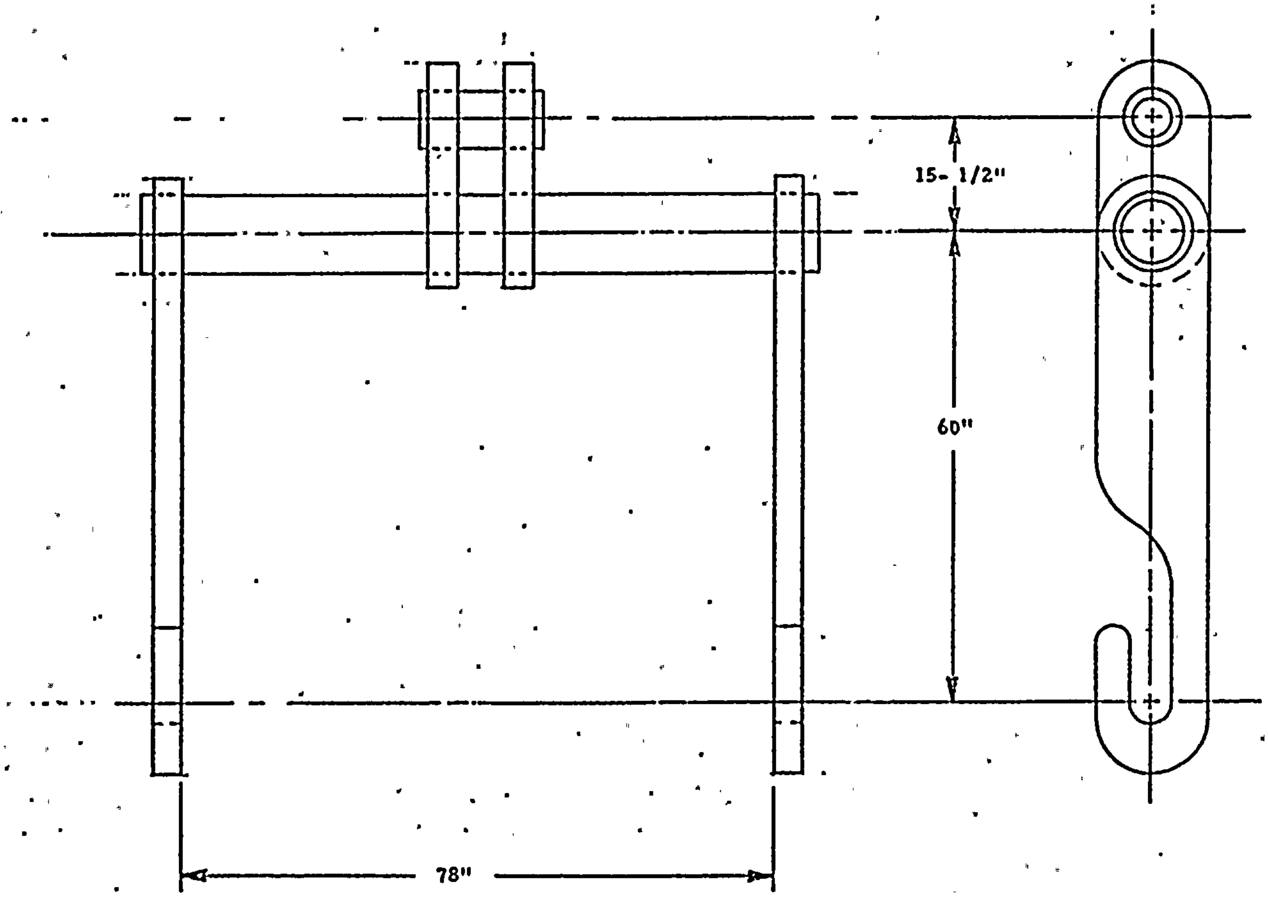
CASK DROP PROTECTION SYSTEM PLAN VIEW ARRANGEMENT

FIGURE 2



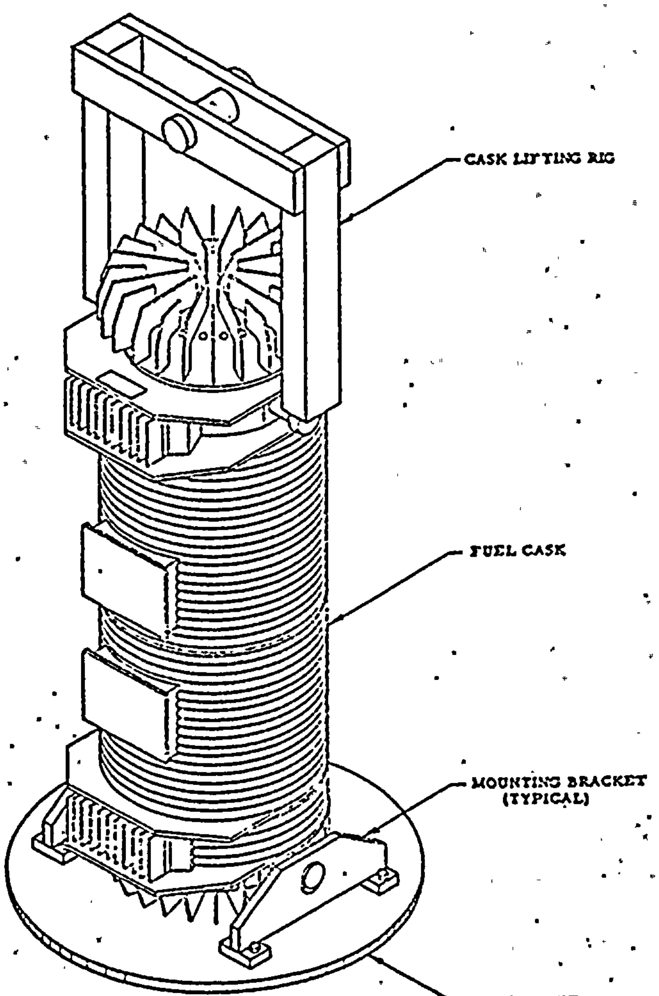
TYPICAL SHIPPING CASK

FIGURE 3



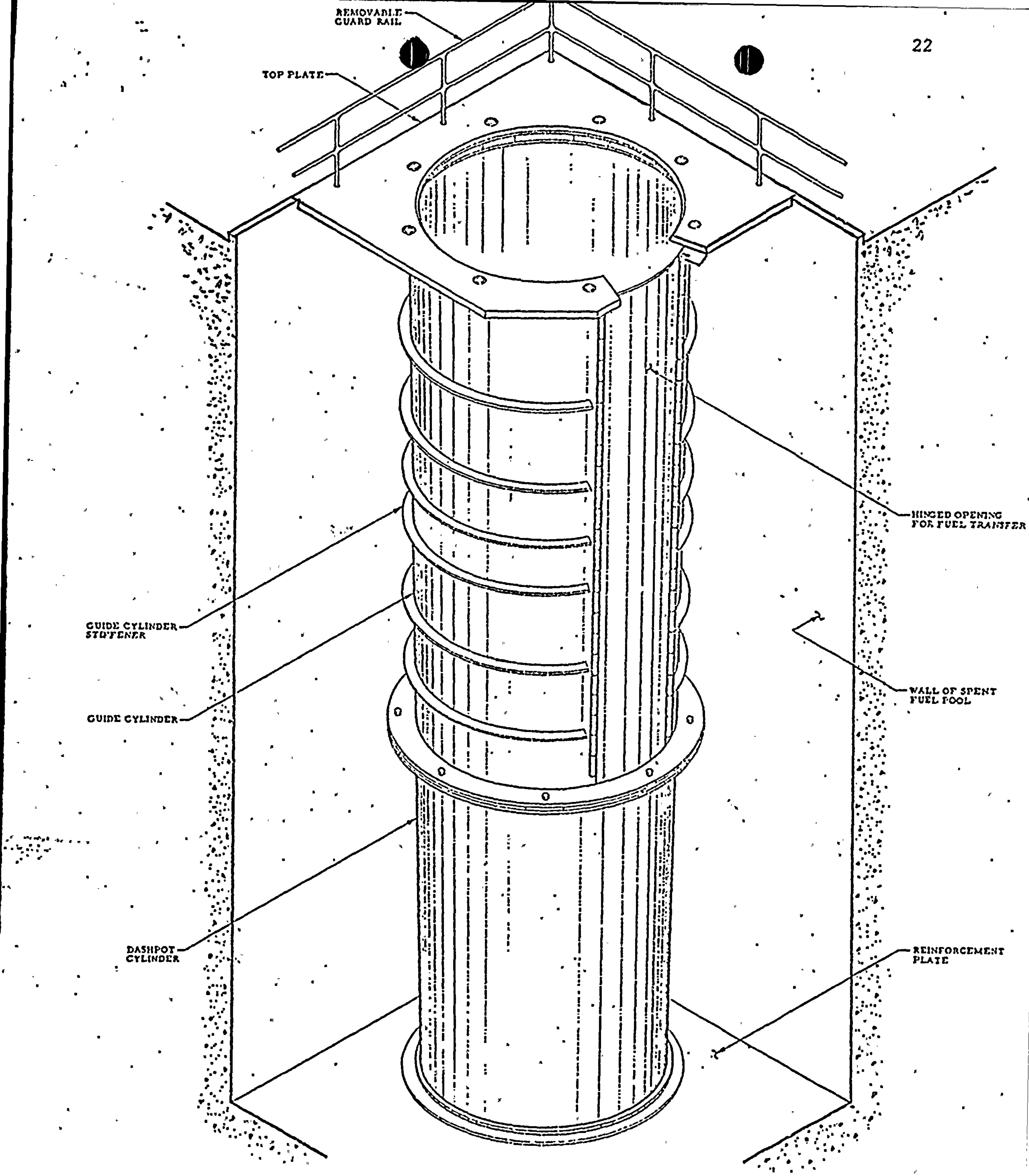
TYPICAL CASK LIFTING YOKE

FIGURE 4



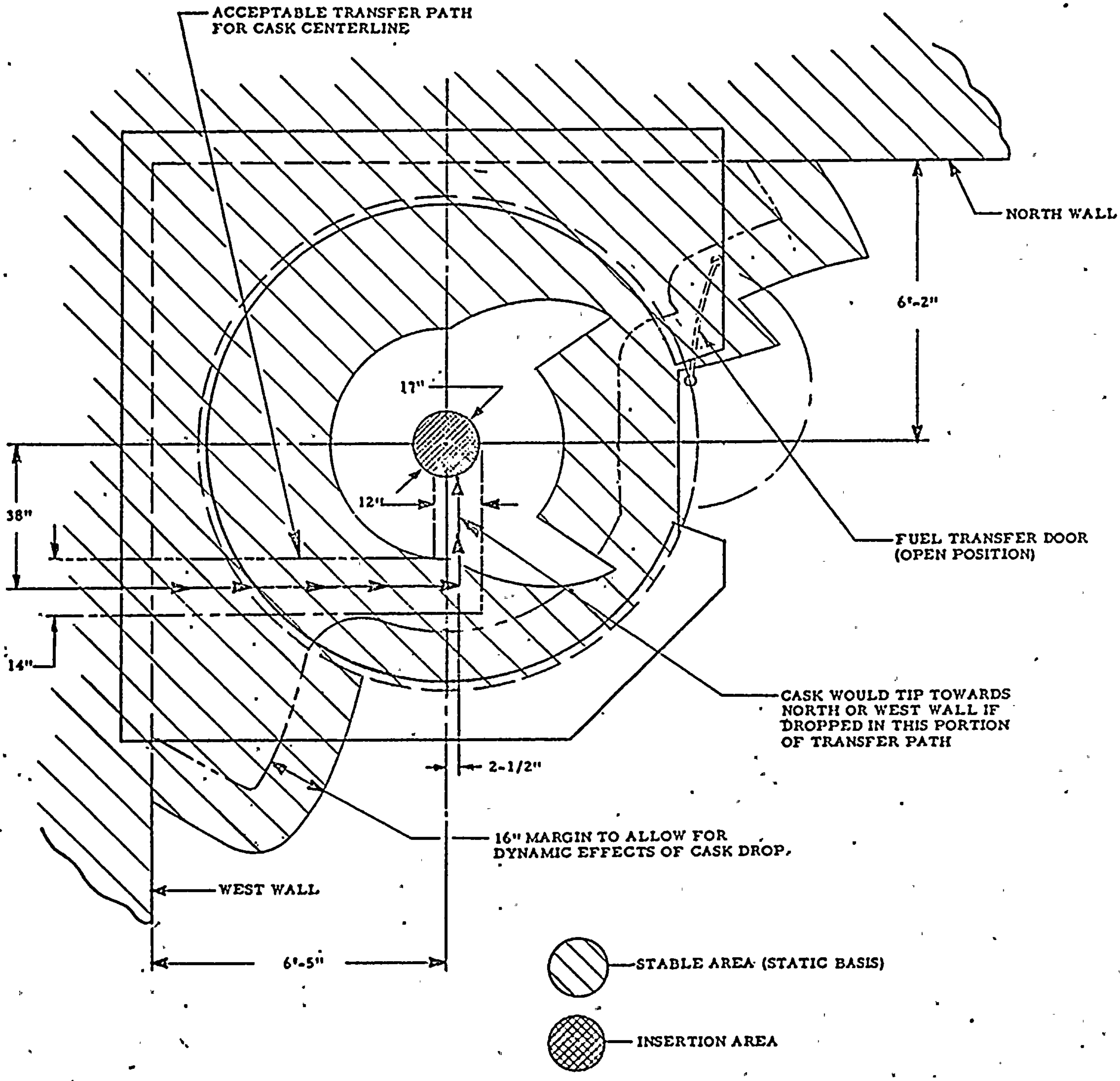
TYPICAL FUEL CASK WITH BASE PLATE ATTACHED

FIGURE 5



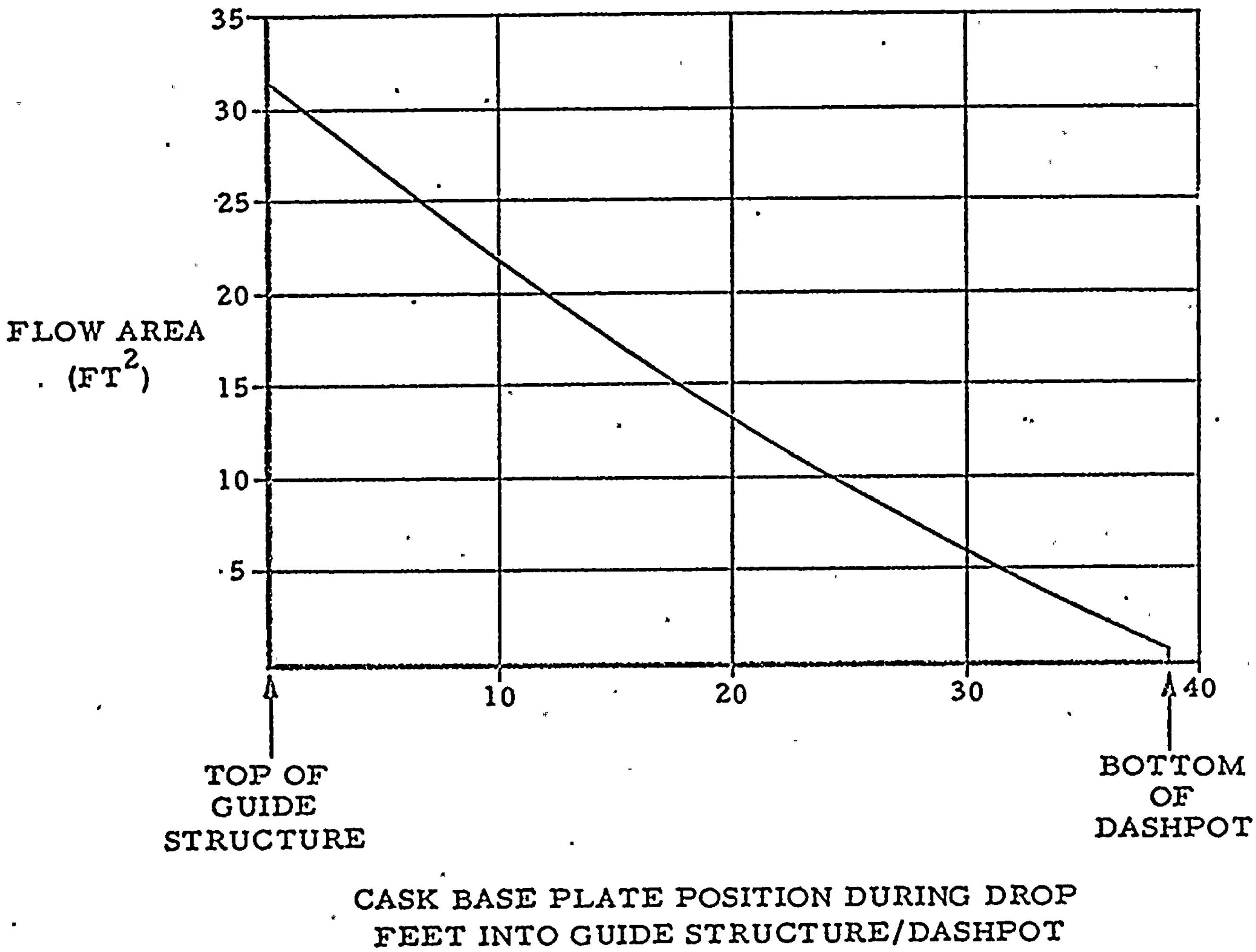
PERMANENTLY INSTALLED GUIDE STRUCTURE AND DASHPOT ASSEMBLY

FIGURE 6



STABLE AREA FOR CASK CENTERLINE

FIGURE 7



FLOW AREA VS. DEPTH

FIGURE 8

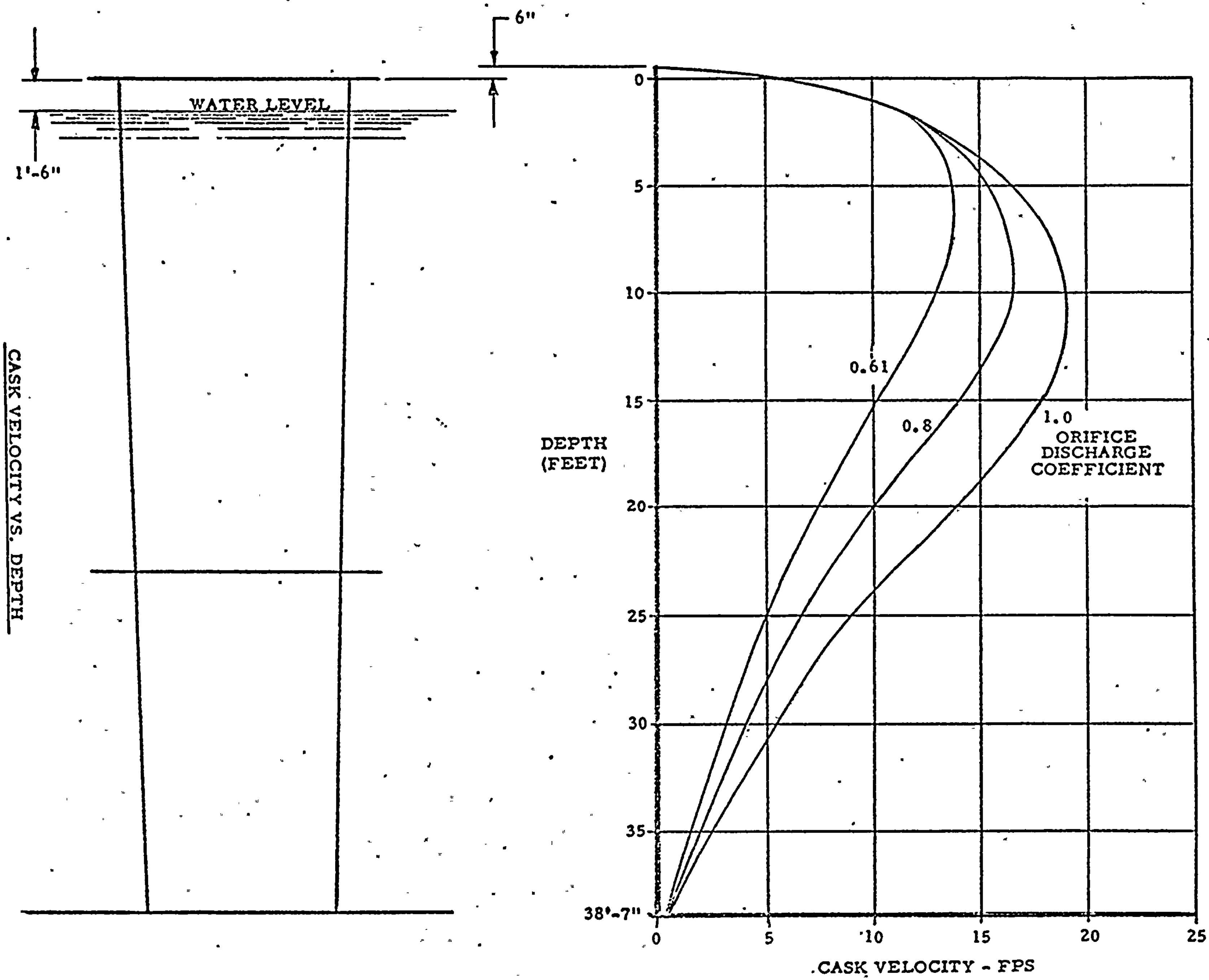
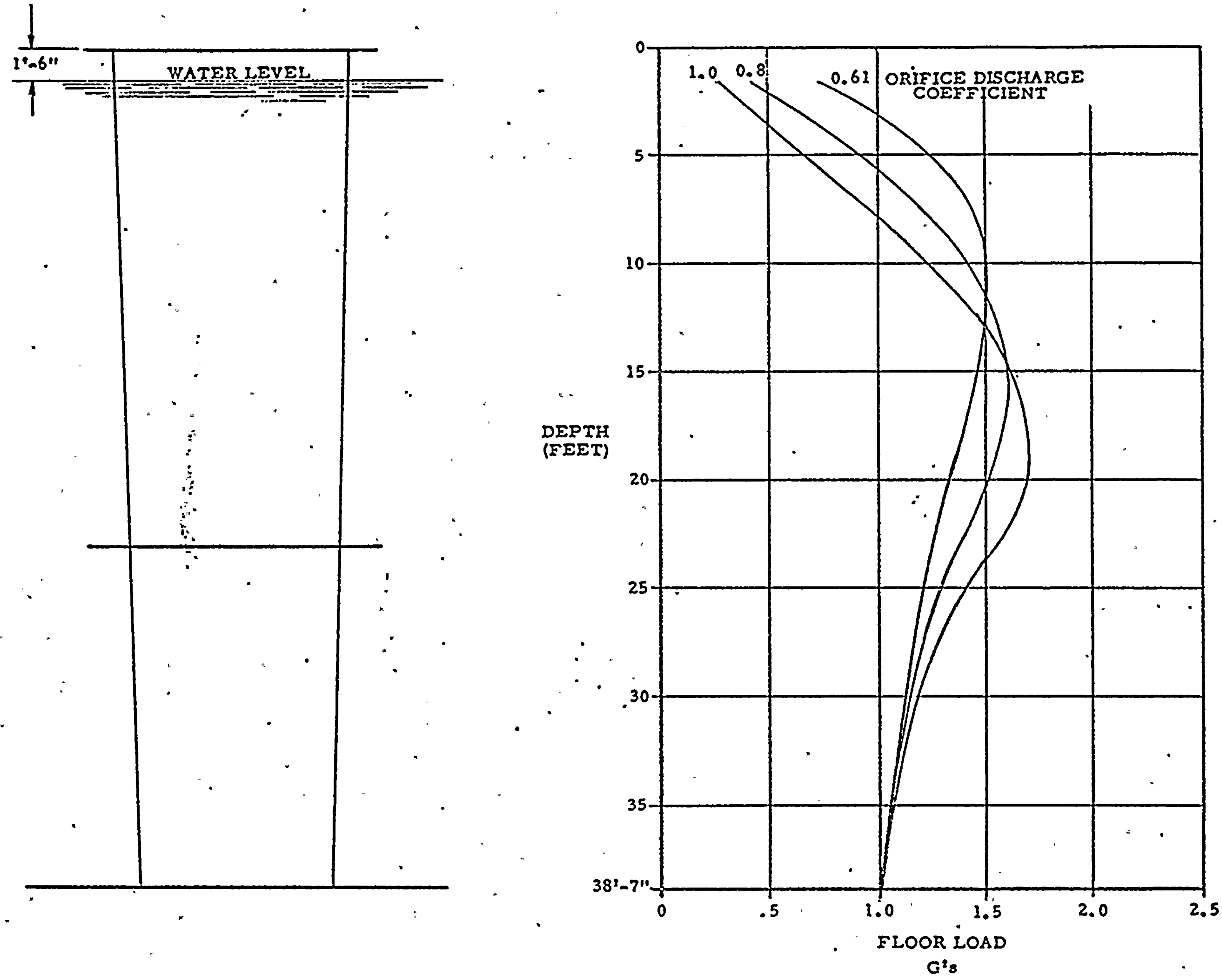


FIGURE 9.

CASK VELOCITY VS. DEPTH



FLOOR LOAD VS. DEPTH

FIGURE 10

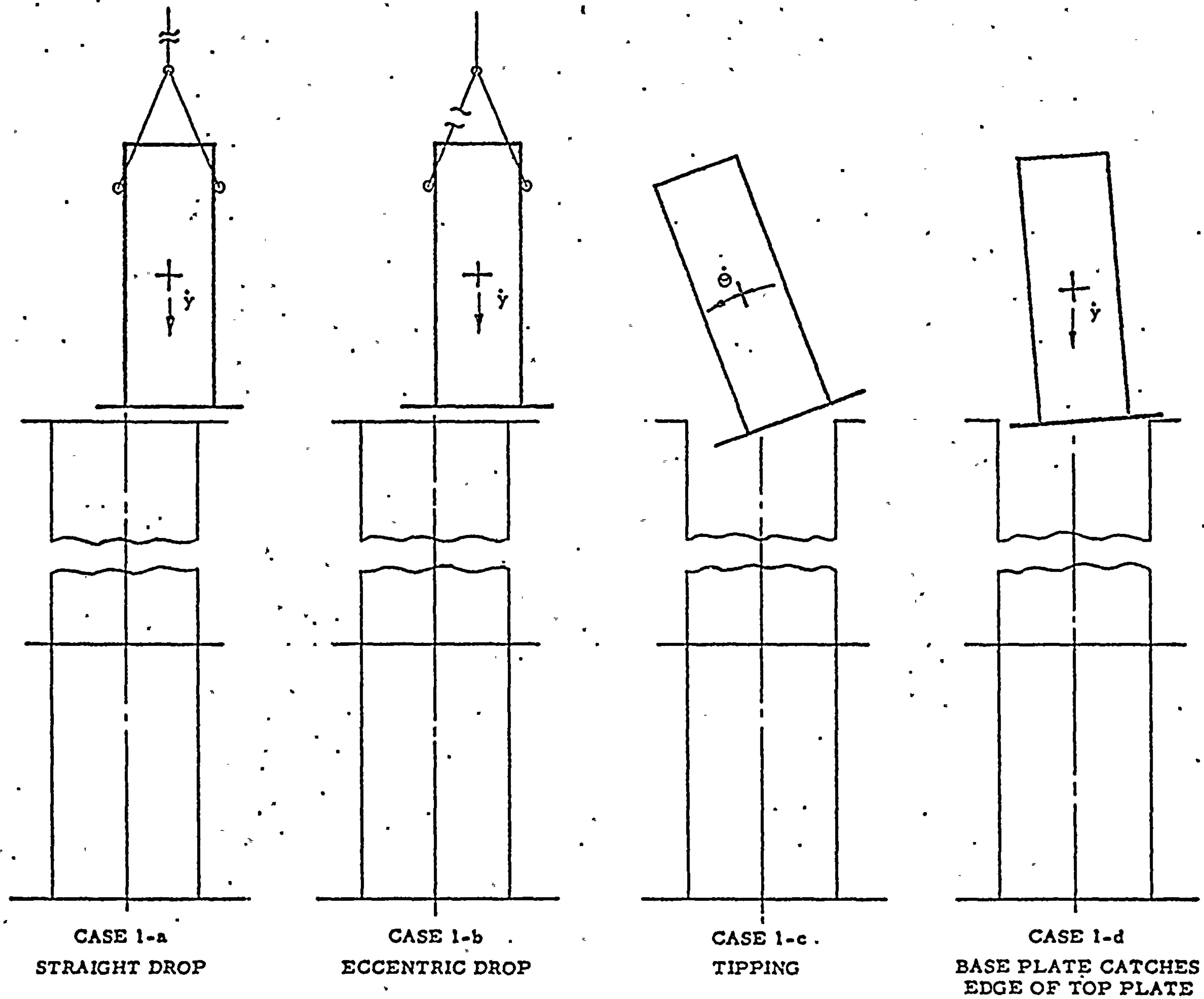
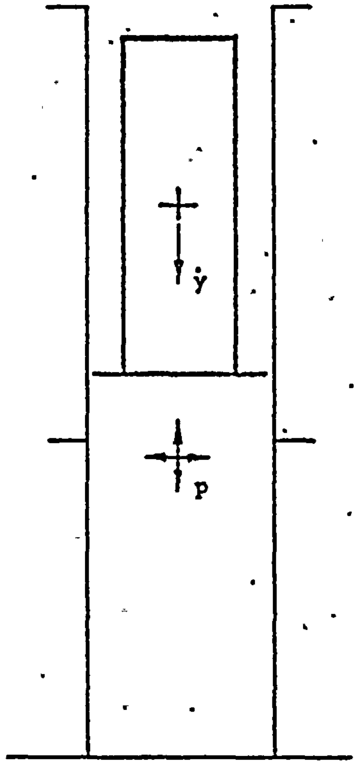
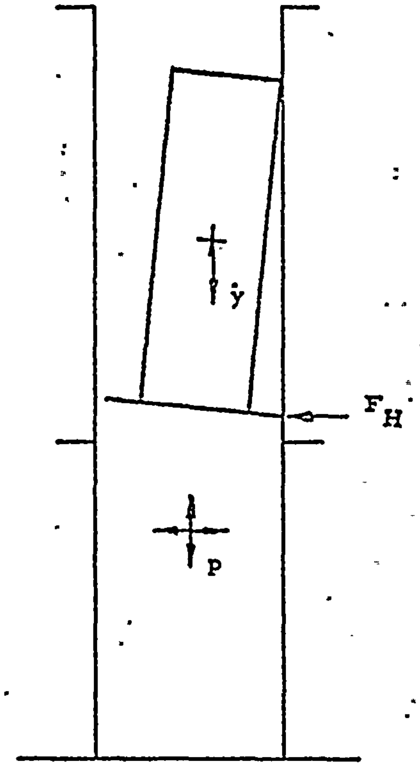


FIGURE 11

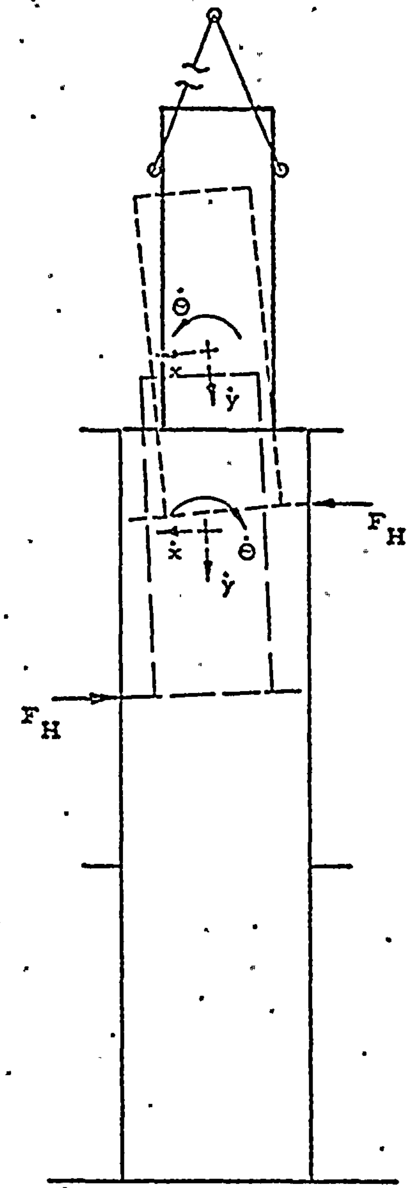
CASK DROPS ONTO TOP PLATE OF GUIDE STRUCTURE



CASE 2-a
STRAIGHT FALL



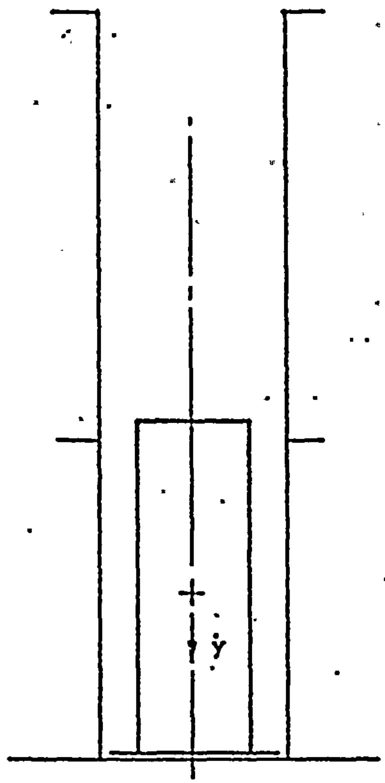
CASE 2-b
STRAIGHT FALL WITH CASK TIPPED
AT MAX. ANGLE OF INCLINATION



CASE 2-c
ECCENTRIC DROP

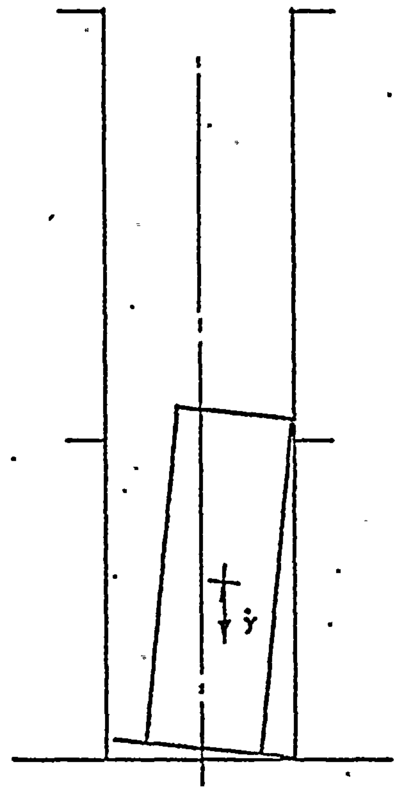
CASK DROPS OVER OR WITHIN GUIDE CYLINDER

FIGURE 12



CASE 3-a

IMPACT FLAT

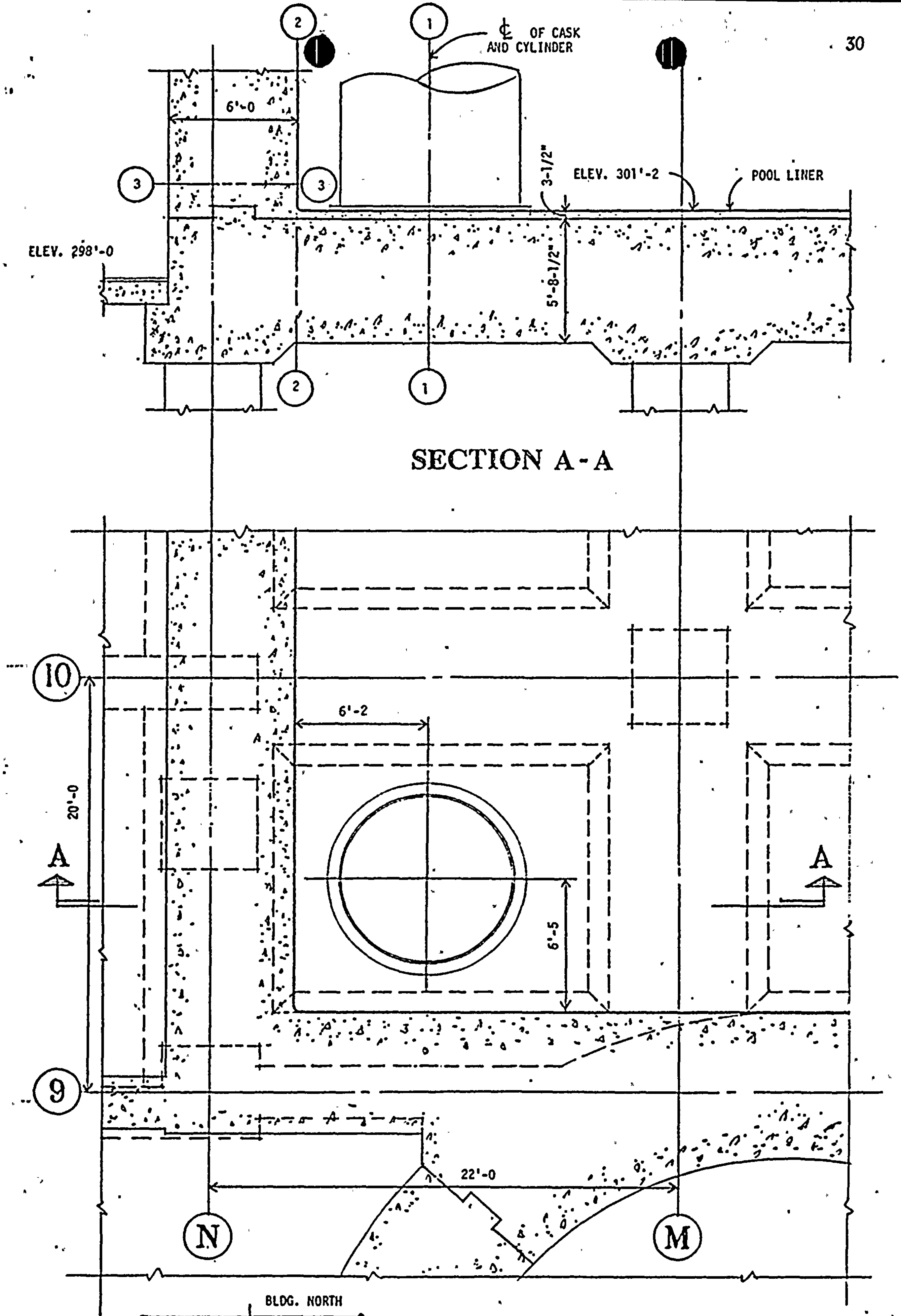


CASE 3-b

IMPACT AT MAXIMUM ANGLE OF INCLINATION

FIGURE 13

IMPACT WITH FLOOR



SECTIONAL PLAN @ N.W. CORNER OF SPENT FUEL POOL

FIG. 14

TABLE 1

PERFORMANCE SENSITIVITY CALCULATION RESULTS

Case	Flow Coefficient	Maximum Deceleration Force (g's)	Peak Velocity (fps)	Impact Velocity (fps)
1	0.61	1.5	14.0	0.33
2	0.8	1.6	16.8	0.42
3	1.0	1.7	19.3	0.52

TABLE 2

DESIGN LOADS FOR POTENTIAL CASK DROP ACCIDENTS

Types of Cask Drops	Vertical Loads (lbs)	Lateral Loads (lbs)
1. Drops Onto Top Plate of Guide Structure		
a. Straight drop, Case 1-a	900,000 (4.3 g's)	---
b. Eccentric drop, Case 1-b	900,000 (4.3 g's)	---
c. Cask tip onto north wall, Case 1-c	Total Kinetic Energy = 1,150,000 ft-lbs	
d. Base plate catches edge of top plate, Case 1-d	393,000 (1.87 g's)	---
2. Drops Within ID of Guide Cylinder and Dashpot		
a. Straight drop, Case 2-a	358,000 (32 psi, 1.7 g's)	---
b. Straight drop with cask tipped at maximum angle of inclination, Case 2-b	358,000 (32 psi, 1.7 g's)	32,000
c. Eccentric drop, Case 2-c	358,000 (32 psi, 1.7 g's)	97,000
3. Impact with Floor		
a. Flat impact, Case 3-a	800,000 (3.8 g's)	---
b. Impact at maximum angle of inclination, Case 3-b	380,000 (1.8 g's)	---
4. Lateral Load on Connection to Operating Floor	---	100,000

*g-loads based on 210,000 lb. cask system

TABLE 3

SUMMARY OF STRESSES AND DEFLECTIONS IN PRINCIPAL PARTS

Part	Governing Design Load	Max. Stress (psi) or Deflection (in)
1. Top Plate of Guide Structure (Aus. St. Steel)	Case 4 - Lateral load of $100 \cdot 10^3$ lb	σ = < 25,000
2. Guide Cylinder		
--Shell (Aus. St. Steel)	Case 2-a - Hydraulic pressure of 32 psi	σ = 5,700 psi
	Case 1-a - Vertical load of $900 \cdot 10^3$ lb.	σ = 13,000 (assumes only 1/2 guide cylinder carries this load)
--Hinge Pins (Aus. St. Steel)	Case 2-a - Hydraulic pressure of 32 psig	τ = < 8000 psi (allowable = 12,000 psi shear)
--Latch Pins (A-286 St. Steel)	Case 2-a - Hydraulic pressure of 32 psig	τ = < 24,000 psi (allowable = 32,000 psi shear)
3. Dashpot Shell (Aus. St. Steel)	Case 2-a - Hydraulic pressure of 32 psi	σ = 3,800 psi
	Case 1-a - Vertical load of $900 \cdot 10^3$ lb	σ = 10,400 psi
4. Base Plate (6061-T6 aluminum)	Case 2-a - Hydraulic pressure of 32 psi	σ = 5,000 psi
	Case 1-d - Base plate catches edge of top plate.	Δ = 4 inches (Bending of base plate)

TABLE 4

MOMENTS, SHEARS AND AXIAL FORCES FOR MAXIMUM IMPACT LOAD (1,200,000 LBS.)

LOCATION ANALYZED (SEE FIG. 14)	CASE NO.	BENDING MOMENT (K-FT/FT) D.L + L.L + HYDRO + SEISMIC	IMPACT	THERMAL	SHEAR (K/FT) D.L + L.L + HYDRO + SEISMIC	IMPACT	TOTAL BENDING MOMENT (K-FT/FT)	TOTAL SHEAR (K/FT)	TOTAL AXIAL FORCE (THERMAL)
1-1	1.1	30	110	96	-	-	236	-	-101
1-1	1.2	30	110	196	-	-	332		-101
2-2	2.1	-100	-240	+ 96	53	270	-244	323	-101
2-2	2.2	-100	-240	-	53	270	-340	323	-
3-3	3.1	-100	-240	+ 96	18	-	-244	18	-
3-3	3.2	-100	-240	-	18	-	-340	18	-

(-) = (TENSION ON INSIDE REINFORCEMENT)
(+) = (TENSION ON OUTSIDE REINFORCEMENT)

TABLE 5

SUMMARY OF STRESSES (PSI) FOR MAXIMUM IMPACT LOAD (1,200,000 LBS.)

LOCATION ANALYZED (SEE FIG. 14)	CASE NO.	CONCRETE COMPRESSION	SHEAR	REINFORCING STEEL INSIDE FACE OF POOL	OUTSIDE FACE OF POOL	STEEL LINER
1-1	1.1	-500		-3,700	4,300	-14,600
1-1	1.2	-800		-5,600	13,800	-19,600
2-2	2.1	-600	435	5,400	-3,800	-14,600
2-2	2.2	-900	435	41,900	-5,200	14,400
3-3	3.1	-340	23	10,000	-4,600	- 3,400
3-3	3.2	-600	23	13,000	-3,000	14,400

(-) COMPRESSION
(+) TENSION

TABLE 4 AND TABLE 5
CASE 1.1 - THERMAL LOADING - SLAB CONSIDERED PARTIALLY RESTRAINED FOR ROTATION AT BOUNDARIES
CASE 1.2 - THERMAL LOADING - SLAB CONSIDERED FULLY RESTRAINED FOR ROTATION AT BOUNDARIES
CASE 2.1 - SAME AS CASE 1.1
CASE 2.2 - THERMAL LOADS EXCLUDED TO PRODUCE MAXIMUM STRESSES (NO THERMAL GRADIENT)
CASE 3.1 - SAME AS CASE 1.1
CASE 3.2 - SAME AS CASE 2.2