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TO: Mr. Victor Stello

FROM: Northern States Power Company, Minneapolis, Minn., L. O. Mayer

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Ltr. re 4/9/76 meeting & their 1/22/76 and 2/13/76 ltrs....trans the following:

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Monticello

ENCLOSURE

Furnishing information concerning the Off-Site Shipment of Spent Fuel with drawings.

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ACKNOWLEDGED

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NSP

NORTHERN STATES POWER COMPANY

MINNEAPOLIS, MINNESOTA 55401

June 16, 1976

Mr Victor Stello, Director
Division of Operating Reactors
U S Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr Stello:

MONTICELLO NUCLEAR GENERATING PLANT
Docket No. 263 License No. DPR-22

Off-Site Shipment of Spent Fuel

On April 9, 1976 we met with several members of your staff to discuss our interim plans for shipping spent fuel from the Monticello Nuclear Generating Plant. Our plans were submitted to you on January 22, 1976 in a report entitled "An Analysis and Safety Evaluation of Spent Fuel Shipping Cask Handling at the Monticello Nuclear Generating Plant". This report was supplemented by our February 13, 1976 submittal on the potential radiological consequences from a cask drop.

The meeting held on April 9 pointed out a number of areas where the members of your staff felt additional information would be required to enable them to complete their review. Attached are forty copies of their questions on our submittals and our responses to these questions. We hope that the attached information will allow a timely completion of your review as spent fuel shipments from Monticello are scheduled for the third quarter of this year.

We would like to reemphasize the fact that our proposed plan to ship spent fuel using the NFS-4 and NAC-1 casks is only a temporary measure. This interim plan is necessary to prevent spent fuel storage space problems during the approximately four-year period required to implement our permanent cask handling program. Our long-term program, and the problems associated with its implementation, are detailed in the attachment to this letter.

Yours very truly,

L. O. Mayer

L O Mayer, PE
Manager of Nuclear Support Services

LOM/ak

cc: J G Keppler
G Charnoff
MPCA
Attn: J W Ferman

Attachment

6174

RESPONSE TO NRC INFORMAL QUESTIONS
DISCUSSED DURING MEETING WITH REGULATORY
STAFF ON APRIL 9, 1976

QUESTION 1

The letter to D L Ziemann dated May 30, 1975 indicates that approximately three years will be required to backfit the existing crane. As an interim measure it is proposed to use the 25 ton NFS-4 shipping cask rather than the 70 ton IF-300 cask. On this basis your January 13, 1976 report presents the bases for this proposal. From the FSAR it appears that in order to refuel during this three-year period the crane will be required to handle reactor vessel components such as the reactor vessel head that weighs on the order of 70,000 pounds. Therefore, it is necessary that you (a) identify and provide the weight and frequency of all lifts that will approximate or exceed the weight of the NFS-4 cask during this interim period, (b) for each item identified in (a) above with the aid of legible building drawings indicate the maximum allowable drop height over its range of travel, (c) indicate the maximum possible drop height of the object during its travel, (d) expand Table 4-1 to show the equivalent factors of safety for these other loads and (e) provide a description, discussion and safety evaluation of each of these lifts if the load should drop.

RESPONSE 1

The loads referred to in this question are the normal reactor and shielding components for BWR's that must be handled to conduct refueling. These loads will be handled approximately two times each year, but only when the plant is in cold shutdown and away from the spent fuel pool. As such, the consequences of dropping any one of these loads would not present a safety hazard. There is sufficient diversity in the plant design to maintain the reactor in a cold shutdown condition should one of the refueling loads be dropped. There are no other loads approximating the weight of the spent fuel shipping cask handled in the Reactor Building during power operations.

While the potential consequences from the drop of one of the refueling loads is not viewed as a safety hazard by Northern States Power, we do feel that there is a potential for sustaining structural and equipment damage. For this reason we have been pursuing the procurement of a redundant trolley for the Reactor Building crane. We are in the process of evaluating several crane designs and expect to reach a decision on a design later this year. It will take approximately three years after starting work on the crane before it will be available for use. Work on the crane will not be allowed to begin until we have some assurance that the selected design is acceptable to your staff. As we stated in our May 30, 1975 letter, there is an extreme reluctance by crane vendors to comply with the requirements of your staff for redundant crane designs. Several of the large crane vendors have refused to bid on the requested design and those that have, have taken numerous exceptions to your requirements.

The interim spent fuel shipping plans contained in our January 22, 1976 report were not intended to serve as plans for long-term handling of heavy loads. They were intended only to provide for the safe handling of the most critical load; i.e., the spent fuel shipping cask, for the approximately four-year period required to implement the long-term plans discussed above. Our interim plans provide for the handling of the NFS-4 shipping cask, described in our January 22 submittal and the identical NAC-1 cask, described in Docket Number 71-6698.

QUESTION 2

In your letter dated February 17, 1975 you stated (a) the Monticello Plant structures cannot withstand the impact of a dropped spent fuel shipping cask in all cases, (b) modifications to increase the strength of plant structures are not feasible, (c) a report on your intended modifications to improve the reliability of the reactor building crane would be submitted by May 30, 1975. It is not apparent from your January 13, 1976 report what modifications you have

or intend to carry out in order to increase the reliability of the reactor building crane. Provide this information.

RESPONSE 2

Answered in response to Qestion 1.

QUESTION 3

In your October 1, 1974 report, Table 1 indicates that the 85 ton rated capacity hoist drive system will have full load speed of 5 FPM and an empty hook speed of 16 FPM. What will be the maximum drum speed (as defined by the drive system) when handling the 25 ton NFS-4 cask?

RESPONSE 3

Based upon the crane drive system load-speed characteristics, a 25 ton load would be hoisted at approximately 15 FPM and lowered at approximately 13 FPM. For the maximum hoisting speed of 15 FPM, this would result in a drum rotational speed of less than 7 rpm.

QUESTION 4

Using the General Electric maxspeed 320 hoist drive system, described in your October 1, 1974 report, describe and discuss the crane operators ability to accurately position the NFS-4 cask a given distance above the operating floor. Since Tables 3-1 and 3-2 establish the upper limit on this distance to be six inches, indicate the minimum acceptable height of the cask above the operating floor without the cask hitting the floor due to swinging of the load during transport. In the discussion, relate the operators' ability to accurately elevate the cask to the proper height to the allowable band established above.

RESPONSE 4

Based upon experience gained during plant refueling operations with heavy loads,

the crane operator has adequate control over load position to enable accurate placement within at least one-half inch of the desired position.

An analysis of the maximum permissible motion to be experienced by the cask, due to a sudden stop in crane travel, indicated that a horizontal movement of less than 12 inches will occur if the bridge is stopped from its design travel speed of 50 FPM. The minimum clearance above the operating floor to prevent the cask from hitting the floor during swing would be 0.8 inches. A minimum clearance between the bottom of the cask and the floor of two inches will be incorporated into the cask handling procedures to eliminate the possibility of the cask hitting the floor should the event described above occur.

QUESTION 5

Assume a hard stop is encountered when the NFS-4 cask is being raised at its maximum lift speed (as established in Question 3) from the transporter to the operating floor. Indicate how the factors of safety presented in Table 4-1 would change if such a situation were to occur, taking into account the maximum short-term stall torque of the drive motor and the kinetic energy stored in the 139 to 1 speed reduction power train and drive motor.

RESPONSE 5

The crane was designed utilizing the Electric Overhead Crane Institute Specification Number 61 (Reference 3) which requires a minimum safety factor of five (5) for the Design Rated Load (DRL). This minimum safety factor provides sufficient allowance for dynamic loading incurred during the handling of any load, including the DRL. The factors of safety involved with the handling of the NFS-4 cask are depicted in Table 4-1 of Reference 2. It can be seen that these factors of safety are at least three times greater (minimum value - 17) than those for the handling of the DRL. Based upon the increased factors of safety with

the lighter load, the crane is adequately designed to prevent damage in the event of a rapid stop from the maximum hoist speed of 15 FPM. Should a rapidly applied load be experienced by the crane hoist, this would slightly reduce the design safety factors. However, this load is limited by the 200% hoist motor stall torque. The dynamic nature of such loads is dependent upon the severity of the sudden stop. Loads due to sudden brake actuation and load applications are included in the design of the hoist mechanisms.

The possibility of a hard stop being experienced during cask hoisting through the equipment hatch will be precluded by means of physical and administrative precautions taken prior to raising the cask from grade level to the operating floor. These precautions will consist of:

1. The bridge and trolley will be manuevered such that the cask is located at Position A on Detail A of Figure 6-1 (Reference 2) prior to hoisting in the equipment hatchway.

2. Power to the trolley and bridge motors will be locked out to prevent horizontal movement while the cask is being hoisted. This action will preclude a hard stop since there are no horizontal obstructions near Position A in the reactor building equipment hatchway.

3. While hoisting the cask in the equipment hatchway, the maximum lift speed will be approximately 5 FPM to reduce the kinetic energy and rotational forces developed in the 369 to 1 speed reduction power train and hoist motor.

4. Prior to cask handling operations, two redundant mechanical limit switches will be provided on the head block of the main hoist. These limit switches will actuate when the load block

reaches a prescribed distance from the head block. Actuation will de-energize the hoist motor and set the brakes, thus preventing a hard stop. Prior to critical lift operations, the crane limit switches will be verified for functional capability as a procedural step during the pre-lift checkout of the crane (see Section 6.2 of reference 2).

QUESTION 6

Considering that (a) the overhead handling system has not been designed single failure proof, (b) the hoist has a rating of 85 tons and (c) you propose to use the 25 ton NFS-4 cask as an interim solution, describe and discuss what interim modifications are possible that will reduce the loading conditions postulated in Question 5 above (such as reducing the lift speed, Question 3), and the drive motor maximum short-term torque capacity.

RESPONSE 6

The response to this question is contained in the response to Question 5.

QUESTION 7

Section 2 of your January 22, 1976 report states "A strictly enforced cask travel path will be employed........". Section 6.1 states "To ensure movement of the shipping cask along the designated path, floor markings will be made with a bright color as indicated in Figure 6-1 to guide the crane operator and plant personnel during cask handling."

Describe and discuss the possible modifications that could be made to physically limit the cask motions to that depicted in Figure 6-1. Further, indicate the allowable path width under which your analysis of a cask drop remains valid.

RESPONSE 7

Limit switches will be installed on the crane bridges and trolley to preclude cask movement outside of the north and west limits shown on Figure 6-1 (Rev. 1).

A verification was also made to demonstrate that there are no critical drop locations within approximately ±2 feet of the designated travel path. The cask will not be permitted to travel near any area which has not been verified for its impact capability.

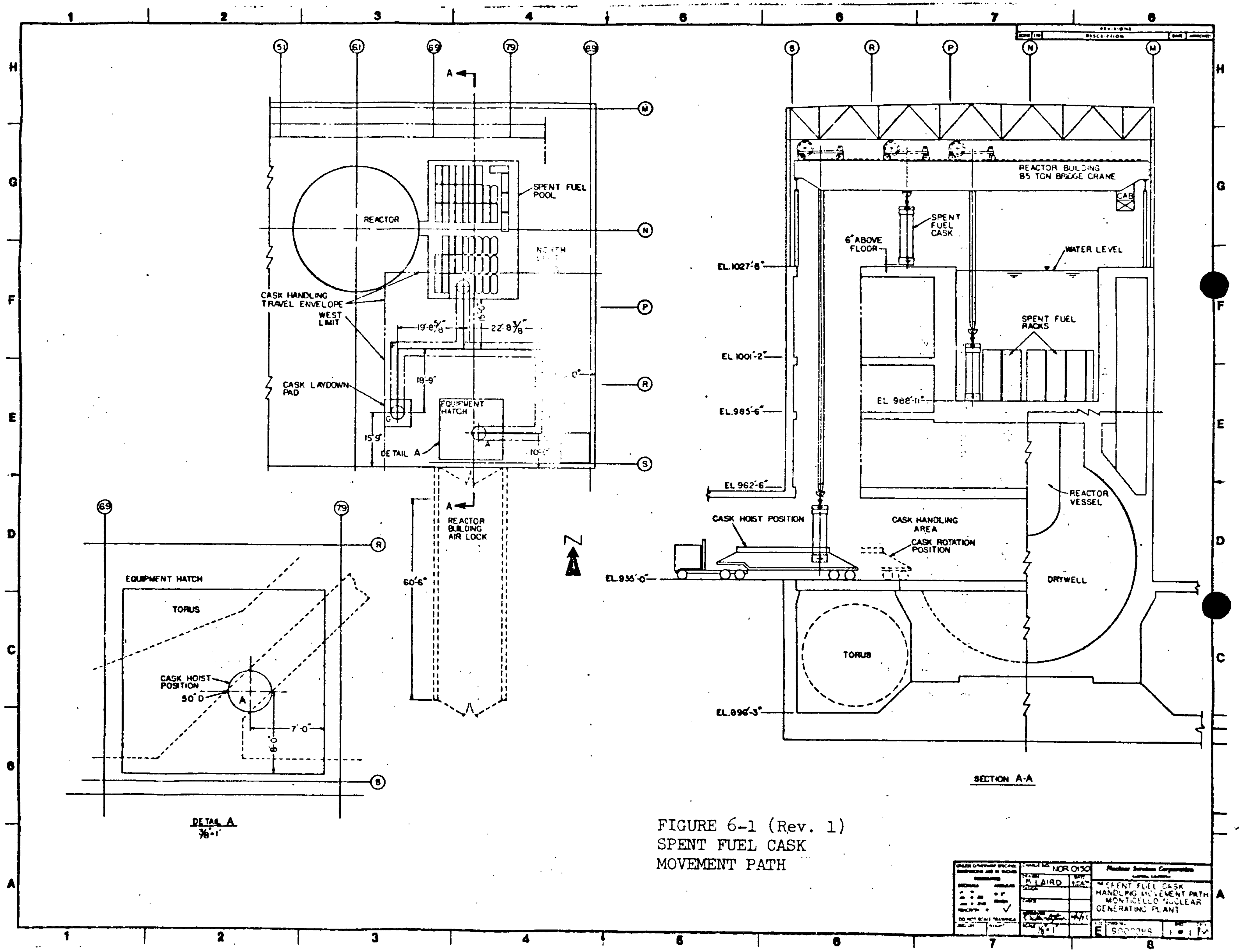


FIGURE 6-1 (Rev. 1)
SPENT FUEL CASK
MOVEMENT PATH

QUESTION 8

Your report, dated October 1, 1974 states the main hoist has two upper hoist travel limit switches. One of the two is located on the top block assembly and the other is directly coupled to the hoist drum and will be activated by drum rotation. We will require two independent upper hoist travel limit switches located on the top block assembly. Confirm that this requirement will be met. Further describe the methods available to the crane operator to detect the condition should any one of the upper hoist travel limit switches lose its functional capability.

RESPONSE 8

Answered in response to Question 5.

QUESTION 9

Section 4.2.1 and Appendix B of your January 13, 1976 report indicates that the failure of the equalizer sheave pin will result in dropping of the load. Modify Table 4-1 by showing the corresponding factors of safety for the equalizer sheave pin at the three indicated loads.

RESPONSE 9

The equalizer sheave pin is constructed of SAE-1045 carbon steel and has a calculated shear stress at the design rated load of 7.5 KSI. Based upon the foregoing stress and the material yield strength, the factors of safety for the equalizer sheave pin at the three loading conditions of Table 4-1 of Reference 2 are:

Crane System Component	Rated Load (85T)	IF-300 Load (70T)	NFS-4 Load (25T)
Equalizer Sheave Pin	6.0	7.3	20.4

QUESTION 10

A review of the Safety Analysis Report for the NFS-4 Shipping Cask (Reference 5 of your January 13, 1976 report) and your report dated January 13, 1976 does not contain sufficient information on the handling yoke as it applies to its onsite use, to enable us to complete our review. Provide the following additional information:

a. Provide legible individual drawings of the shipping cask showing the lifting trunnions, the handling yoke and the twin sister hook and shackle hole.

b. Describe and discuss the load carrying capabilities of the shipping cask lifting trunnions, the handling yoke and the point of attachment of the handling yoke to the main hoist twin sister hook.

c. Modify Table 4-1 by adding the factors of safety for the items identified in (b) above.

d. Describe and discuss what modifications or means are possible for devising redundant load paths from the shipping cask to the main hoist hook.

RESPONSE 10

The NFS-4 shipping cask is described in Appendix A of Reference 2. A complete description of the cask and its load carrying components are provided in Reference 4. The NAC-1 cask is essentially identical to the NFS-4 cask and the description may be found in Docket Number 71-6698. A supplemental review of the items discussed are given below:

a. Figure A-2, attached, gives a sectional drawing of the NFS-4 cask as described with lifting trunnions included. Figure A-3

provides an individual drawing of the lifting trunnions described in Reference 4. Figure A-4 shows the cask handling yoke and its primary structural components. A twin sister hook arrangement is not employed with the cask lifting yoke.

b. The cask trunnions are designed to accommodate transportation load conditions which are in excess of three times the cask weight. The trunnions consist of two 8.625 inch diameter cylindrical steel section, 0.5 inch thick. This section is welded to a 1.0 inch flat plate and a support box section which is attached to the cask body by a ring framework as illustrated in Figure A-3. The trunnions are each engaged by yoke arms, one which pivots into position over its lifting trunnion. The yoke arms are secured and locked in place using a Ball-loc-pin. The trunnion eyes are eccentrically designed to ensure positive engagement of the yoke arms and the trunnions as illustrated in Figure A-4.

The cask lifting yoke and trunnions are qualified by a 2g load test per fabrication requirements. The yoke is lifted by a conventional crane hook to be supplied by Northern States Power Company. The crane hook is rated for 85 ton and its requirements are in accordance with the existing crane and bottom block assembly design as provided for Monticello in 1968 by Crane Manufacturing and Service Corporation.

c. The cask lifting trunnions are constructed of low carbon steel per ASTM-A480 with an allowable strength of 24,500 psi at 300^{o}F. The cask lifting yoke is manufactured of low carbon steel (USS-Core 10B) and is rated for 52,000 lbs. The yoke

is proof tested to 130,000 lbs (65,000 lbs on each arm) based upon a 250% load test criteria. The safety factors employed in the design of the trunnions and yoke assemblies are as follows:

Cask Lifting Device	Safety Factor at Rated Load
Cask Lifting Trunnions	5.7
Cask Lifting Yoke	3.0

d. Our previous submittals and the responses to the preceding questions have demonstrated acceptable consequences for the drop of the NFS-4 cask; therefore, redundant lifting devices for this interim plan are not necessary.

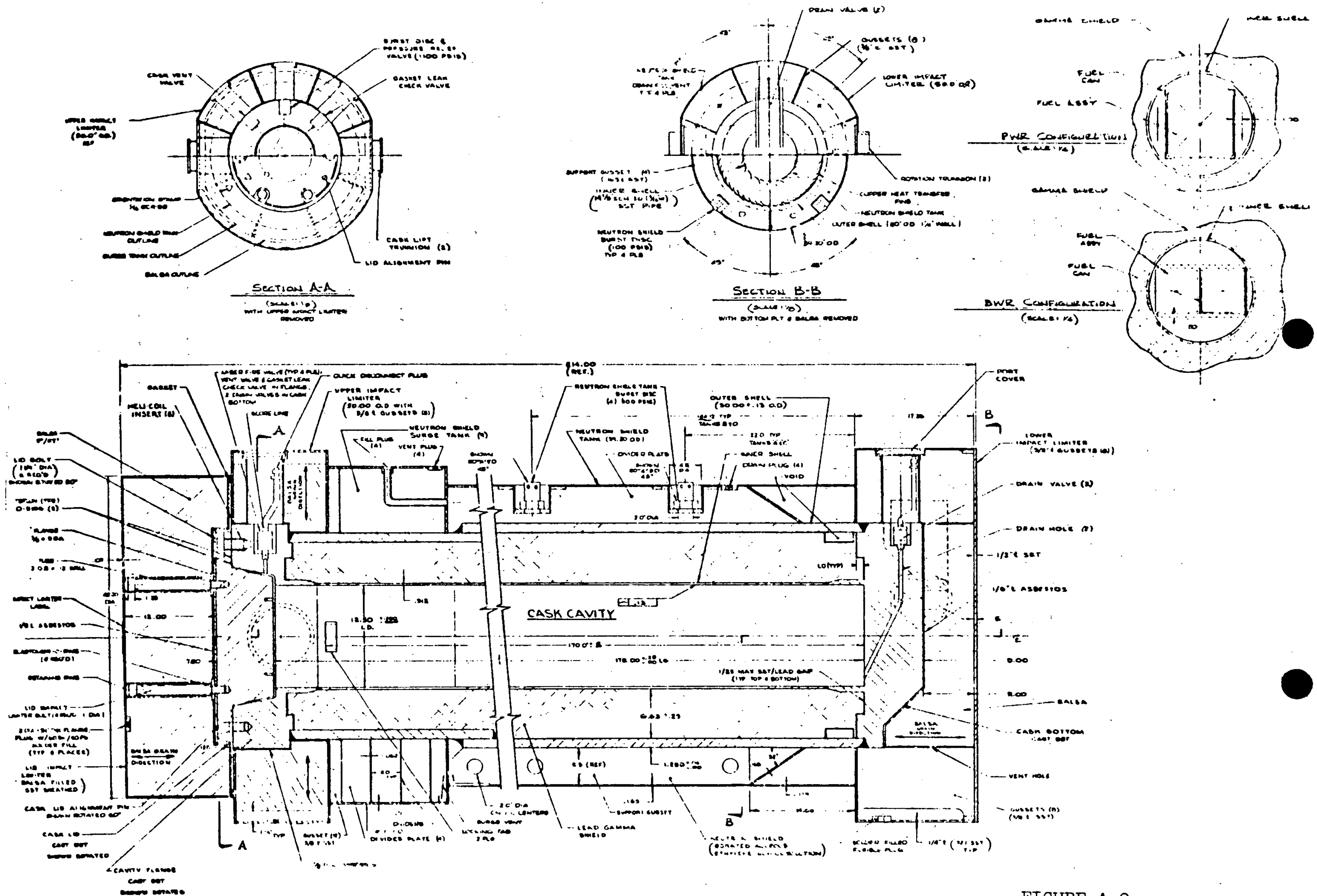
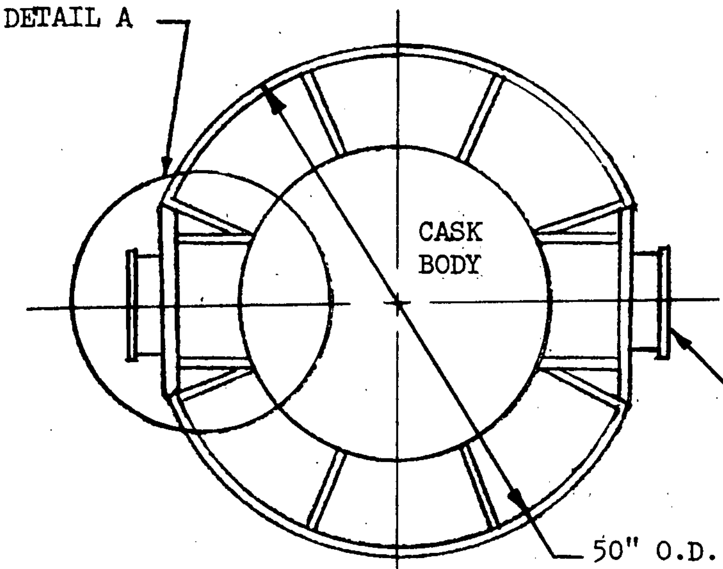
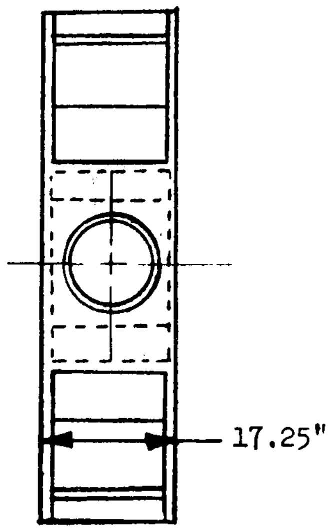


FIGURE A-2

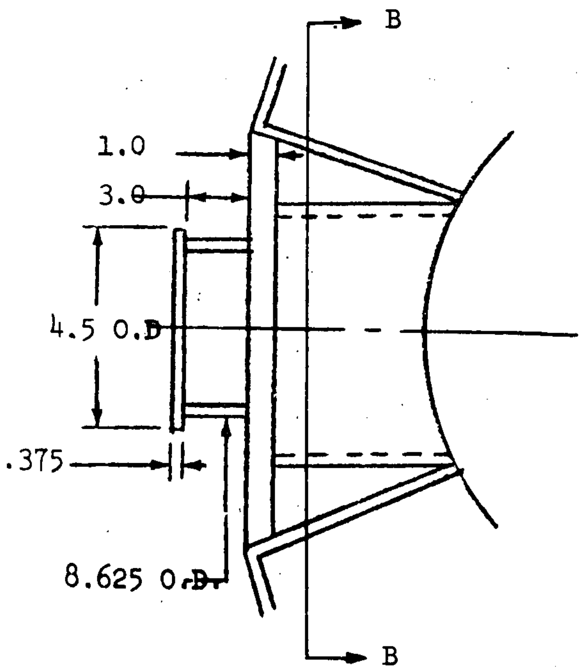
SECTIONAL DRAWING OF NFS-4
FUEL SHIPPING CASK



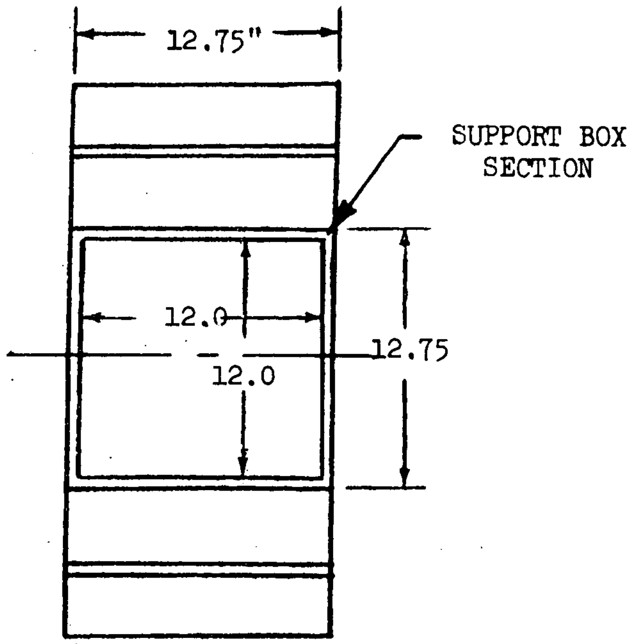
TOP VIEW OF IMPACT LINER



SIDE VIEW OF IMPACT LIMITER



DETAIL A



SECTION B-B

FIGURE A-3

DESIGN DETAILS OF NFS-4 FUEL SHIPPING CASK
LIFTING TRUNNION ASSEMBLY (per Reference 4)

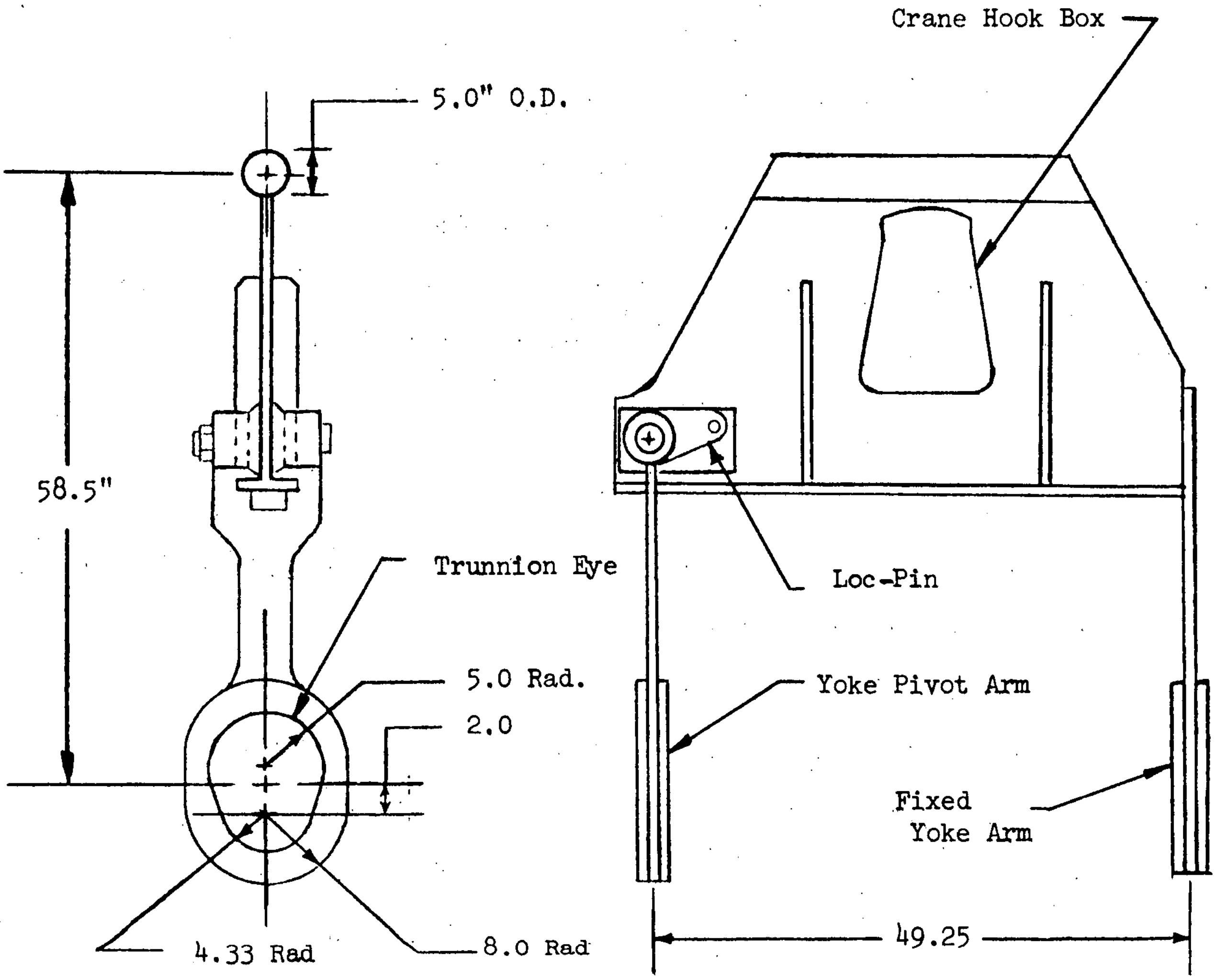


FIGURE A-4

NFS-4 FUEL SHIPPING CASK LIFTING YOKE

QUESTION 11

Your October 1974 report indicates that the hoist has two solenoid operated brakes, each capable of holding 150% of the rated full load (85 ton) hoist torque at base speed. Further both of these brakes are spring loaded and automatically set whenever electrical power is removed. Assume the NFS-4 cask is being lowered at its maximum speed (as established in Question 3) when a loss of power is experienced by the hoist. Indicate the magnitude of the deceleration forces developed by the two automatically spring set brakes on the handling yoke and cask trunnions in such an event and the factors of safety that exist at these points as well as the point of attachment of the handling yoke to the hoist hook.

RESPONSE 11

As discussed in the response to Questions 3, 5 and 10, the design of the crane hoist components and the cask lifting devices includes adequate allowance for dynamic loads incurred during cask handling. Existing design codes and specifications for crane hoist systems provide allowance for impact (dynamic) loads in the large safety factors required. These provisions are employed in lieu of dynamic analyses to allow for variable operating conditions, design margin, and manufacturing tolerances. Impact allowance requirements per Reference 3 are established at 15% of the rated load.

QUESTION 12

In the October 1, 1974 report it is stated "A cask drop from the maximum drop height in the equipment hatch area could cause structural and possibly cask damage. Cask handling procedures are being evaluated to provide adequate protection to plant structures and equipment in this area." The FSAR reactor building drawings indicate that the suppression pool torus and a corner

compartment housing engineered safety feature equipment is below and in close proximity to the equipment hatch shown in your January 22, 1976 report. Provide the information supporting the conclusion in your February 13, 1976 letter regarding the continued functional capability of the torus (and engineered safety feature equipment, housed in the corner compartment beneath the equipment hatch) in the event of a cask drop in the Reactor Building equipment hatch as not being a relevant consideration. This supporting information is to include: (a) the loss of the primary containment barrier, (b) the loss of suppression pool water and the loss of the engineered safety equipment resulting from both primary and secondary missiles generated by a 93'-2" NFS-4 cask drop height, and (c) cask handling procedures that have been developed to provide adequate protection to plant structures and equipment in this area.

RESPONSE 12

The fuel shipping cask will be precluded from damaging either the reactor building structures, the suppression chamber or engineered safety feature equipment by the controls implemented in Section 6.0 of Reference 2 in conjunction with the crane system design modifications and procedural precautions to be taken as described in the response to Question 5.

Reference 5 demonstrates that the radiological consequences are negligible for such an event. In addition, the equipment housed beneath the equipment hatchway is not required to maintain the functional capability of the reactor plant. A drop down the equipment hatch would not impair the ability to complete a normal reactor shutdown or the ability to maintain cold shutdown conditions.

QUESTION 13

Appendix B, Failure Mode and Effects Analyses, has a column titled Method of Detection. For all failures considered, the entry in this column is "Self Annunciating." Is this phrase intended to indicate that an annunciator will alert the operators that a failure is imminent, or that the actual failure will serve as the annunciator notifying the operator that a failure has occurred? Clarify.

RESPONSE 13

The phrase self-annunciating is intended to indicate that the actual failure will alert the operator of its occurrence. There is no annunciator to serve this function.

QUESTION 14

Section 5.2 of your January 13, 1976 report appears to conclude, with the aid of Figure 5-1, that a tipped cask type drop at the pool edge would not result in damage to spent fuel since the fuel would be located in the north end of the pool. Figure 5-1 shows the area of influence for a tipped cask covers the area where empty fuel storage racks and control rod racks are located. With the aid of drawings of these structures describe and discuss the reasons why they will not in turn tip and/or collapse against the stored spent fuel located in the north end of the pool as a result of the tipped cask drop.

RESPONSE 14

An analysis of the fuel storage racks for lateral and crushing loads has been conducted in order to determine if a cask drop into the spent fuel pool would tip the empty racks into the spent fuel stored in the north end of the fuel pool. The analysis was performed by determining the effects of the kinetic energy of the falling cask on the empty racks. The analysis considered the spent fuel storage racks, their buckling load capacity and post buckling performance. The buckling load was computed using the Euler equation and the post buckling deflections were computed using the equation for a pinned end column given by Reference 13, and as shown below:

$$\frac{y_m}{h}\left[\frac{1}{2}\left(\frac{\sigma_y}{\sigma_a}-1\right)-\frac{y_m}{h}\right]^2=\frac{1}{54}\,\frac{\sigma_a}{\sigma_E}\left(\frac{\sigma_y}{\sigma_a}-1\right)^3$$

where:

y_m = deflection at center of column

σ_y = yield stress

σ_E = stress at Euler load

σ_a = stress at actual load

h = depth of section in the direction of buckling

The limiting elastic deflection is given in Reference 13 by:

$$y_m = \frac{h}{6}\left(\frac{\sigma_y}{\sigma_E}-1\right)$$

Using these expressions, the load-deflection curve for the rack was obtained to determine the energy absorbed in buckling and crushing. This total energy absorbed in crushing the empty racks was computed and found to be small when compared to the kinetic energy at impact of the cask. Hence, for a vertical impact on top of the empty racks, the racks would buckle and crush, not topple.

For a cask drop in which the orientation of the cask is neither horizontal nor vertical, the velocity of the cask would still be in a vertical direction and the kinetic energy of the cask would result in buckling and crushing of the empty storage racks. In addition, if the obliquely oriented cask hits the edge of a rack, the rack will experience a horizontal force due to friction between the cask and the rack, equal to the static friction coefficient times the weight of the cask. This horizontal force would cause a moment and shear to be transmitted to the hold down lugs of the rack. Evaluation of the lugs shows that they are adequate to resist both the moment and shear at impact. Hence, the storage racks will not topple due to a cask drop of either orientation, and damage to the spent fuel located in the north end of the pool will be prevented.

QUESTION 15

Taking the characteristics of the NFS-4 impact limiter into account and the possibility of one side of the handling yoke failing when the cask's center of gravity is just over the edge of the pool, provide further information to support the statement "Moreover, if the cask were dropped on the pool edge, its impact would cause the pool edge to spall and force the cask into the fuel pool in a nearly vertical attitude."

RESPONSE 15

Since no credit is taken for spalling of the fuel pool edge to preclude fuel or structural damage, the referenced statement should be disregarded.

QUESTION 16

In your interim program using the two fuel element, 25 ton NSF-4 shipping cask, it is stated your analysis indicates that a six inch drop height is permissible for the operating floor. Also, the resulting calculated impact loads are based on the deformation and/or energy absorbing characteristics of the impact limiting device (utilizing dry balsa wood encased in a stainless steel container) that is attached to the cask. From Reference 5 "Safety Analysis Report for Nuclear Fuel Services Inc. Spent Fuel Shipping Cask Model No. NFS-4" the crushing strength for the various pieces of balsa is assumed to be either 1,600 psi or 2,100 psi.

a. Page A-3 of Reference 5 shows that the crushing strength of dry balsa wood varies from 650 psi to 3,000 psi depending on its density. Tables 3-1 and 3-2 of your report shows the Factors of Safety for the various assumed NFS-4 cask drops. Indicate the limiting range in density of the various peices of dry balsa (i.e., crushing strength) that would be allowable without causing the Factors of Safety for the floor slab shown in Tables 3-1 and 3-2 to become less. Further, indicate the tolerance on the density of the balsa wood (i.e., crushing strength for dry balsa wood) used by the cask manufacturer in the fabrication of the attached impact limiting devices.

b. During the loading of the cask, the impact limiting devices will be submersed in the spent fuel storage pool water. Assume the stainless steel water barrier encasing the balsa wood develops a leak as the cask is being lowered and placed on the pool bottom and thereby allowing the balsa wood to become water logged. Indicate how the energy absorbing characteristics of the impact limiting device changes when the balsa wood becomes water logged.

Assuming the most adverse combination of balsa wood densities and water logging, indicate for each case analyzed in Tables 3-1 and 3-2 what the new allowable cask drop height would be assuming the factors of safety presented in Tables 3-1 and 3-2 were unchanged.

c. Describe how it is possible to detect if the stainless steel water barrier encasing material developed a leak as a result of the cask being lowered and placed on the pool bottom. Further provide information which demonstrates a rupture of the encasing material will not occur taking into account its rate of descent as it contacts the pool bottom.

d. Assuming the balsa wood becomes water logged while the cask is in the spent fuel pool and its crushing strength changes to such an extent as to be unacceptable for safe handling, describe the measures which will be taken to assure safe cask handling during (i) the lift from the pool, (ii) movement above the operating floor, and (iii) lowering the cask through the equipment hatch to its transporter.

RESPONSE 16

The NFS-4 shipping cask is shown in Figure A-2 as submitted with the response to Question 10. The impact limiter device attached to the cask bottom head surrounds the cask body and consists of a 50 inch diameter by 17.25 inch high stainless steel ring with 3/8 inch stainless steel gusset plates filled with balsa wood for impact absorption. The impact limiter is encased in a 1/4 inch shell of stainless steel with a 1/2 inch bottom plate and a 1/2 inch shock tube for impact resistance. This design ensures maintenance of impact limiter integrity during routine handling.

a. Reference 4 provides data on the material properties for balsa used with the NFS-4 shipping cask. High density balsa is employed for the impact limiter design based upon several cask impact test cases discussed in Section 3.1.6.1 of Reference 4. Page 3-90 of Reference 4 indicates that the high density balsa has a crush strength of 2100 psi at 11 lb/ft^3. This is in accordance with the referenced material property measurements reported in Appendix A to reference 4.

If it is assumed that balsa of minimum desntiy, 5 lb/ft^3, and minimum strength, 650 psi, were actually employed, the shear safety factor for drop location No. 5 (see Table 3-2 of reference 2) would be increased to 3.19. If the highest balsa density reported in Appendix A to reference 4 were employed the shear safety factor would not be reduced below the value of 1.5 shown in Table 3-2 of reference 2. These values are adequate to ensure continued structural integrity of the spent fuel pool floor slab. The balsa pieces used in the lower impact limiter were individually selected for size and weight according to the desired material properties. The impact limiter was fabricated by Stearns-Roger from 15-20 such pieces, each measured, fit into place and verified for density prior to assembly. Thus, the likelihood of any piece not meeting the prescribed density values is very remote.

b. Each of the individual balsa wood pieces have been coated with epoxy. Once each piece has been joined together, the entire assembly is recoated with epoxy to ensure bonding. Thus, the potential for balsa water-logging is minimal due to the structural design and the protection afforded by the epoxy coatings.

c. The leaktight integrity of the cask impact limiter is ensured by periodic leak testing and the favorable experience gained during cask handling. The NFS-4 cask impact devices have been leak tested, and dye-penetrant checked prior to initial operation. The impact limiter is also leak tested annually by a bubble check method at the facilities of Nuclear Fuel Services per recent revisions to the transportation license. In addition, the cask receives a thorough visual inspection in accordance with maintenance procedures at both the reactor site and at the NFS facilities.

   Operating experience with two casks of this design have resulted in no leakage or damage to the impact devices. This includes over 400 shipments by trailer transport with a minimum of 6 cask setdown steps during each shipment. During these 2500 setdown conditions, no observable damage or leakage has occurred to the impact limiters.

d. The response to this question is contained in parts (a) and (c) above, and in Section 6.3 of reference 2.

QUESTION 17.4

In Tables 3-1 and 3-2 provide bases to support the numbers shown for M_u and V_u.

RESPONSE 17.4

Slabs

The ultimate moment carrying capacity M_u was computed by considering a foot width of the slab and using the ultimate strength design approach as described in Reference 8.

The ultimate shear capacity (V_u) was determined based on either a punching shear stress method per Equation 3-8 given in Response 17.2 or a shear friction force method per Reference 8. However, V_u was limited to a maximum value of 0.2 f'_c or 800 psi (per Reference 8), depending on the slab drop location.

Beams

For the composite beams considered, the effective width of the flange was determined per AISC specifications. The section was transformed and its moment carrying capacity was also determined per AISC specifications.

For impact location No. 4, the beam WF 36 x 160 was analyzed as a simple steel beam due to the presence of the equipment hatch on one side of the beam. For this beam, M_u is equal to the plastic moment carrying capacity computed per AISC specifications.

The web of the WF section was checked for shear using Equation 2.5-1 of Reference 9. In addition, the allowable shear at the beam end connections was evaluated per Reference 9 and increased by a factor of 1.7 for factored load conditions in accordance with Reference 11.

QUESTION 17 - STRUCTURAL ENGINEERING BRANCH QUESTIONS

QUESTION 17.1

On page 3-3, verify that the strength properties of concrete and reinforcing steel used for the analysis conservatively represent the in-situ properties of the structures concerned.

RESPONSE 17.1

The following material properties were used in the analysis:

(1) The compressive strength of concrete, f'_c = 4000 psi.
(2) The tensile strength of steel reinforcement, f_y = 60,000 psi
(3) The yield strength of structural steel, F_y = 36,000 psi
(4) Weight of concrete is 150 lbs/ft^3

These values are taken from Bechtel Drawing No. 5828-C-229, Rev. 3 (Monticello Nuclear Generating Plant - Unit 1, Standard Concrete Details) and structural design specifications 5828-C-13 and 5828-C-16.

The properties of concrete at the present time should be higher due to aging. The yield stress allowable for rebar is the minimum prescribed by ASTM specification for A615 steel (or A432 per Bechtel drawing). Hence, the properties given above conservatively represent the in-situ properties of the structures concerned.

QUESTION 17.2

On page 3-8 it is indicated that the force acting on the structure is checked for punching shear and end shear on the slab and beam. Indicate what limits are used to arrive at the acceptance criteria.

RESPONSE 17.2

Method Employed for Slab Punching Shear

The design expression for shearing resistance of a slab according to the ACI Manual of Concrete Practice (Reference 6), must satisfy the following conditions:

1. The ultimate shear stress v_u shall be a function of $\sqrt{f'_c}$ and r/d.

2. As r/d approaches zero, the ultimate shear load capacity V_u approaches a finite value.

3. Therefore, when r/d approaches zero, v_u approaches infinity.

4. When r/d approaches infinity, v_u approaches $4.0\sqrt{f'_c}$

5. The shear stress v_u must decrease continuously to $4.0\sqrt{f'_c}$ as r/d increases.

The above conditions are satisfied by a hyperbolic equation of the form $v_u = (Ad/r + B)\sqrt{f'_c}$. This equation when fitted conservatively to a series of test data given in Table 8-2 of Reference 6 gives:

$$v_u = 4\left(\frac{d}{r} + 1\right)\sqrt{f'_c} \qquad (8\text{-}14)$$

where:

d = effective depth of slab

r = equivalent side length of loaded square area

Comparison of this equation with an expression developed by Moe from test data (see Reference 7) is reported in Reference 6 and reproduced in attached Figure 3-7. This plot shows the validity of Equation 8-14.

RESPONSE 17.2 (continued)

The Reference 2 analysis for punching shear was based on Equation 8-14. However, the capacity of the slabs has also been recalculated using an allowable shear stress value given by:

$$v_u = 4.4\phi\sqrt{f'_c} \qquad (3\text{-}8)$$

where ϕ = .85 for shear

and a 10% increase is allowed for aging. Using Equation 3-8, Tables 3-1 and 3-2 of Reference 2 would be revised as follows:

ITEM	DROP LOCATIONS			
	1	5	6	7
Shear Capacity V_u	492 k	5049 k	13280 k	1040 k
Actual Shear V	309 k	2005 k*	3596 k	11831 k
Shear Factor of Safety $\frac{V_u}{V}$	1.6	2.52	3.7	0.09

The minimum factor of safety for drop location No. 1 is 1.39 due to flexure since shear is not the governing mechanism for cask drop height on the operating floor.

The foregoing comparison analysis demonstrates that the conclusions reached in Section 3.5 of Reference 2 would not be altered if Equation 3-8 is employed to check punching shear for slabs.

Method Employed for Slab End Shear

For a small height of drop, shear deformation of concrete sections and the cask penetration into the slab are extremely small. Hence, the longitudinal reinforcement (bottom reinforcing only) passing through the section at the edge of the slab support is used to calculate the shear friction force in accordance with Reference 8. Using the energy balance equation, the permissible drop height is

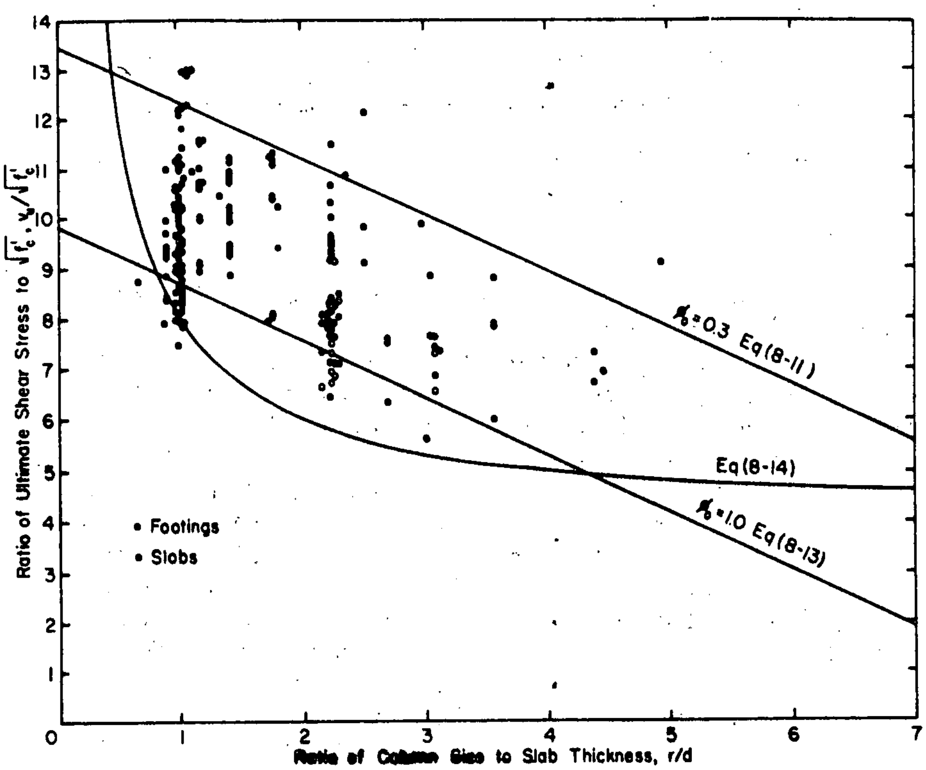
RESPONSE 17.2 (continued)

computed as described in Section 3.4.2.2 of Reference 2. The allowable shear stress v_u, for this case, is limited to a maximum of 800 psi per Section 11.15 of Reference 8.

Method Employed for Beam End Shear

The allowable shear for the existing beam end connections is based on Tables I and II of Reference 9. The values in these tables are increased by 1.7 per Reference 11 for this loading condition.

*It should be noted that for drop location 5, the value of actual shear (V) is different from that shown in Table 3-2 of Reference 2. This is because the original analysis conservatively assumed the total kinetic energy at impact to be completely transmitted to the target pool slab. By considering the strain energy required to stop the target-missile combination based on plastic impact and the effective target mass, a more appropriate analysis has been performed. This impact is considered plastic because of the local permanent deformation of either the cask or the slab, or both. From Bechtel Corporation Topical Report, BC-TOP-9A, Revision 2, "Design of Structures for Missil Impact", September 1974, the strain energy imparted to the slab is computed and compared to the energy absorbing capacity of the slab.



Equation 8-11: Moe's Equation, $\phi = 0.3$

Equation 8-13: Moe's Equation, $\phi = 1.0$

Equation 8-14: Design Equation proposed by ACI Committee 426

FIGURE 3-7

COMPARISON OF DESIGN EQUATIONS AND TEST DATA FOR SHEAR RESISTANCE (per Reference 6)

QUESTION 17.3

On page 3-9, indicate the limiting value of ductility ratio, μ, to arrive at the available strain energy of the beam.

RESPONSE 17.3

Based on Reference 10, acceptable values of the ductility ratio, μ, to determine the available strain energy for beams are as follows:

For steel beams in flexure $\mu = 20$.

However, based on your criteria stated during our April 9 meeting, drop locations 1, 3 and 6 were reevaluated using a ductility factor of 10. Based on this reevaluation the factors of safey, shown in Table 3-1 of reference 2; for drop locations 1, 3 and 6 should be revised to read 1.23, 3.63 and 3.73 respectively.

QUESTION 17.5

On page 5-5, the ground acceleration value of .06g is indicated to be the DBE. However, the safe shutdown earthquake for the plant is 0.12g horizontal. Establish stability against overturning moment using this higher earthquake.

RESPONSE 17.5

An additional stability analysis of the cask for a safe shutdown earthquake with acceleration values of 0.12 g horizontal and 0.08g vertical was performed in accordance with Reference 12. Using this method, the maximum kinetic energy (E_s) in the cask due to seismic motion is equated to the energy required (E_o) to overturn the cask. The cask is defined to be stable against overturning when the ratio E_o/E_s exceeds 1.5.

For the cask on the operating floor (El. 1027'-8"), the ratio of E_o/E_s is 8.8 and for the pool floor (El. 998'-11"), this ratio is 18.0. The analysis indicates that a considerable margin exists compared to the value 1.5 and hence the cask is stable for the design SSE.

QUESTION 17.6

In Figure 3-1, cask drop locations are indicated. Specify which beams are constructed compositely and provide justification for not considering the cask drop on beam W30 x 108 on column line 6.9 and beam W30 x 116 on column line 7.9.

RESPONSE 17.6

Bechtel design drawing No. 5828-C-315 specifies all the floor beams (including W36 x 100, W12 x 55, W30 x 116, W30 x 108, W24 x 68 and W27 x 84) over which the cask travels to be composite beams. Analyses of beams W30 x 116 and W30 x 108 for cask impact show that a factor of safety greater than for impact location No. 3 exists in these cases. Hence, these beams were not reported in the Reference 2 evaluation.

QUESTION REFERENCES

1. L. O. Mayer, letter to D. L. Ziemann, Chief, Operating Reactors Branch #2, U. S. Nuclear Regulatory Commission, from Northern States Power Company, Manager of Nuclear Support Services; Re: License No. DPR-22, May 30, 1975.

2. L. O. Mayer, letter to V. Stello, Director, Division of Operating Reactors, U. S. Nuclear Regulatory Commission, from Northern States Power Company, Manager of Nuclear Support Services; Re: Licensing Report LS&R-NOR-0150-06, "An Analysis and Safety Evaluation of Spent Fuel Shipping Cask Handling at the Monticello Nuclear Generating Plant (1-13-76)," January 22, 1976.

3. Electric Overhead Crane Institute (EOCI), "Specification No. 61 for Electric Overhead Traveling Cranes," One Thomas Circle, N.W., Washington, D.C.

4. Safety Analysis Report. "Spent Fuel Shipping Cask Model No. NFS-4". Nuclear Fuel Services Corporation, West Valley, New York, December 30, 1971, updated September 29, 1972.

5. L. O. Mayer, letter to V. Stello, Director, Division of Operating Reactors, U. S. Nuclear Regulatory Commission, from Northern States Power Company, Manager of Nuclear Support Services; Re: Off-Site Shipment of Spent Fuel (License No. DPR-22), February 13, 1976.

6. ACI Manual of Concrete Practice, Part 2, American Concrete Institute, 1973.

7. Johannes Moe, "Shearing Strength of Reinforced Concrete Slabs and Footings Under Concentrated Loads", Portland Cement Association, Bulletin No. D47, April, 1961.

8. American Concrete Institute (ACI). "Building Code Requirements for Reinforced Concrete". Code ACI-318-71, 1971.

9. American Institute of Steel Construction, "Manual of Steel Construction". Seventh Edition. New York, New York, 1970, page 4-23.

10. Newmark, N. W. and Haltiwanger, T. W. "Air Force Design Manual". AFSWC-TDR-62-138. Prepared by the University of Illinois for Air Force Special Weapons Center, Kirtland Air Force Base, N. M., 1962.

11. U. S. Nuclear Regulatory Commission. Standard Review Plan 3.8.3, "Other Category I Structures". Directorate of Licensing, 1974.

12. Topical Report BC-TOP-4A, "Seismic Analysis of Structures and Equipment for Nuclear Power Plants", Bechtel Power Corporation, San Francisco, California, November, 1974.

13. William McGuire, "Steel Structures", Prentice Hall, 1968.