

Calculation Cover Sheet (Cont.)

Calc. No. 91-E-0094-01 Unit: 1

Rev. No: 3 Verification Method: Design Review Design Review: X
Alternate Calculation: _____ Qualification Testing: _____

Pages Revised and/or Added: REVISED 2, 3, 4, 7, 7a, 8 Thru 17 & 19
ADDED 9a, 9b, 6a, 6b, 7c, 8a, 8b, 9a, 9b, 10a, 10b, 10c
12a, 14a, 15a & 16a

Purpose of Revision: TO ADDRESS THE IMPACT ON 27' SLAB
SPAN DUE TO 17 TON CASK DROP

Initiating Documents	Resulting Document(s)	Reference Calcs.
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

Amends Calc(s): CIVIL CALC. 11406-136

Supersedes Calc(s): _____

Computer Software(Ver.): _____
By: TONY DUB / TD / 10/17/91 Rvw'd: ND / 1 / 1
Chk'd: KEVIN BOND / KB / 10/15/91 Apv'd: DOYLE G. ADAMS / DA / 10.15.91
(Print Name) (Initials) (Date) (Print Name) (Initials) (Date)

Rev. No: _____ Verification Method: _____ Design Review: _____
Alternate Calculation: _____ Qualification Testing: _____

Pages Revised and/or Added: _____

Purpose of Revision: _____

Initiating Documents	Resulting Document(s)	Reference Calcs.
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

Amends Calc(s): _____

Supersedes Calc(s): _____

Computer Software(Ver.): _____
By: _____ Rvw'd: _____
Chk'd: _____ Apv'd: _____
(Print Name) (Initials) (Date) (Print Name) (Initials) (Date)

9110290157 911016
PDR ADOCK 05000313
P PDR

Check if Additional Revisions _____



ARKANSAS NUCLEAR ONE

Calculation Cover Sheet (Cont.)

Calc. No: 91-E-0094-01 Unit: 1

Rev. No: 1 Verification Method: Design Review Design Review: X
 Alternate Calculation: _____ Qualification Testing: _____
 Pages Revised and/or Added: REVISED PG 3, 4, 7 & 18, ADDED PG. 79
ADDED 17' SPAN (15 Pgs)

Purpose of Revision: TO QUALIFY UNIT-1 CONTROL RM. SLAB FOR 17 TON
CASK DROP w/ 27' SPAN.

Initiating Documents	Resulting Document(s)	Reference Calcs.
_____	_____	<u>11406-130 (Civil)</u>
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

Amends Calc(s): CIVIL CALC. 11406-130

Supersedes Calc(s): _____

Computer Software(Ver.): _____
 By: TONY DIB / TD / 9/19/91 Rvw'd: _____ / _____ / _____
 Chk'd: KEH BENO / KB / 9/19/91 Apv'd: DOYLE G. ADAMS / DA / 9/29/91
(Print Name) (Initials) (Date) (Print Name) (Initials) (Date)

Rev. No: 2 Verification Method: _____ Design Review: X
 Alternate Calculation: _____ Qualification Testing: _____
 Pages Revised and/or Added: REVISED PG. 19

Purpose of Revision: TO ADDRESS SPALLING DUE TO 17 TON CASK
DROP.

Initiating Documents	Resulting Document(s)	Reference Calcs.
_____	_____	<u>11406-130 (Civil)</u>
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

Amends Calc(s): CIVIL CALC. 11406-130

Supersedes Calc(s): _____

Computer Software(Ver.): _____
 By: TONY DIB / TD / 10-1-91 Rvw'd: _____ / _____ / _____
 Chk'd: KEH BENO / KB / 10-1-91 Apv'd: DOYLE G. ADAMS / DA / 10-1-91
(Print Name) (Initials) (Date) (Print Name) (Initials) (Date)

Check if Additional Revisions _____



ARKANSAS NUCLEAR ONE

Calculation Cover Sheet

Calc. No: 91-E0094-01
 Calc. Title: 17 TON CASK
DROP ANALYSIS FOR
CONCRETE FLOOR ABOVE
UNIT-1 CONTROL ROOM
 Component No(s): -

Unit: 1 Category: 2
 System(s): -
 Topic(s): STRU.
 Calc. Type: CG.
 Plt Area: Bldg. 1AB Elev. 404
 Room _____ Wall _____
 Coordinates: _____

Abstract (Include Purpose/Results): _____

PURPOSE: TO EVALUATE / PERFORM 17 TON (712 mm) CASK
DROP ANALYSIS, LIMITED TO 9" DROP FOR THE FLOOR
ABOVE THE UNIT-1 CONTROL ROOM.

RESULTS: 1) THE FLOOR IS QUALIFIED FOR MAX. OF 3" DROP
WITHOUT HEXAGONAL HONEYCOMB ENERGY ABSOR. MAT'L.
2) THE FLOOR IS QUALIFIED FOR 9" DROP WITH 3"
OF HEXAGONAL HONEYCOMB ENERGY ABSOR. MAT'L.
(200 PSI)

Rev. No: 0 Verification Method: Design Review: X
 Alternate Calculation: _____ Qualification Testing: _____
 Pages Revised and/or Added: ALL NEW AG 1 THRU 19

Purpose of Revision: SAME AS ABSTRACT.

Initiating Documents	Resulting Document(s)	Reference Calcs.
_____	_____	<u>11406-130 (CIVIL)</u>
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

Amends Calc(s): CIVIL CALC. 11406-130

Supercedes Calc(s): -


Computer Software(Ver.): _____
 By: Tony Doherty / TD / 8/8/91 Rvw'd: KEJ BAKER / MS / 8-12-91
 Chk'd: Kirby Bushong / KBS / 8/9/91 App'd: H. NUGENT / David J. Linn / HW / 8-9-91 / 2/91
Print Name Initial Date Print Name Initial Date


Check if Additional Revisions: _____



ARKANSAS NUCLEAR ONE

TABLE OF CONTENTS

Table of Contents _____	Page	1
Purpose _____		2
References _____		2a 
Notes and Assumptions _____		3
Calculation _____		4 - 18
Conclusion _____		19

				 Entergy Operations ARKANSAS NUCLEAR ONE	CALCULATION NUMBER	
3	10/10/91	TD	<i>VJS</i>		91-E-0094-01	
0	8/8/91	TD	<i>KOB</i>	PAGE NUMBER	1 OF 19	
REV.	DATE	BY	CHK'D			

PURPOSE:


To evaluate and perform shipping cask drop analysis for the concrete floor area above the ANO-1 Control Room, with and/or without hexagonal honeycomb, using the following data:

- Shipping cask diameter = 712 mm = 28"
- Shipping cask weight = 17 Ton, use 35 kips
- maximum drop = 9"

DESIGN APPROACH:

Using Bechtel Topical Report BC-TOP-9A, Rev. 2, an analysis will be performed utilizing Kinetic Energy Formulas to determine the true Kinetic Energy the slab may absorb. Steps in this analysis are:

- 1) Establish four different loading cases taken for this analysis, page 3 to page 4a.
- 2) Determine the combined moment of inertia for the structure, page 5 to page 6.
- 3) Calculate the maximum moment Mu capacity of the slab for all four (4) cases, page 6a to page 6b.
- 4) Calculate the ultimate load (Pu) based on Mu for each of the four cases, page 7 to page 8.
- 5) Calculate the deflection (Δu) based on Pu for each of the four cases, page 7 to page 8.
- 6) Calculate the ultimate shear capacity of the slab, Vmax. based on concrete/reinforcement strength, page 8a to page 9a.
- 7) Calculate the maximum Ps to cause Vmax. for each of the four (4) cases, page 8b to page 9a.
- 8) Calculate the deflection due Ps and compare with deflections due to Pu and dead weight of slab, for each of the four (4) cases. page 9a to page 9a.
- 9) Check bond stress at the face of concrete wall, page 9b to page 9b.
- 10) Plot the deflection VR load curve to calculate the kinetic energy for each of the four (4) cases, page 10C.
- 11) Calculation of maximum drop height of cask that the slab can take based on equivalency of strain energy to kinetic energy, page 11 to page 12a.

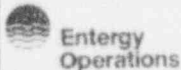
				 Entergy Operations ARKANSAS NUCLEAR ONE	CALCULATION NUMBER 91-E-0094-01	
					PAGE NUMBER 2 OF 19	
3	10/19/91	TD	VJS			
REV.	DATE	BY	CHK'D			

DESIGN APPROACH: (cont.)

- 12) Calculation of the required energy absorption material required for 9" cask drop, page 13 to page 13,
- 13) Calculation of the safety factors using the max. allowed height drop without any energy absorption material for all four cases, page 14 to page 16.
- 14) Calculation of the safety factors using 3" energy absorption material with 9" cask drop, page 17 to page 18,

REFERENCES:

- 1) ACI 318-77
- 2) ACI 318-63
- 3) Topical Report BC-TOP-9A Rev. 2
- 4) Civil Calculation No. 88 Book 26, Pg. J23-J26 & J70-J78
- 5) Civil Calculation No. 11406-130
- 6) Reinforced Concrete Design by Wang & Salmon, Third Ed
- 7) Drawing No. C-206 Rev. 16
- 8) Drawing No. C-212 Rev. 9
- 9) AISC Eighth Edition
- 10) Design of Concrete Structures by Winter & Nilson
- 11) Calculation NO. 83-D-2200-11 Pg. 124 of 555
- 12) Specification 6600-C-302

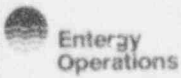
				 Energy Operations	CALCULATION NUMBER	
					91-E-0094-01	
				ARKANSAS NUCLEAR ONE	PAGE NUMBER	2a OF 19
3	10/10/91	TD	VCS		REV.	DATE

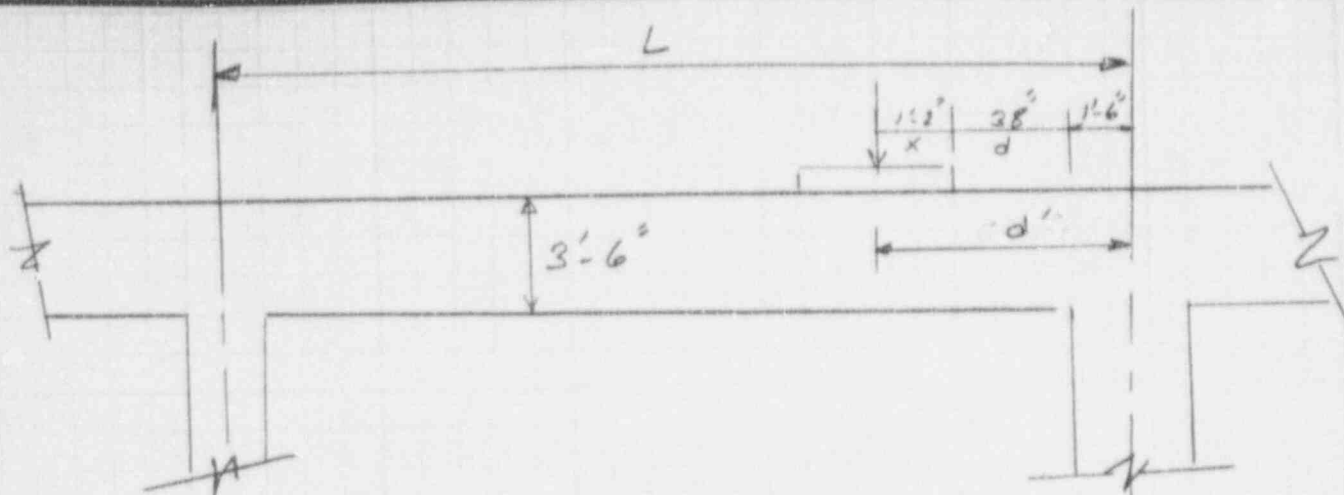
NOTES AND ASSUMPTIONS:

- 1) $f'_c = 4850$ psi @ 28 days (Pour No. 517) (Ref. no. 11)
 $f'_c = 6230$ psi @ 90 days (Pour No. 517) (Ref. no. 11)
 $f'_c = 6230 \times 1.1 = 6850$ psi @ 4 years (Ref. 10)
 Use $f'_c = 6500$ psi @ 4 years (Conservative)
 $F_y = 48300$ psi per mil. test report (Ref. no. 5)

- 2) This calculation is to qualify the slabs between Column Lines B, C, and the north face of the Cask Pit which is located 3 feet north of Column Line D, and Column Lines 4 and 5. The span length between B and C is 27 feet. The span between C and the north face of the Cask Pit is 24 feet. Four cases were considered in this calculation:
Case # 1 : Span length = 24 feet and the cask drop location is at a distance equal to the effected depth of the slab from the face of the wall.
Case # 2 : Span length = 27 feet and the cask drop location is at a distance equal to the effected depth of the slab from the face of the wall.
Case # 3 : Span length = 24 feet and the cask drop location is at Mid Span.
Case # 4 : Span length = 27 feet and the cask drop location is at Mid Span.

These four (4) loading cases will provide worst condition stress in the slab for each load drop.

				 Energy Operations	CALCULATION NUMBER 91-E-0094-01	
					ARKANSAS NUCLEAR ONE	PAGE NUMBER 3 OF 19
3	10/10/91	TD	VW			
REV.	DATE	BY	CHK'D			



CASE # 1 & 2

$X = \frac{1}{2}$ (DIA. OF CASK) = $\frac{1}{2}$ (28") = 14" = 1'-2" (Ref. Pg. 2)

$t =$ Slab Thickness = 3'-6" = 42" (Ref. # 7 & 8)

$d =$ Effective Depth = $t - 4" = 42" - 4" = 38"$ (Ref. # 7 & 8)

Reinforcing Rebars:

This slab has Top and Bottom reinforcing rebars. To be conservative, ignore the Top rebars. Bottom rebars are 3 # 11 per foot. (Ref. # 7 & 8)

5 stirrups @ 3'-10" in E-W (Ref. # 7 & 8)
 # 5 stirrups @ 1'-0" in N-S (Ref. # 7 & 8)


For this case, the critical location for moment and shear is @ a distance d from the face of the wall and the load is located at a distance (d') from the center of the wall. $d' = X + d + \frac{1}{2}$ wall thickness

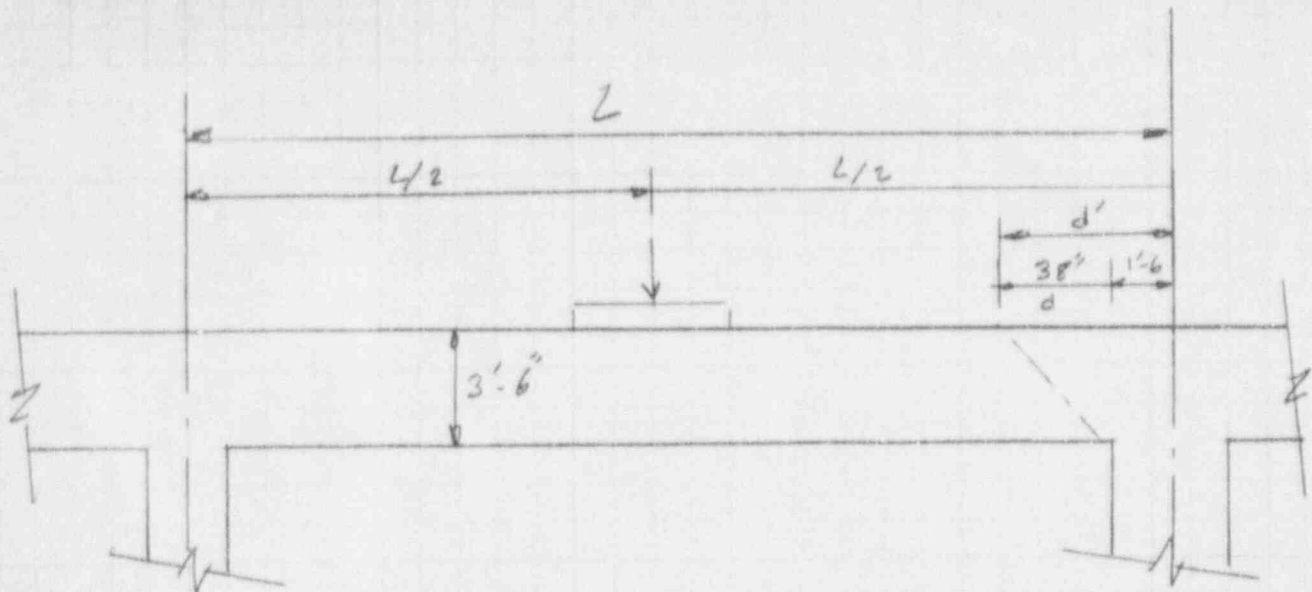
$d' = 1'-2" + 3'-2" + 1'-6" = 5'-10"$

Used distance $d' = 6'-0"$ from the center of the wall.

$L = 24'$ for Case # 1

$L = 27'$ for Case # 2

				 ARKANSAS NUCLEAR ONE	CALCULATION NUMBER	
					91-E-0094-01	
3	10/10/91	TD	VAS		PAGE NUMBER	4 OF 19
REV.	DATE	BY	CHK'D			



CASE # 3 & 4

$X = \frac{1}{2} (\text{DIA. OF CASK}) = \frac{1}{2} (28") = 14" = 1'-2"$ (Ref. Pg. 2)

$t = \text{Slab Thickness} = 3'-6" = 42"$ (Ref. # 7 & 8)

$d = \text{Effective Depth} = t - 4" = 42" - 4" = 38"$ (Ref. # 7 & 8)

Reinforcing Rebars:

This slab has Top and Bottom reinforcing rebar. To be conservative, ignore the Top rebar. Bottom rebar are 3 # 11 per foot. (Ref. # 7 & 8)

5 stirrups @ 3'-10" in E-W (Ref. # 7 & 8)

5 stirrups @ 1'-0" in N-S (Ref. # 7 & 8)

For this case, the critical location for moment is @ mid span and the critical location for shear is @ a distance d from the face of the wall or at a distance (d') from the center of the wall.
 $d' = d + \frac{1}{2} \text{ wall thickness}$

$d' = 3'-2" + 1'-6" = 4'-8"$ (Ref. # 1, Sec. 11.1.3.1)

$L = 24'$ for Case # 3

$L = 27'$ for Case # 4

					CALCULATION NUMBER	
						91-E-0094-01
				ARKANSAS NUCLEAR ONE	PAGE NUMBER	40 OF 19
3	10/10/91	TD	VJB			
REV.	DATE	BY	CHK'D			

CALCULATION:

CALCULATE THE BEAM PROPERTIES

I. EFFECTIVE WIDTH OF BEAM = b

$$b = T + 2d$$

$T =$ Dim. OF CASK = 710mm = 2'-4" (REF. PG. 2)

$d =$ distance FROM EXTREME COMPRESSION FIBER TO the Centroid OF the tension reinforcing.

$$d = 3'-2" \text{ (SEE PG 4-4a)}$$

$$\therefore b = 2'-4 + 2(3'-2") = 8'-8" = 8.66'$$

$$= 104 \text{ in}$$

USING BC-TOP-9 (REF #3 FORMULA 4-2)

$$I_a = \frac{1}{2} (I_g + I_c) = \frac{1}{2} \left(\frac{bt^3}{12} + Fbd^3 \right)$$

where:

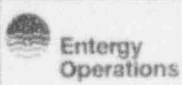
$I_a =$ AVERAGE MOMENT OF INERTIA

$I_g =$ MOMENT OF INERTIA OF GROSS CONCRETE

$I_c =$ MOMENT OF INERTIA OF THE CRACKED CONCRETE sec.

$t =$ THICK. OF THE BEAM = 42" = 3.5' (FLOOR)

$F =$ COEFFICIENT FOR MOMENT OF INERTIA OF CRACKED SECTION w/ TENSION REINFORCING ONLY.

				 Entergy Operations	CALCULATION NUMBER	
					91-E-0094-01	
				ARKANSAS NUCLEAR ONE	PAGE NUMBER	5 OF 19
0	8/8/91	TJ	KDZ			
REV.	DATE	BY	CHK'D			

CALCULATION: (Cont.)

$$\rho = \frac{A_s}{bd} \quad (\text{Ref \# 1, Chapter 8})$$

Where A_s = Area of Tensile reinforcing steel / i.e.
 FOR 3 # 11 = $3 \times 1.56 = 4.68 \text{ in}^2$ (see PG. 4-4a)

$$\rho = \frac{3 \times 1.56}{12'' \times 38''} = 0.010263$$

$$E_c = w^{1.5} 33 \sqrt{f'_c} \quad (\text{Ref \# 1, 8.5.1}), w = 145 \text{ lb/ft}^3 \quad (\text{Ref \# 5})$$

$$E_c = (145)^{1.5} 33 \sqrt{6500} = 4,887,733 \text{ PSI}$$

USE $E_c = 4888 \text{ KSI}$
 (Ref # 5)

$$E_s = 29 \times 10^6 \text{ PSI}$$

$$n = \frac{E_s}{E_c} = \frac{29,000,000}{4,887,733} = 6$$

3

USE $n = 6$

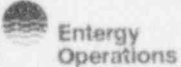
FROM FIG. 4-1 OF BC-TOP-9 (Ref-# 3)

$$(\rho = 0.010263, n = 6) \Rightarrow F = 0.045$$

$$\therefore I_a = \frac{1}{2} \left(\frac{104''(42'')^3}{12} + 0.045 \times 104'' \times 38''^3 \right)$$

$$I_a = \frac{1}{2} (642096 + 256801)$$

$$I_a = 449448 \text{ in}^4$$

				 Entergy Operations	CALCULATION NUMBER	
					ARKANSAS NUCLEAR ONE	91-E-0094-01
3	10/10/91	TD	VJR		PAGE NUMBER	6 OF 19
0	8/8/91	TD	KDZ			
REV.	DATE	BY	CHK'D			

CALCULATION :

CALCULATE THE MAX. MOMENT CAPACITY OF THE SLAB (M_u) USING TENSION REINFORCEMENT ONLY

$$M_u = \phi [A_s F_y (d - a/2)] \quad (\text{REF \#6, EQ. 3.3.4})$$

WHERE $\phi = 0.9$ (REF \#1)

$A_s =$ AREA OF TENSION STEEL $= 4.68 \text{ in}^2/\text{FT}$ (REF)

$$a = \frac{A_s F_y}{0.85 F'_c b} = \frac{4.68 \text{ in}^2/\text{FT} \times 8.66' \times 48.3 \text{ KSI}}{0.85 \times 6.5 \text{ KSI} \times 8.66' \times 12''}$$

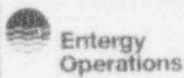
$$a = 3.41''$$

$$\Rightarrow M_u = 0.9 [4.68 \text{ in}^2/\text{FT} \times 8.66 \text{ FT} \times (3' - \frac{3.41''}{2}) \times \frac{1 \text{ FT}}{12''}]$$

$$M_u = 5328.6 \text{ K-FT}$$

USING BEAM FORMULAS, CALCULATE THE MAX. LOAD P_u THAT THE SLAB CAN TAKE, USING MAX. MOMENT CAPACITY OF THE BEAM M_u .


CONSIDER A S.S. BEAM, FIND THE MAX. P_u IN ADDITION TO D.W. OF THE BEAM IN ALL FOUR CASES ADDRESSED ON SHT-3.

				 Entergy Operations	CALCULATION NUMBER	
					ARKANSAS NUCLEAR ONE	91-E-0094-01
?	10/10/91	TD	VLS		PAGE NUMBER	6a OF 19
REV.	DATE	BY	CHK'D			

CALCULATION:

PG NO 7 TO PG NO 8 CALCULATED, FOR EACH OF THE FOUR (A) CASES ADDRESSED ON PG 3, THE MAX. LOAD "Pu" THAT THE SLAB CAN TAKE, IN ADDITION TO THE D.W. OF THE SLAB, WHICH WILL IMPOSE A MOMENT EQUAL TO THE MAX. CAPACITY OF THE SLAB M_u (SEE PG 6a)

ALSO, DEFLECTIONS @ Pt. OF LOAD DUE TO THE MAX LOAD P_u (ULTIMATE) WERE CALCULATED, WHICH WILL BE USED LATER IN THIS CALCULATION TO FIND THE KINETIC ENERGY THIS SLAB WOULD ABSORBE IN EACH OF THE 4 CASES.

				 Energy Operations ARKANSAS NUCLEAR ONE	CALCULATION NUMBER	
					91-E-0094-01	
3	10/10/91	TD	VJB		PAGE NUMBER	66 OF 19
RLV.	DATE	BY	CHK'D			

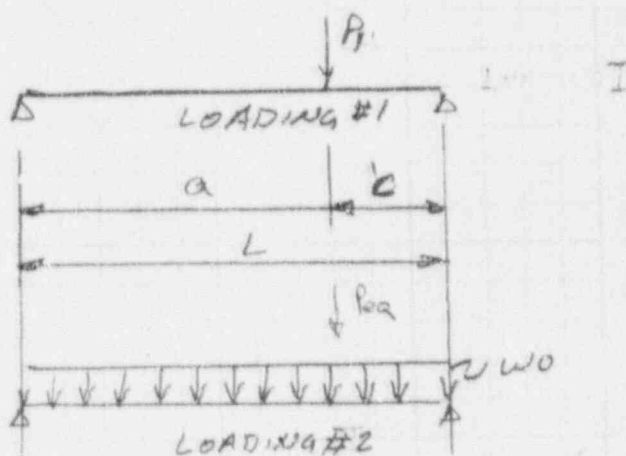
FOR CASE # 1 & 2, CALCULATE THE MAX LOAD P_u , IN ADDITION TO D.W. OF THE BEAM, @ DISTANCE d FROM THE FACE OF THE WALL.

LOADING #1

$$M_u = \frac{P_1 a c}{L} \quad (\text{Ref \# 9})$$

$$\Rightarrow P_1 = \frac{M_u L}{a c}$$

LOADING #2



w_0 = wt. OF CONCRETE BEAM.

$$w_0 = b \times H \times .15 \quad (\text{USE WT. OF CONCRETE } .15 \text{ K/ft}^3)$$

$$w_0 = 8.66' \times 3.5' \times .15 \text{ K/ft}^3 = 4.546 \text{ K/ft}$$

\Rightarrow EQUIVALENT CONCENT. LOAD OF P_{eq}

$$M_0 = \frac{w_0 a}{2} (L-a) = P_{eq} \frac{a c}{L} \quad \text{--- Ref \# 9}$$

$$\Rightarrow P_{eq} = \frac{M_0 L}{a c} = \frac{w_0 a}{2} (L-a) \left(\frac{L}{a c} \right)$$

				 Energy Operations ARKANSAS NUCLEAR ONE	CALCULATION NUMBER	
					91-E-0094-01	
3	10/10/91	TD	WSP		PAGE NUMBER	7 OF 19
REV.	DATE	BY	CHK'D			

CALCULATION:

$$P_u = \frac{M_u L}{a \times c} - \frac{1}{2} w_o \times a (L-a) \times \frac{L}{a+c}$$

$$P_u = \frac{L}{a \times c} [M_u - \frac{1}{2} w_o \times a (L-a)] \quad (1)$$

FOR $L = 24'$ (CASE # 1)

$a = 18' = (L - d')$ (see pg. 4)

$c = 6' = d'$

$$P_u = \frac{24'}{6' \times 18'} [5328.6 \text{ K}' - \frac{1}{2} \times (8.66' \times 3.5' \times 15 \text{ K/ft}^2) \times 18' (24' - 18')]$$

$$P_u = 1184.1' - 54.56 \text{ K} = 1129.6 \text{ K}$$

- CALCULATE THE DEFLECTION Δ_u DUE TO P_u & D.W.

$$\Delta_u = \frac{P_u a^2 c^2}{3 E I L} + \Delta_o \quad (\text{Ref # 9})$$

Def D.W. = $[\frac{1}{2} \times (8.66' \times 3.5' \times 15 \text{ K/ft}^2) \times 18' (24' - 18')] [\frac{24'}{6' - 18'}] = 54.56 \text{ K}$

$\Delta_o = \text{DEF. DUE TO D.W.}$


$$\Delta_o = \frac{w_o}{24 E I L} (L^3 - 2 L c^2 - c^3) \quad (2) \quad (\text{Ref-9})$$

$$\Delta_o = \frac{(8.66' \times 3.5' \times 15 \text{ K/ft}^2) \times 6'}{24' \times 4888 \text{ KSI} \times 449,448 \text{ in}^4} [(24')^3 - 2(24')(6')^2 + (6')^3] (\frac{12'}{\text{ft}})^3$$

$$\Delta_o = 0.017'' \text{ Due to D.W. per } 54.56 \text{ K}$$

$$\Delta_u = \frac{1129.6 \text{ K} (6' \times 18')^2 (12'/\text{ft})^3}{3 \times 4888 \text{ KSI} \times 449448 \text{ in}^4 \times 24'} + 0.017'' =$$

$$\Delta_u = .156''$$

				 Entergy Operations ARKANSAS NUCLEAR ONE	CALCULATION NUMBER	
					91-E-0094-01	
3	10/10/91	TD	VSS		PAGE NUMBER	7a OF 19
REV.	DATE	BY	CHK'D			

CALCULATION CONT.

USING THE SAME METHOD AS IN CASE #1, CALCULATE
MAX. P_u & Δ_u FOR CASE #2

FOR $L = 27'$ (CASE #2, SEE PG. 3)

$$a = L - d' = 27' - 6' = 21'$$

$$c = d' = 6'$$

FROM EQ. (1) ON PG 7a

$$P_u = \frac{27}{21 \times 6'} [5328.6 \text{ K} - \frac{1}{2} \times (8.66' \times 3.5' \times .15 \text{ K/FT}) \times 21 (27' - 21')]$$

$$P_u = 1141.8 - 61.38 = 1080.5 \text{ KIPS}$$

* EQUIV. D.W. LOAD = 61.38

$$\Delta_u = \frac{P_u^2 c^2}{3 E_c I_b L} + \Delta_0 \quad (\text{REF \# 9, 2-116})$$

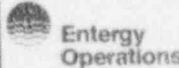
FROM EQ. (2) ON PG. 7a

$$\Delta_0 = \frac{(8.66' \times 3.5' \times .15 \text{ K/FT}^3) \times 6'}{24' \times 4888 \text{ KSI} \times 449448.144} [(27')^3 - 2(27')(6')^2 + (6')^3] \left[\frac{12''}{1 \text{ FT}} \right]^3$$

$$\Delta_0 = 0.016''$$

$$\Delta_u = \frac{1080.5 \text{ K} (6')^2 (21')^2 \left(\frac{12''}{1 \text{ FT}} \right)^3}{3 \times 4888 \text{ KSI} \times 449448 \text{ IN}^2 \times 24'} + 0.016''$$

$$\Delta_u = 0.182''$$

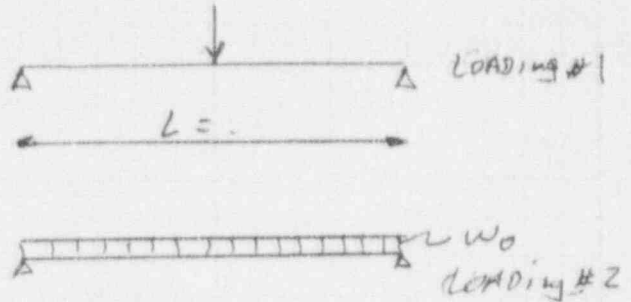
				 Entergy Operations	CALCULATION NUMBER	
					ARKANSAS NUCLEAR ONE	91-E-0094-01
3	10/10/91	TD	VJB	PAGE NUMBER	76 OF 19	
REV.	DATE	BY	CHK'D			

FOR 'L'-SPAN & LOAD @ MID SPAN.

LOADING #1

$$M = \frac{PL}{4} \Rightarrow \text{(Ref #9) Pg. 2-116 (7)}$$

$$Q = \frac{Mu \times 4}{L}$$



LOADING #2

$$w_0 = b \times H \times .15$$

$$w_0 = 8.66' \times 3.5' \times .15 \text{ K/ft}^2$$

$$M @ \text{MID SPAN} = \frac{wL^2}{8} = P_{eq} \times \frac{L}{4} \Rightarrow P_{eq} = \frac{4wL^2}{8L}$$

(Ref #9) Pg. 2-114 (1)

$$P_u = \text{LOADING \#1} - \text{LOADING \#2}$$

$$P_u = \frac{Mu \times 4}{L} - \frac{wL^2}{8} \times \frac{4}{L}$$

$$P_u = \frac{4}{L} \left[Mu - \frac{wL^2}{8} \right] \quad \text{--- (3)}$$

FOR L = 24' (CASE #3)

$$P_u = \frac{4}{24'} \left[5328.6 \text{ KHS} - \frac{1}{8} (8.66' \times 3.5' \times .15 \text{ K/ft}^2) (24')^2 \right]$$

$$P_u = 88.11^* - 54.56^* = 819.5$$

$$P_u = 833.5 \text{ KIPS}$$

$$\Delta_u = \frac{PL^3}{48EI_2} + \Delta_0 \quad \text{(Ref #9) Pg. 2-116 (7)}$$

$$\Delta_0 = \frac{5wL^4}{384EI_2} \quad \text{(Ref #9) Pg. 2-114 (1)}$$

*equiv. P For D.W = 54.56 K ← Pg 72

				Energy Operations ARKANSAS NUCLEAR ONE	CALCULATION NUMBER	
					91-E-0094-01	
3	10/10/91	TD	VCS	ARKANSAS NUCLEAR ONE	PAGE NUMBER	7C OF 19
REV.	DATE	BY	CHK'D		PAGE NUMBER	

CALCULATION (CONT.)

$$\Delta_0 = \frac{5 \times (8.66' \times 3.5' \times .15 \text{ K/FT}^2) \times (24')^4 \times \left(\frac{12''}{1\text{FT}}\right)^3}{384 \times 4888 \text{ KSI} \times 449448 \text{ IN}^4} = .0154''$$

$$\Delta_u = \frac{833.5 \text{ K} \times (24')^3 \times \left(\frac{12''}{1\text{FT}}\right)^3}{48 \times 4888 \text{ KSI} \times 449448 \text{ IN}^4} + .0154 =$$

$$\Delta_u = .204$$

FOR $L = 27'$ (CASE # 4)

USING EQ. NO. (3) ON PG. 7C

$$P_u = \frac{4}{27'} \left[5328.6 \text{ K} - \frac{1}{8} (8.66' \times 3.5' \times .15 \text{ K/FT}^2) (27')^2 \right]$$

$$P_u = 789.4 \text{ K} - 61.38 \text{ K} = 728.0 \text{ KIPTS.}$$

* CR. P FOR D.W = 61.38 K ← PG. 7b


$$\Delta_u = \frac{PL^3}{48E_c I_a} + \Delta_0 \quad (\text{REF # 9, PG. 2-116 (7)})$$

$$\Delta_0 = \frac{5WL^4}{384E_c I_a} = \frac{5 \times (8.66' \times 3.5' \times .15 \text{ K/FT}^2) (27')^4 \times \left(\frac{12''}{1\text{FT}}\right)^3}{384 \times 4888 \text{ KSI} \times 449448}$$

$$\Delta_0 = .0246''$$

$$\Delta_u = \frac{728 \text{ K} \times (27')^3 \times \left(\frac{12''}{1\text{FT}}\right)^3}{48 \times 4888 \text{ KSI} \times 449448 \text{ IN}^4} + .0246'' = .260''$$

$$\Delta_u = .260''$$

				 Energy Operations ARKANSAS NUCLEAR ONE	CALCULATION NUMBER	
					91-E-0094-01	
3	10/10/91	JD	WAS		PAGE NUMBER	8 OF 19
REV.	DATE	BY	CHK'D			

CALCULATION (CONT.)

CALCULATE THE MAX. SHEAR CAPACITY OF THE SLAB
 II MAX. SHEAR CAPACITY

a) SHEAR CARRIED BY CONCRETE

$$V_c = \phi (1.9 \sqrt{f'_c} + 2500 \rho \frac{V_d}{m}) b d \quad (\text{Ref \#1 of 11-6})$$

where $\frac{V_d}{m} = 1$ (Ref #1, section 11) (Factor 1.9)
 $\phi = .85$ For SHEAR (Ref #1 sec. 11)

$$V_c = .85 (1.9 \sqrt{6500 \text{ PSI}} + 2500 \times 1.010263) (104" \times 38")$$

$$V_c = 600,760 \text{ Lb} < 3.5 \sqrt{f'_c} \times b d = 1,115,171 \text{ Lb}$$

$$= 3.5 \sqrt{6500 \text{ PSI}} (104" \times 38") = 1,115,171 \text{ Lb}$$

(Ref #1, eq. 11-6)

$$\therefore V_c = 600.76 \text{ KIPS}$$

b) SHEAR CARRIED BY WEB REINFORCEMENT

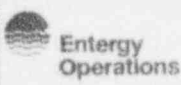
(#5 STIRRUPS @ 3'-10" in E-W = 46" (Ref #8)
 1'-0" in N-S = 12" (Ref #8))

$$A_v = 0.31 \text{ in}^2 \quad (\text{Consider one leg})$$

$$V'_c = \phi \frac{A_v f_y}{b w_s} b d \quad (\text{Ref \#6, 5.10.7})$$

$$V'_c = .85 \times \frac{.31 \text{ in}^2 \times 48300 \text{ PSI}}{46" \times 12"} \times 104" \times 38" = 91,118 \text{ Lb} = 91.1 \text{ K}$$

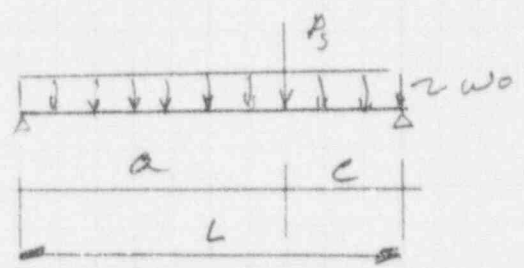
$$V_{max} = V_c + V'_c = 600.76 \text{ K} + 91.1 \text{ K} = 691.86 \text{ K}$$

				 Energy Operations	CALCULATION NUMBER	
						91-E-0094-01
3	10/10/91	TD	VBS	ARKANSAS NUCLEAR ONE	PAGE NUMBER	80 OF 19
REV.	DATE	BY	CHK'D			

FOR ALL 4 CASES MAX. SHEAR WILL OCCUR @ A DISTANCE d FROM THE FACE OF THE WALL (SEE PG. 4A) (REF. #1, SECT 11.1.3.1)

CALCULATE THE MAX. LOAD " P_s ", IN ADDITION TO THE D.W. OF THE SLAB, THAT WILL CAUSE A SHEAR OF 691.8 KIPS @ DISTANCE d FROM THE FACE OF WALL. ($d' = 1'-6" + 38" = 56" = 4.7'$)

CASE # 1 & 2



$V_{MAX} = \text{SHEAR DUE TO } P_s + \text{SHEAR DUE TO DW } (w_o)$

$V_{MAX} = 691.86 \text{ KIPS (REF PG 8A)}$

$\text{SHEAR DUE TO } P_s = P_s \times \frac{a}{L} \text{ (REF \# 9, 2-114)}$

$\text{SHEAR DUE TO D.W.} = \left[\frac{1}{2}(L)(w_o) - d'(w_o) \right] \text{ --- REF \# 9 2-114}$

$w_o = b \times H \times .15 = 8.66' \times 3.5' \times .15 \text{ K/FT} = 4.5465 \text{ K/FT}$

$V_{max} = P_s \frac{a}{L} + \frac{1}{2} L (4.5465) - d' (4.5465) \text{ --- (A)}$

CASE # 1, $L = 24'$, $a = 18'$

$691.86 = P_s \times \frac{18'}{24'} + \frac{1}{2} (24) (4.5465 \text{ K/FT}) - 4.7' (4.5465 \text{ K/FT})$

$\Rightarrow P_s = 878.2 \text{ KIPS}$

				 ARKANSAS NUCLEAR ONE	CALCULATION NUMBER 91-E-0094-01	
3	10/10/91	TD	VAS		PAGE NUMBER	86 OF 19
REV.	DATE	BY	CHK'D			

CASE # 2

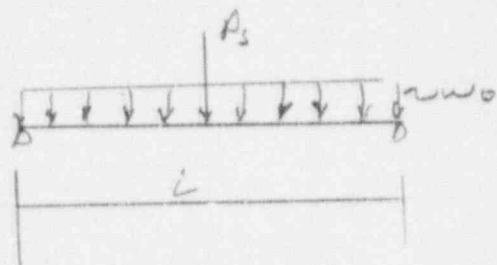
$L = 27'$, $a = 21'$

USING EQ. (4) ON PG. 86

$$P_{max} \times \frac{21'}{27'} + \left(\frac{1}{2} \times 27' \times 4.5465 \text{ K/FT} \right) - 4.7' \times 4.5465 \text{ K/FT} = 691.86 \text{ K}$$

$$P_s = 838.1 \text{ KIPS}$$

CASE # 3 & 4



CALCULATE THE SHEAR @ d' WHEN THE LOAD @ MIDSPAN

$$V \text{ due to } P_s = \frac{P_s}{2} \quad \text{--- (Ref # 9, pg. 2-114)}$$

$$V \text{ due to } Dw = w_0 \left(\frac{L}{2} - d' \right) \quad \text{--- (Ref # 9, pg. 2-116)}$$

$$\frac{P_s}{2} + w_0 \left(\frac{L}{2} - d' \right) = V_{max} = 691.86 \text{ KIPS} \quad \text{--- (5)}$$

CASE # 3

$$\frac{P_s}{2} + 4.5465 \text{ K/FT} \left(\frac{27'}{2} - 4.7' \right) = 691.86 \text{ KIPS}$$

$$\Rightarrow P_s = 1317.2 \text{ KIPS} > P_u \text{ due to ULTIMATE MOMENT} = 533.5 \text{ KIPS (pg. 70)}$$

CASE # 4 , USING EQ. (5)

$$\frac{P_s}{2} + 4.5465 \text{ K/FT} \left(\frac{27'}{2} - 4.7' \right) = 691.86 \text{ KIP}$$

$$\Rightarrow P_s = 1315.5 \text{ KIPS} > P_u \text{ due to ULT. MOMENT} = 728.0 \text{ KIP (pg. 8)}$$

				 ARKANSAS NUCLEAR ONE	CALCULATION NUMBER 91-E-0094-01	
3	10/10/91	TB	VJS		PAGE NUMBER 9 OF 19	
REV.	DATE	BY	CHK'D			

CALCULATE DEFLECTION IN ALL 4 CASES

CASE # 1

$L = 24 \text{ FT.}$, LOAD @ dist. d' (see pg 4)

FOR $P_u = 1129.6^k \Rightarrow \Delta = .155''$ (Ref pg 7a) ,

$P_s = 878.2^k \Rightarrow \Delta = \frac{878.2}{1129.6} \times .155 = .121''$ (Ref pg 8b)

$P_{DL} = 54.56^k \Rightarrow \Delta = .011''$ (Ref pg. 7a)

CASE # 2

$L = 27 \text{ FT.}$, LOAD @ dist. d' (see pg. 4)

FOR $P_u = 1080.5^k \Rightarrow \Delta = .182''$ (Ref pg 7b)

$P_s = 838.1^k \Rightarrow \Delta = \frac{838.1}{1080.5} \times .182 = .143''$ (Ref pg. 9)

$P_{DL} = 61.38^k \Rightarrow \Delta = .016''$ (Ref pg. 7b)

CASE # 3

$L = 24 \text{ FT.}$, LOAD @ MID SPAN (see pg 4a)

FOR $P_u = 833 \Rightarrow \Delta = .204''$ (Ref pg 7c)


$P_{DL} = 54.56 \Rightarrow \Delta = .0154''$ (Ref pg 7c)

CASE # 4

$L = 27'$, LOAD @ MID SPAN (see pg. 4a)

FOR $P_u = 728^k \Rightarrow \Delta = .260''$ (Ref pg 8)

$P_{DL} = 61.38^k \Rightarrow \Delta = .0246''$ (Ref pg 8)

				 Entergy Operations ARKANSAS NUCLEAR ONE	CALCULATION NUMBER	
					91-E-0094-01	
3	10/18/91	TD	WJ		PAGE NUMBER	9a OF 19
REV.	DATE	BY	CHK'D			

CALCULATION (CONT.)

CHECK BOND STRESS @ FACE OF COLUMN.

$$V_u = \frac{V}{(N \pi d_b) J d} \leq \frac{9.5 \sqrt{f_c}}{d_b} \leq 800 \text{ PSI}$$

$V = 691.86 + D_w$ (REF # 6 sec. 6.3.2)

$d = \text{dist. } d \text{ FROM THE WALL}$ (6.4.2 & TABLE 6.9.2)

$N = \text{NO OF BARS} = 3$ (per foot) \therefore x b eff. width of beam

$d_b = \text{DIA OF BAR}$

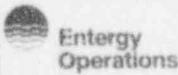

$J = 1 - \frac{K}{3}$ (REF # 6)

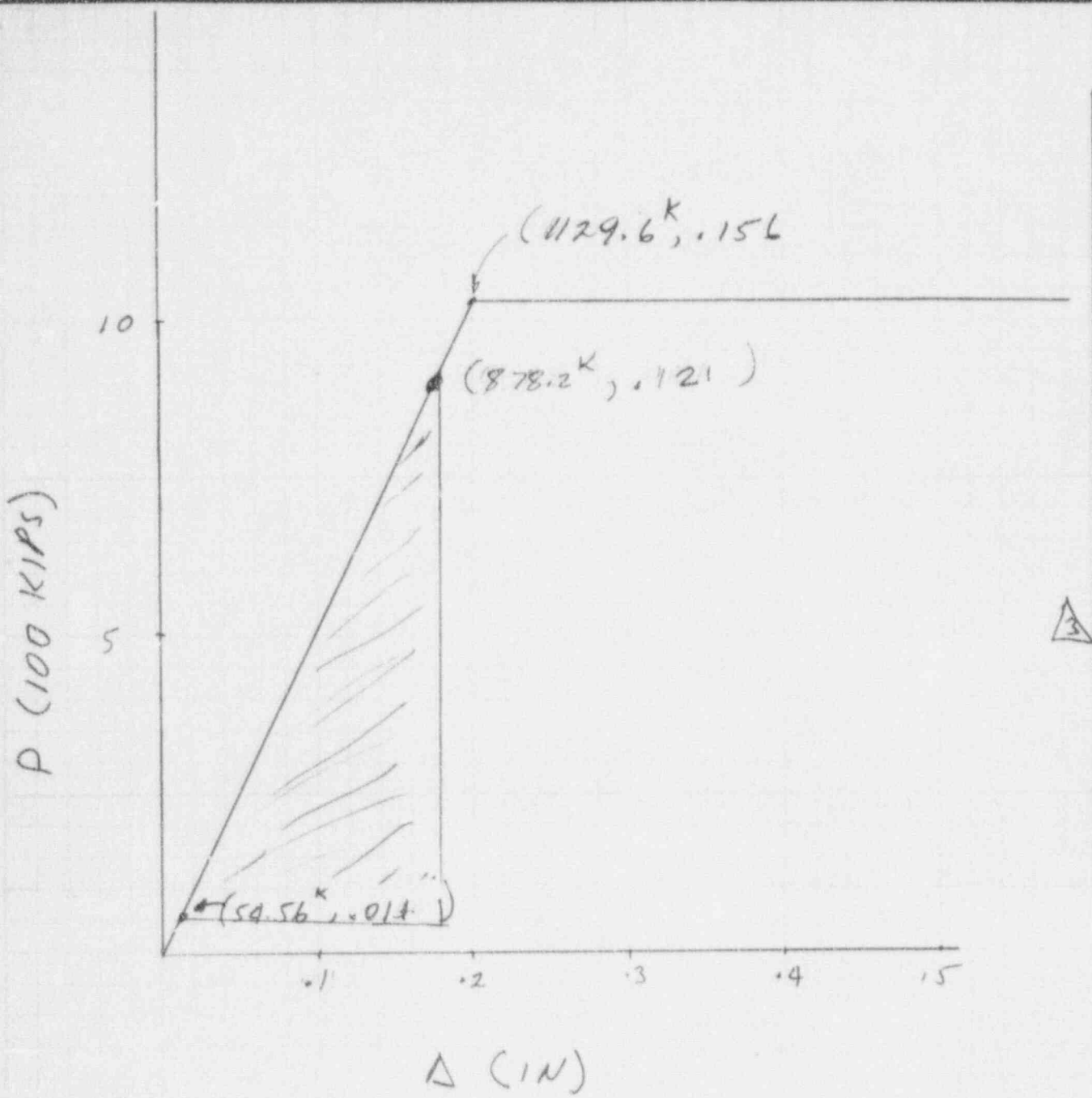
$K = \frac{1}{1 + (f_y / \mu f_c)} = \frac{1}{1 + (48.3 \text{ ksi} / 6 \times 6.5 \text{ ksi})} = 0.44$

$J = 1 - \frac{0.44}{3} = .852$

$$V_u = \frac{691.86 \text{ KIP} + (4.5465 \text{ K/FT} \times 3.2') \times 1000 \frac{\text{lb}}{\text{K}}}{(3 \pi \times 1.41") \times 8.66' \times (.852 \times 38")}$$

$V_u = 189.6 \text{ PSI} < \frac{9.5 \sqrt{6500}}{1.41} = 543.2 \text{ PSI}$

				 Energy Operations ARKANSAS NUCLEAR ONE	CALCULATION NUMBER 91-E-0094-01	
3	10/10/91	TD			PAGE NUMBER 96 OF 19	
REV.	DATE	BY	CHK'D			



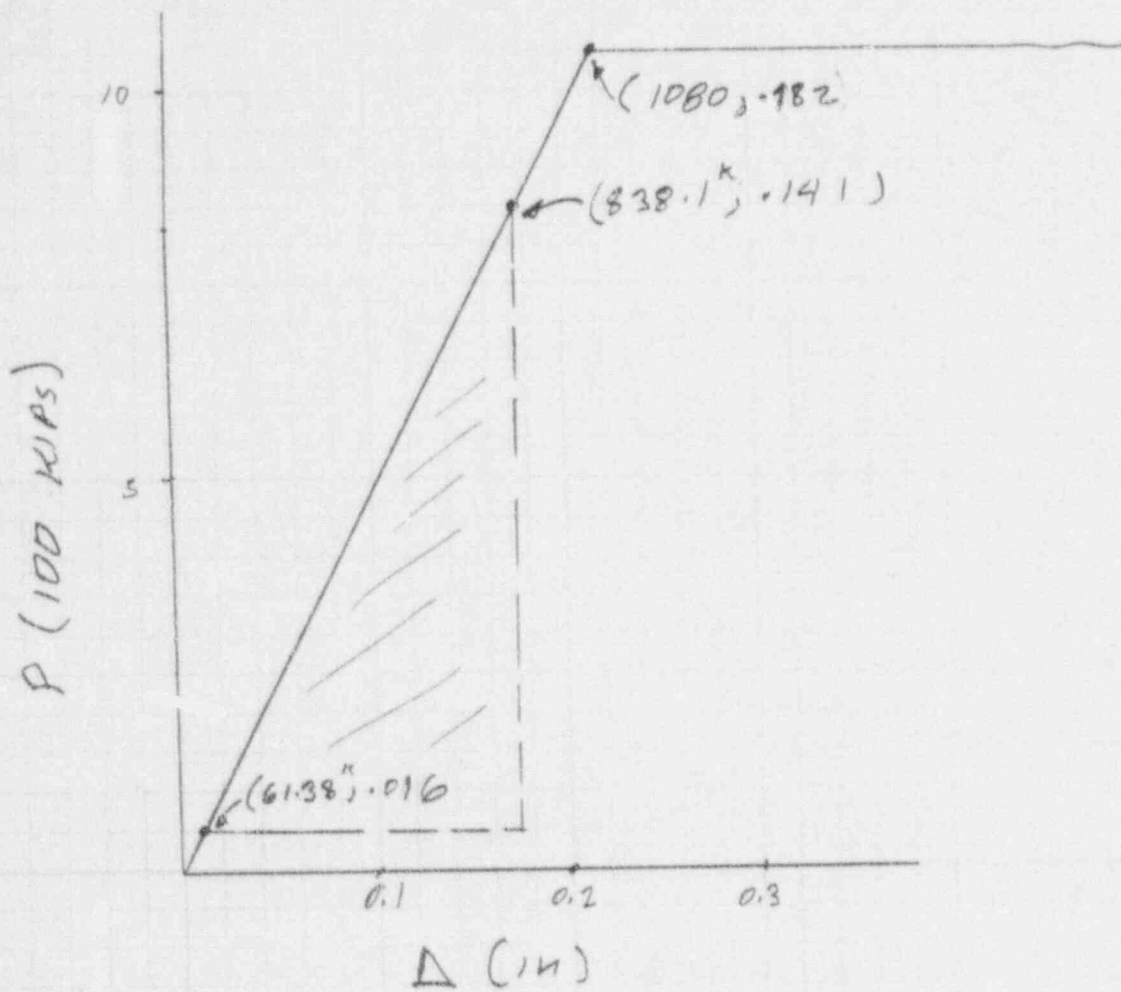
3

CASE # 1

LOAD VY. DEFLECTION

THE SHADED AREA IS = TO KINETIC ENERGY THAT THE BEAM CAN ABSORB @ CASE #1 (REF # 3)


				 Energy Operations	CALCULATION NUMBER	
					91-E-0094-01	
3	10/9/91	TD	VJB	ARKANSAS NUCLEAR ONE	PAGE NUMBER	10 OF 19
0	8/8/91	TD	KDB			
REV.	DATE	BY	CHK'D			

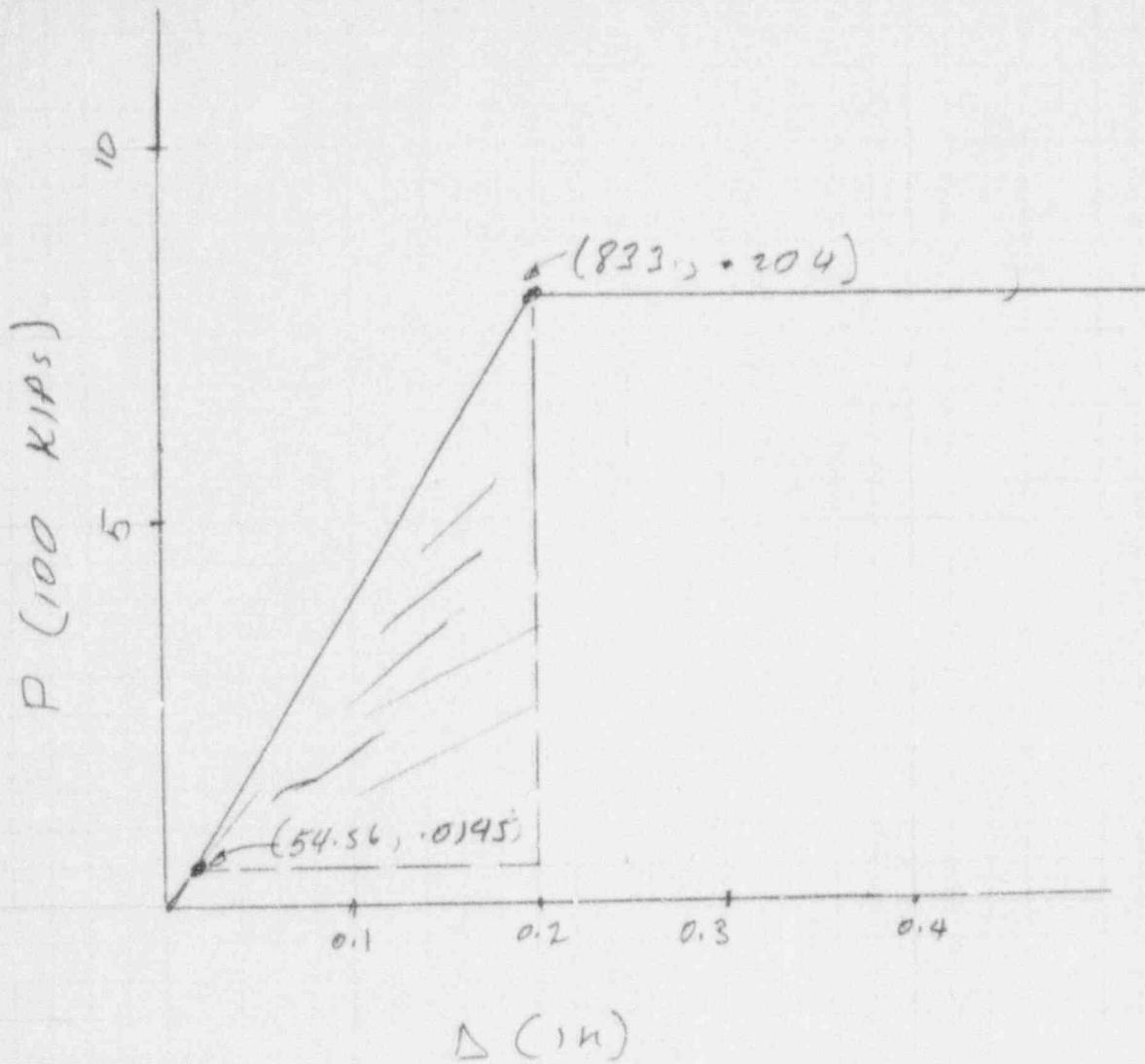


LOAD VY. DEFLECTION

(CASE # 2)


THE SHADED AREA IS = TO THE KINETIC ENERGY THAT THE BEAM CAN ABSORB @ CASE#2
(Ref#3)

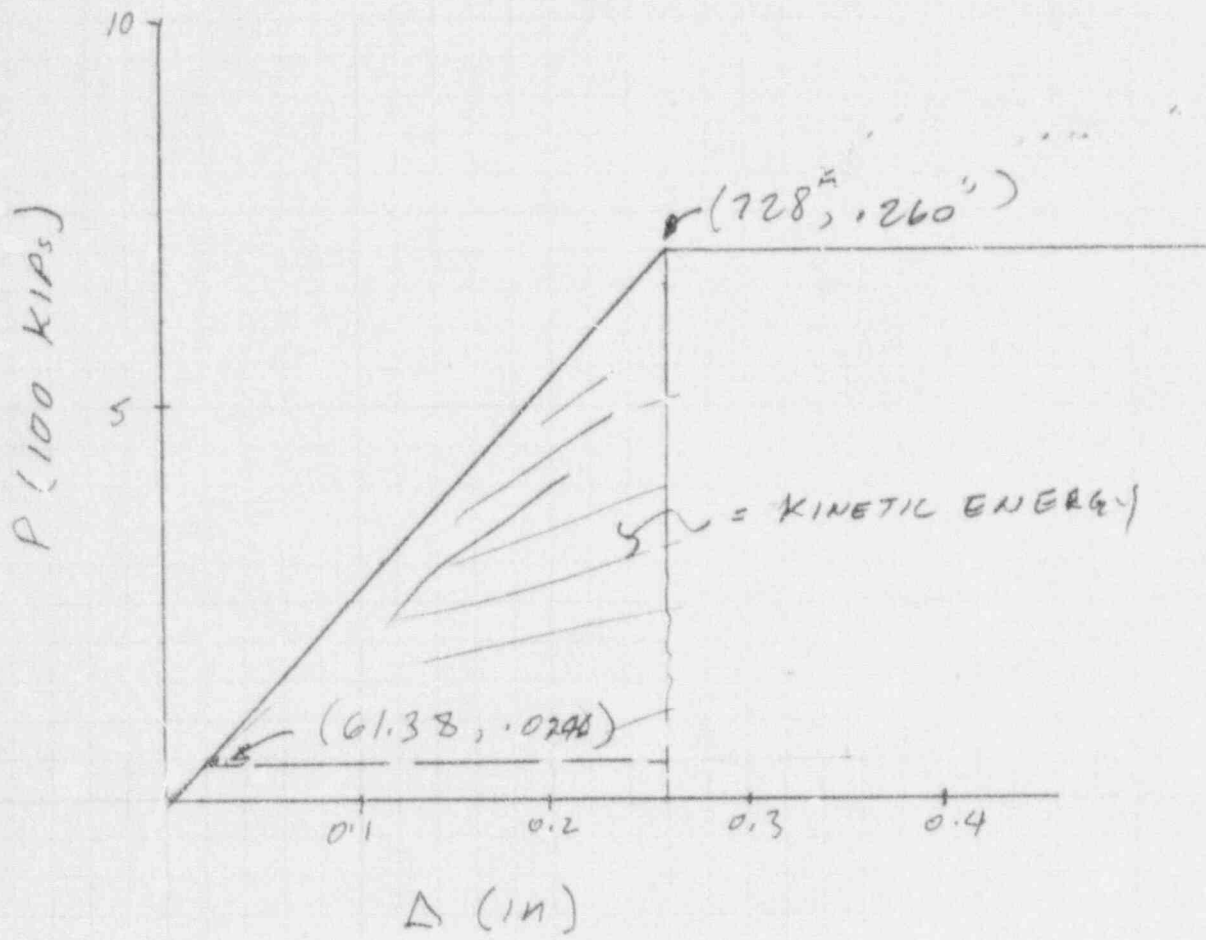
				 Energy Operations ARKANSAS NUCLEAR ONE	CALCULATION NUMBER	
					91-E-0094-01	
3	10/10/91	TD	VSS		PAGE NUMBER	109 OF 19
REV.	DATE	BY	CHK'D	ONE		



CASE #3


THE SHADED AREA = KINETIC ENERGY

				 Energy Operations	CALCULATION NUMBER	
					91-E-0094-01	
3	10/10/91	TD	<i>WJS</i>	ARKANSAS NUCLEAR ONE	PAGE NUMBER	106 OF 19
REV.	DATE	BY	CHK'D			



(CASE # 4)

CALCULATE THE MAX. HEIGHT OF DROP THAT THE SLAB CAN TAKE IN EACH OF THE 4 CASES, WHICH WILL CAUSE A STRAIN ENERGY EQUAL TO THE KINETIC ENERGY THE SLAB COULD ABSORB

				 Energy Operations ARKANSAS NUCLEAR ONE	CALCULATION NUMBER	
					91-E-0094-01	
3	10/10/91	TD	VJD		PAGE NUMBER	100 OF 19
REV.	DATE	BY	CHK'D			

CALCULATION (CONT.)

II ALLOWABLE HEIGHT OF DROP:

$$V_s^2 = 2gh \quad (\text{Ref \# 3})$$

where

EQ 3-4)

V_s = CASK STRIKING VELOCITY

h = MAX. HEIGHT

$$M_m = \frac{35^k}{g} = \text{MASS OF CASK}$$

M_e = Average effective mass

$$= \frac{\gamma_c T}{g} (D + 2T) (D + 2T) \quad (\text{Ref \# 3})$$

(EQ. 3-15)

Since THE CASK IS CIRCLE, $D_{IA} = 2.8' = 2.33' (\pi^2)$

$$\Rightarrow M_e = \frac{\gamma_c T}{g} \left(\frac{\pi (D + 2T)^2}{4} \right)$$

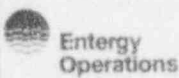
where

γ_c = weight per unit volume of concrete = $15 \frac{k}{ft^3}$

T = Thickness of FLOOR

$$M_e = \frac{15 \times 3.5}{g} \times \frac{\pi (2.33 + 7)^2}{4} =$$

$$M_e = \frac{35.92}{g}$$

				 Energy Operations	CALCULATION NUMBER	
					ARKANSAS NUCLEAR ONE	91-E-0094-01
0	8/8/91	TD	K. MB		PAGE NUMBER	11 OF 19
REV.	DATE	BY	CHK'D	ONE		

CALCULATION (CONT.)

$$ES = \frac{M_m^2 V_s^2}{2(M_m + m_c)} \quad (\text{REF \# 3 EQ 3-8})$$

ES = STRAIN ENERGY = Σ KINETIC ENERGY
= SHADED AREA (PG 10-10c)

FOR CASE #1, $L = 24'$, LOAD @ dist. h .

$$ES = \frac{\left(\frac{35}{g}\right)(29h)}{2\left(\frac{35}{g} + \frac{35.9}{g}\right)} = \frac{1}{2}(878.2^k - 54.5^k)(.121'' - .011'')$$

$$ES = \frac{\frac{1225}{g} + 29h}{2(70.9)} = 45.5$$

$$\Rightarrow 17.278h = 45.5$$


$$\Rightarrow \boxed{h = 2.62''}$$

FOR CASE #2 (USING THE SAME EQ'S AS CASE #1)

$$ES = \frac{\left(\frac{35}{g}\right)(29h)}{2\left(\frac{35}{g} + \frac{35.9}{g}\right)} = \frac{1}{2}(838.1^k - 61.38^k)(.141'' - .016'')$$

$$17.278h = 48.50$$

$$\Rightarrow \boxed{h = 2.8''}$$

				 Energy Operations	CALCULATION NUMBER	
					ARKANSAS NUCLEAR ONE	91-E-0094-01
3	10/10/91	TD	VLS		PAGE NUMBER	12 OF 19
REV.	DATE	BY	CHK'D			

CASE # 2

$$17.278 h = \frac{1}{2} (833^k - 54.56^k) (.204 - .0154)$$

$$17.278 h = 73.4$$

$$\Rightarrow \boxed{h = 4.24''}$$

CASE # 4

$$17.278 h = \frac{1}{2} (728^k - 67.38^k) (.26 - .0246)$$


$$17.278 h = 78.5$$

$$\boxed{h = 4.5''}$$

\therefore CASE # 1 IS GOVERNING; $h = 2.62''$

∴ HONEYCOMB ENERGY ABSORPTION MAT'L IS REQUIRED FOR 9" DROP.

III CALCULATE THE REQUIRED THICKNESS OF HONEYCOMB FOR 9" DROP

				 Energy Operations	CALCULATION NUMBER	
					ARKANSAS NUCLEAR ONE	91-E-0094-01
3	10/01/91	TD	VLS		PAGE NUMBER	129 OF 19
REV.	DATE	BY	CHK'D			

CALCULATION:

$$K.E. = P_{CV} A (.7) t_c \quad (\text{REF \#5})$$

PG-20

$$\Rightarrow t_c = \frac{K.E.}{P_{CV} A (.7)} \quad , \text{ USE } P_{CV} = 260 \text{ PSI}$$

$$K.E. = \frac{M_m V_s^2}{2} \quad (\text{REF \#3 EQ. 3-5})$$

$$= \frac{1}{2} \left(\frac{35000 \text{ lbs}}{g} \right) (2) (g) (g) \quad (\text{wt. cask} = 35 \text{ K lbs})$$

$$\Rightarrow t_c = \frac{\dots}{260 (28)^2 \left(\frac{\pi}{4} \right) (.7)}$$

$t_c = 2.80'' \quad \text{USE } 3 \text{ IN}$

\therefore 2.8" OF 260 PSI HEXCELL HONEYCOMB MAT'L IS REQUIRED FOR 9" DROP OF 17.5 TON CASK.

THE REST OF THIS CALCULATION IS TO CALCULATE THE SAFETY FACTORS USING 3" OF 260 PSI HEXCELL HONEYCOMB MAT'L @ THE BOTTOM OF THE CASK.

				Entergy Operator.s ARKANSAS NUCLEAR ONE	CALCULATION NUMBER	
3	10/9/91	TD	VLS		91-E-0094-01	
1	9/19/91	TD	VLS	PAGE NUMBER	13 OF 19	
0	8/8/91	TD	KDB	NUMBER		
REV.	DATE	BY	CHK'D			

CALCULATION ; (CONT.)

SUMMARY OF STRESSES FOR 17.5 TON CASK DROP

DATA : $f'_c = 6500$ PSI @ .4 YEARS

$f_y = 48,300$ PSI (MILL CERTIFICATE)

(1) Calculate the LOAD P THAT THE SLAB WILL SEE AS A RESULT OF 2.5" DROP FOR ALL 4 CASES ADDRESSED ON PG. 3

CASE #1

$L = 24'$, DROP LOCATION = 6'-0" FROM END SUPPORT WHICH WILL HAVE THE MAX. SHEAR.

$$E_s = \frac{M_m^2 V_s^2}{2(M_m + M_c)} = \frac{1}{2} (P - 54.56) (\Delta P - .011")$$

$$M_m = \frac{35^k}{9} , V_s^2 = 29h , M_c = \frac{35.92}{9}$$

$$\Rightarrow \frac{\left(\frac{35}{9}\right)^2 \times 29(25)}{2\left(\frac{35}{9} + \frac{35.92}{9}\right)} = \frac{1}{2} (P - 54.56^k) \left(\frac{P}{1129.6} (.155) - .011''\right)$$

$$43.2 = \frac{.156}{2259.2} P^2 - \frac{21}{2259.2} P + \frac{678}{2259.2}$$


$$.156 - 21P - 96919 = 0$$

$$P = \frac{21 + \sqrt{(21)^2 + 4(.156)(96919)}}{2(.156)} = 858.3 \text{ KIPS}$$

USE EQ (4) ON PG 8b

$$V_{max} = \frac{18}{24} (858.3^k) + \frac{1}{2} (24') (4.5465^k/ft - 4.7' (4.5465^k/ft))$$

$$V_{max} = 697 \text{ KIPS}$$

				 Entergy Operations	CALCULATION NUMBER	
					91-E-0094-01	
3	10/10/91	TD	VJS	ARKANSAS NUCLEAR ONE	PAGE NUMBER	14 OF 19
REV.	DATE	BY	CHK'D			

CALCULATION (cont.)

ALLOWABLE COMBINED SHEAR CAPACITY OF CONCRETE &
WEB REINFORCEMENT = 691.86^K (Pg. 8b)

$$S.F. = \frac{691.86^K}{677^K} = 1.022$$

- MAX. MOMENT & SAFETY FACTOR

MOMENT @ DPOB P+. = MAX. MOMENT FOR THIS CASE

$$M = \frac{358^K \times 18' \times 6'}{24'} + (\frac{1}{2})(8.66' \times 3.5' \times 15' \times 18' (24' - 18'))$$

$$M = 386^K + 245.5^K = 4106.5 \text{ K-FT}$$

ALLOW. MOMENT CAPACITY = 5328.6 K-FT (Pg. 7)

$$S.F. = \frac{5328.6^K}{4106.5^K} = 1.3$$

CASE #2

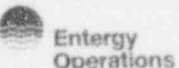
$$L = 27'$$

USING THE SAME EQ. AS IN CASE #1

$$E_s = \frac{M_m^2 V_s^2}{2(M_m - M_e)} = \frac{1}{2} (P - 61.38) (\Delta P - .016'')$$

$$\Rightarrow \frac{(\frac{35}{9})^2 \times 29(45)}{2(\frac{35}{9} + \frac{35.7}{9})} = \frac{1}{2} (P - 61.38) \left(\frac{P}{1080.5^K} (.182') - .016 \right)$$

$$43.2 = \frac{.182}{2161} P^2 - \frac{28.5}{2161} P + \frac{1061}{2161}$$

				 Energy Operations	CALCULATION NUMBER	
						91-E-0094-01
3	7/9	TD	VBS	ARKANSAS NUCLEAR ONE	PAGE NUMBER	149 OF 19
REV.	DATE	BY	CHK'D			

CALCULATION: (CONT.)

$$.182 P^2 - 28.5 P - 92294 = 0$$

$$P = \frac{28.5 + \sqrt{(28.5)^2 + 4(.182)(92294)}}{2(.182)}$$

$$P = 795 \text{ KIPS}$$

Using EQ. 4 on pg.

$$V_{max} = \frac{21'}{27'} (795) + \frac{1}{2} (27' \times 4.5465 \text{ K/F}) - 4.7 (4.5465 \text{ K/F})$$

$$V_{max} = 658.6 \text{ KIPS} < 677 \text{ K} \quad (\text{CASE \# 1})$$

pg. 14

ALLOW. shear = 691.86 K (pg. 8b)

$$S.F. = \frac{691.86}{658} = 1.05$$

- MAX. MOMENT

$$M = \frac{795 \text{ K} \times 21' \times 6'}{27'} + \left(\frac{1}{2}\right) (8.66') (2.5') (.15 \text{ K/F}) (21') (27' - 21')$$


$$M = 3996.4 \text{ K-FT} < 4106.5 \text{ K'} \quad (\text{CASE \# 1})$$

pg. 14a

ALLOW. moment = 5328.6 K' (pg. 7)

$$S.F. = \frac{5328.6}{3996.4} = 1.33$$

∴ MOMENT & SHEAR IN CASE #1 IS CONTROLLING.

				 Energy Operations	CALCULATION NUMBER	
					ARKANSAS NUCLEAR ONE	91-E-0094-01
3	10/10/91	JD	VJB		PAGE NUMBER	15 OF 19
REV.	DATE	BY	CHK'D			

CALCULATION (CONT.)

CASE #3

$L = 24'$, DROP LOCATION @ MID SPAN

MAX. MOMENT IS LOCATED @ MID SPAN & MAX.

SHEAR @ DISTANCE d FROM THE FACE OF THE WALL.

$$E_s = \frac{M_m^2 V_s^2}{2(M_m - M_c)} = \frac{1}{2} (P - 54.56) (\Delta P - .0188)$$

$$E_s = \frac{\left(\frac{35^k}{g}\right)^2 (29(25))}{2\left(\frac{35^k}{g} + \frac{35.9^k}{g}\right)} = \frac{1}{2} (P - 54.56) \left(\frac{P}{833} \times .204 - .0154\right)$$

$$43.2 = \frac{.204 P^2}{1666} - \frac{24}{1666} - \frac{700}{1666}$$

$$\Rightarrow .204 P^2 - 24 - 71271 = 0$$

$$P = \frac{24 + \sqrt{(24)^2 + 4(.204)(71271)}}{2(.204)}$$

$$\boxed{P = 652.8 \text{ KIPS}} < 677.7 \text{ KIP (CASE #1) (PG. 14)}$$

(MAX. SHEAR)


\(\therefore\) SHEAR IN CASE #1 IS CONTROLLING

$$M = \frac{PL}{4} = \frac{652 \text{ K} \times 24'}{4} = 3912 \text{ K-FT (REF #9)}$$

2.114

$$\boxed{M = 3912 \text{ K-FT}} < 4106.5 \text{ K-FT (CASE #1) (PG. 14a)}$$

\(\therefore\) MOMENT IN CASE #1 IS CONTROLLING.

				 Energy Operations ARKANSAS NUCLEAR ONE	CALCULATION NUMBER	
					91-E-0094-01	
3	10/10/91	TD	VSS		PAGE NUMBER	159 OF 19
REV.	DATE	BY	CHK'D	ONE		

CALCULATION (Cont.)

CASE # 4

$L = 27'$, DROP LOCATED @ MID SPAN

MAX. MOMENT IS LOCATED @ MID SPAN & MAX SHEAR @ Distance d FROM THE FACE OF THE WALL.

$$ES = \frac{M_m^2 V_s^2}{2(M_m - M_c)} = \frac{1}{2} (P - 61.38) (DP - .0246)$$

$$= \frac{\left(\frac{25}{9}\right)^2 (296.5)^2}{2\left(\frac{25}{9} + \frac{35.9}{9}\right)} = \frac{1}{2} (P - 61.38) \left(\frac{P}{728} \times .269 - .0246\right)$$

$$43.2 = \frac{126}{1456} P^2 - \frac{33.87}{1456} P - \frac{1099.2}{1456}$$

$$\Rightarrow .26 P^2 - 33.87 P - 61800 = 0$$

$$P = \frac{33.87 + \sqrt{(33.87)^2 + 4(126)(61800)}}{2(.26)}$$

$$P = 556.9 \text{ KIPLS} < 677 \text{ K (CASE # 1)} \text{ (PG. 10)}$$


(MAX. Shear)

∴ Shear in CASE # 1 IS CONTROLLING

$$M = \frac{PL}{4} = \frac{556.9 \times 27}{4} = 3759 \text{ K-FT}$$

$$M = 3759 \text{ K-FT} < 4106.5 \text{ K'} \text{ (CASE # 1)} \text{ (PG. 10a)}$$

∴ MOMENT IN CASE # 1 IS CONTROLLING

				 Energy Operations ARKANSAS NUCLEAR ONE	CALCULATION NUMBER	
					91-E-0094-01	
3	10/10/91	TP	VJS		PAGE NUMBER	16 OF 19
REV.	DATE	BY	CHK'D	ONE		

CALCULATION (cont.)

Since CASE #1 is GOVERNING, CHECK THE 9" DROP W/ 3" THICK, $f_{cr} = 260$ PSI HEXCELLS, FOR CASE #1 ONLY.

$$K.E. = f_{cr} A \times 7 \text{ tc} \quad (\text{see pg. 13})$$

$$V_s^2 = 2gh$$

$$f_{cr} = \frac{K.E.}{A \times 7 \text{ tc}}$$

$$h = 9''$$

$$K.E. = \frac{M_m V_s^2}{2} = \frac{1}{2} \times \frac{35000}{g} (2) g (9)$$

$$K.E. = 315000 \text{ K-in}$$

$$f_{cr} = \frac{315000}{(28)^2 \frac{\pi}{4} \times 7 \times 3} = 243.6 \text{ PSI} < 260 \text{ PSI}$$

$$P = 260 \times (28)^2 \times \frac{\pi}{4} = 160095 \text{ lb} = 160.1 \text{ k}$$

-MAX. SHEAR FORCE AND SAFETY FACTORS


USE EQ (4) ON PG 8b

$$V_{max} = \frac{18}{24} (160.1 \text{ k}) + \frac{1}{2} (24 \text{ k}) (4.5465 \text{ K/FT}) - 4.7 (4.5465 \text{ K/FT})$$

$$V_{max} = 153.26 \text{ KIP}^S$$

ALLOW. COMBINED SHEAR CAPACITY = 691.86 (PG 8b)

$$\text{SAFETY FACTOR} = \frac{691.86}{153.26} = \underline{\underline{1.51}}$$

				 Energy Operations ARKANSAS NUCLEAR ONE	CALCULATION NUMBER	
					91-E-0094-01	
3	10/19/91	TD	VJS		PAGE NUMBER	17 OF 19
0	8/8/91	TD	KPB			
REV.	DATE	BY	CHK'D			

Calculation (cont.)

- MAX. MOMENT AND SAFETY FACTOR:

M_{max} @ D&OP pt.

USE EQ.

$$M_{max} = \frac{100.1 \times 18 \times 18}{24} + \frac{1}{2} \times 8.66 \times 3.5 \times 1.15 \times 18 (24 - 18)$$

$$M_{max} = 965.96 \text{ K'}$$

ALLOW. MOMENT CAPACITY = 5243.6 K' (PG 7)

$$\text{SAFETY FACTOR} = \frac{5243.6 \text{ K'}}{965.96 \text{ K'}} = 5.42$$

(C) BOND STRESS, USE THE SAME EQ. AS ON PG 96

$$u = \frac{V}{n\pi d_b s} \quad (\text{PG. 96})$$


$$V = \frac{18}{24} (100.1 \text{ K}) + \frac{1}{2} \times 24 \times 8.66 \times 3.5 \times 1.15 - 1.5 \times 8.66 \times 3.5 \times 1.15$$

$$V = 167.813 \text{ K}$$

$$u = \frac{167.813}{3 \times \pi \times 1.41 \times 8.66 \times 1.852 \times 38} = 75.0 \text{ PSI}$$

ALLOW BOND STRESS = 543.2 PSI (PG. 96)

$$\text{SAFETY FACTOR} = \frac{543.2}{75.0} = 7.24$$

				 Energy Operations ARKANSAS NUCLEAR ONE	CALCULATION NUMBER	
3	10/10/91	TD	VLS		91-E-0094-01	
0	8/8/91	TD	MDP	PAGE NUMBER	18 OF 19	
REV.	DATE	BY	CHK'D			

CONCLUSION:


- Drop evaluation is performed in this calculation for all the four cases addressed on page 3. Case # 1 is found to be the most critical case for the 17 Ton cask drop.
- Drop evaluation summaries for the 17 Ton handling cask (28" diameter) at elevation 404 (Over the U-1 Control Room) are listed below:

CONDITION-A - A drop evaluation for 2.5" travel height with no hexagonal honeycomb.

CONDITION-B - A drop evaluation for 9" travel height with 3" of hexagonal honeycomb.

	CONDITION-A		CONDITION-B
Shear Capacity	691.36 kips	= 1.022 ;	691.86 kips
Shear Computed	677.0 kips		153.26 kips
Moment Capacity	5328 kip-ft	= 1.3 ;	5328 kip-ft
Moment Computed	4106.5 kip-ft		966.0 kip-ft
Bond Stress Capacity	543.20 psi	= 2.94 ;	543.20 psi
Bond Stress Computed	184.7 psi		45.0 psi
Development Length Provided (Ref. # 5)	33 in.	= 1.10 ;	33 in.
Development Length Required (Ref. # 5)	30 in.		30 in.

- The maximum allowable travel for 17 Ton cask drop, 2'-4" Dia., with no hexagonal honeycomb = 2.5".
- The minimum thickness of a 260 psi hexagonal honeycomb required for the 17 Ton cask drop of 9 inches travel = 3".
- Spalling is designed not to occur because the analysis of the above cases that the slab stays in elastic range.

				 Energy Operations	CALCULATION NUMBER	
						91-E-0094-01
3	10/10/91	TD	KAS	ARKANSAS NUCLEAR ONE	PAGE NUMBER	19 OF 19
REV.	DATE	BY	CHK'D	ONE		