SAFETY ANALYSIS REPORT

for

CHEM-NUCLEAR SYSTEMS INC.

SGC-1

TYPE A RADWASTE SHIPPING CASK

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TABLE OF CONTENTS (Continued)

2

Revision 2
March, 1981

EFFECTIVE PAGES

PAGE	DATE
1-1	January 1981
1-4	"
1-5	"
1-6	"
1-7	"
1-8	"
1-9	March, 1981
1-10	"
1-11	January, 1981
1-12	March, 1981
1-13	
1.3.1-1	January, 1981
1.3.1-2	"
1.3.2-1	"
1.3.3-1	"
1.3.3-2	"
1.3.3-3	"
1.3.3-4	"
1.3.3-5	"
1.3.3-6	"
1.3.3-7	"
1.3.3-8	"
1.3.3-9	"
1.3.3-10	"
1.3.3-11	"
2-1	"
2-2	"
2-3	"
2-4	"
2-6	"
2-7	"
2-8	"

EFFECTIVE PAGES (CONT.)

EFFECTIVE PAGES (CONT.)

PAGE	DATE
7-2	March 1981
9-1	January 1981
A-1	"
A-2	"
A-3	"
A-4	"
A-5	"
2.10.1-2	March 1981
2.10.1-3	"
2.10.1-4	"
7-3	"
7-4	"
7-5	"
iv	"
v	"
viii	"
ix	"
B-1	"
B-2	"
B-3	"
B-4	"
B-5	"

1.2.4 Steam Generator Lower Assembly Sealing Containment

The Steam Generator Lower Assembly is sealed and prepared for shipment by the following operations: (Ref. Figures 1.2-3, 1.2-4, 1.2-5.

1. The top of the assembly (transition cone cut-line) is sealed with a cap assembly. This cap assembly consists of a 3 - 5" thick 24-inch wide, steel plate skirt ring rolled to a 12'-6" O.D.. The ends of the ring butt welded with a full penetration weld. The top of the skirt ring is then capped with a 3-5" thick flat plate, 12'-2" in diameter, welded to the skirt ring with a 1 1/2-inch fillet weld, 1-inch thick at the throat of the weld. The complete cap assembly is welded to the Steam Generator Lower Assembly transition cone cut line with a 1 1/2-inch fillet weld, 1-inch thick at the throat completely sealing the cap to the transition cone and the internal primary system tubing.

2. The bottom of the Steam Generator Lower Assembly, at the Chnnel Head cut-line, is closed with a 3 - 5" thick, 11'-1 diameter steel plate welded to the Steam Generator Lower Assembly shell by a 1 1/2-inch fillet weld, 1-inch thick at the throat.

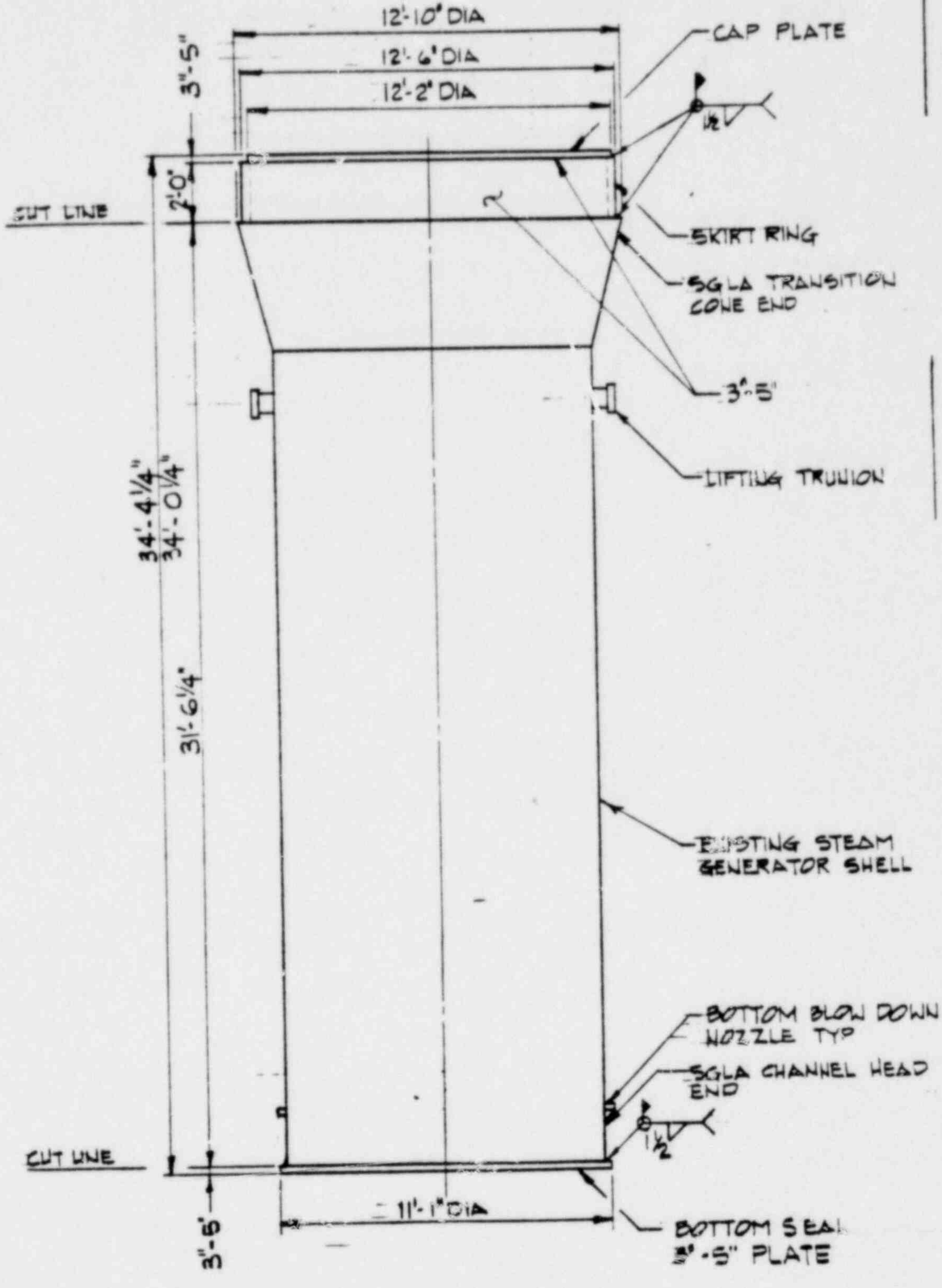
3. All Steam Generator Lower Assembly small nozzle connections (i.e., (2) Bottom Blowdown, 2-in.; (1) Shell Drain, 1-in.; (1) Long Range Level Top, 3/4-in.) are sealed by inserting a minimum 2-in. long barstock welded closed with an appropriate fillet weld around the O.D. of the protruding barstock end.

4. All Steam Generator Lower Assembly 6-in. handhole openings are sealed with 2-in. minimum thickness steel plate, 5.990-in. O.D., welded with an appropriate fillet weld to the inside of the handhole opening. The handhole cover plates are put back in place and bolted after welding as an additional cover.

   All weld material will be E70XX welding electrodes or equivalent, and welding is done in accordance with ASME Section IX procedures and standards or equivalent.

1.2.5 Steam Generator Lower Assembly Shielding Preparation

Before loading the assembly into the shipping cask, the assembly shell and closures will be surveyed to assure that no reading above the cask design limit of 200 mR/hr is evident.



STEAM GENERATOR LOWER ASSEMBLY (SGLA)

SEALING CONTAINMENT

FIGURE 1.2-3

Actual survey readings of the generators during regular shutdowns, and in a drained conditions indicate contact levels well below 200 mR/hr. In the event areas of the Steam Generator Lower Assembly and its plate seal closures are found to exceed the 200 mR/hr limit, additional steel and/or lead plate shielding will be fastened by clipping and/or welding over these areas on the SGLA outer shell surface.

Dose rates at these points will not exceed 1^R/hr at 3 ft prior to the installation of additional shielding.

APPENDIX 2.10.1

Tiedown Criteria Discussion

Due to the large mass of the SGC-1 package it is unrealistic to demonstrate that the accelerations required in 10 CFR 71.31(d)(1) could ever be reached under normal conditions of transport. Examining the actual transport conditions, there are two seperate environments: 1) Land Transportation and 2) Marine Transportation

LAND TRANSPORTATION:

The loads that the cask could possible see during normal land transport are greatly affected by its transport controls, and trailer design. The cask/transport speed islimited to less than 10 MPH and the cask carried on a hydraulic suspension platform trailer with 104 wheels. It is highly unlikely that any noticeable vertical or horizontal accelerations will be generated. The package is further protected by the transport controls and procedures requiring traffic control and escort. It should be noted that for normal loads of this size only friction and gravity are used to secure the load to the trailer. The requirement that the trailer tiedowns carry any lateral loads in excess of friction is added conservitism. Additionally securing the package to the trailer so that the trailer stays with the package is the maximum tiedown the package can have in the vertical direction.

MARINE TRANSPORTATION:

The loads that the package can be subjected to during marine transport are greater than those imposed during land transport. These actual loads are far less than those loads imposed by 10 CFR 31 (d). This is further demonstrated by the L.R. Glosten and Associates, Inc, study prepared for the transport of the Surry Steam Generator to Hanford intitled "A Study of the Single Voyage Risk Levels Associated with Extreme Motion Values for a Barge Voyage from Norfolk, Virginia to Astoria, Oregon", January, 1980. This study develops extreme environments based upon a winter voyage which was dominated by North Pacific storms. The maximum g loadings developed are considerably less than 1g. Added conservatism is included by using the proposed rules of ANSI 14, N552, Draft #3, October 1976, "Proposed Guide for Water Transportation of Irradiated Nuclear Fuel". Section IV of the proposed guide, specifies 1.5g loadings in the horizontal direction with sufficient vertically in the tiedowns to allow recovery of the package with the hull, in case of capsizing. Note that no allowance was taken for friction which adds an additional element of conservatism.

The marine tiedown of the SGC-1 package are designed to withstand loads of 1.5 g's in all directions. This exceeds the criteria of ANSI N-14, N552 Draft #3, October, 1976, checking the tiedown criteria for simultaneous loadings from pitch, heave and roll. From ANSI N14 N552 for barge vessels:

a) "Rolling 15° each side (60°) in 5 seconds"

b) "Pitching 4° half amplitude (16°) in 5 seconds"

c) "Heaving use 0.3 g's"

Assuming a sine form for the motion

$$\theta = A \sin Bt$$

$$\frac{d\theta}{dt} = AB \cos Bt$$

$$\frac{d\theta^2}{dt^2} = -AB^2 \sin Bt$$

Boundary Conditions

$t = 0$	$t = 1.25$ secs. (¼ period)
$\theta = 0$	$\theta = .262$ radians
$\frac{d\theta}{dt} = \max$	$\frac{d\theta}{dt} = 0$
$\frac{d\theta^2}{dt^2} = 0$	$\frac{d\theta^2}{dt^2} = \max$

From

$$\frac{d\theta}{dt} = AB \cos Bt$$

$t = 1.25$

$0 = A(B) \cos B\,(1.25)$

A and B $\neq 0$

Therefore

$\cos Bt = 0 \qquad Bt = \pi/2$ radians

$B = \pi/21.25 \text{ sec} = 1.26$ radians/sec.

$.262 = A \sin 1.26\,(1.25) = A \sin \pi/2 = A$

To find max $\frac{d\theta^2}{dt^2}$:

$$\frac{d\theta^2}{dt^2} = A\,B^2 \sin Bt = -.262\,(1.26)^2 \sin 1.25\,(1.26)$$

$$= .416 \text{ radians/sec}^2$$

A bounding condition is for the center of bouyancy to be 20 ft below the CG at of cash.

$$a_r = \frac{d\theta^2}{dt^2} R = .416\,(20) = 8.313 \text{ ft/sec}^2.$$

$$= .26 \text{ g's}.$$

Similarly for pitching

Boundary conditions

$t = 0$ $\quad\quad t = 1.25$ sec.

$\phi = 0$ $\quad\quad \phi = 0.07$

$\frac{d\phi}{dt} = \max$ $\quad\quad \frac{d\phi}{dt} = 0$

$\frac{d\phi^2}{dt^2} = 0$ $\quad\quad \frac{d\phi}{dt^2} = \max$

$$\phi = C \sin Dt$$

$$\frac{d\phi}{dt} = C\,D \cos Dt$$

$$\frac{d^2\phi}{dt^2} = -C\,D^2 \sin Dt$$

$$\frac{d\phi}{dt} = C\,D \cos Dt$$

Implies $D = 1.26$ radians/sec.

At $t = 1.25$ sec.

$$\phi = 0.070 = C \sin [(1.26)(1.25)]$$

$$C = .070$$

$$\frac{d^2\phi}{dt^2}_{max} = -C\,D^2 \sin Dt$$

$$= -.070\,(1.26)^2 \sin [(1.26)(1.25)]$$

$$= -.111 \text{ radians/sec}^2$$

The cask CG is within 20 ft of the CG of loaded barge

$$a_p = \frac{Rd^2}{dt^2} = -(20)\,(.111) = 2.217 \text{ ft/sec}^2$$

$$= 0.07 \text{ g's.}$$

Combining all accelerations simultaneously

$$A = \sqrt{a_p{}^2 + a_r{}^2 + a_h{}^2}$$

$$= \sqrt{(.26)^2 + (.07)^2 + (.3)^2}$$

$$= .40 \text{ g's.}$$

This is considerably less than the 1.5 g's that the tiedowns are designed for.

The sufficiency of the 1.5 g criteria can also be checked by looking at the accelerations that are predicted in "A Study of the Single Voyage Risk Levels Associated with Extreme Motion Values for a Barge Voyage from Norfolk, Virginia, to Astoria, Oregon." L.R. Glosean and Associates, Inc. 1980. This is a detailed study of the barge motions resulting from various sea conditions. The results of the studies include roll, pitch,

2

and heave. At a 1% risk level without consideration for seamanship at 8 knots, the following acceleration values were determined: Surge: 9.75 ft/sec^2, Sway: 23.6 ft/sec^2 and Heave: 11.4 ft/sec^2. Adding these vectorially, max acceleration equals 27.95 ft/sec^2 or 0.87 g's. If the barge was to turn over in these type of seas, it would see basically the same motion and forces, except that gravity would have to be added to the heave component. The speed would be zero knots. The accelerations are predicted to be: Sway: 23.6 ft/sec, Surge: 10 ft/sec, and Heave: 41.7 ft/sec. This would give a maximum acceleration of 49. ft/sec or 1.5 g's. An over turned barge is an accident condition. The design of tiedowns is based on withstanding 1.5 g's at yield. 2

In an accident condition the full strength of the tiedowns based on tensile strength can be applied. Therefore, the tiedowns would adequately keep the cask with the barge even if the barge turned over. It should be noted that the probability of the barge seeing these maximums simultaneously is very small. There is even a smaller probability that the barge will capsize.

In conclusion, the 1.5 g tiedown criteria is adequate to secure the cask to a barge. The criteria is adequate for both the motions described in the ANSI N-14, N552 Draft #3, October, 1976, document and those described by a study of barge motions (Glosten Report). The criteria is adequate even in accident conditions.

The top of the tube bundle has a similar self-shielding capability from innermost tube loop to the outer tube loops, with a final steel cap of 3- 5" thick steel plate welded to the end of the SGLA shell.

The open ends of the tubes penetrating through the tube sheet are spaced approximately 2 1/4-in. from the 3- 5" thick plate welded to, and closing, the bottom of the SGLA shell.

There is 72-in. of air space between this bottom SGLA closure plate and the inner surface of the cask end plate.

There is 8-in. average air space between the outer SGLA shell wall and the cask plate inner surface.

There is 12-in. approximately of air space between the top cap closing the SGLA shell and the inner surface of the cask end plate.

5.4.3 Actual Radiation Readings

Contact radiation readings have been made from typical steam generators, showing contact reading levels ranging from 50 mR/hr at the bottom of the channel head to 75 mR/hr on the sides of the SGLA. Figure 5.5-5 in Appendix 5.5 illustrates these readings.

5.4.4 Shielding Criteria

As a conservative standard, a nominal reading of 200 mR/hr on the surface of the SGLA was established as a cask design limit, even though much lower levels of radiation are expected.

7) Move the lower half/payload and trailer to the final unloading area under the lifting device.

8) Remove the internal tiedowns.

9) Lift the payload out of the lower half.

10) Move the trailer and lower half of the cask out from under the payload.

11) Set the payload down.

12) Inspect the cask and take any necessary surveys.

13) Reassemble cask internal tiedowns.

14) Place the upper half on the lower half per the procedures set forth in Section 7.1.

7.3 Preparation of an Empty Package for Transport

1) Follow the same steps as set forth in Section 7.1, except omit the steps involving the contents.

7.4 Controls for Ground Transportation

7.4.1 Maximum speed for the loaded transporter and cask is 10 mph.

7.4.2 On all curves and grades the transporter will be slowed to a walking speed or less.

7.4.3 A back-up prime mover will be with the loaded transporter.

7.4.4 A mechanic with reasonable spare parts for the transporter and prime mover will be with the transporter.

7.4.5 A detailed inspection of the route is made prior to the movement identifying all culverts, overhead wires, etc. Wires are raised as necessary before the movement. Required reinforcement of the culverts or other weak areas are made either by replacing the culvert (coordinated with the applicable Highway Department) or by using prefabricated portable jump bridges which span the weak area. These bridges are existing standard equipment that are used in heavy hauling. Immediately prior to the transport, the route is inspected with the applicable highway officials. During the actual transport the roadway is reinspected prior to the transporter moving. 2

7.4.6 Prior to barge unloading, all necessary Federal, State and County officials, including emergency organizations, will be notified of the impending haul and latest update of schedule.

7.4.7 Prior to movement of the SGC-1 package loaded or unloaded over public roads, a detailed traffic control plan will be worked out with the applicable authorities (State police, County sheriff or police) for the particular route. The actual traffic control will be coordinated by the applicable law enforcement agency. Depending on the particular road, route and normal traffic patterns, the traffic control plan will take one of two forms: 1) traffic in both directions stopped while the transporter is moving, or 2) traffic in the direction of travel of the transporter is stopped while the transporter is moving.

In the first case, the transporter will move up to a predetermined passing point and stop. The traffic will then move around it in both directions as directed by the applicable officials. The next section of roadway is then blocked off and the transporter continues to the next predetermined point. In the second case, the oncoming traffic is slowed and directed around the transporter convoy. Traffic moving in the direction of the transporter follows the convoy to a predetermined passing point. The transporter is then stopped while the traffic is directed around the convoy. 2

7.4.8 At all times the transporter (prime mover, hydraulic trailer and cask) move in a convoy. This convoy will consist of a minimum of the applicable traffic control personnel, backup prime mover, health physics personnel with survey equipment, and portable barrier material and other emergency equipment, mechanic with tools and spare parts, communication equipment, and emergency equipment. Constant communication will be maintained between the lead and rear vehicle and prime mover of this convoy. The lead and rear vehicle will have flashing warning lights.

7.4.9 Communication will be available in the convoy to communicate with appropriate emergency organizations and/or response teams.

7.5 Controls for Marine Transport

7.5.1 All marine equipment including barge and tiedowns will be inspected by the Coast Guard and a marine surveyor prior to the start and at completion of each trip as required.

7.5.2 The route of the barge and cask will be coordinated with the Coast Guard. Alternate routes in case of bad weather will also be designated.

7.5.3 Daily contact will be made with the tug which will report its position and status.

7.5.4 Marker buoys will be placed on the barge.

7.5.5 Insurance for recovery of the cask/steam generator where required will be in effect.

7.5.6 When in ports the barge transporting the loaded cask will be located in accordance with the Coast Guard and Captain of the Port instructions to minimize the probability of collision with passing harbor traffic and explosion or fire from nearby hazardous materials.

7.5.7 The loaded cask, barge and tug will make a minimum number of ports-of-call. Ports-of-call other than departure point and unloading point will only be made in case of an emergency (mechanical failure, very severe weather).

7.5.8 The barge will be under single tow.

7.5.9 The movement of the barge in the Savannah River will be coordinated with the U.S. Army Corp of Engineers to insure adequate water depth.

7.5.10 The Coast Guard and other appropriate authorities along the marine transport routing will be contacted prior to the start of any transport operations. The Coast Guard will be contacted daily during marine transport to update status and location.

7.5.11 In the event of an accident during marine transportation, the Coast Guard, NRC and other appropriate authorities will be notified immediately. Necessary precautions and activities to insure the public's safety will be instituted immediately. Corrective and/or recovery requirements will be identified and programs developed.

7.6 Health Physics Controls

7.6.1 Prior to each loading operation the cask will be surveyed for both external and internal contamination. Decontamination will be carried out, as required.

7.6.2 Continous radiation monitoring will be performed during all phases of the loading operation.

7.6.3 Following cask loading a contamination survey will be made. Decontamination of cask external surfaces will be effected as required. The cask will be released for shipment when contamination levels are at or less than the limits set forth in Section 173.397 of the DOT regulations.

7.6.4 Radiation surveys of the loaded cask will be performed to determine that radiation levels do not exceed 200 mr/hr at the surface, 10 mr/hr at 2 meters (6.6 feet), and 2 mr/hr in the occupied portion of the prime mover. Radiation surveys will be made in occupied areas of the tug when it is along side the barge for maneuvering. Personnel dosimetry will be supplied as required.

7.6.5 A Health Physics Technician will be available during all phases of marine and ground transport. The Technician will have all required instrumentation such that he will be able to make radiation surveys and evaluate the results of such surveys.

7.6.6 Access to the loaded cask will be controlled during all phases of marine and ground transport. During ground transport appropriate barricades, posting etc. will be used to restrict access to the cask when it will be parked for longer than one hour. 2

7.6.7 Unloading and final burial at the disposal facility will be carried out in accordance with specific procedures for that operation.

APPENDIX B

ACCIDENT DISCUSSION

Possible accidents involving the SGC-1 cask are at best difficult to define. Because of its large mass and size, there are numerous special controls that are inherent with its movement that make most common accidents unlikely. The tremendous rigidity built into the cask and its payload a steam generator lower assembly (SGLA) causes most of the energy of any type of impact by the SGC-1 package to be absorbed by the surface being impacted.

Two areas are addressed. The type of accident where the question of loss of shielding is raised and the situation where the package is submerged.

Loss of Shielding

The first type of accident is unlikely, due to the strength of the package. No concievable accident was determined to cause the SGLA to separate from the cask. Even if it did, the required 200 mr/hr. contact reading of the SGLA would not exceed the 1 R/hr at 3ft. requirement for accident conditions. Although the welds may crack on the end plates of the SGLA, no accident could be derived where they could come off. 2

To give an idea of the energies and forces required, the 30 ft. drop of the cask on the small end was examined.

Energy to be absorbed =EA= hw = 722,000 lbs x $\frac{30\text{ft } 12 \text{ in}}{\text{ft}}$

= 260×10^6 in-lbs.

Consider the volume of steel required to absorb this energy.

Vol. steel $= \frac{\text{EA}}{\text{average stress required for plastic deformation (Sp)}}$

Assume Sp average = 45,000 psi for ASTM-A516-Gr.70

Vol. steel $= \frac{260 \times 10^6}{45 \times 10^3} = 5.78 \times 10^3 \text{ in}^3$

Assuming a flat end drop on the small end.

The steel deformed is the side walls, 2.5 in. thick.

Area of steel = $5.78 \times 10^3/2.5 = 2.312 \times 10^3 \text{ in}^2$

Diameter = 12 ft. Radius = 72 in. Perimeter = 2 (72) π

Area = Ph. $h = \frac{2.312 \times 10^3 \text{in}^2}{2\pi(72)} = 5.11$ in.

Only 5.11 in. of the cask would be deformed.

The 5.11 inch deformation is insufficient to cause contact with the cask and the SGLA with the channel head cut off. It is recognized that not all of the deformation will occur at the localized area, but the total deformation remains the same.

Similarly, corner drops and side drops would require the same or less amount of deformation. The deformation required to absorb the energy could cause the steam generator lower assembly to come in contact with the cask wall. Once the two walls come in contact, the loads are projected into the SGLA with very little deformation, since the lower assembly is a highly stiffened shell. The small end has a 21 in. thick tube sheet within 2½ in. of the welded seal plate. Throughout the entire assembly there are tube supports which stiffen the shell preventing a catastrophic failure of the shell. These supports greatly reduce the potential of any 2
type of accident that will separate the steel shell from the contaminated tubes.

Based on the foregoing, it is highly improbable that an accident could occur that would cause the cask to separate from the SGLA. Furthermore it is even more unlikely that the plates welded on the SGLA with 1½ in. fillets will separate from the assembly after the majority of the energy is absorbed by the cask.

The tremendous amount of force required for this deformation makes such an accident unlikely. Based on the 30 ft. drop previously described, the average force seen by the cask is:

$$A = pt = 2\pi (72)(2.5) = 1131 \text{ sq. in.}$$

$$\text{Force} = 1131 \text{ sq. in.} (45{,}000) = 50.9 \times 10^6 \text{ lbs.}$$

This tremendous force would find very few if any objects capable of reacting it along a normal barge route or overland route.

SUBMERGENCE OF SGC-1

The SGC-1 cask's primary mode of transport is by barge transport. Although all possible precautions are taken to have quality equipment and to avoid accidents, the possibility of the package sinking does exist.

The cask gasket is designed for 25 psig pressure differential. This corresponds to 56.25 ft. of seawater. This is greater than the recorded depth of approximately 50 ft. for the rivers and bays this cask is expected to travel.

The cask can react these pressures. The area of greatest concern would be the end plates.

From Roark, and Young, Formulas for Stress and Strain, 5th ed. McGraw-hill page 371, table 24

for a semicircular plate

$$\text{max. stress} = -.42 \frac{qa^2}{t^2}$$

a = radius of plate

t = thickness

q = load per unit area

$$\text{Maximum stress} = \frac{-.42(25)\ 85^2}{(2.75)^2} \qquad \text{for large end}$$

$$= 10031.4 \text{ psi}$$

Margin of safety on yield.

$$\text{M.S.} = \frac{36000}{10031.4} - 1 = 2.59$$

Therefore, even if the gasket holds to a higher pressure, the gasket is likely to fail before the end plates, equalizing the pressure.

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In an accident situation it cannot be guaranteed that the cask flange or the cask welds will remain intact such that when immersed there would be no leakage of water into the cask equalizing the pressure.

The second barrier against water mixing with the radioactivity is the steam generator lower section itself. The only end of concern is the small end where the end plate seals the open tube ends.

$$2a = 10'\ 9\tfrac{1}{4}"$$

From Timoshenko, S. Strength of Materials Part II. Krieger, N.Y. 1956 page 97. For a circular plate with fixed edges.

$$M_r = \frac{qa^2}{8} \qquad \text{Max stress} = 3/4\ \frac{qa^2}{t^2}$$

For a minimum 3 in. plate

Maximum stress at failure is 70,000 psi

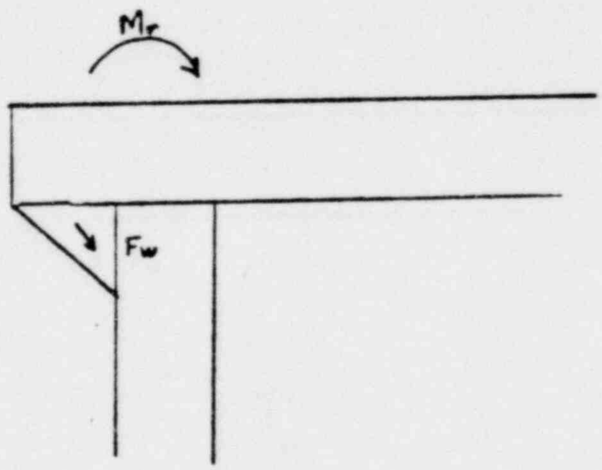
$$q = \frac{70{,}000\ (3)^2 3}{(64.63)^2 4}$$

q = 113.14 psi

This is equivalent to 257 ft of sea water.

Examining the weld:

The weld will react to the applied bending moment.



The reaction force of the weld can be applied at the center of the weld throat.

$$L = 1.5 \sin 45° = 1.06 \text{ in.}$$

$$Mr = \frac{L}{2} Fw$$

Min weld material tensile = 70,000 psi

$$Fw = .707\ (70{,}000)\ (1.5) = 74235 \frac{\text{lbs}}{\text{in}}$$

$$Mr = \frac{1.06}{2} (74235) = 39369 \text{ lbs } \frac{\text{in}}{\text{in}}$$

$$\frac{qa^2}{8} = 39369$$

$$q = \frac{39369(8)}{(64.63)^2} = 75.4 \text{ psi}$$

Approximately 171 ft. of sea water 2

Although the welds and plate on the larger end will see greater moments and stresses and will fail at a lesser depth, the consequences are less. The large plate only covers the secondary side of the steam generator. The tubes exposed have been hydrostatically tested well above the 2000 psi operating pressure they have operated at. Any damaged and plugged tubes would have a very small release. They have also been thoroughly flushed in operations by the secondary side water.

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