UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION II
101 MARIETTA STREET, N.W.
ATLANTA, GEORGIA 30303

AUG 0 7 1979

IE Investigation Report Nos. 50-369/78-20 and 50-370/78-15

Subject:

Duke Power Company
McGuire Nuclear Plant
Units 1 and 2
Docket Nos. 50-369 and 50-370

Allegation that certain formal written statements made by Duke Power Company to the NRC were incorrect and materially affected the staff's review and acceptance of a revision to the McGuire Final Safety Analysis Report (FSAR).

Period of Investigation: April 11-13, May 3-5, July 6-28, September 10-11, November 8, and December 5-6, 1978

Investigators:

M. V. Annast, Investigator — 12/20/7 Date
Office of the Director

M. D. Hunt, Principal Inspector — 12/21/7 Date
Projects Section
Reactor Construction and Engineering Support Branch

Reviewed by:

D. Thompson, Deputy Director — 12/20/ Date
Office of the Director

7910250 544

TABLE OF CONTENTS

POOR ORIGINAL

I. INTRODUCTION

The Nuclear Regulatory Commission in several telephone conversations and by letter received information indicating that safety related design calculations were inadequate and certain design analyses were incorrect or misleading.

The Region II Office of Inspection and Enforcement conducted an investigation into the allegations and reported the findings in IE Investigation Report Nos. 50-369/78-10 and 50-370/78-4 dated August 2, 1978. This report concluded that of twelve separate allegations, eleven were not substantiated; however, one allegation resulted in an unresolved item. This allegation was stated as follows:

> "Duke Power Company (DPC) has an existing accident analysis which indicates that a dropped fuel shipping cask can fall into the spent fuel pool during certain conditions. DPC representatives have informed the NRC and stated in the FSAR the fuel cask cannot fall into the pool.

Region II continued the investigation of the unresolved item regarding the cask drop accident analysis as authorized by Part 1.64, Title 10 Code of Federal Regulations.

II. SCOPE OF INVESTIGATION

The scope of this investigation included the following:

A. Interviews with present and former Duke Power Company employees.

B. An examination of documents and records related to the allegation.

C. An evaluation by NRR of the FSAR submittal with regard to a material false statement.

III. CONCLUSIONS

Duke Power Company (DPC) performed several accident analyses, requested by NRR, involving the spent fuel shipping cask. One of the calculations, based on conservative assumptions, indicated that the cask could enter the spent fuel pool under certain circumstances. DPC engineering management reviewed the facts and believed that this calculation was hypothetical and unrealistic. The supervisory engineer reviewed this issue and, based on his experience and professional judgment, prepared a formal FSAR revision to the Office of Nuclear Reactor Regulation (NRR). This response to NRR questions concluded, without any reservations, that the cask would not enter the spent fuel pool. Review by NRR resulted in the conclusion that the DPC submittal was material to the FSAR review process because it omitted discussion regarding the disputed calculation, which if known to exist would have resulted in the need for additional NRR review.

POOR ORIGINAL

IV. DETAILS OF INVESTIGATION

A. Persons Contacted

L. C. Dail, Vice President, Design Engineering
J. R. Wells, Corporate QA Manager
L. R. Barnes, QA Manager, Construction
E. Brafford, Design Engineering
C. L. Ray, Jr., Design Engineering
R. B. Priory, Design Engineering

In addition to the above, three former DPC employees were interviewed.

B. Allegation, Discussion and Finding

Allegation: DPC has an existing accident analysis which indicates that a dropped fuel shipping cask can fall into the spent fuel pool under certain conditions. DPC representatives have informed the NRC and stated in the FSAR that the fuel cask cannot fall into the pool.

Discussion: The licensee had been asked by NRR to provide the results of an evaluation demonstrating that dropping of the spent fuel shipping cask in its vertical or tipped position would not result in the cask entering the spent fuel storage area. The investigators examined DPC calculations, including three postulated accidents assuming a hypothetical 100-ton cask of the maximum envelope dimensions of possible casks to be used at McGuire. The first case assumed that the cask breaks loose from a height of two feet when the crane hits the end-of-travel stops at maximum speed. The second case assumed that the crane is traveling at maximum speed with the cask at floor level when the cask breaks loose and strikes the forward edge of the cask storage pit. In these two instances, the calculations indicate the cask could not tip over into the spent fuel pool. The third calculation assumed that the stationary cask is dropped from a height of 2 feet 11½ inches, with the back edge landing on and pivoting about the back edge of the cask storage pit. This calculation indicates that the cask would fall into the pool.

The results of the study provided by DPC in Revision 6 to the FSAR, paragraph 9.1.2.3, included only the first two postulated accidents described above. The stated conclusion was: "Based upon this evaluation it is concluded that the cask would not enter the spent fuel pool due to maximum horizontal swing or tipping of the cask." No potential limitations on cask handling such as special cask travel patterns, maximum lift height or modifications to fuel storage area structure were mentioned. The third calculation (Exhibit C-1) was preliminary in that it was checked, but not approved. The calculation checker had made

POOR ORIGINAL

notations on calculation sheet numbers 7, 7a, 9 and 10 disagreeing with the basic assumptions made by Individual A, the person performing the calculation. The original calculator's assumptions were:

1. No energy loss due to impact.
2. Friction is not considered.
3. Material deformation is not considered.
4. Cask is infinitely rigid and does not deform.

The calculation checker, Individual B, had noted that: "Reinforced concrete has the ability to absorb energy. Therefore, energy is lost on impact. Material deformation does occur. The concrete spalls off near the edge and the cask can be deformed if dropped." Individual B had left DPC in August, 1977 and could not be immediately located, to verify his notes. His written comments appeared, however, to be adequate to support his position.

The immediate supervisor of both men, Individual C, and the principal engineer, Individual D, agreed with the checker that the assumptions were unrealistically conservative. No attempt was made, however, to recalculate the postulated load case using more realistic assumptions. The principal engineer prepared the input for Revision 6 to the McGuire FSAR in response to NRR Question 020.2 and supplied it to the licensing engineer for submittal to NRC. The licensing engineer confirmed this submittal. Thus, the submittal to NRC was made when persons in responsible positions were aware of the existence of admittedly conservative calculations that tended to cast some doubt on the validity of assurances included in the submittal.

Duke Power Company representatives stated that until this disputed calculation was performed all previous calculations were based on the assumption that the majority of the kinetic energy of the cask would be absorbed at impact and the potential energy of the cask would cause it to fall away from the spent fuel pool. Load cases No. 1 and 2, previously discussed, and three additional load cases, postulated by Individual B, the checker, were analyzed. The conclusion was that the cask would not fall into the spent fuel pool under any of the postulated accidents.

Individual A, the author of load cases 1 and 2 was then assigned as the checker of the three additional load cases calculated by Individual B. In lieu of checking these three calculations, Individual A instead postulated a Load Case No. 3 and on June 11, 1975, performed an analysis for this new load case. Individual A used the basic assumptions previously considered for load cases 1 and 2. Using the assumptions of no loss of energy from impact,

POOR ORIGINAL

no consideration of friction or material deformation and an infinitely rigid cask, he concluded that the cask would fall into the spent fuel pool. The calculations were checked on June 12, 1975 by Individual B who apparently noted his objections on various calculation sheets.

Individual C, the immediate supervisor, was interviewed by the investigators and stated that he agreed with the checker and brought the disputed calculation to the attention of his supervisor, Individual D, the Principal Engineer. They discussed the assumptions and Individual D also agreed that the assumptions were unrealistic. There was a subsequent meeting with Individual A to determine Individual A's reasons for the conservative approach in the calculations. During this meeting, Individual A said that since there was no firm information on the cask, he thought a conservative approach should be used. Individual D returned the calculation to Individual C and indicated that a final resolution could not be reached until all parameters identifying the cask to be purchased in the future, could be obtained. Individual C and Individual D discussed several ways to preclude the cask from falling into the pool. These included: (1) administrative controls on the operation of the crane transporting the cask; (2) modification of the north wall of the upper cask storage level by sloping the wall to a degree such that it would preclude the cask from dipping into the pool; and (3) modification of the concrete in certain areas between the decontamination pit and the upper level of the cask storage area. Individual C placed the calculation back in the files with the understanding that the matter would be resolved when the actual cask was identified.

Individual D, the Principal Engineer no longer employed by DPC, was interviewed by the investigators. He stated that in 1975 he was the senior supervisor responsible for the review and resolution of NRC questions relative to the cask drop accident as defined in Question 020.2 of the McGuire FSAR (Exhibit C-2). Individual D clearly recalled the details involved in the disputed calculation and stated that he had given serious attention to the difference in opinions and had discussed the whole issue, in detail, with all parties involved. He felt that the assumptions made for Load Case 3 were unrealistic. Individual D believed along with Individual C and Individual B, that if more realistic yet conservative assumptions were used, the analysis would show that the cask could not enter the spent fuel pool. However, actual calculations were not performed to verify this belief. The calculations were to remain open for a final review when the physical details of the actual cask could be defined. In Individual D's opinion, the disputed calculation had received appropriate and proper attention by qualified supervisory personnel and the final conclusion was based on proper review and good engineering judgment. Individual D's position was that, based on the foregoing actions, the statement which he submitted for the FSAR revision was correct; i.e., the cask could not enter the spent fuel pool (Exhibit C-3).

POOR ORIGINAL

Duke Power Company arranged for a formal briefing of events involving the cask drop accident calculations and to explain the history of the disputed calculation. Further information and documents were provided voluntarily and in full cooperation with the investigators.

Region II forwarded a memorandum, with enclosed statements and documents involving the cask drop issue to Headquarters, Office of Inspection and Enforcement on July 28, 1978 requesting review of the case. The facts submitted by Region II were summarized as follows:

1. Duke Power Company had information that, using conservative assumptions, the cask could conceivably enter the spent fuel pool.

2. This information had not been provided to the Office of Nuclear Reactor Regulation (NRR).

3. No recalculation was made of Load Case 3 using more realistic assumptions.

4. Duke Power Company's decision not to include the disputed Load Case 3 as part of the FSAR submittal was a conscious act.

5. No formal review procedure had been established which specifically required that later calculations, using actual cask design parameters, would consider the load case in question.

The Office of Inspection and Enforcement reviewed the case and forwarded the documents to the Office of Nuclear Reactor Regulation (NRR) for a determination of materiality. NRR concluded that the omitted information would have been material in the FSAR review process and could have affected the staff's acceptance of the FSAR revision. NRR concluded that the response to the staff question was a material false statement by omission (Exhibit C-4).

Region II was asked to provide additional information and documentation concerning the cask drop accident analysis. This included further interviews with the principals directly involved in the cask drop analysis. The following additional effort was requested in support of Headquarters review of the case:

1. Determine various individuals' background and experience.

2. Obtain individuals opinions regarding the performance of the calculations.

POOR ORIGINAL

3. Reverify all facts and statements. Obtain additional statements.

4. Attempt to locate Individual B, the checker of the disputed calculation.

Region II continued the investigation and reinterviewed Individual A, no longer employed by DPC, who performed the original calculation. At this time Individual A was given a copy of the calculation to examine. He confirmed that he was the author of the calculation and explained his rationale in reaching the conclusion that the cask would fall into the spent fuel pool. He readily admitted that the assumptions he had used for Load Case 3 were conservative but pointed out that the same assumptions were used for Load Cases 1 and 2. Individual A stated that he did not recall the notations made in the calculations by Individual B, the checker. Individual A said that Individual B was a young inexperienced engineer, recently graduated from college, at the time he checked the calculation. According to Individual A, the checker only perfomed a mathematical verification of the calculation and "did not express any strong opinions about the assumptions." Individual A commented that he would have initialed any additional sheets which would have been added to the calculation by the checker. This was not the case with page 7.a which contained Individual B's disagreement with the assumptions.

Further examination of the document revealed that calculation sheets (Form 184), used for the calculations in question, were a version of Revision 12-74 i.e. the sheets were printed in December, 1974. The calculation was performed on June 11, 1975 and was checked on June 12, 1975. Page 7.a was also dated June 12, 1975, however this page was a version of Form 184 revised in May 1976. This meant that Individual B could not have recorded his objections to the assumptions on page 7.a. on June 12, 1975 because this particular page was not in existence.

Individual B was located in Springfield, Virginia and was interviewed on October 10, 1978. After initially denying any knowledge of the questionable page, Individual B admitted that he had recorded his backdated comments approximately one year later, apparently in order to please Individual C, his former supervisor. He stated that, initially, in 1975 he checked the mathematics of the calculation and found them to be correct. Although he did feel that the assumptious used by Individual A were unrealistic and thus conservative, he made no further comments at that time, partially because he was inexperienced and deferred to Individual A's experience. In June, 1976, Individual C told him to go over the figures again, this time very carefully. Individual B stated that he was not directly ordered to add any comments but felt that to document his comments at this time would please supervision and enhance his career with DPC. At the same time, the additional

year's experience had given him confidence to state that the issue at hand seemed trivial and the assumptions were, in fact, too conservative. Individual B rechecked his own figures and found them to be correct. He then added the comments on pages 7, 7a, 9 and 10. Page 7a was a new page which he inserted at this time and dated this page to agree with the rest of the pages. Individual B then returned the calculation to Individual C without comment. He recalls no further discussions on the matter.

The investigators reinterviewed Individual C on November 8, 1978. When confronted with the backdated page 7a, Individual C stated that he had asked Individual B approximately one year after the original calculation was performed and checked, to take another close look at it and to document any comments he might have. Individual C confirmed that Individual B gave the calculation back to him with the added comments but maintained that he did not notice the backdated date and did not instruct Individual B to backdate anything. He explained that the reason for his request for the recheck was the fact that Individual B had been transferred to another design group and was also planning to attend graduate school. Individual C stated that he wanted the checker to review the calculation again to record his opinions before he departed. Individual C returned the calculation to the files. He stated that he made Individual D's successor in the design group, Individual E, aware of the calculation, insofar as telling him about the preliminary status and disputed nature of the document.

Further investigation disclosed that, with the exception of Individual C, no other DPC employee was apparently aware of the later addition of page 7a and the other comments on pages 7, 9, and 10.

Individual D, the Principal Engineer, was reinterviewed on October 5, 1978. He still maintained that the assumptions made by Individual A were unrealistically conservative. His basis for this was the fact that major energy dissipation would occur during any cask drop accident. He stated that concrete is commonly accepted as a good energy absorber and that the cask would also deform on impact, resulting in energy dissipation. Individual D is presently the head of his own engineering consulting firm. His background and experience include thirteen years involved in nuclear power plant design including direct experience with cask accident evaluations. Individual D stated that, in his opinion, there were adequate internal controls within the DPC design engineering organization to assure future review of the preliminary calculation when an actual cask had been selected. Individual D stated frankly that, based on his experience and engineering judgment, in retrospect he would still have provided the input for the FSAR submittal without reservations.

POOR ORIGINAL

Additional review of documentation and discussions with DPC technical staff during the course of the additional investigation revealed that DPC had still not decided on the final specifications of the spent fuel cask. During discussions about the cask selection the investigators found that Duke Power Company Quality Assurance Manual, Section PR-301, paragraph 5.9, requires formal approval of all engineering divisions for all specifications of safety related equipment which is to be purchased. The cask specifications when finalized would, therefore, receive a formal review and this process would apparently include the resolution of any outstanding calculations.

Findings: The allegation is substantiated as stated. Duke Power Company formally submitted information to the Nuclear Regulatory Commission in the form of a revision to the Final Safety Analysis Report which omitted the fact that an existing preliminary accident analysis calculation indicated that the cask could fall into the spent fuel pool under certain circumstances. This constitutes a material false statement by omission. The investigation disclosed that the omission was based on engineering judgement of an experienced supervisor after appropriate review with all parties concerned. Several internal procedural controls exist which tend to give reasonable assurance that the cask drop issue would be addressed when the final cask specifications are finalized. There is no evidence which indicates a willful or intentional attempt by DPC to deceive the NRC in the course of the FSAR submittal.

The backdating of page 7a in 1976 impacts on the integrity of the individuals involved but does not materially affect the calculation results or the FSAR submittal in 1975. There was no evidence that the calculation was further modified as a result of the NRC investigation begun on April 11, 1978. This incident appears to be an isolated case since no other similar backdated documents were identified. The investigators, through interviews, concluded that other DPC employees and management were not aware of the backdating incident.

POOR ORIGINAL

CERTIFICATION OF DESIGN CALCULATION

Station and Unit Number McGuire Nuclear Station

Title of Calculation Fuel Cask Accident

File Number AB 1000.08

These design calculations cover items relating to nuclear safety. In accordance with established procedures, the quality has been assured and I certify that the above calculation has been performed, checked or approved as noted below:

Performed By	INDIVIDUAL A	Date	5-1-75 6/16/75
Checked By	INDIVIDUAL B	Date	6/16/75 6/16/75
Approved By		Date	
Approved By QA		Date	

Revision Log.

1. __________
2. __________
3. __________
4. __________
5. __________

EXHIBIT C

Form ...

POOR ORIGINAL

Form 184 (Rev. 12 74)

Unit 1 & 2 File No. A51000-0-

Dev./Station McGUIRE NUCLEAR STA

Subject FUEL CASK ACCIDENT By "A" Date 4/23

Checked By Date

Sheet No. 1 of

The following study is undertaken to determine the possibility of the fuel cask tumbling into the SPENT FUEL POOL in the event it breaks loose from its ... The first two of several possible situations to consid... as follows: (1) The cask breaks loose while suspended ... two feet above the floor. (2) The cask contacts the floor, breaks loose and its momentum tends to ove... the cask. These two load cases both occur w... the hoist is moving at maximum (horiz) speed an... stopped by the stop-bumper at the end of its r... Much of the data used in the following study is ... as noted. For simplicity, energy loses due to friction ... material deformation in the cask and hoisting e... is not considered.

The conclusion is that the fuel cask will ... tumble into the SPENT FUEL POOL, for the two cases, but for an accident as depicted by load case ... spent fuel pool ... cask will topple into the spent fuel pool....

POOR ORIGINAL

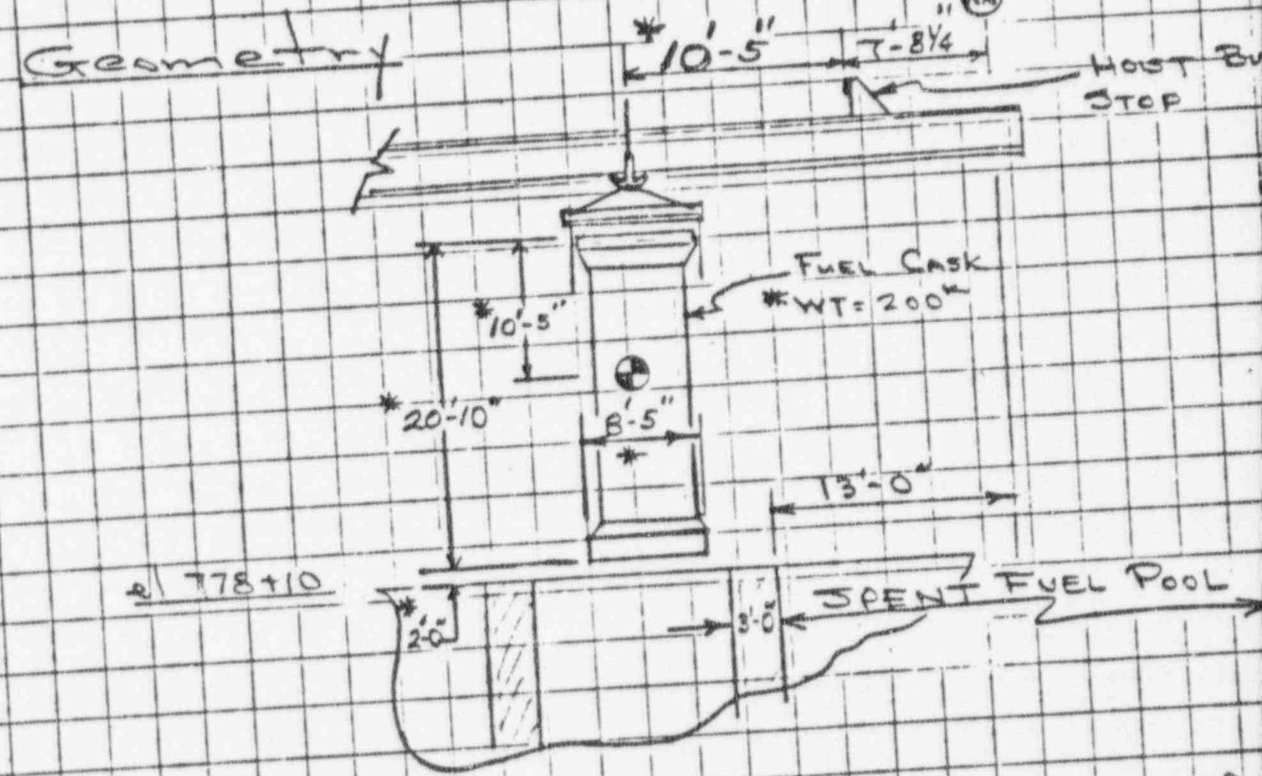
Form 164
(Rev. 12 74)

Dev./Station McGUIRE NUCLEAR STA. Unit #1 & #2 File No. AB1000...

Subject FUEL CASK ACCIDENT By "A" Date 2/23/7

Checked By ___ Date ___

Sheet No. 2 of ___



*Assumed (Ref National Lead Company Dwg #70446F, Re

*Dimensions from old drawings

POOR ORIGINAL

Form 184 (Rev. 12 74)

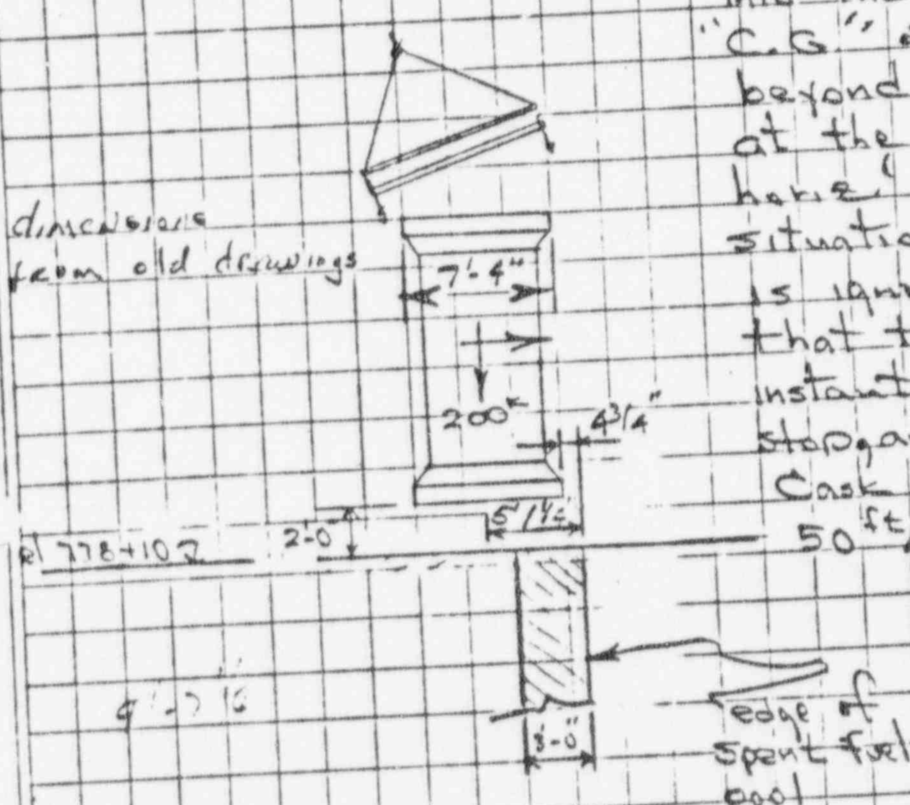
Dev./Station McGuire Nuclear Sta. Unit #1 & #2 File No. AB 1000

Subject Fuel Cask Accident By "A" Date 2/23

Checked By ____ Date ____

Sheet No. 3 of ____

Load Case ①



In order for the cask to tu[rn] into the spent fuel pool, t[he] "C.G." of the cask must b[e] beyond the edge of the [pool] at the completion of a[ll] horiz. movement. For th[is] situation, rotation of the ca[sk] is ignored. It is also assum[ed] that the cask breaks loos[e] instant the trolley hits the stop, and no energy is lost. Cask is traveling at a spe[ed of] 50 ft/min.

t = time for cask to drop 2.0'

$y = v_0 t - \frac{1}{2} g t^2$

$2.0 = 0 - \frac{1}{2} \times 32.2 t^2$

$t = \left(\frac{2 \times 2}{32.2}\right)^{1/2} = .352$ sec.

therefore, @ 50'/min & @ t = .352 sec, horiz. distanc[e]

$d = vt$

$d = \left(\frac{50}{60}\right) \times .352 = .293' = 3.52''$

Therefore, the C.G. of the Cask

in 4' ... 3.52"

POOR ORIGINAL

Form 184 (Rev. 12/74)

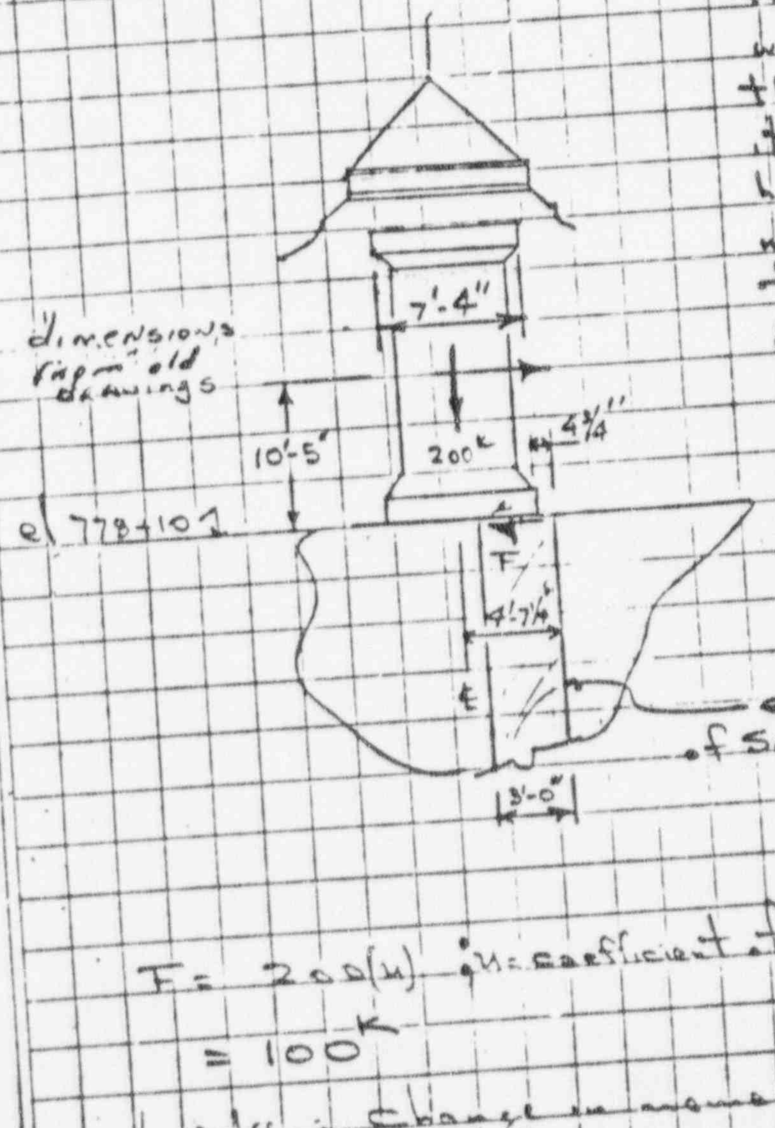
Dev./Station McGUIRE NUCLEAR STA. #1, #2 Unit ______ File No. [illegible]

Subject FUEL CASK ACCIDENT By "A" Date 4/23

Checked By ______ Date ______

Sheet No. 4 of ______

LOAD CASE #2



For this load case it is ass[umed] that the cask is in conta[ct] with the spent fuel pool's w[all], the trolley has bottomed out [on] its bumper stop and the cas[k] has broken loose with no los[s of] momentum. The cask is traveling at a speed of 5[...]. A similar situation would [occur] if the bottom of the cask [is] below the floor level & it h[its the] spent fuel pool's wall & simu[ltaneously] breaks loose from the hoist.

$F = 200(\mu)$; μ = coefficient of friction = .5 (Ref. AN INTRODUCTI[ON TO THE] MECHANICS OF [SOLIDS] by CRANDALL & DA[HL])

$= 100^k$

Impulse = change in momentum

$F(t) = \frac{m}{2}(V_0 - V_1) = \frac{mV_0}{2}$; $V_0 = \frac{50}{60} = \frac{5}{6}$

$t = \frac{mV_0}{2F} = \frac{200000}{32.2} \times \frac{5}{6} \times \frac{1}{2} \times \frac{1}{100000} = .026$ sec

d = distance traveled = $\frac{50}{60} \times \frac{.026}{2} = .011 = .132"$

Check tendency to overturn.

Form 104
(Rev. 12 74)

Dev./Station McGUIRE NUCLEAR STA. Unit "1 & "2 File No. AE 100...

Subject FUEL CASK ACCIDENT By "A" Date 4/23/-

Checked By ______ Date ______

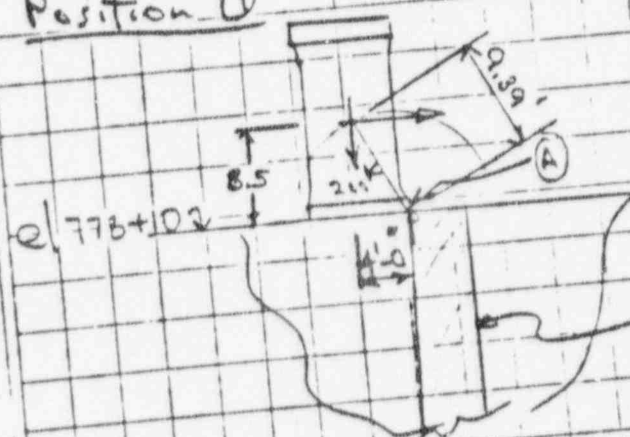
Sheet No. 5 of ______

Load Case #2 (continued)

Check tendency to overturn

Position #1

$\rightarrow v_1 = 50'/min = .833'/sec$



Use principle of impulse and momentum

System momentum(1) + System External Impulse = System momentum(2)

Σ(Moments about (A)):

$$(mv_1)(8.5) + 0. = mv_2(9.39) + \bar{I}\omega_2 \; ;$$

$$v_2 = 9.39\,\omega_2$$

$$\bar{I} = \frac{m}{12}(3a^2 + \ell^2) = \frac{200000}{32.2 \times 12}\left[(3 \times \ldots\right.$$

$$= 174430$$

$$\left(\frac{200000}{32.2}\right)(.833)(8.5) = \left(\frac{200000}{32.2}\right)\overset{54{,}653}{(9.39)^2}\,\omega_2 + 174430\,\omega_2$$

$$\omega_2 = \frac{44.0 \times 10^3}{722 \times 10^3} = .061 \text{ rad/sec}$$

Form 104
(Rev. 12 74)

Dev./Station McGUIRE NUCLEAR STA. Unit #1 & #2 File No. [illegible]

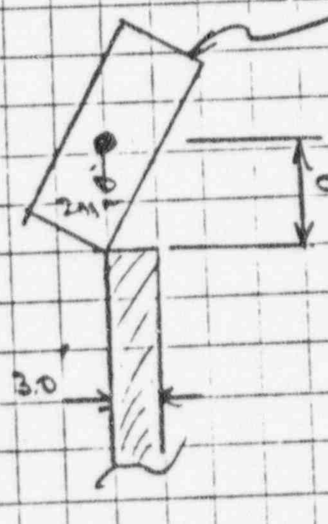
Subject FUEL CASK ACCIDENT By "A" Date 6/12/[illegible]

Checked By "B" Date 6/16/[illegible]

Sheet No. 6 of

Load Case #2 (continued)

Position #2



Use principle of conservation of e[illegible]

T_1 = Kinetic energy at positio[illegible] when cask is stopped

$= \frac{m\bar{v}_2^2}{2} + \frac{\bar{I}\omega_2^2}{2}$; $v_2 = 8.5\omega$

$= \frac{200000}{2 \times 32.2}\left[(8.5)(.061)\right]^2 + \frac{170030}{2}(.061)^2$

$= 1659 = 1.66 \times 10^3$

$T_2 = \frac{m\bar{v}_3^2}{2} + \frac{\bar{I}\omega_3^2}{2}$; $v_3 = 9.39\omega$

$= \frac{200000}{2 \times 32.2}(9.39 \times \omega_3)^2 + \frac{170030}{2}(\omega_3)^2$

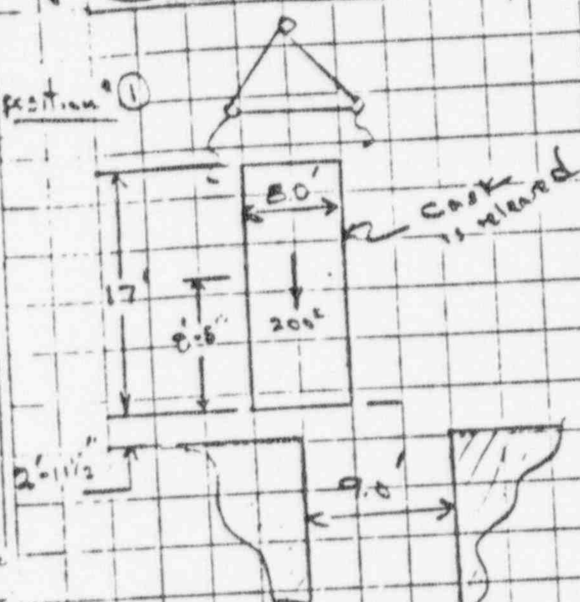
$= (361 \times 10^3)\,\omega_3^2$

$T_2 + V_2 = T_1 + V_1$

• The cask will / $(361 \times 10^3)\omega_3^2 + 200000 \times 9.39 = 1.66 \times 10^3$

Case #3

Position #1



In the following analysis the following assumptions are ma

* 1. no energy loss due to impa material deformation or friction.
* 2. friction is not considered
* 3. material deformation is n considered.
* 4. Cask is infinitely rigid & does not defor

*see following PAGE

t: time for cask to drop 2'-

$y = v_0 t - \frac{1}{2} g t^2$

$2.958 = 0 - \frac{32.2}{2} t^2$

$t = \left[(2 \times 2.958)/32.2\right]^{1/2} = .42$

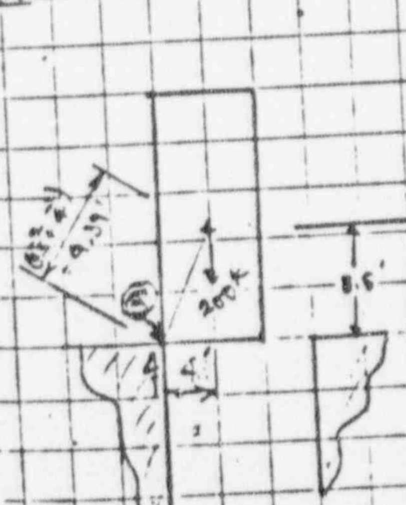
$v_0 = gt = 32.2 \times .429 = 1$

To determine angular velocity (ω_2)

Syst Momentum + Syst Ext Imp$_{1\to2}$ = Syst M

ΣMom$_{A}$:

Position #2



$m v_1 (4) + 0.0 = m \bar{v}_2 (9.39) + \bar{I} \omega_2$

$\bar{I} = \frac{m}{12}(3a^2 + l^2) = \frac{200000}{32.2 \times 1}$

$= 174$

$\bar{v}_2 = 9.39\,\omega_2$

$4 \times \frac{200000}{32.2} \times 13.8 = \frac{200000}{32.2}(9.39)\omega + 174$

$\omega = \left[\frac{343 \times 10^3}{722 \times 10^3}\right] = .475$ ra

Form 184 (5-76)

Dev./Station Mc Guire Nuclear Unit —— File No. ——

Subject Fuel Cask Accident By "B" Date 8-12-7

Checked By —— Date ——

Sheet No. 2a of —— Problem No. ——

The that assumptions made are too conservative. Consider them below:

A) No energy loss due to impact, material deformati[on] or friction

Comment: Reinforced concrete has the ability to abso[rb] energy. Therefore energy is lost @ impact

Material deformation does occur. The concret[e] spalls off near the edge and the cask can be deformed if dropped

Form 184
(Rev. 12 74)

Dev./Station McGUIRE NUCLEAR STA. Unit #1 & #2 File No. 46.1000.0

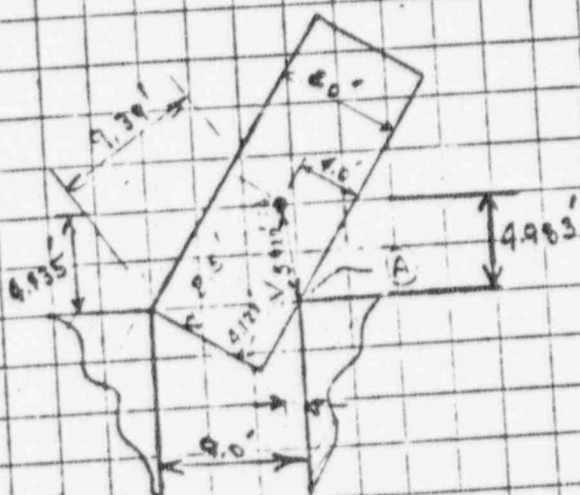
Subject FUEL CASK ACCIDENT By "A" Date 6/11/

Checked By "B" Date

Sheet No. 8 of 11

Case #3 (continued)

Position #3
Before Impact @ A



By principle of Conservation of energy:

For Position 2 ; $\omega = .475$; $\bar{v}_2 = 9.39 \times$

T_2 = Kinetic energy

$= \frac{1}{2}\bar{I}\omega^2 + \frac{m}{2}\bar{v}_0^2$;

V_2 = Potential Energy

$= 200^k(8.5) = 1700^{1-k}$

For Position 3

$T_3 = \frac{1}{2}\bar{I}\omega_3^2 + \frac{m}{2}\bar{v}_3^2$; $\bar{v}_3 = 9.39\omega_3$

$V_3 = 200(4.983) = 996.6^{1-k}$

$T_2 + V_2 = T_3 + V_3$

$\frac{174930(.475)^2}{2} + \frac{200000}{32.2\times2}(4.46)^2 + 1700000 = \frac{174930}{2}\omega_3^2 + \frac{200000}{32.2\times2}($

$19680. + 61780 + 1700000 = 87265\omega_3^2 + 273830\omega_3^2 +$

$\omega_3 = \left(\frac{1781460 - 996600}{361.0\times10^3}\right)^{1/2}$

$= \left(\frac{784.86\times10^3}{361.0\times10^3}\right)^{1/2} = 1.474$

Form 184
(Rev. 12 74)

Dev./Station McGUIRE NUCLEAR STA.	Unit # [1] # 2 File No. A2 1000
Subject FUEL CASK ACCIDENT	By - "A" Date 6/13
	Checked By - "B" Date 6/14
Sheet No. 9 of 11	

Case #3 (continued)

Position #④

The geometry of position #④ is the same as positio[n] ... But at position ④ the cask has made cont[act] at point Ⓐ and has begun to Rotate about this p[oint] ... No

CONCRETE will ... CASK WILL NOT ROTATE about point "A". ... at point A. At point "B" it will lose contact with CONCRETE f... back into POOL SINCE CENTER OF GRAVITY IS INSIDE OF CASK AREA. (see prec...)

$$T_3 + V_3 = 87215\omega_3^2 + 273830\omega_3^2 + 996600$$

$$= 87215(1.470)^2 + 273830(1.470)^2 + 996600.$$

$$= 188463. + 591719. + 996610.$$

$$= 1776.8 \times 10^3$$

$$T_4 + V_4 = \frac{I\omega_4^2}{2} + \frac{mv_4^2}{2} + 200000 \times 4.983 \; ; V_4 = 5.9...$$

$$T_4 + V_4 = T_3 + V_3$$

$$\overset{87215}{179930}\frac{\omega_4^2}{2} + \frac{200000}{32.2 \times 2}(5.93)^2\omega_4^2 = (1776.8 \times 10^3) - (99...$$

$$\omega_4^2(196.422 \times 10^3) = 780.2 \times 10^3$$

$$\omega_4 = \left(\frac{780.2 \times 10^3}{196.422 \times 10^3}\right)^{1/2}$$

$$\omega_4 = 1.99 \text{ rad/sec.}$$

Form 184
(Rev. 12-74)

Dev./Station McGUIRE NUCLEAR STA. Unit 1 & 2 File No. AB1202...

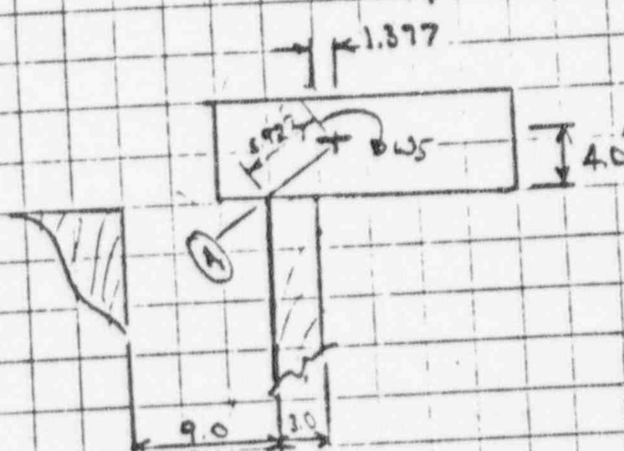
Subject FUEL CASK ACCIDENT By "A" Date 6/11/7

Checked By "B" Date 6/11/

Sheet No. 10 of

Case 3 (continued)

position 5



$T_5 = \frac{I\omega_5^2}{2} + \frac{mV_5^2}{2}$; $V_5 = 5.92$

$= \frac{174430\,\omega_5^2}{2} + \frac{200000}{2\times32.2}(5.9$

$= (196.4\times10^3)\,\omega_5^2$

$T_4 + V_4 = 1774.5\times10^3$

$T_5 + V_5 = T_4 + V_4$

$(196.4\times10^3)\,\omega_5^2 + (200000\times4) = 17$

$\omega_5 = \left[\frac{(1774.5-800)\times10^3}{196.4\times10^3}\right]$

$= 2.22$ rad/s

Cask will NOT TOPPLE INTO POOL DUE TO ENERGY LOSS UPON CONTACT WITH CONCRETE, SPALLING ACTION OF CONCRETE @ CORNERS & LOCATION OF CENTER OF GRAVITY INSIDE OF CASK AREA before SLIPING OCCURS. EXPLAINED ON page 9.

∴ The cask will topple int the spent fuel pool, sinc the C.G. extends ove pool edge & there is rotational energy availab

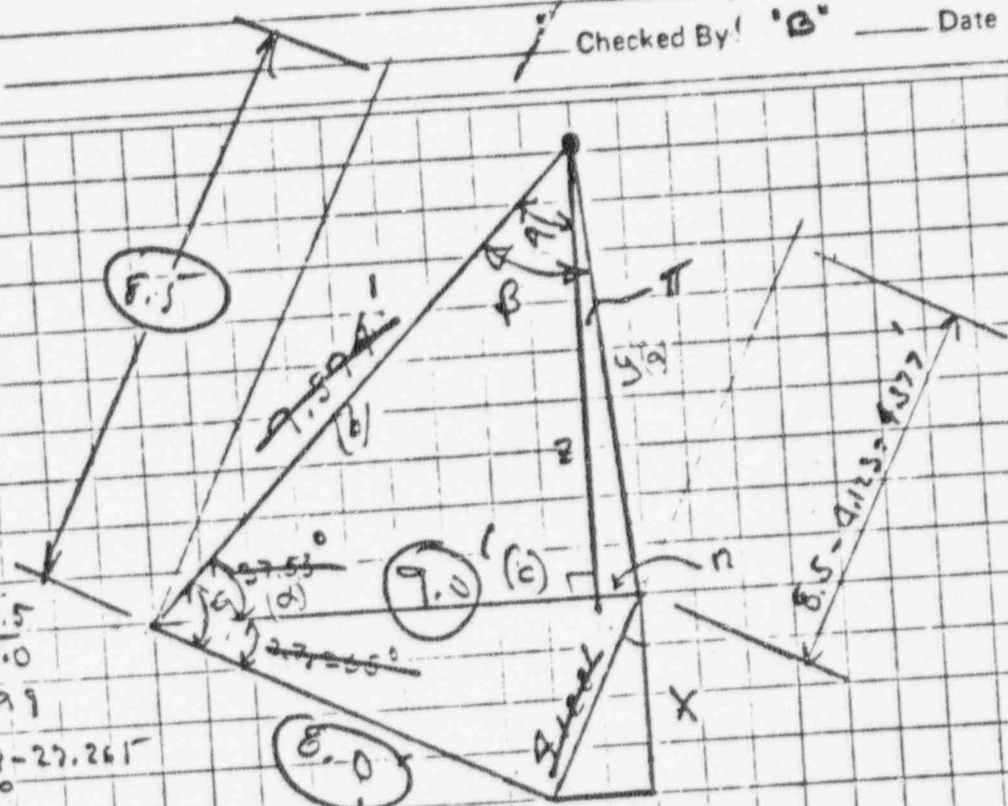
Form 184
(Rev. 12-74)

Dev./Station McGuire Nuclear Sta. Unit "1" 2 File No. LE 1.00

Subject Fuel Cask Accident By "A" Date 6/13

Checked By "B" Date 6/ /

Sheet No. 11 of



$\epsilon = \tan^{-1}\frac{8.5}{4.0}$

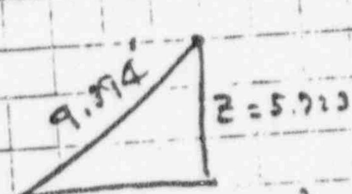
$\epsilon = 64.799$

$\alpha = 64.799 - 27.261$
$= 37.53°$

$\frac{4.123}{9.0} = \frac{x}{8.0}$

$x = \frac{8}{9}(4.123)$

$z = 9.394 \sin 37.53$
$= 5.723$



$m = \sqrt{9.394^2 - 5.723^2}$
$= 7.45'$

$n = 9 - 7.45 = 1.55'$

$\sigma = \sin^{-1}(7.45/9.394)$
$= 52.47°$

$y = (z^2 + n^2)^{1/2}$
$= (5.723^2 + 1.55^2)^{1/2} = 5.929'$

$\pi = \sin^{-1}\frac{1.55}{5.723} = 15.71°$

Form 184
(Rev. 12-74)

Dev./Station McGuire Nuclear Station Unit 1 & 2 File No. AB 1000 [illegible]

Subject Fuel Cask Displacement By "B" Date 4-28-[illegible]

Checked By ______ Date ______

Sheet No. 1 of ______

These calculations are not [illegible] because [illegible] duplicate the procedure

These calculations are presented to determine whether or not a failure of the fuel cask lifting rig assembly would cause the fuel cask to be thrust into the spent fuel pool. Three cases are presented:

(1) Lifting Rig is in it's up position and while moving at 60 ft/min it hits the bumper stop. At this instant the lifting rig fails

(2) Lifting Rig is two feet below it's highest position and while moving at 60 ft/min it hits the bumper stop. At this instant the lifting rig fails

(3) Lifting Rig is in it lowest possible position

This item relates to nuclear safety in that involves a fuel handling process

Energy considerations were used to find the horizontal displacement of the cask

There are no applicable codes pertaining to the calc[illegible]

Tabulations cited in PSAR & FSAR do not have bearing these calculations

The assumptions employed are stated in the body of the calculations

References are cited in the body of the calculat[illegible] when used

Form 184
(Rev. 12-74)

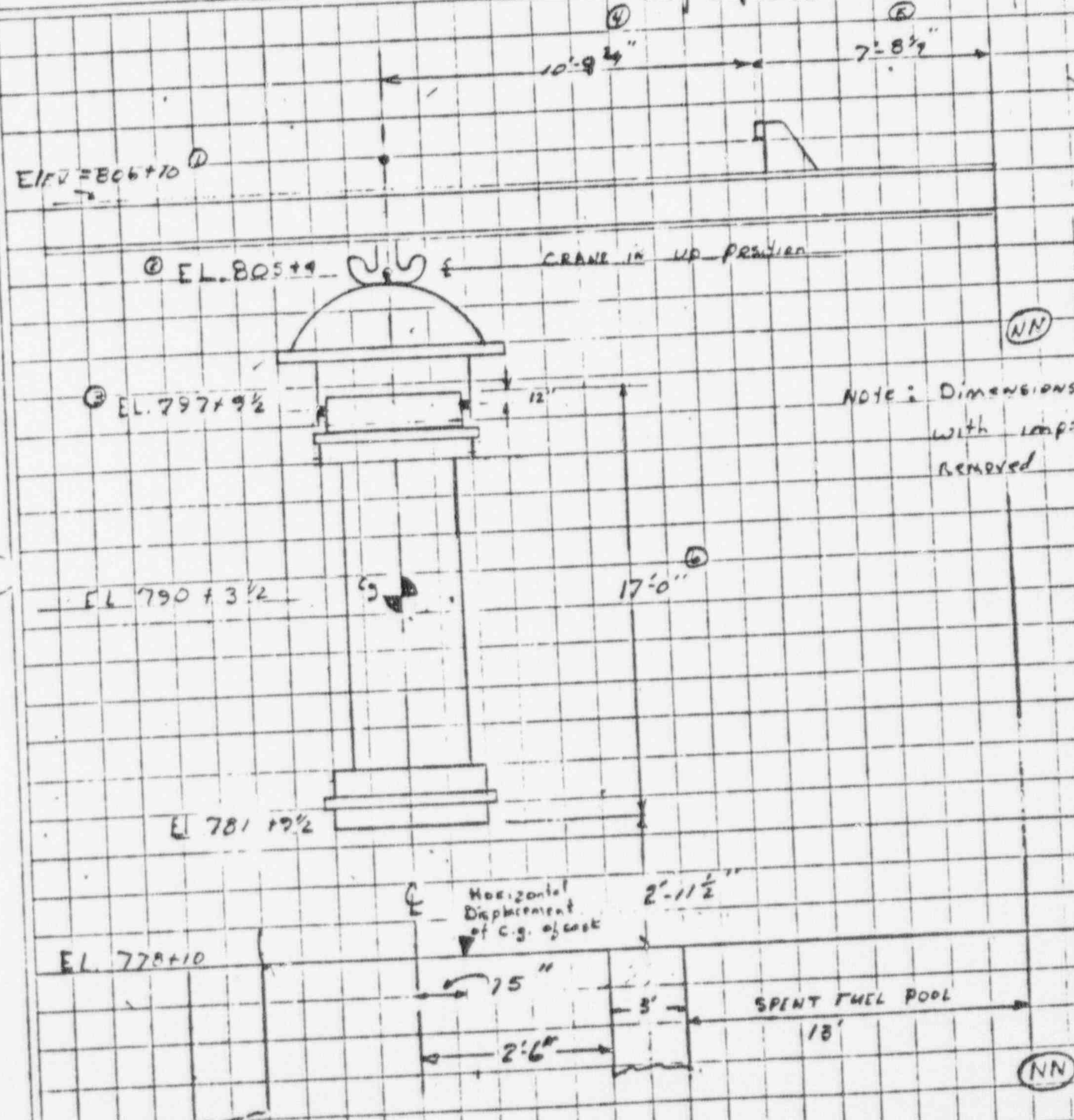
Dev./Station McGuire Nuclear Station Unit 1 & 2 File No. AG 1000.0

Subject Fuel Cask Displacement By "B" Date 4-28-7[illegible]

~~Checked By~~ "A" Date

Sheet No. 2 of

These calculations haven't been checked; they duplicate the previous calc[illegible]



⑥ Ref: Nat'l Lead Co. Drawing # 20027B

① Ref. MC1211-01

② Ref. MCM 1185.01-11

③ Ref. Nat'l Lead Co. Drawing # 70735F Rev 3

Form 184
(Rev. 12-74)

Unit 1 & 2 File No. AB 1C[illegible]

Dev./Station McGuire Nuclear Station

Subject Fuel cask Displacement By "B" Date [illegible]-23-[illegible]

~~Checked By~~ Date

These calculations haven't been check
they duplicate the previous [illegible] calc

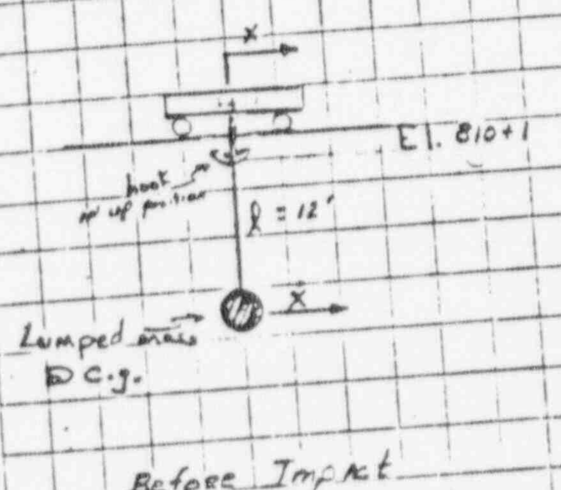
Sheet No. 3 of

Case I Generalized Co-ordinates X & θ

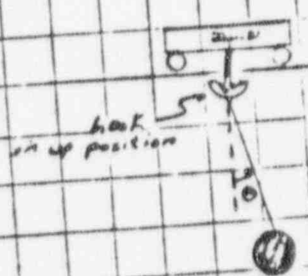
Note: we are assuming that all motion is planar
for these calculations
Assume also that the trolley and the cask
are travelling at the same velocity before impact

Kinetic Energy $= \frac{1}{2} m v^2$

Potential Energy $= mgh$



Before Impact



After Impact

Form 181
(Rev. 12-74)

Dev./Station McGuire Nuclear Station Unit 1 & 2 File No. MS 1000.08

Subject Fuel Cask Displacement By "B" Date 4-28-75

Checked By Date

These calculations haven't been checked because they ...

Sheet No. 4 of

CONSERVATION of ENERGY

$$KE_1 + PE_1 = KE_2 + PE_2$$

$\dot{X}_1 = 50 \frac{ft}{min} = .833 \frac{ft}{sec}$

m_1 = mass of cak

m_2 = mass of cask

Before I...

Kinetic Energy of Mass 1 $= \frac{1}{2} m_1 \dot{x}_1^2$

Kinetic Energy of Mass 2 $= \frac{1}{2} m_2 \dot{x}_1^2$

Potential Energy of mass 1 & 2 $= 0$

After I...

Kinetic Energy of Mass 1 & 2 $= 0$

Potential Energy of Mass 1 $= 0$

Potential Energy of Mass 2 $= mgh$
$= mgl(1-\cos\theta)$

$$\frac{1}{2} m_1 \dot{x}_1^2 + \frac{1}{2} m_2 \dot{x}_2^2 = m_2 g l (1-\cos\theta)$$

$M_1 = \frac{40^k}{g}$

$l = 15.0$ ft

$g = 32.2 \frac{ft}{sec^2}$

$M_2 = \frac{200^k}{g}$

$\dot{X}_1 = .833$ ft/sec

Form 184
(Rev. 12-74)

Dev./Station McGuire Nuclear Station Unit 1 & 2 File No. MC-1222-25

Subject Fuel Cask Displacement By "B" Date 4-28-7

Sheet No. 5 of Checked By Date

These calculations haven't been checked since they duplicate the preceeding calculations

$$\frac{.5\,(40,000)\,lb}{32.2\,\frac{ft}{sec^2}} \times \left(.833\,\frac{ft}{sec}\right)^2 + \frac{.5\,(200,000)\,lb}{32.2\,\frac{ft}{sec^2}} \times \left(.833\,\frac{ft}{sec}\right)^2$$

$$= \frac{200,000\,lb}{32.2\,\frac{ft}{sec^2}} \times 32.2\,\frac{ft}{sec^2} \times 15.0\,ft\,(1-\cos\theta)$$

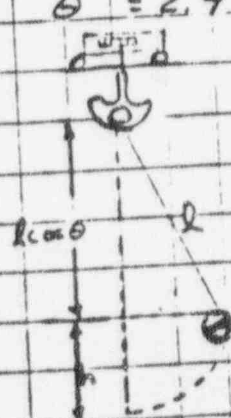
$$621.12\,ft\cdot lb + 2155.28\,ft\cdot lb = 3000200\,ft\cdot lb\,(1-\cos\theta)$$

$$621.12\,ft\cdot lb + 2155.28\,ft\cdot lb = 3020000\,ft\cdot lb - 3000000\,ft\cdot lb\,\cos\theta$$

$$-2997223.6\,ft\cdot lb = -3000000\,ft\cdot lb\,\cos\theta$$

$$.99907 = \cos\theta$$

$$\theta = 2.47°$$



$$h = l(1-\cos\theta)$$
$$= 15.0\,(1-.99907)$$
$$= .01394\,ft = .16 ...$$

$$x = l\sin\theta = 15.0\,ft \times ...$$
$$= 7.74 ...$$

Maximum displacement = 7.74 inches.

Form 184
(Rev. 12-74)

Dev./Station McGuire Nuclear Station   Unit 1 & 2   File No. MB 1000.0

Subject Fuel Cask Displacement   By "B"   Date 4-28-7

Checked By   Date

These calculations haven't been checked because they duplicate the preceding calc.

Sheet No. 6 of

Assume All motion is planar

Case II   Hook has been let down, 2.0 ft.

Kinetic Energy Before impact

$$KE_1 = \frac{1}{2} m_1 \dot{x}^2 + \frac{1}{2} m_2 \dot{x}^2 + \frac{1}{2} m_3 \dot{x}^2$$

m_1 = mass of

m_2 = mass of h

m_3 = mass of

$m_2 \approx 17002$ lb

ref MCM-1125

Potential Energy before Impact

$$PE = mgh = 0$$

Kinetic Energy After Impact

$$KE = 0$$

Potential Energy After Impact

$$PE = mgh = m_2 g\, l_1 - l_1 \cos\theta_1 + m_3 g\, l_2 - l_2 \cos\theta_2$$

Form 184
(Rev. 12-74)

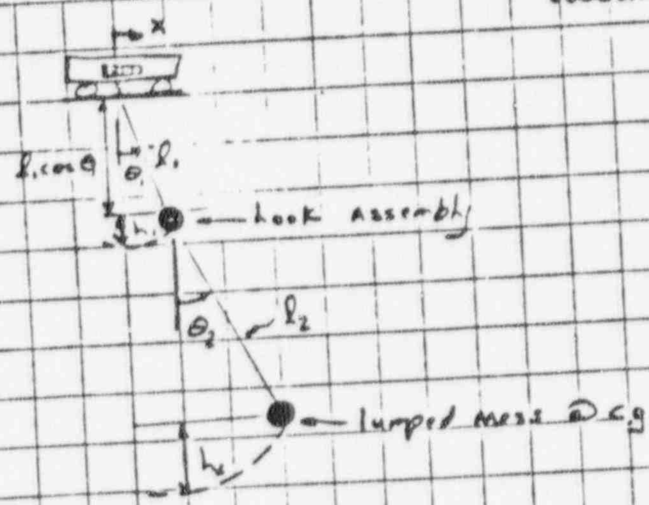
Dev./Station McQuire Nuclear Station Unit 1 & 2 File No. ... 1000 ...

Subject Fuel Cask Displacement By "B" Date 4-28-7...

Checked By Date

Sheet No. 2 of

These calculations haven't been c... because they duplicate the previous c...



Conservation of Energy

$$KE_1 + PE_1 = KE_2 + PE_2$$

$$\frac{1}{2} m_1 \dot{x}^2 + \frac{1}{2} m_2 \dot{x}^2 + \frac{1}{2} m_3 \dot{x}^2 = m_2 g\, l_1 - l_1 \cos\theta_1 + m_3 g\, l_2 - l_2 \cos\theta_2$$

Note: $Mass_2$ of hook assembly is not known. As a v... conservative estimate, its weight will be taken 20^k. Ref. MCM-1125.01-17

$$.5 \frac{(40,000)\,lb}{32.2\ \frac{ft}{sec^2}} \times \left(.833 \frac{ft}{sec}\right)^2 + .5 \frac{(20,000)\,lb}{32.2\ \frac{ft}{sec^2}} \times \left(.833 \frac{ft}{sec}\right)^2 + .5 \frac{(20...}{32...}$$

$$= \frac{20,000\ lb}{32.2 \frac{ft}{sec^2}} \times 32.2 \frac{ft}{sec^2}\ 3.0\,ft\,(1 - \cos\theta_1) + \frac{200,000\ lb}{32.2 \frac{ft}{sec^2}} \times 32.2 \frac{ft}{sec^2} ...$$

Form 181
(Rev. 12.74)

Dev./Station McQuire Nuclear Station Unit 1 & 2 File No. AB 1200.0

Subject Fuel Cask Displacement By "B" Date 4-28-75

Checked By These calculations haven't been checked, they duplicate the preceding calculations Date

Sheet No. 8 of

621.12 ft-lb $+ 310.56$ ft-lb $+ 2155.3$ ft lb

$= 60,000$ ft-lb $(1-\cos\theta_2) + 3000000$ ft-lb $(1-\cos\theta_1)$

3087.0 ft-lb $= 60000$ ft-lb $- 60000$ ft-lb $\cos\theta_2 + 3000000$ ft-lb $- 3000000 \ldots$

Assu. : $\theta_1 = \theta_2$

3056913.0 ft-lb $= 3060000$ ft-lb $\cos\theta$

$$\frac{3056913}{3060000} = \cos\theta$$

$.9989 = \cos\theta$

$\theta = 2.574°$

$h_2 = l_2 (1-\cos\theta_2)$

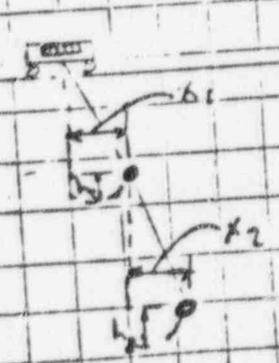
$= 15.0 (1-.9989)$

$= .01513$ ft $= .182$ in

$X_2 = l_2 \sin 2.57°$

$= 15$ ft $(.044906)$

$= .6736$ ft $\times 12$ in/ft



$h_1 = l_1 (1-\cos\theta_1)$

$= 3.0 (1-.9989)$

$= .0033$ ft $= .0396$ in

$x_1 = l \sin 2.574°$

$= 3.0$ ft $\times .04049$

$= .1347$ ft $= 1.6$ inches

Form 184
(Rev. 12-74)

Dev./Station McQuire Nuclear station Unit 1 & 2 File No. AS 1200.0

Subject Fuel Cask Displacement By "B" Date 5-1-75

Sheet No. 9 of Checked By Date

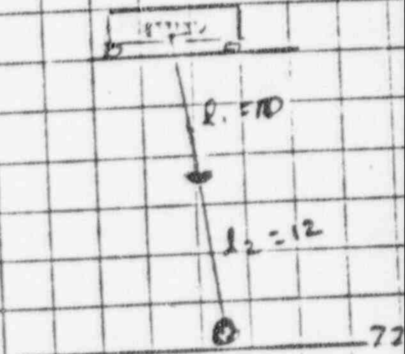
These calculations haven't been checked to duplicate the previous

Cask swinging in lowest possible Position

Case III $l_1 = 10'$ $l_2 = 15'$ $M_1 = 40^k$ $M_2 = 20^k$ $M_3 = 200^k$

Kinetic Energy Before Impact

$$KE_1 = \frac{1}{2} m_1 \dot{x}^2 + \frac{1}{2} m_2 \dot{x}^2 + \frac{1}{2} m_3 \dot{x}^2$$



Potential Energy Before Impact

$$PE_1 = mgh = 0$$

Kinetic Energy After Impact

$$KE_2 = 0$$

Potential Energy After Impact

$$PE_2 = mgh = m_2 g l_1 - l_1 \cos\theta_1 + m_3 g l_2 - l_2 \cos\theta_2$$

Conservation of Energy

$$KE_1 + PE_1 = KE_2 + PE_2$$

$$\frac{(.5)(40{,}000)\,lb}{32.2\,\frac{ft}{sec^2}} \times \left(.833\,\frac{ft}{sec}\right)^2 + \frac{.5(20{,}000)\,lb}{32.2\,\frac{ft}{sec^2}} \times \left(.833\,\frac{ft}{sec}\right)^2 + \frac{.5(200{,}000)\,lb}{32.2\,\frac{ft}{sec^2}} \times (.8\ldots$$

$$= \frac{20{,}000\,lb}{32.2\,\frac{ft}{sec^2}} \times 32.2\,\frac{ft}{sec^2} \times 10\,ft\,(1-\cos\theta_1) + \frac{200000\,lb}{32.2\,\frac{ft}{sec^2}} \times 32.2\,\frac{ft}{sec^2} \times 15\,ft\,(\ldots$$

$\therefore$

$621.12\,ft\cdot lb + 310.56\,ft\cdot lb + 2155.3\,ft\cdot lb = 200000\,ft\cdot lb - 200000\,ft\cdot lb\,\cos\ldots$
$+ 3000000\,ft\cdot lb - 3000000\ldots$

Form 184
(Rev. 12 74)

Dev./Station McGuire Nuclear Station Unit 1 & 2 File No. AB 1000.0

Subject Fuel Cask Displacement By "B" Date 6-1-75

Checked By Date

Sheet No. 2 of

These Calculations haven't been checked because duplicate the preceding calculations

$\therefore$ -3196913.02 ft-lb $= -200020$ ft-lb $\cos\theta_1 - 3000002$ ft-lb $\cos\theta_2$

Divide by -3196913.02 ft-lb

$1 = .0628 \cos\theta_1 + .9384 \cos\theta_2$

(1) $\cos\theta_1 = 15.97 - 14.990 \cos\theta_2$

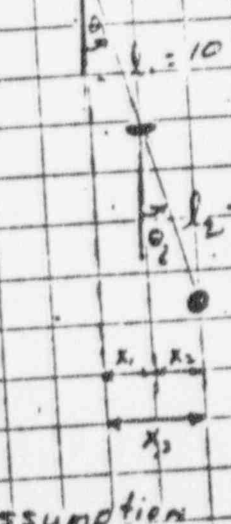
Assume $\theta_1 = \theta_2$ ①

$1 = .0628 \cos\theta_1 + .9384 \cos\theta_2$

$1 = 1.001 \cos\theta_1$

$\cos\theta_1 = \frac{1}{1.0012} = .9990$

$\theta_1 = 2.56° = \theta_2$ say $\theta_1 = 3° = \theta_2$



$x_2 = l_1 \sin 3°$
$= 10\,ft\,(.0523) = .523$ ft $= 6.2$ inches

$x_2 = l_2 \sin 3°$
$= 15\,ft\,(.0523) = .7845$ ft $= 9.414$ in

MAX. Total Displacement of c.g i.e. X_3	$= 9.414$ / $= 15.4$

(center ...)

Assumption

① Since cask is so heavy & will cause so much

Form 184
(Rev. 12-74)

Dev./Station McGuire Nuclear Station Unit 1 & 2 File No. MC 1000.0

Subject Fuel Cask Displacement By "B" Date 5-1-7

Checked By ______ Date ______

These calculations haven't been checked because they duplicate the previous

Sheet No. 11 of

center of mass displaces 15.414"
the lowest point on the cask would displace 21.0" leaving 90" to the wall (see calculations below)

distance from rotation to cg = 25'
Distance from cg to bottom of cask = 8.5

$\therefore$

25' + 8.5' = 33.5

$x = l \sin 3^\circ$
$= 33.5'(.0523)$
$= 1.75'$
$= 21.0"$

Conclusion: For the cask to tumble into the fuel pool area, the center of gravity of the

020.1
(20, 3.4)

Provide the description of the methods for sealing of penetrations, doorways and other openings that could be subjected to flooding. This should include details of penetrations provided in the Auxiliary Building wall for the nuclear service intake pipes from the pond and the low level intake pipe from Lake Norman. Also describe the means provided to periodically check the functional capability of such seals.

Response:

See revised Section 3.4.

020.2
(9.1.2)

Provide the results of an evaluation to demonstrate that dropping of the spent fuel shipping cask in its vertical or tipped position can not permit the cask to enter the spent fuel storage area or damage safety related equipment.

Response:

See revised Subdivision 9.1.2.3.

6

020.3
(9.1.3)
(RSP)

It is our position that any connection with the Spent Fuel Pool Cleanup System should be designed to Seismic Category I requirements, up to and including the first normally closed or automatically closed valve. Figure 9.1.3-1 indicates that 4-inch valve (1KFB3) on the supply line from the refueling water storage tank is Duke Class E, which is not designed for seismic loading. This valve should be seismic Category I and Quality Group C. State your intent to comply with this staff position.

Response:

See revised Figure 9.1.3-1.

EXHIBIT C

9.1.2.3 Safety Evaluation

6 In the fuel storage racks, fuel is stored vertically in an array with a
10 nominal center-to-center distance of 15 1/2 inches between assemblies to assure
K_{eff} <.95 even if immersed in unborated water. The racks are designed to
preclude insertion of fuel assemblies in other than permitted locations,
thereby assuring the necessary spacing between assemblies. To further assure
subcritical arrays in the fuel handling facilities, only one assembly can be
manipulated at a time.

Since each unit has its own fuel pool, there are no safety considerations related to sharing of components.

To preclude the cask entering the spent fuel pool, the cask crane stops are located in a position to prevent the cask from being moved into the fuel pool area. The cask area is separated from the spent fuel pool by a three ft. reinforced concrete wall (Reference Figures 9.1.1-1 and -2).

An evaluation has been performed to assess the possibility of the cask enter-
ing the spent fuel pool in the lifted (vertical) and tipped position. To
evaluate the cask in the lifted position, the crane is assumed to impact
against the crane stops traveling at the maximum crane speed of fifty ft. per
minute with the cask in a position to give the maximum swing and horizontal
6 displacement. Assuming that the cask rotates about the center of the crane
drum and a rigid crane and rail stop, the cask center of gravity remains on
the cask area side of the three ft. divider wall. For details of this cask
position, refer to Figure 9.1.2-1, Sheet 1 of 2. To evaluate the cask in
the tipped position, the cask is assumed to catch the edge of the concrete
wall of the cask area and tip toward the spent fuel pool. For this condition
the maximum envelope (dimensions) are used for the possible casks to be used
at McGuire. As shown in Figure 9.1.2-1, Sheet 2 of 2, the center of gravity
of the cask remains on the cask area side of the divider wall. Based upon
this evaluation it is concluded that the cask would not enter the spent fuel
pool due to maximum horizontal swing or tipping of the cask.

The fuel pool is designed to withstand the following:

a. normal dead and equipment loads plus design seismic loads,

b. all normal dead, equipment and live loads,

c. normal dead and equipment loads plus tornado wind load,

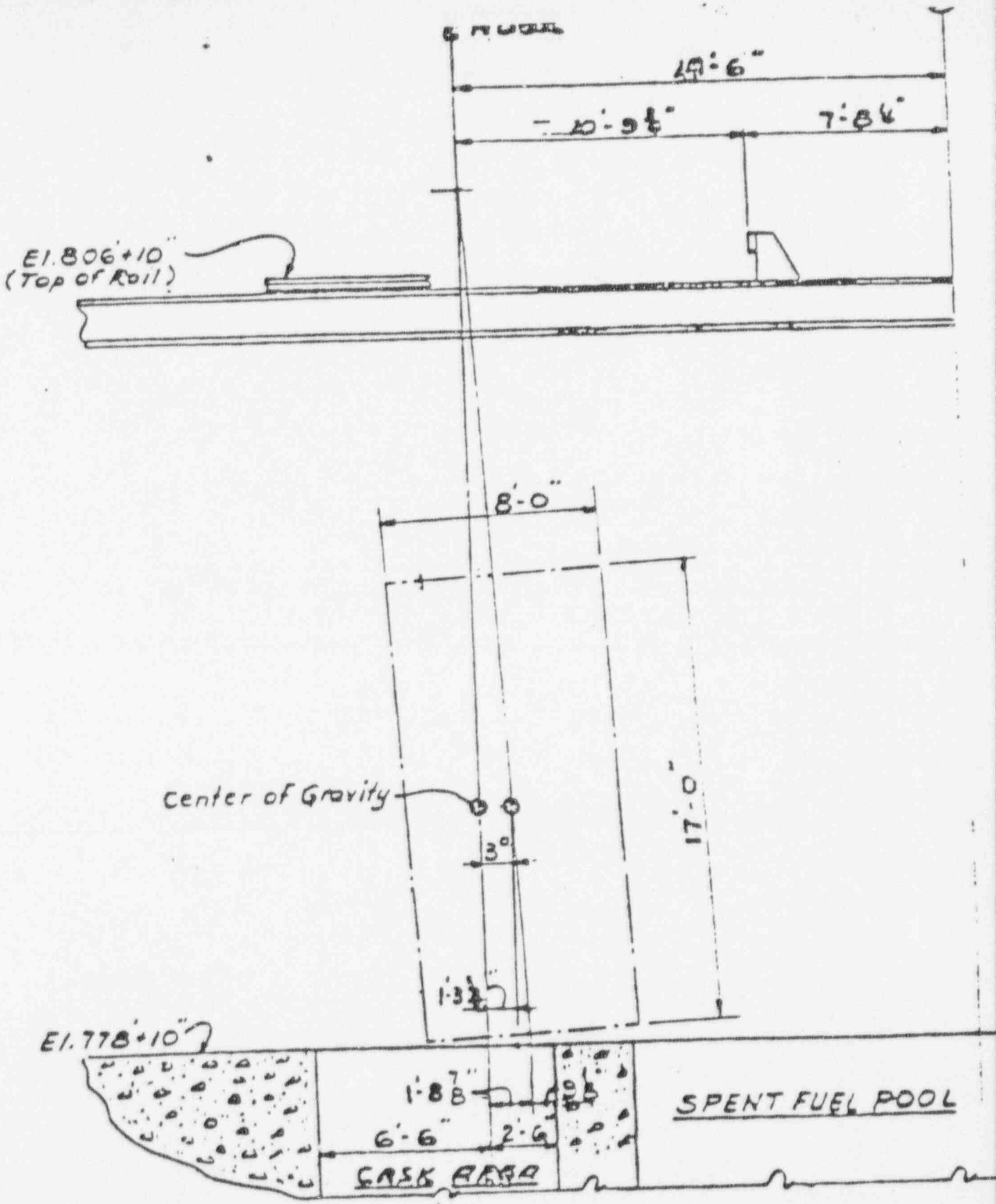
d. thermal stresses, and

e. cask drop accident.

Additionally, Subdivision 9.1.3.3 presents a safety evaluation of the Spent Fuel Cooling System explaining in detail the provisions for continuous spent fuel cooling as required by Regulatory Guide 1.13. These provisions include:

a. redundant active components,

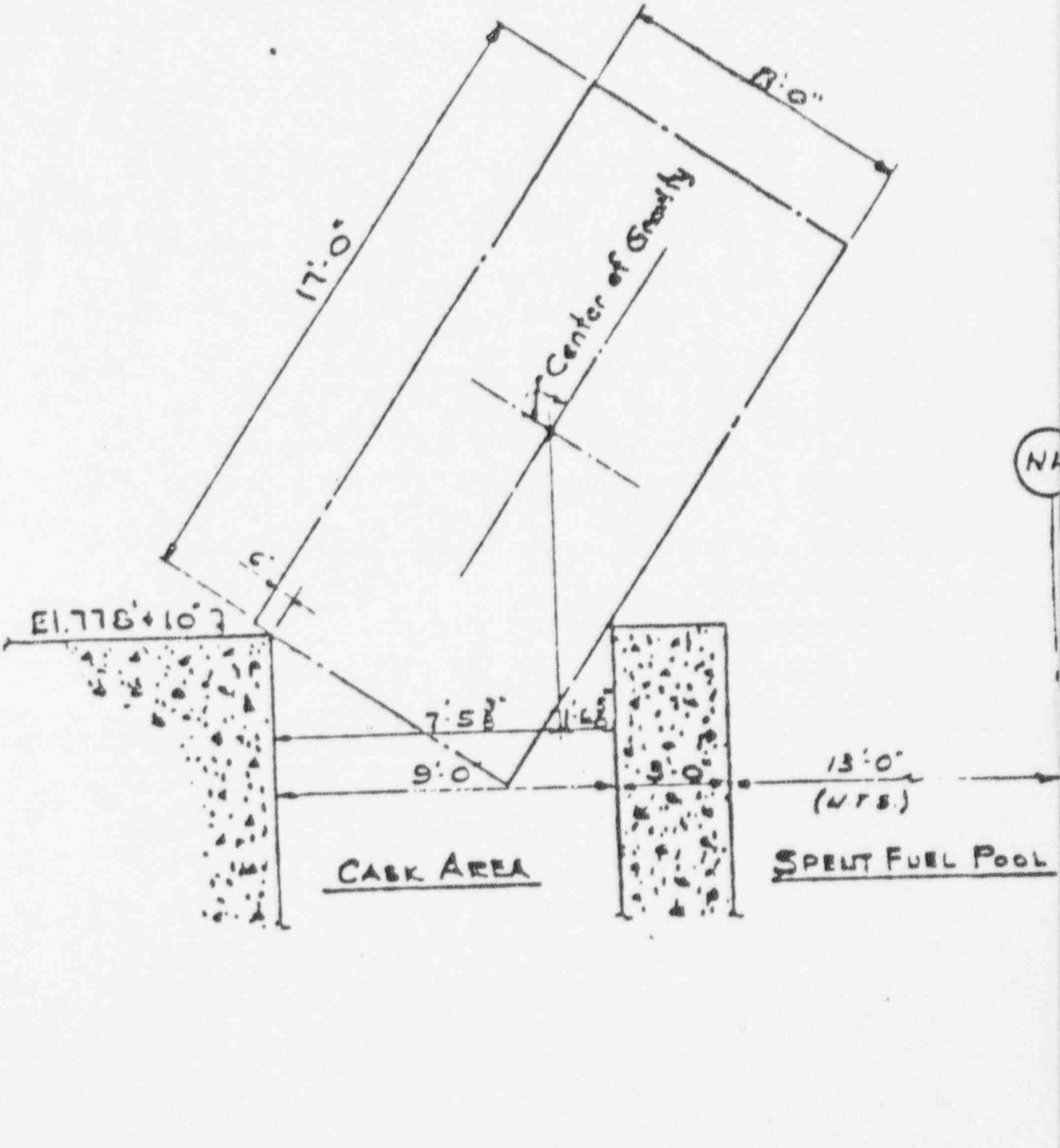
EXHIBIT



CASK DROP EVALUATION

MCGUIRE NUCLEAR STA

Figure 9.1.2-1
(1 of 2)
Revision 6



CASK DROP EVALUATION

McGUIRE NUCLEAR STATION
Figure 9.1.2-1
(2 of 2)
Revision 6

NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

September 14, 1978

MEMORANDUM FOR: John G. Davis, Acting Director
Office of Inspection and Enforcement

FROM: Harold R. Denton, Director
Office of Nuclear Reactor Regulation

SUBJECT: REVIEW FOR POSSIBLE MATERIAL FALSE STATEMENT IN THE McGUIRE NUCLEAR PLANT FSAR

As requested by your memorandum of August 21, 1978, we have reviewed the material you provided relating to a possible material false statement made by Duke Power Company in the McGuire FSAR concerning a dropped fuel shipping cask's capability of entering the spent fuel pool. Based on our review, we are of the opinion that the PSAR response to the staff question on this subject was a material false statement by omission, in that the answer did not include the fact that with regard "case 3," which was part of the licensee's evaluation described in the FSAR, it had been concluded by responsible Duke Power Company officials that the question could not be resolved "until all parameters identifying the cask could be obtained." (Quotations from statement by INDIVIDUAL C ; similar quotes could also be extracted from statements included in the material you provided by other involved Duke personnel.)

With regard to the conclusion reached by Duke personnel that the assumptions used by INDIVIDUAL A in case 3 were conservative, my staff agrees. However, we do not believe that the assumptions used were so unrealistically conservative that one could conclude, without doing or having previously performed further parametric calculations using more realistic assumptions, that the cask could not fall into the fuel pool.

H R Denton

Harold R. Denton, Director
Office of Nuclear Reactor
Regulation

cc: J. Murray, ELD

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