CP&L
Carolina Power & Light Company

SEP 16 1982

Office of Nuclear Reactor Regulation
ATTN: Mr. D. B. Vassallo, Chief
Operating Reactors Branch No. 2
United States Nuclear Regulatory Commission
Washington, D.C. 20555

BRUNSWICK STEAM ELECTRIC PLANT, UNIT NOS. 1 AND 2
DOCKET NOS. 50-325 AND 50-324
LICENSE NOS. DPR-71 AND DPR-62
RESPONSE TO REQUESTS FOR ADDITIONAL INFORMATION
SPENT FUEL POOL STORAGE MODIFICATION

Dear Mr. Vassallo:

On April 16, 1981, Carolina Power & Light Company (CP&L) submitted a license amendment application seeking modification of the Brunswick Steam Electric Plant (BSEP) Unit Nos. 1 and 2 spent fuel storage pools (SFP) for increased storage capacity of spent fuel.

By letter dated March 16, 1982, CP&L provided information responding to Mr. T. A. Ippolito's requests for additional information dated July 14, 1981 and November 5, 1981 and to provide additional information supporting our April 16, 1981 submittal. Subsequent to our March 16, 1982 letter, NRC has requested additional information pertinent to concluding the review on the SFP modification. The attached information responds in toto to outstanding NRC questions (NRC letters dated November 5, 1981 and July 14, 1981) and your letter dated April 30, 1982.

We trust this information satisfactorily responds to your questions. Should you require additional information, please contact my staff.

Yours very truly,

S. R. Zimmerman
Manager
Licensing & Permits

MSG/WRM/lr (n-42)
Enclosures

A001

Limited Dist

cc: Mr. J. P. O'Reilly (NRC-RII)
Mr. J. A. Van Vliet (NRC)
Mr. D. O. Myers (NRC-BSEP)

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ATTACHMENT

CAROLINA POWER & LIGHT COMPANY (CP&L) RESPONSES TO ADDITIONAL QUESTIONS REGARDING THE BRUNSWICK STEAM ELECTRIC PLANT (BSEP) UNIT NOS. 1 AND 2 SPENT FUEL POOL STORAGE EXPANSION

NRC QUESTION 1

Pages 3-1 and 4-3.

The "Light-Gage Cold-Formed Steel Design Manual" 1961 Edition, AISI is referenced. Besides being an obsolete edition, this document does not pertain to stainless steel. Please specify a proper reference.

CP&L RESPONSE

Page 3-1, Item 11:

Delete "Light Gage" and insert in its place "Stainless Steel."
Delete "1961" and insert in its place "1974".

Page 4-3, Item (e) under "Analysis ..."

Delete "Light-Gage" and insert in its place "Stainless Steel."
Delete "1961" and insert in its place "1974".

Page 4-3, Item (c) under "Acceptance ..."

Delete "Light-Gage and insert in its place "Stainless Steel."

The changes noted above are found in Attachment 1.

NRC QUESTION 2

What are the standard ASME Code specifications for all the materials used in the racks?

CP&L RESPONSE

All rack materials, except the neutron absorber material, are stainless steel specified by ASTM standards for wrought materials and ASME standards for castings.

Tubes gr 304 ASTM A-240
Fittings ASME SA-351 gr CF-8
Clip angles gr 304 ASTM A-240
Closure plates gr 304 ASTM A-240
Closure pl shims gr 304 ASTM A-240
Lift lug gr 304 ASTM A-240
Base plate gr 304 ASTM A-240
Fuel support pls gr 304 ASTM A-240 or ASME SA 351 gr CF-8

The neutron absorber material and the slider pad material are not standard materials. Materials for these two items are proprietary formulations and accepted by specific testing.

NRC QUESTION 3

Load combinations seem to be at variance with O.T. Position (Page 4-4). Explain and justify if necessary.

CP&L RESPONSES

The load combinations recommended by the O.T. Position were used. An explanation of the results is found in the paragraph following (d) on page 4-4. There were no live loads in accordance with the definition in Standard Review Plan Section 3.8.4.

NRC QUESTION 4

Only Level D acceptance criteria are referenced for all loading conditions (Pages 4-8 and 4-4). This is not in accordance with O.T. position for loads involving OBE or T_o. Provide an explanation and justification.

CP&L RESPONSE

Level A and B acceptance criteria were used for the OBE loading condition allowables shown on Table 4-1. The footnotes are in error and should be revised as shown in Attachment 2.

NRC QUESTION 5

Figures 4-1 and 4-2 show the same peak acceleration for OBE and SSE. Please explain. What is the source reference for these figures?

CP&L RESPONSE

The figures were presented first in "Responses to AEC comments to DR 4 (Addendum B)", a document transmitted by Carolina Power & Light Company to the U. S. Atomic Energy Commission (Mr. John F. O'Leary) on November 8, 1972. The similarity of the peaks is coincidence. Please observe that Figure 4-1 is for structural/equipment damping of 4%/1% and Figure 4-2 is for structural/equipment and piping damping of 7%/2%.

NRC QUESTION 6

It is not explicitly stated that the one-third increase in allowable stresses (permitted by some specifications) was not permitted. The staff does not usually accept such an increase. Please state that this allowance was not taken, or provide justification if it was permitted.

CP&L RESPONSE

For the license submittal under consideration, a review was made of the concrete pool structure. For this review ultimate strength design was used in accordance with Regulatory Standard Review Plan Section 3.8.4 with the structural acceptance criteria stated therein. The one third increase in allowable stresses is not applicable to the method used.

NRC QUESTION 7

The statement at the bottom of page 4-4 that "thermal stresses need not be considered in the stress calculations" is only true for Level D service conditions. Provide an explanation and justification.

CP&L RESPONSE

The boundaries of the spent fuel storage module are not fixed, thereby making temperature-induced stresses insignificant. But even if the modules were restrained, at the maximum postulated temperature gradient (44°F) for abnormal conditions, the load combination $D + L + T_a + E$ is less than the OT acceptance limit of 1.6 times normal limits.

NRC QUESTION 8

Provide details and results of the analysis of the effects of the new rack loads on the pool structure. Include a sketch of the mathematical model.

CP&L RESPONSE

The information requested may be found in Attachment 3.

NRC QUESTION 9

State the proposed travel path of the storage racks during the modification. Are procedures available for moving the racks?

CP&L RESPONSE

Specific travel path instructions requiring no heavy loads over stored spent fuel will be part of the plant procedures to be developed for this modification. By reference to Figures 2-1 and 2-6 of the April 16, 1981 license amendment application, it can be seen that no heavy loads need be transported over stored spent fuel for this modification. During the

modification, spent fuel will be moved so that no spent fuel is located in the racks adjacent to the work area.

NRC QUESTION 10

Provide a list and description of the lifting devices and attachments (i.e. load rating, material, compliance with applicable ANSI standards such as ANSI N14.6, ANSI B30.9) which will be used during the expansion modification.

CP&L RESPONSE

A single-failure-proof lifting device is provided by the manufacturer (see attached Drawings C5472-E-113, 114, and 115 in Attachment 4) for placing the new racks in the pool. The device is rated at 39,000 lb. and tested at 125% capacity. The material is certified ASTM A-36 carbon steel.

Removal of the existing racks will use the existing lifting device. This device is a rigid, structural steel frame designed to AISC, 7th Edition, with a safety factor of 5 on yield stress for a design load of 9,400 lb. (maximum empty rack weight).

OUTSTANDING NRC QUESTIONS

NRC QUESTION 1 (Requested by NRC letter dated July 14, 1981)

Provide key calculations of the natural convection analysis.

CP&L RESPONSE

The calculations of the natural convection analysis are contained in the analysis for loss of spent fuel pool cooling. This analysis is provided in the thermal analysis enclosed in Attachment 5 and its revision enclosed in Attachment 6. In addition, the analysis of the radiological consequences of a loss of spent fuel pool cooling is provided in Attachment 7.

NRC QUESTION 2 (Requested by NRC letter dated November 5, 1981)

What volume of solid radioactive waste is expected to be generated as a result of re-racking of the Brunswick, Unit Nos. 1 and 2, spent fuel pool? Estimate the volume, as prepared for shipment (in drums, boxes or wrapped) to the disposal site. Estimate the curie content of this waste.

CP&L RESPONSE

We conservatively estimate a maximum volume of 300 cubic feet of waste (in the form of structural steel and miscellaneous tools) to be disposed as a result of this modification. A conservative estimate of curie content is 200 millicuries.

NRC QUESTION 3 (Requested by NRC letter dated November 5, 1981)

Our records indicate that the spent fuel storage pool cleanup system contains two 500 gpm, 300 ft. head, 60 HP pumps upstream of two heat exchangers and two filter/demineralizers. Please indicate if your design for the proposed modifications includes any change to the automatic backwash of the filter/demineralizers or automatic bypass to maintain a minimum total flow of 1000 gpm through the SFP system (Figure 8-1). Also, indicate if the proposed expansion is expected to have any impact on the anticipated annual volume of demineralizer resin waste from this source; if so, provide your estimate of the annual volume and curie content.

CP&L RESPONSE

No changes are proposed to the SFP Clean-up System. Since the loading on the filter/demineralizers is primarily from the most recently discharged fuel, we anticipate no increase of annual volume of demineralizer resin waste resulting from this modification.

Attachment 1

3.0 DESIGN BASES

The new spent fuel storage system was designed to conform to the applicable provisions of the following codes, standards and regulations:

1. General Design Criterion 2 (per 10CFR50, Appendix A) as related to components important to safety being capable of withstanding the effects of natural phenomena.

2. General Design Criterion 3 as related to protection against fire hazards.

3. General Design Criterion 4 as related to components being able to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation and postulated accidents.

4. General Design Criterion 62 as related to the prevention of criticality by physical systems.

5. Regulatory Guide 1.13 as it relates to the fuel storage facility design to prevent damage resulting from the SSE and to protect the fuel from mechanical damage.

6. Regulatory Guide 1.29 as related to the seismic design classification of facility components.

7. Regulatory Guide 1.92 as related to combination of loads for seismic analysis.

8. 10CFR20.

9. ASME Section III.

10. Branch Technical Position ASB 9-2 contained in the Standard Review Plan.

11. Stainless Steel Cold-Formed Steel Design Manual, 1974 Edition, American Iron and Steel Institute.

12. 10CFR100.

conditions, and the minimum 2-inch clearance between modules precludes contact during a seismic event.

4.2 STRESS ANALYSIS

The HDFS module has been designed to meet Seismic Category I requirements. Structural integrity of the module has been demonstrated for the load combinations below using linear elastic design methods.

Analysis was based upon the criteria and assumptions contained in the following documents:

a) ASME Boiler and Pressure Vessel Code Section III, Subsection NF.
b) USNRC, Regulatory Guide 1.92, Combining Modal Responses and Spatial components in Seismic Response Analysis.
c) BSEP-1&2 Final Safety Analysis Report, Seismic Design Criteria.
d) OBE - Operating Basis Earthquake
   DBE - Design Basis Earthquake
e) Stainless Steel Cold-Formed Steel Design Manual, 1974 Edition, American Iron and Steel Institute.

Acceptance criteria were based on:

a) Normal and upset (OBE) Appendix XVII, ASME, Section III.
b) Faulted DBE Paragraph F-1370, ASME Section III, Appendix F.
c) Local Buckling stresses in the spent fuel storage tubes were calculated according to Stainless Steel "Cold-Formed Steel Design Manual" of American Iron and Steel Institute in lieu of Appendix XVII, ASME, Section III, because of its applicability to these light-gage tubes. Only the strength of the outer wall thickness of 0.090 inch nominal is considered in the stress calculations.

The applied loads to the module are:

a) Dead loads which are weight of module and fuel assemblies, and hydrostatic loads.
b) Live loads - effect of lifting an empty module during installation.
c) Thermal loads - the uniform thermal expansion caused by pool temperature changes from the pool water and stored fuel.
d) Seismic forces of OBE and DBE.
e) Accidental drop of a fuel assembly from the maximum poss.ble height.

Attachment 2

TABLE 4-1

Comparison of Calculated Stress vs. Allowables (psi)

	OBE		SSE	
Location/Type	Calc. Stress	Allowables[2]	Calc. Stress	Allowables[1]
Tube wall shear	5,520	9,260	8,230	15,400
Tube wall compression	6,470	13,900	9,380	23,100
Tube weld throat shear	5,520	9,260	11,640	15,400
Angle, weld throat shear	7,810	9,260	11,640	15,400
Casting wall shear	3,340	9,260	9,170	15,400
Casting wall compression	8,900	15,300	14,220	23,100
Casting base weld shear	3,830	9,260	7,660	15,400
Support plate weld throat shear	3,870	9,260	15,330	15,400
Upper Closure Plate				
Compression	5,820	13,900	7,800	23,100
Shear	4,470	9,260	5,260	15,400
Weld Shear	6,320	9,260	7,440	15,440
Lower Closure Plate				
Compression	4,000	13,900	5,660	23,100
Shear	7,340	9,260	11,490	15,400
Weld Shear	7,340	9,260	13,580	15,400
Corner tube local compressive stress check for local buckling	-	-	9,120	23,100

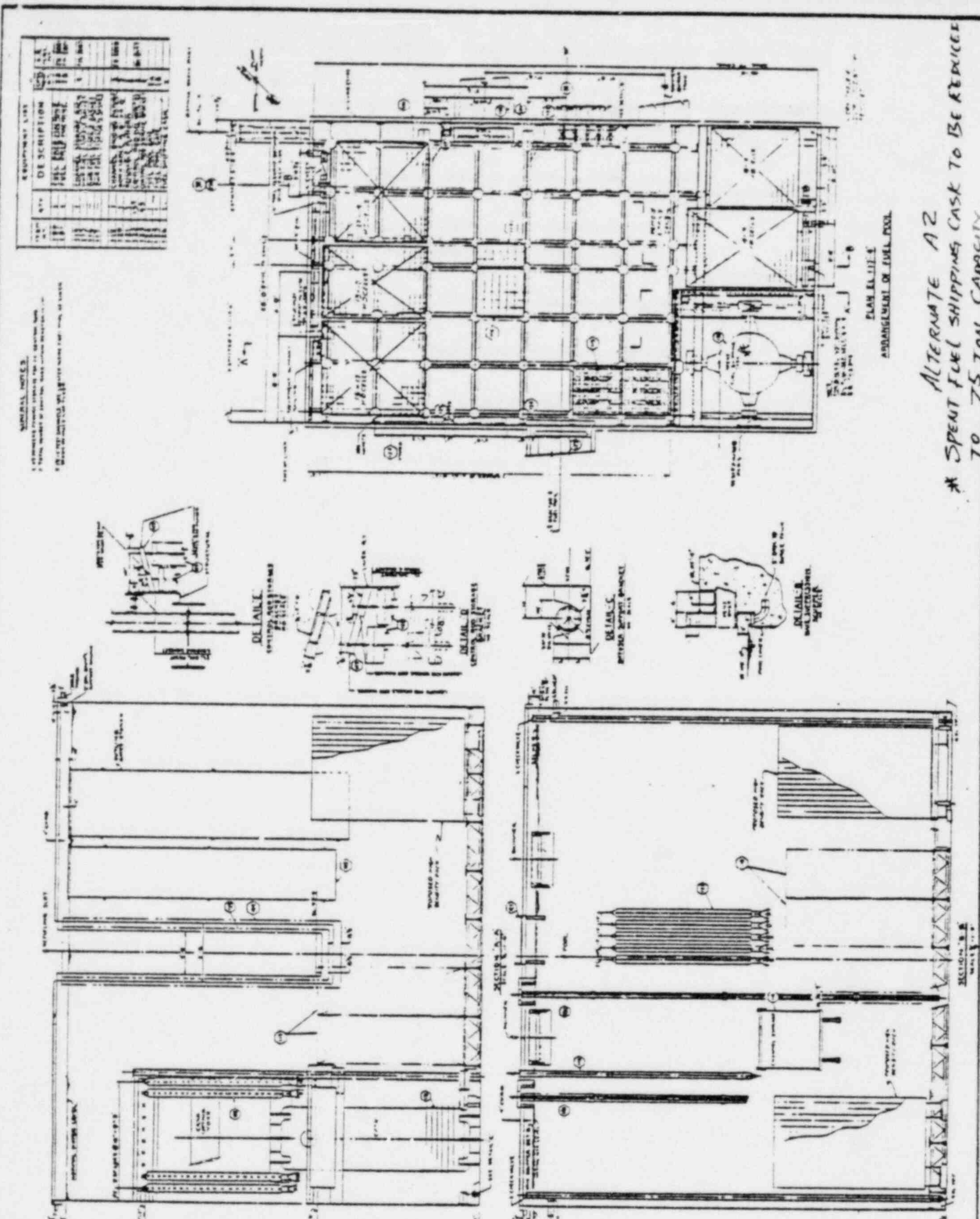
[1]Allowable stresses referenced in ASME Section III, NF3231.1c (Appendix F, Section F-1370).

[2]Allowable stresses referenced in ASME Section III, NF3231.1a (Appendix XVII).

Attachment 3

Table of Contents

Part 1: Configuration of Rack/Cask Arrangment

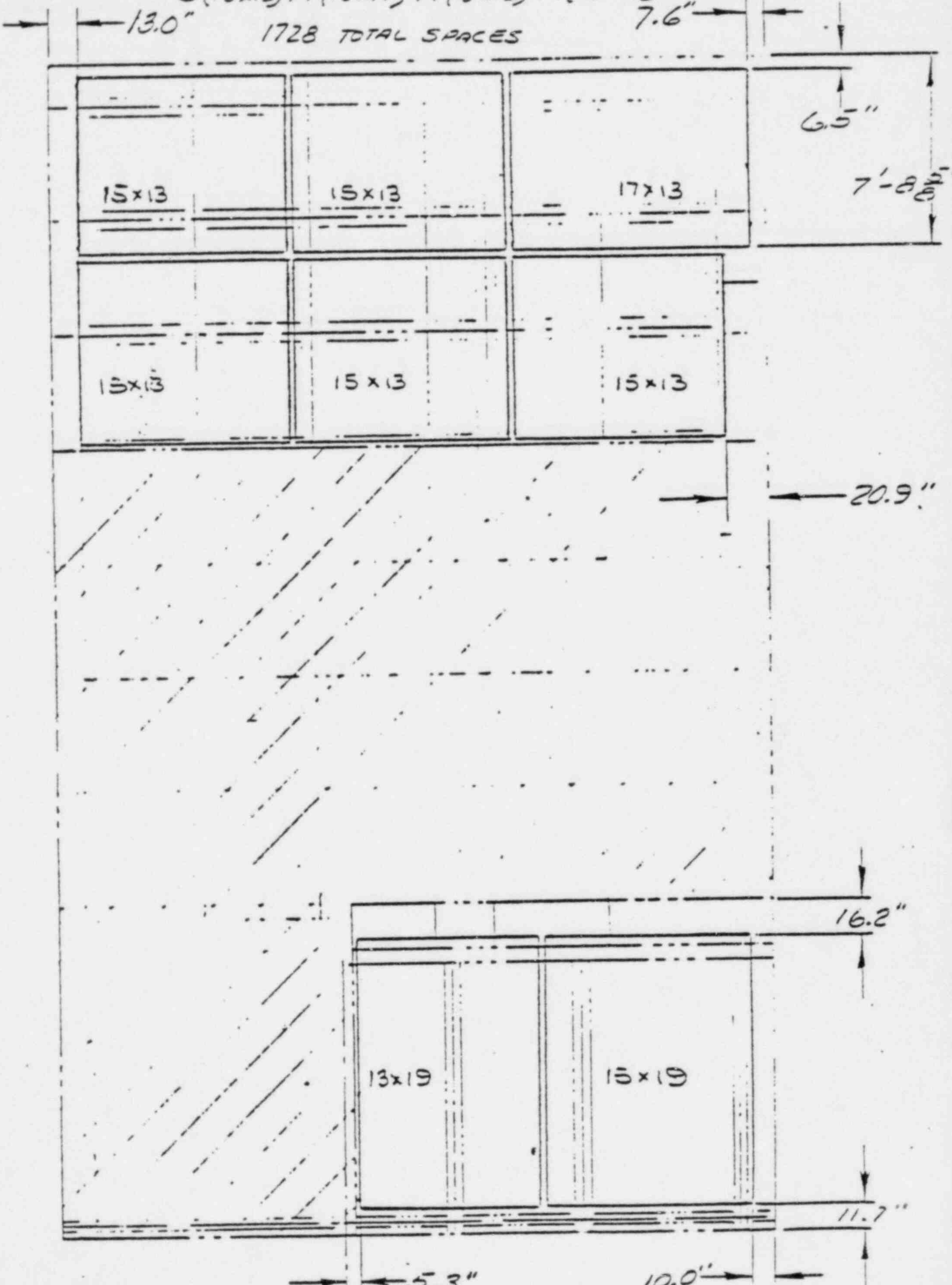


BRUNSWICK STEAM ELECTRIC PLANT Carolina Power & Light Company SPENT FUEL POOL STORAGE EXPANSION		FIGURE 1

PROPOSAL No. 4

5(13x15) + 1(13x17) + 1(13x19) + 1(15x19)

1728 TOTAL SPACES

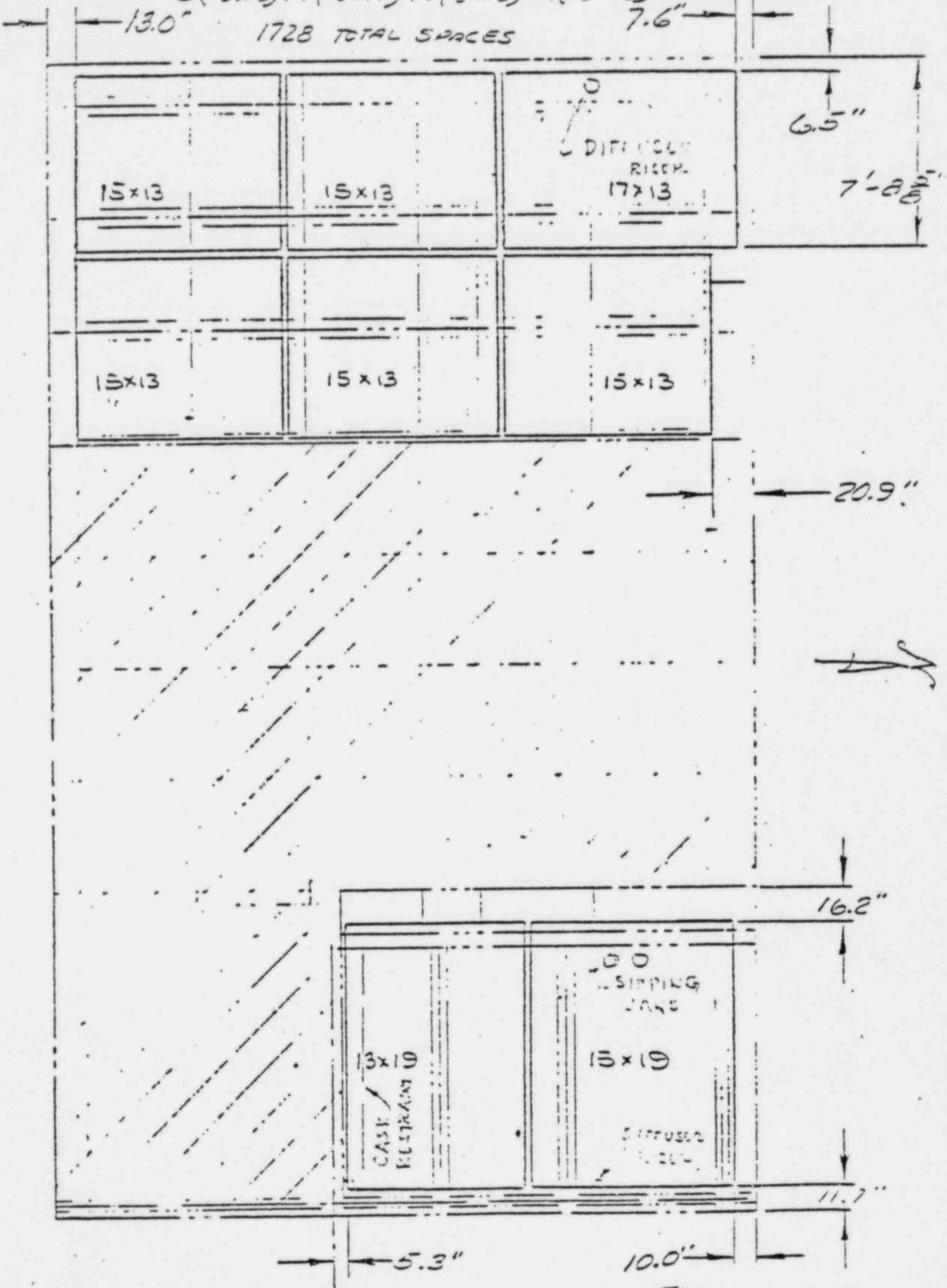


FM 7/21/80

PROPOSAL NO. 7

5(13x15) + 1(13x17) + 1(13x19) + 1(15x19)

1728 TOTAL SPACES



FM 7/21/80

Part 2: Loads Definition for Floor Slab

A. Free Standing Rack Module

Part 2: Loads Definition for Floor Slab

B. UE&C Loading Generation on Existing Racks

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GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc.

CALC. SET NO.		
PRELIM.		9527-
FINAL	X	1-RB-FP-04-F
VOID		
SHEET 229 OF 327		
J.O. 9527.085		

REV	COMP. BY	CHK'D BY
0	KHD DATE 8/21/80	AAM DATE 9/12/80
	DATE	DATE

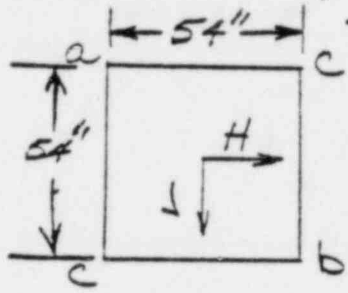
NAME OF COMPANY CP&L (BSEP) UNIT/S 1&2

SUBJECT BWR SPENT FUEL RACKS IMPACT LOADS

REFERENCE: CALC. 9527-1-RB-FP-01 p.13
DWG F-1804, F-1805

N →

FOR DBE



36 CELL RACK

AT CORNER a

DUE TO H: $\frac{2614''K}{2 \times 54''} = x = 24.20^K \uparrow$ (2614"K FROM p. OF OF SEISMIC ANALYSIS)

DUE TO ⊥: $\frac{2614''K}{2 \times 54''} = y = 24.20^K \uparrow$

DUE TO V: $\frac{11.2K}{4} = z = 2.8^K \uparrow\downarrow$

(CONSERVATIVE)

$SRSS = \sqrt{x^2+y^2+z^2} = \sqrt{(24.2)^2+(24.2)^2+(2.8)^2} = \underline{34.34K}$

CONSIDERING DRY WT − BOUYANCY (B): $W_D = 33.7^K$ (FROM p.6)

BOUYANCY ≅ 3.2K (FROM p.6)

Σ FORCES AT a $= \Sigma F_a = 34.34K - \left(\frac{33.7K - 3.2K}{4}\right) = \underline{\underline{26.72K \uparrow}}$

AT CORNER b

$SRSS = 34.34K \downarrow$

$\frac{W_D - B}{4} = 7.63K \downarrow$

$\Sigma F_b = 34.34 + 7.63 \cong \underline{42K \downarrow}$

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SUBJECT BWR SPENT FUEL RACK IMPACT LOADS.

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AT CORNER C

DUE TO V: $\frac{11.4K}{4} = 2.8K$ ↑↓

DUE TO W_D-B: $\frac{33.7^K - 3.2^K}{4} = 7.63K$ ↓

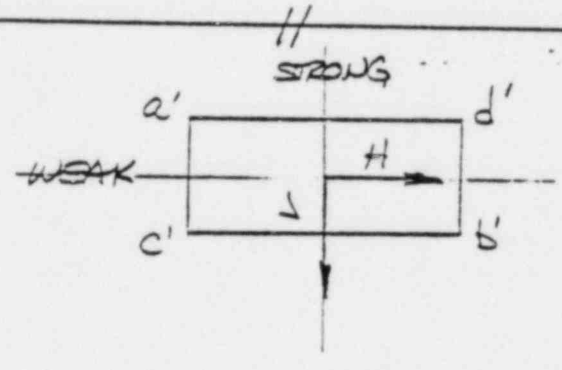
ΣF_C = SEISMIC UP = 2.8 − 7.63 = 4.83 ↓

SEISMIC DOWN = 2.8 + 7.63 = 10.43 ↓

CHECK SHEAR

SHEAR = $\frac{1}{2}H = \frac{23.62K}{2} = 11.81K$/FACE

FOR DBE



18 CELL BWR RACK

AT CORNER a':

DUE TO H: $\frac{1307''K}{2 \times 54''} = 12.1^K$ ↑

DUE TO ⊥: $\frac{1475''K}{2 \times 27''} = 27.3^K$ ↑

DUE TO V: $\frac{5.6^K}{4} = 1.4^K$ ↑↓

SRSS = $\sqrt{(12.1)^2 + (27.3)^2 + (1.4)^2} = 29.9^K$ ↑ (CONSV.)

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NAME OF COMPANY CP&L BSEP UNIT/S 1&2

SUBJECT Spent Fuel Storage Capacity Improvement

CALC. SET NO.		
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VOID		
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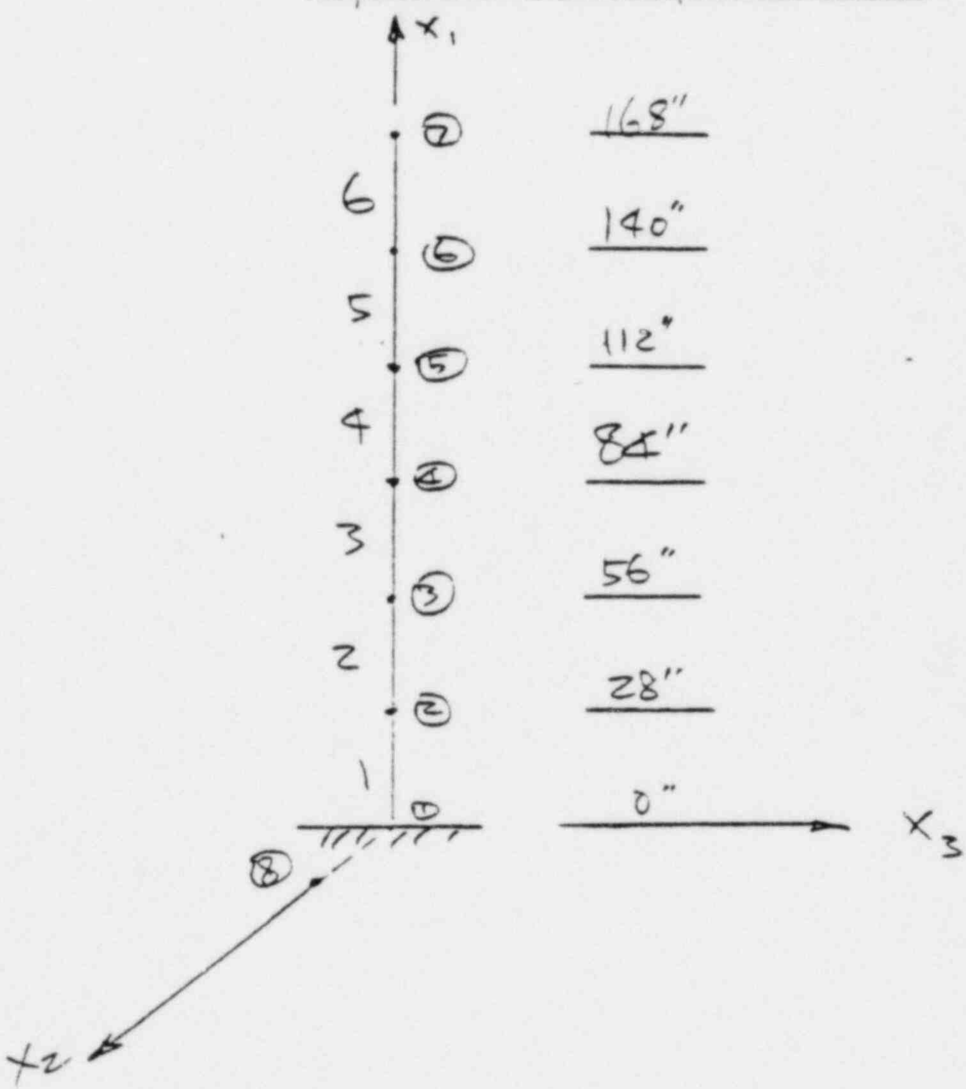
REV	COMP. BY	CHK'D BY
0	SAY DATE 8-21-80	AAM DATE 9/12/80
	DATE	DATE

36 cell Racks:

Section 1.0 - SRSS Modal Response Spectrum Analysis OBE



Seismic Mathematical Model

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NAME OF COMPANY CP&L BSEP UNIT/S 1&2

SUBJECT SPENT FUEL STORAGE CAPACITY IMPROVEMENT

REF. (1) CALCULATION # 9527-1-RB-FP-01 (SHT. 6 of 83)
(2) # 9527-028 MAG REPORT.

MATERIAL PROPERTIES.

$E = 29 \times 10^6$ PSI.

$\rho = 0.30$

$A = 140.20$ IN^2

$I_{x2} = I_{x3} = 32,948$ IN^4

$SF_2 = SF_3 = 0.53$ (ASSUMED SHEAR SHAPE FACTOR)

TOTAL WEIGHT :

$W_T = W_R + W_F + W_W$ (RACK + FUEL + WATER ENVELOPE)

$= 47200$ #

ASSUME DISTRIBUTED UNIFORMLY IN THE SEISMIC MODEL

BOUNDARY CONDITION

FULLY RESTRAINED AT BASE.

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GENERAL COMPUTATION SHEET

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NAME OF COMPANY CP&L BSEP UNIT/S 1 & 2

SUBJECT SPENT FUEL STORAGE CAPACITY IMPROVEMENT

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	DATE	DATE

REF. (3) COMPUTER RUN #5

MODAL ANALYSIS, & RESPONSE

SPECTRUM ANALYSIS - MRI/STARDYNE.

TABLE 1:

NATURAL FREQUENCY: (HORIZONTAL)

MODE No.	FREQUENCY (CPS)	NATURAL PERIOD (SEC).
1	20.62	0.05
2	90.90	0.011
3	111.66	0.0090

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NAME OF COMPANY CP&L BSEP UNIT/S 1&2

SUBJECT Spent Fuel Storage Capacity Improvement

CALC. SET NO.		
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0	SAY DATE 8-21-80	AAM DATE 9/15/80
	DATE	DATE

TABLE 2: PEAK DISPLACEMENT*, VELOCITY*, & ACCELERATION**
(SRSS MODAL SUPERPOSITION)
COMP. RUN #5

RACK ELEV.	NODE NO.	OBE - HORIZONTAL		
		DISP (IN)	VEL (IN/SEC)	ACCEL (G'S)
28"	2	0.00119	0.185	0.21
56"	3	0.00348	0.481	0.31
84"	4	0.00653	0.862	0.39
112"	5	0.010	1.299	0.47
140"	6	0.014	1.766	0.60
168"	7	0.017	2.236	0.82

* RELATIVE VALUE

** ABSOLUTE VALUE

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PRELIM.		9527
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VOID		
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J.O. 9527.085		
REV	COMP. BY	CHK'D BY
0	SAY DATE 9-21-80	AA DATE 9/15/80
	DATE	DATE

NAME OF COMPANY CP&L BSEP UNITS 1&2

SUBJECT SPENT FUEL STORAGE CAPACITY IMPROVEMENT

TABLE 3: MAXIUM FORCES & MOMENTS
(SRSS MODAL SUPERPOSITION)
COMP. RUN #5

RACK ELEV.	BEAM NO.	OBE - HORIZONTAL	
		SHEAR (KIPS)	MOMENT (IN-KIPS)
0"	1	15.41 *	1795.0 *
28"	2	14.73	1377.0
56"	3	13.30	977.0
84"	4	11.07	614.0
112"	5	7.85	309.0
140"	6	3.24	91.0

* SHEAR & MOMENT @ THE BASE OF THE FUEL RACK.

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united engineers & constructors inc.

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	DATE	DATE	

NAME OF COMPANY CP&L (BSEP) UNIT/S 1&2

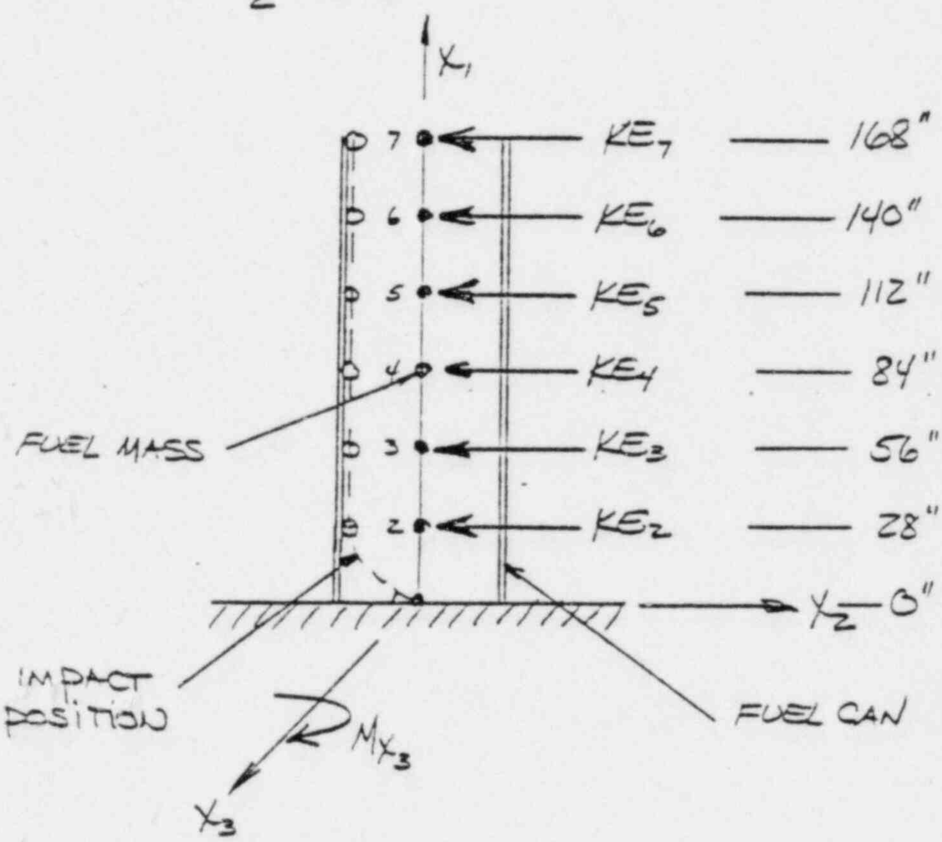
SUBJECT BWR SPENT FUEL RACK IMPACT LOADS

36 CELL BWR RACK FOR OBE

KINETIC ENERGY

$$KE_T = \sum_{i=2}^{i=7} KE_i \quad (\text{IN}\#)$$

WHERE $KE_i = \frac{1}{2} M_i V_i^2$



WT OF FUEL = 27036#

$$WT/IN = \frac{27036\#}{168"} = 160.9\#$$

$W_2 = W_3 = W_4 = W_5 = W_6 = 160.9\# \times 28" = 4505.2\#$

$W_1 = W_7 = 160.9\#/IN \times 14" = 2252.6\#$

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GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc.

CALC. SET NO.		
PRELIM.		9527 -
FINAL	X	1-23-FP-04
VOID		
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J.O. 4527.025		

REV	COMP. BY	CHK'D BY
0	KHD DATE 8/22/80	AAM DATE 9/15/80
	DATE	DATE

NAME OF COMPANY CP&L (BSEP) UNIT/S 1&2

SUBJECT BWR SPENT FUEL IMPACT LOADS

FUEL ASSEMBLY

KINETIC ENERGY DISTRIBUTION

$$KE_2 = \frac{1}{2}\left(\frac{4505.2^{\#}}{386.4 \text{ in/sec}^2}\right)(.185 \text{ in/sec})^2$$

$$= 5.83\ (.185)^2 = .200\ ''\#$$

$$KE_3 = 5.83\ (.481)^2 = 1.349\ ''\#$$

$$KE_4 = 5.83\ (.862)^2 = 4.332\ ''\#$$

$$KE_5 = 5.83\ (1.299)^2 = 9.838\ ''\#$$

$$KE_6 = 5.83\ (1.766)^2 = 18.182\ ''\#$$

$$KE_7 = 2.92\ (2.236)^2 = 14.60\ ''\#$$

$$KE_T = 48.50\ ''\#$$

REACTION FORCE (BASE SHEAR) DUE TO KE: (H)

$$H_{imp.} = \left[\sum_{i=2}^{i=7} H_i^2\right]^{1/2} \text{ (LBS.)} \quad \text{WHERE } H_i = \left[2K_i(KE_i)\right]^{1/2}$$

FUEL RACK: (ABSORBING KE)

$$K_i = \frac{3EI}{l_i^2} \text{ (LBS/IN)}$$

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GENERAL COMPUTATION SHEET

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NAME OF COMPANY CP&L (BSEP) UNIT/S 1&2

SUBJECT BWR SPENT FUEL RACK IMPACT LOADS

$$K_2 = \frac{3(29\times10^6)(32948)}{(28)^3} = 2.87\times10^{12}\left(\frac{1}{28^3}\right)$$

$$= 2.87\times10^{12}(4.56\times10^{-5}) = 1.31\times10^8 \text{ \#/in.}$$

$$K_3 = 2.87\times10^{12}\left(\frac{1}{56^3}\right) = 1.63\times10^7 \text{ \#/in.}$$

$$K_4 = 2.87\times10^{12}\left(\frac{1}{84^3}\right) = 4.84\times10^6 \text{ \#/in.}$$

$$K_5 = 2.87\times10^{12}\left(\frac{1}{112^3}\right) = 2.04\times10^6 \text{ \#/in.}$$

$$K_6 = 2.87\times10^{12}\left(\frac{1}{140^3}\right) = 1.04\times10^6 \text{ \#/in.}$$

$$K_7 = 2.87\times10^{12}\left(\frac{1}{168^3}\right) = 6.05\times10^5 \text{ \#/in.}$$

SHEAR FORCES:

$$H_2 = \left[2K_2(KE_2)\right]^{1/2}$$

$$= \left[2(1.31\times10^8)(.200)\right]^{1/2} = 7.24\times10^3 \text{ \#}$$

$$H_3 = \left[2(1.63\times10^7)(1.349)\right]^{1/2} = 6.63\times10^3 \text{ \#}$$

$$H_4 = \left[2(4.84\times10^6)(4.332)\right]^{1/2} = 6.48\times10^3 \text{ \#}$$

$$H_5 = \left[2(2.04\times10^6)(9.838)\right]^{1/2} = 6.34\times10^3 \text{ \#}$$

$$H_6 = \left[2(1.04\times10^6)(18.182)\right]^{1/2} = 6.15\times10^3 \text{ \#}$$

$$H_7 = \left[2(6.05\times10^5)(14.60)\right]^{1/2} = 4.20\times10^3 \text{ \#}$$

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NAME OF COMPANY CP&L (BSEP) UNIT/S 1 & 2

SUBJECT BWR SPENT FUEL RACK IMPACT LOADS

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$$H_{imp} = \sqrt{[(7.24)^2+(6.63)^2+(6.48)^2+(6.34)^2+(6.15)^2+(4.2)^2](10^3)^2}$$

$= \underline{\underline{15.30\,K}}$ TOTAL BASE SHEAR DUE TO IMPACT!

<u>BASE MOMENT DUE TO KE</u> : (M)

$$M_{imp} = \left(\sum_{i=2}^{i=7} M_i^2\right)^{1/2} \quad \text{WHERE } M_i = H_i\, l_i \ ('' \#)$$

$M_2 = H_2 \cdot l_2$

$= (7.24 \times 10^3 \#)(28'') = 2.03 \times 10^5\ '' \#$

$M_3 = (6.63 \times 10^3 \#)(56'') = 3.71 \times 10^5\ '' \#$

$M_4 = (6.48 \times 10^3 \#)(84'') = 5.44 \times 10^5\ '' \#$

$M_5 = (6.34 \times 10^3 \#)(112'') = 7.10 \times 10^5\ '' \#$

$M_6 = (6.15 \times 10^3 \#)(140'') = 8.61 \times 10^5\ '' \#$

$M_7 = (4.20 \times 10^3 \#)(168'') = 7.06 \times 10^5\ '' \#$

$$M_{imp} = \sqrt{[(2.03)^2+(3.71)^2+(5.44)^2+(7.1)^2+(8.61)^2+(7.06)^2](10^{10})}$$

$\underline{1490\,''K}$ TOTAL BASE MOMENT DUE TO IMPACT!

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NAME OF COMPANY CP&L (BSEP) UNIT/S 1 & 2

SUBJECT BWR SPENT FUEL RACK IMPACT LOADS

EFFECTIVE NUMBER OF IMPACTING FUEL ASSEMBLIES:

ASSUME $\pm\sigma$ DISTRIBUTION:

% = 68.27

REF: MECHANICAL DESIGN AND SYSTEMS HANDBOOK HA ROTHBART PP 1-109 & 1-110

$N_{EFF. FUEL ASS'Y} = .6827(36) = 24.6$ (IMPACT. AT THE SAME TIME)

IMPACT SHEAR & MOMENT (100% NO. OF IMPACT. FUEL ASS'Y)

$H_{imp} = 15.30K$ - p.8

$M_{imp} = 1490$ "K - p.8

ADJUSTED IMPACT SHEAR & MOMENT (68% IMPACT)

$H'_{imp} = 15.30K(.6827) = 10.45K$

$M'_{imp} = 1490$ "K$(.6827) = 1017.2$ "K

SRSS COMBINATION: (SEISMIC + IMPACT)

$MAX\ H = [(15.41)^2 + (10.45)^2]^{1/2} = \underline{\underline{18.62\ K}}$

$MAX\ M = [(1795)^2 + (1017.2)^2]^{1/2} = \underline{\underline{2063.2\ "K}}$

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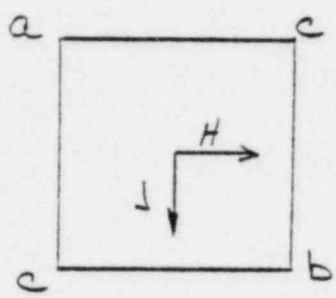
NAME OF COMPANY CP&L (BSEP) UNIT/S 1&2

SUBJECT BWR SPENT FUEL RACK IMPACT LOADS

36 CELL BWR RACK FOR OBE



AT CORNER a:

DUE TO H: $\frac{2063.2''^{K}}{2 \times 54''} = X = 19.10^{K} \uparrow$

DUE TO ⊥: $\frac{2063.2''^{K}}{108''} = Y = 19.10^{K} \uparrow$

DUE TO V: $\frac{7.9}{4} = Z \cong 2.0 \downarrow\uparrow$ (REF SH. 14 OF RB-FP-01)

$SRSS = \sqrt{X^2+Y^2+Z^2} = \sqrt{(19.1)^2+(19.1)^2+2^2} = 27.09^{K} \uparrow$

FROM $W_D - B = \frac{33.7-3.2}{4} = 7.63^{K} \downarrow$

$\Sigma F_a = 27.09 - 7.63 = \underline{19.46^{K}} \uparrow$

AT CORNER b:

$SRSS = 27.09^{K} \downarrow$

$\frac{W_D - B}{4} = 7.63^{K} \downarrow$

$\Sigma F_b = 27.09 + 7.63 = \underline{34.72^{K}} \downarrow$

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NAME OF COMPANY CP&L (BSEP) UNIT/S 1&2

SUBJECT BWR SPENT FUEL RACK IMPACT LOADS.

AT CORNER C:

DUE TO V: $\frac{7.9k}{4} = 2.0k$ ↓↑

DUE TO W_b-B: $\left(\frac{33.7 - 3.2}{4}\right) = 7.63k$ ↓

ΣF_c = SEISMIC UP = 7.63 - 2.0 = 5.63k ↓

SEISMIC DOWN = 7.63 + 2.0 = 9.63k ↓

SHEAR = $\frac{1}{2}H = \frac{18.62k}{2} = 9.31k$ /FACE

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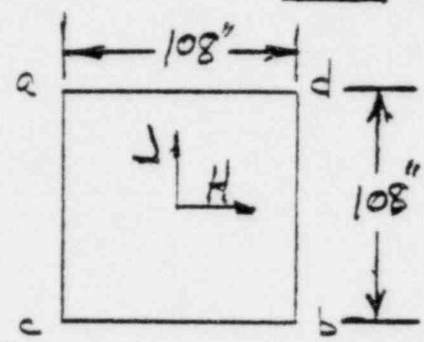
NAME OF COMPANY CP&L (BSEP) UNIT/S 1 & 2

SUBJECT BWR SPENT FUEL RACK IMPACT LOADS

RE-ANALYSIS — H LOAD IN OPP. DIR. (SOUTH)

36 CELL RACK OBE



(SEE SHTS 254 & 255 OF 327)

AT CORNER a:

DUE TO H: $X = \frac{2063.2''^{K}}{108''} = 19.1^{K} \uparrow$

DUE TO ⊥: $Y = \frac{2063.2''^{K}}{108''} = 19.1^{K} \downarrow$

DUE TO V: $Z = \frac{7.9}{4} = 2^{K} \downarrow\uparrow$ (SHT 14 OF RB-FP-01)

$\frac{W_D - B}{4} = 7.63^{K} \downarrow$

$\Sigma F_a =$ SEISMIC UP $= 5.63^{K} \downarrow$ ✓

SEISMIC DOWN $= 9.63^{K} \downarrow$ ✓

AT CORNER b:

DUE TO H: $X = 19.1^{K} \downarrow$

DUE TO ⊥: $Y = 19.1^{K} \uparrow$

DUE TO V: $Z = 2^{K} \downarrow\uparrow$

$\frac{W_D - B}{4} = 7.63^{K} \downarrow$

$\Sigma F_b =$ SEISMIC UP $= 5.63^{K} \downarrow$

SEISMIC DOWN $= 9.63^{K} \downarrow$

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NAME OF COMPANY CP&L (BSEP) UNIT/S 1 & 2

SUBJECT BWR SPENT FUEL RACK IMPACT LOADS

AT CORNER c:

DUE TO H: X = 19.1k ↑

DUE TO ⊥: Y = 19.1k ↑

DUE TO V: Z = 2k ↑↓

SRSS = 27.1k ↑ (CONSV)

$\frac{W_D - B}{4}$ = 7.63k ↓

ΣF_c = 27.1 - 7.63 = 19.47k ↑ ✓

AT CORNER d:

H: X = 19.1k ↓

⊥: Y = 19.1k ↓

V: Z = 2k ↓↑

SRSS = 27.1k ↓ (CONSV.)

$\frac{W_D - B}{4}$ = 7.63k ↓

ΣF_d = 34.73k ↓ ✓

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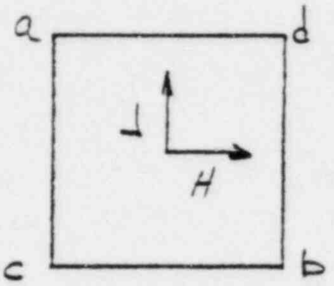
NAME OF COMPANY CP&L (BSEP) UNIT/S 1&2

SUBJECT BWR SPENT FUEL RACK IMPACT LOADS

36 CELL BWR RACK — DBE



(SEE SHTS. 229 & 230 THIS SET)

AT CORNER a:

H: X = 24.2K ↑

⅃: Y = 24.2K ↓

V: Z = 2.8K ↓↑ (SHT 13 OF RB-FP-01)

$\frac{W_D - B}{4}$ = 7.63K ↓

ΣF_a = SEISMIC UP = ~~5.63K~~ 4.83 ↓

SEISMIC DOWN = ~~9.63K~~ 10.43 ↓

AT CORNER b:

H: X = 24.2K ↓

⅃: Y = 24.2K ↑

V: Z = 2.8K ↓↑

$\frac{W_D - B}{4}$ = 7.63 ↓

ΣF_b = SEISMIC UP = ~~5.63K~~ 4.83 ↓

SEISMIC DOWN = ~~9.63K~~ 10.43 ↓

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GENERAL COMPUTATION SHEET

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NAME OF COMPANY CP&L UNIT/S 1&2

SUBJECT

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AT CORNER C:

H: X = 24.2K ↑

J: Y = 24.2K ↑

V: Z = 2.8K ↓↑

SRSS = 34.34K ↑ (CONSV.)

$\frac{W_D - B}{4}$ = 7.63K ↓

ΣF_c = 26.7K ↑ ✓

AT CORNER d:

H: X = 24.2K ↓

J: Y = 24.2K ↓

V: Z = 2.8K ↓↑

SRSS = 34.34K ↓ (CONSV.)

$\frac{W_D - B}{4}$ = 7.63K ↓

ΣF_d = 42K ↓ ✓

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GENERAL COMPUTATION SHEET

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united engineers & constructors inc

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FINAL	X	RB-FD-04-F		DATE 9/8/80	DATE 9/17/80
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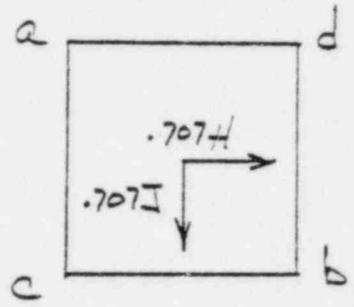
NAME OF COMPANY: CP&L (BSEP) UNIT/S: 1 & 2

SUBJECT: SPENT FUEL POOL

DBE

36-CELL RACK



CORNER a: DBE

DUE TO H: $X = \frac{2614 \times .707}{108"} = 17.1 K \uparrow$

DUE TO J: $Y = \frac{2614 \times .707}{108"} = 17.1 k \uparrow$

DUE TO V: $Z = \frac{11.2 K}{4} = 2.8 K \downarrow\uparrow$

SRSS = 24.3 K ↑ $\Sigma F_a = 24.3 - 7.6 = 16.7 K \uparrow$

$\frac{W_D - B}{4} = 7.6 K \downarrow$

CORNER b:

SRSS = 24.3 K ↓ $\Sigma F_b = 24.3 + 7.6 = 31.9 K \downarrow$

$\frac{W_D - B}{4} = 7.6 K \downarrow$

CORNER c:

$X = 17.1 K \uparrow$

$Y = 17.1 K \downarrow$

$Z = 2.8 K \downarrow\uparrow$

$\frac{W_D - B}{4} = 7.6 K \downarrow$

ΣF_c = SEISMIC UP = 4.8 ↓

SEISMIC DN = 10.4 K ↓

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GENERAL COMPUTATION SHEET

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united engineers & constructors inc

NAME OF COMPANY: CPÉL (BSEP) UNIT/S: 1 & 2

SUBJECT: SPENT FUEL POOL

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CORNER d:

$X = 17.1K \downarrow$

$Y = 17.1K \uparrow$

$Z = 2.8K \downarrow\uparrow$

$\frac{W_D - B}{4} = 7.6K \downarrow$

$\Sigma F_d =$ SEISMIC UP = 4.8K ↓

SEISMIC DN = 10.4K ↓

CORNER LOADS FOR RACKS S, T, Y, Z.

CORNER a:

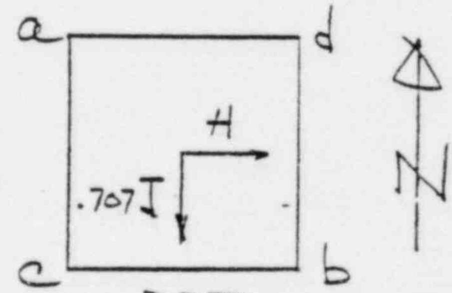
$X = \frac{2614''K}{108''} = 24.2K \uparrow$

$Y = \frac{2614''K \times .707}{108} = 17.1K \uparrow$

$Z = 2.8K \downarrow\uparrow$

SRSS = 29.8K ↑

$\frac{W_D - B}{4} = 7.6K \downarrow$



DBE

$\Sigma F_a = 29.8 - 7.6 = 22.2K \uparrow$

CORNER b:

$X = 24.2K \downarrow$

$Y = 17.1K \downarrow$

$Z = 2.8K \downarrow\uparrow$

$\frac{W_D - B}{4} = 7.6K \downarrow$

SRSS = 29.8K ↓

$\Sigma F_b = 29.8 + 7.6 = 37.4K \downarrow$

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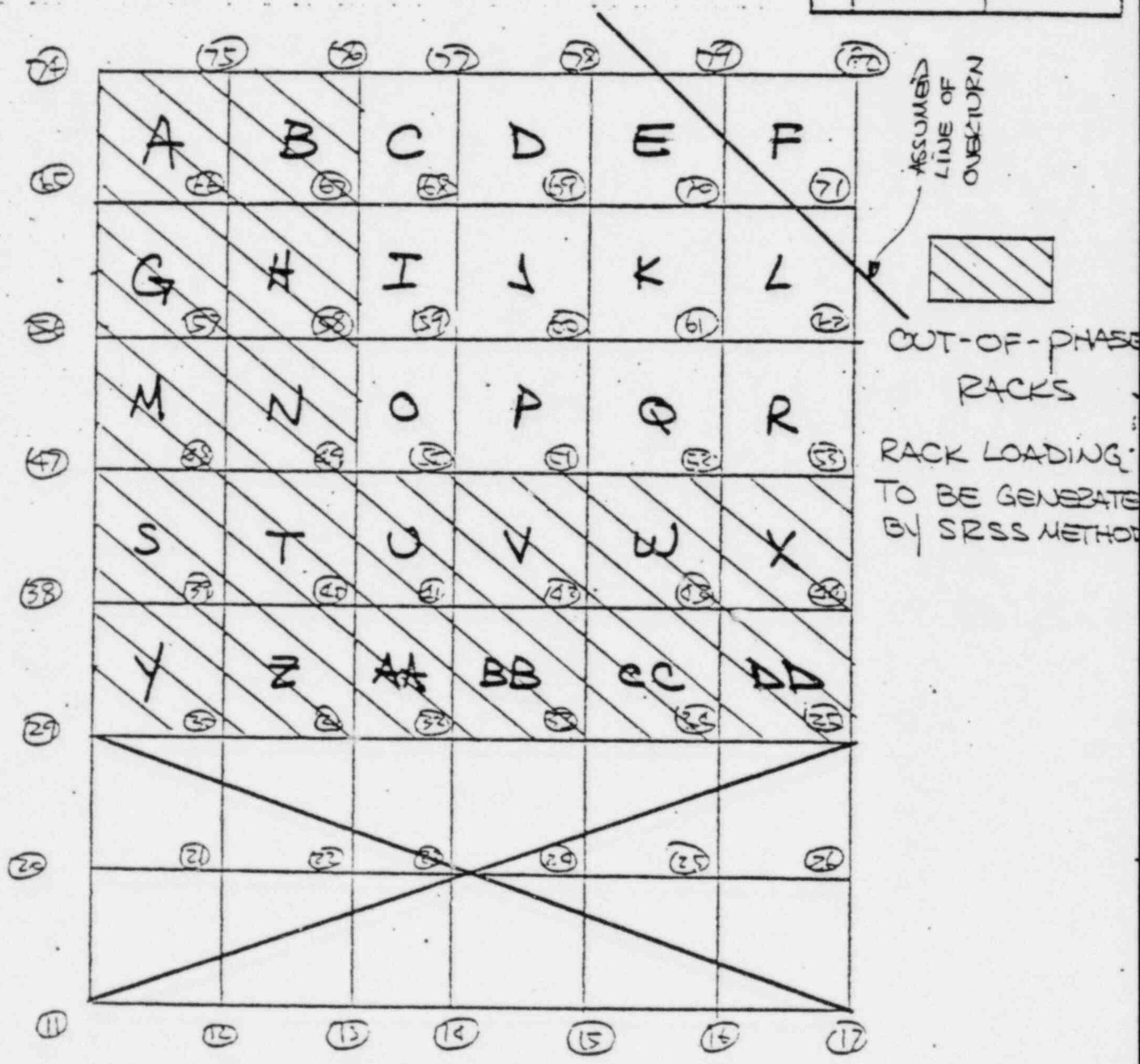
NAME OF COMPANY CP&L BSEP UNIT/S 1&2

SUBJECT Spent Fuel Storage Capacity Improvement

DBE



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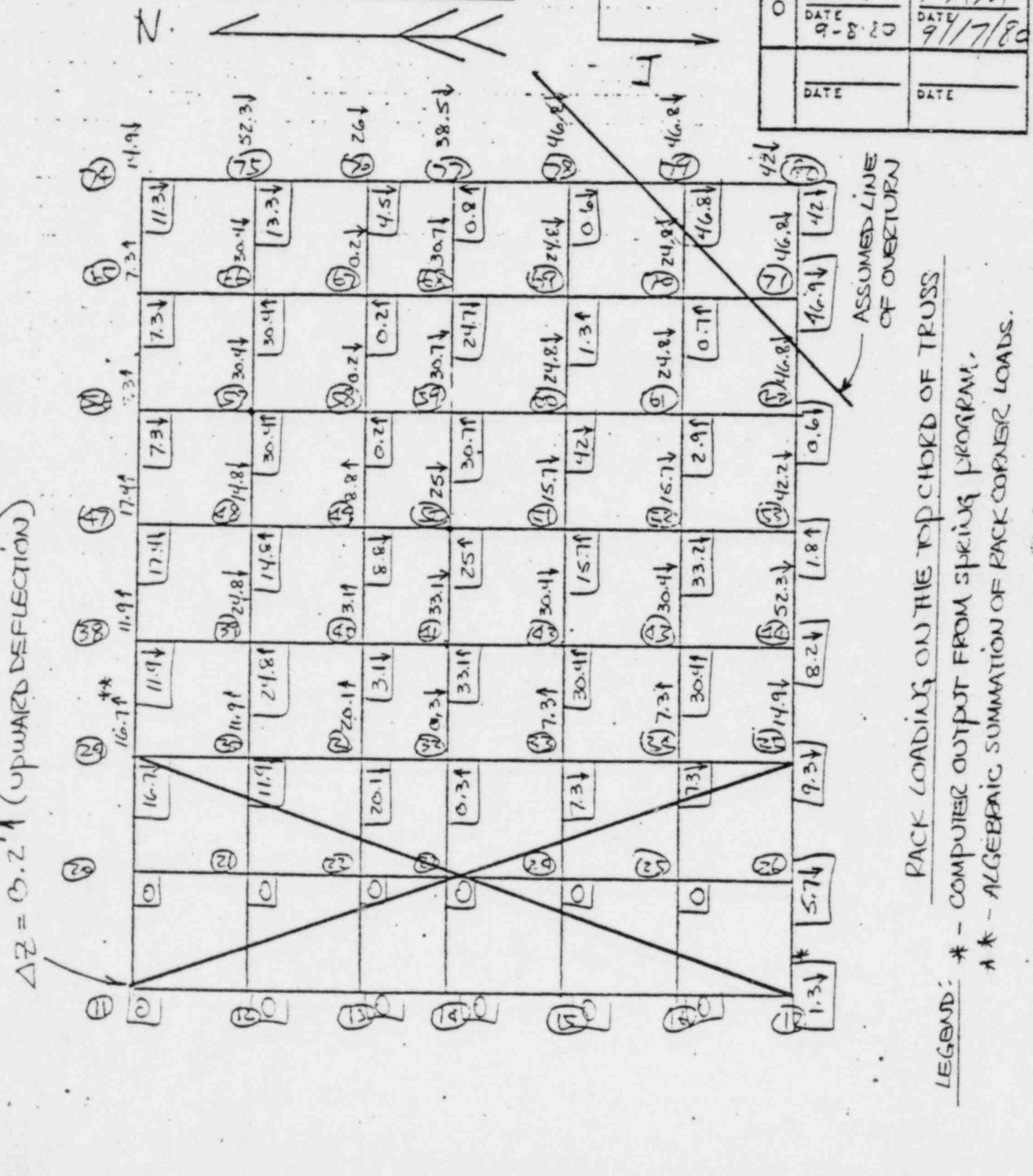
NAME OF COMPANY CP&L BSEP UNIT/S 1 & 2

SUBJECT Spent Fuel Storage Capacity Improvement

DBE (SEISMIC UP)

36 CELL & 18 CELL RACKS



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NAME OF COMPANY CP&L BSEP UNITS 1&2

SUBJECT Spent Fuel Storage Capacity Improvement

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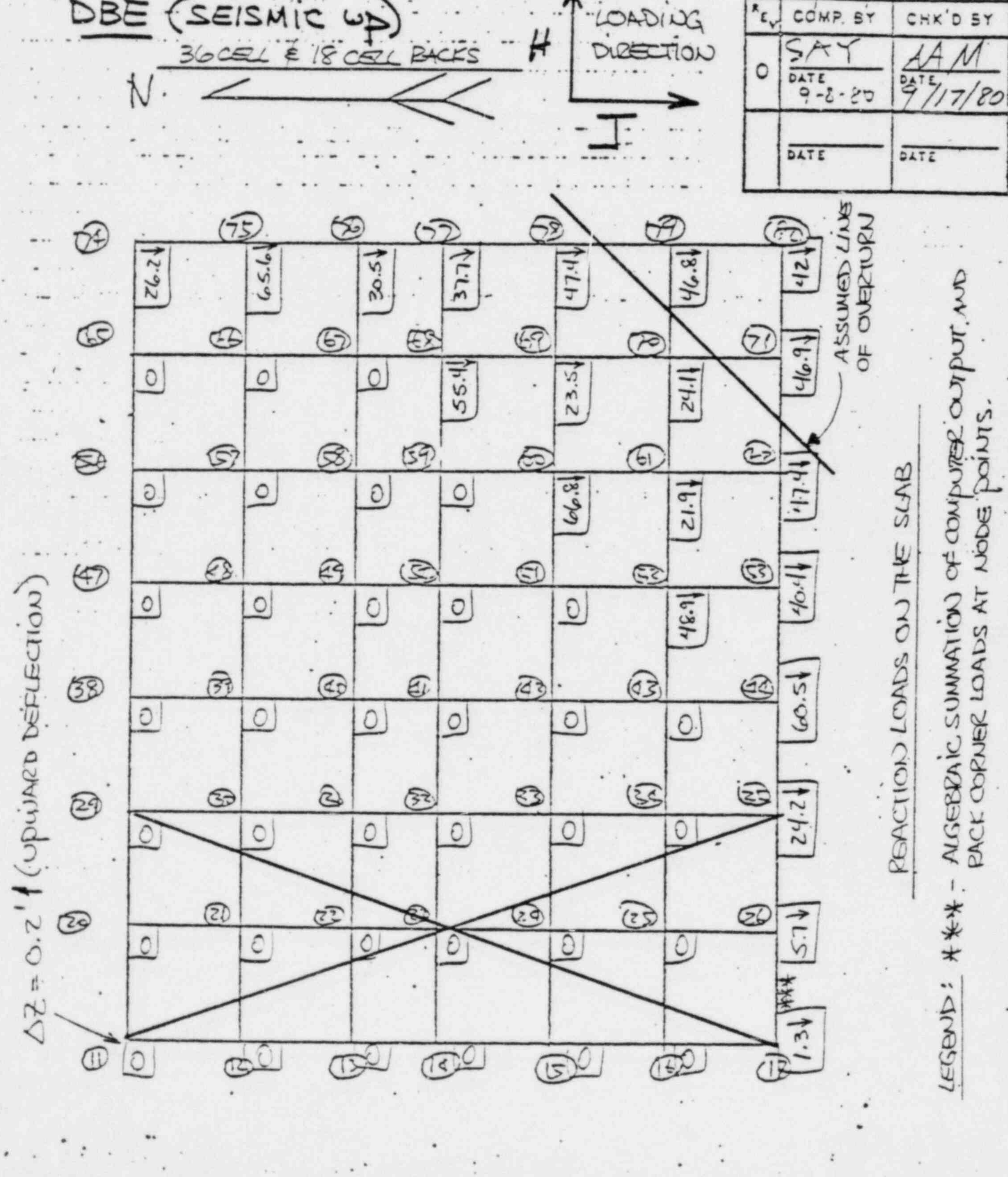
DBE (SEISMIC UP)

36 CELL & 18 CELL RACKS



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NAME OF COMPANY: CP&L BSEP UNIT/S: 1&2

SUBJECT: Spent Fuel Storage Capacity Improvement

36 CELL & 18 CELL RACKS

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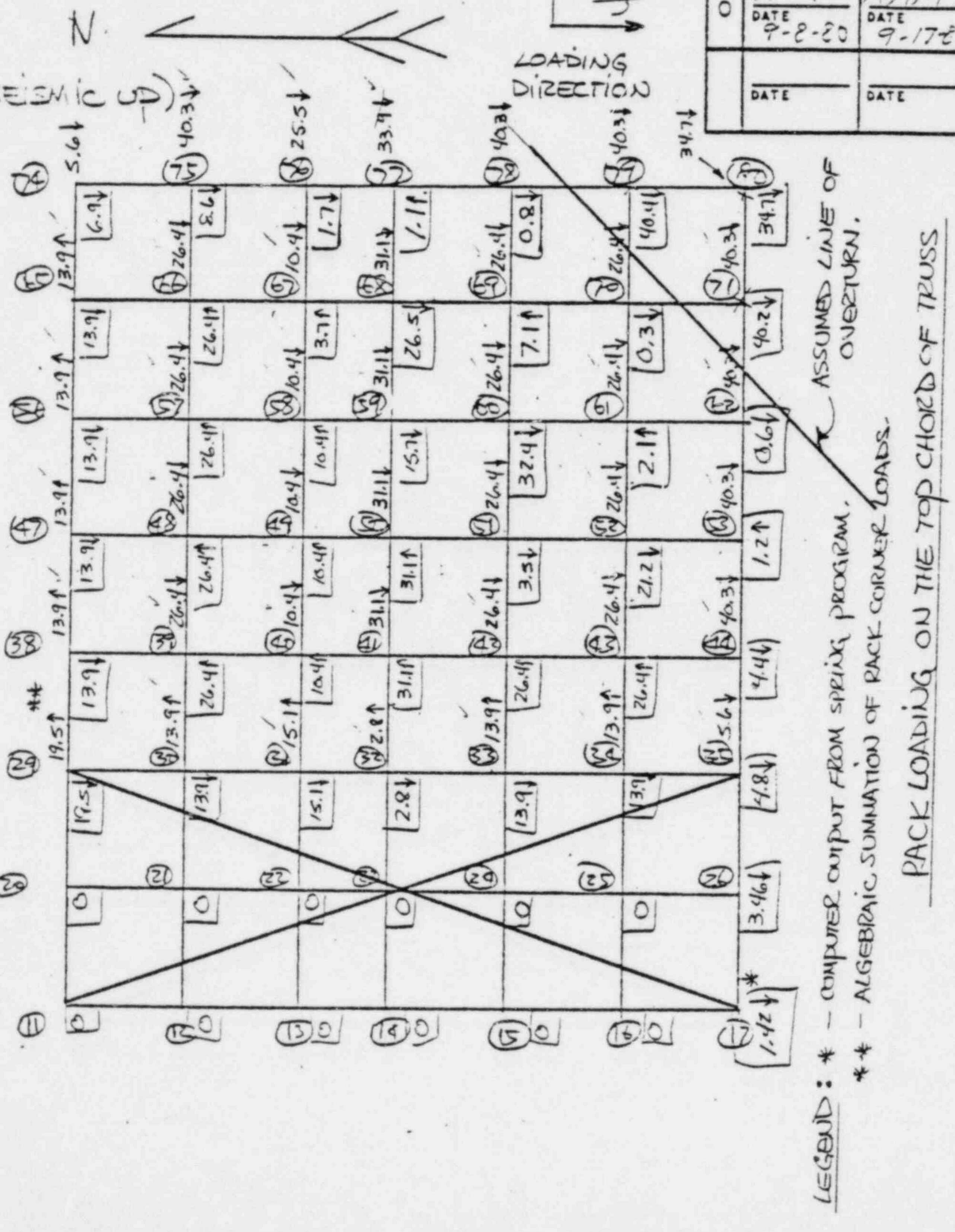
OBE (SEISMIC UP)



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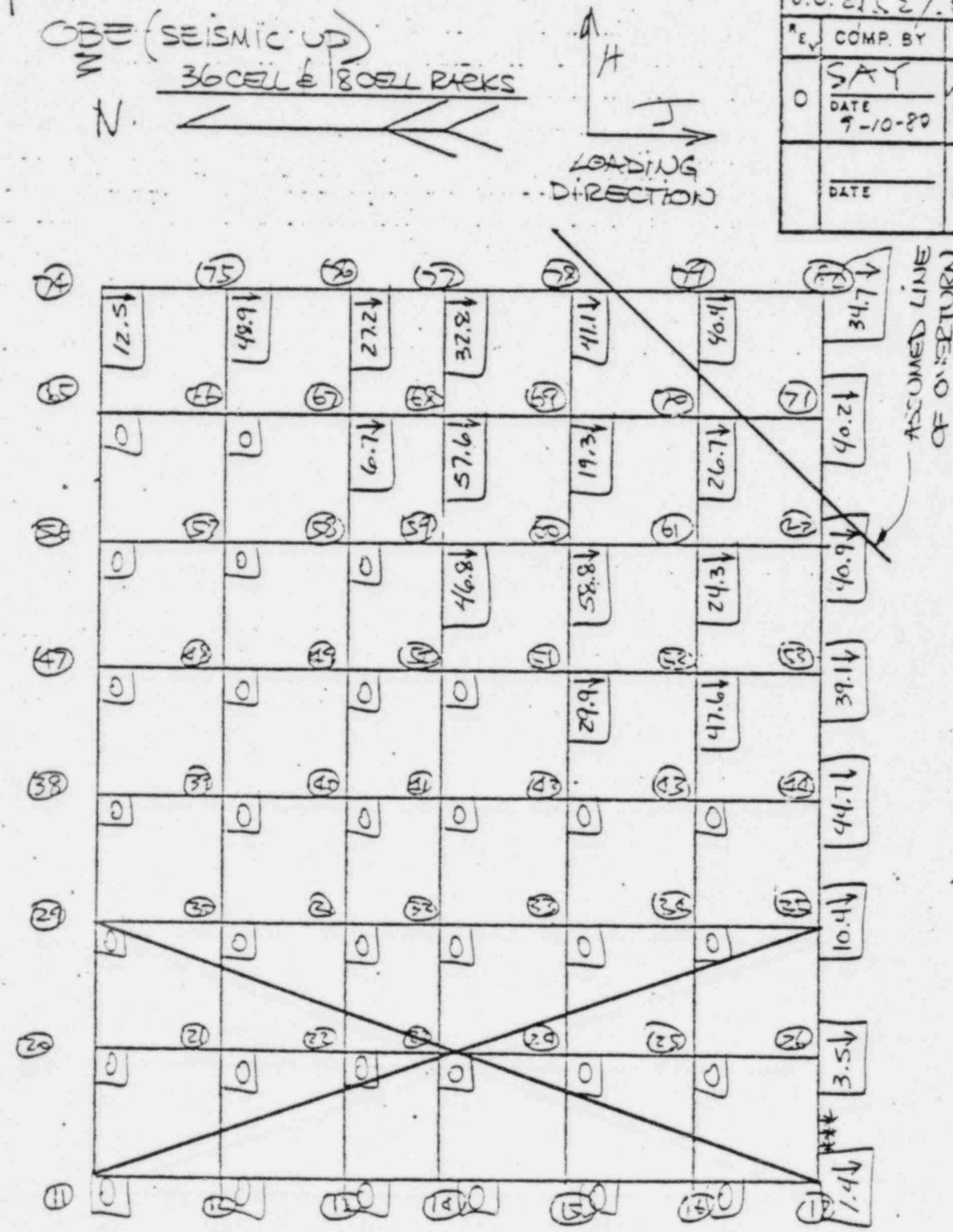
NAME OF COMPANY CP&L BSEP UNIT/S 1&2

SUBJECT Spent Fuel Storage Capacity Improvement

OBE (SEISMIC UP)

36 CELL & 18 CELL RACKS



REACTION LOADS ON THE SLAB

LEGEND: *** - ALGEBRAIC SUMMATION OF COMPUTER OUTPUT AND RACK CORNER LOADS AT NODE POINTS.

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GENERAL COMPUTATION SHEET

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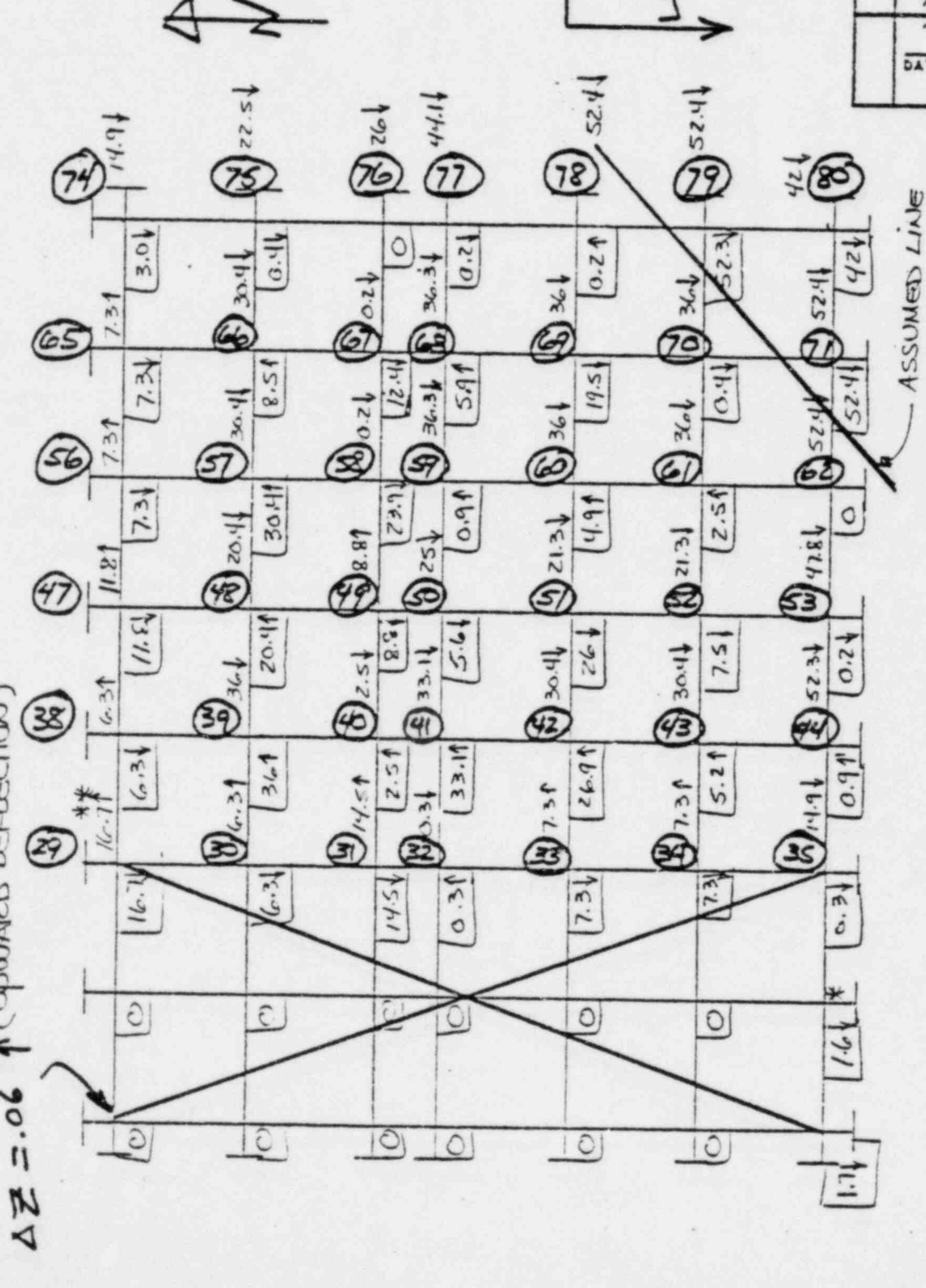
NAME OF COMPANY CP&L (BSEP) UNIT/S 1&2

SUBJECT Spent Fuel Storage Capacity Improvement

36 CELL & 18 CELL RACKS

DBE (SEISMIC DOWN)

LOADING DIRECTION



RACK LOADING ON THE TOP CHORD OF TRUSS

LEGEND: * - COMPUTER OUTPUT FROM SPRING PROGRAM.

** - ALGEBRAIC SUMMATION OF RACK CORNER LOADS.

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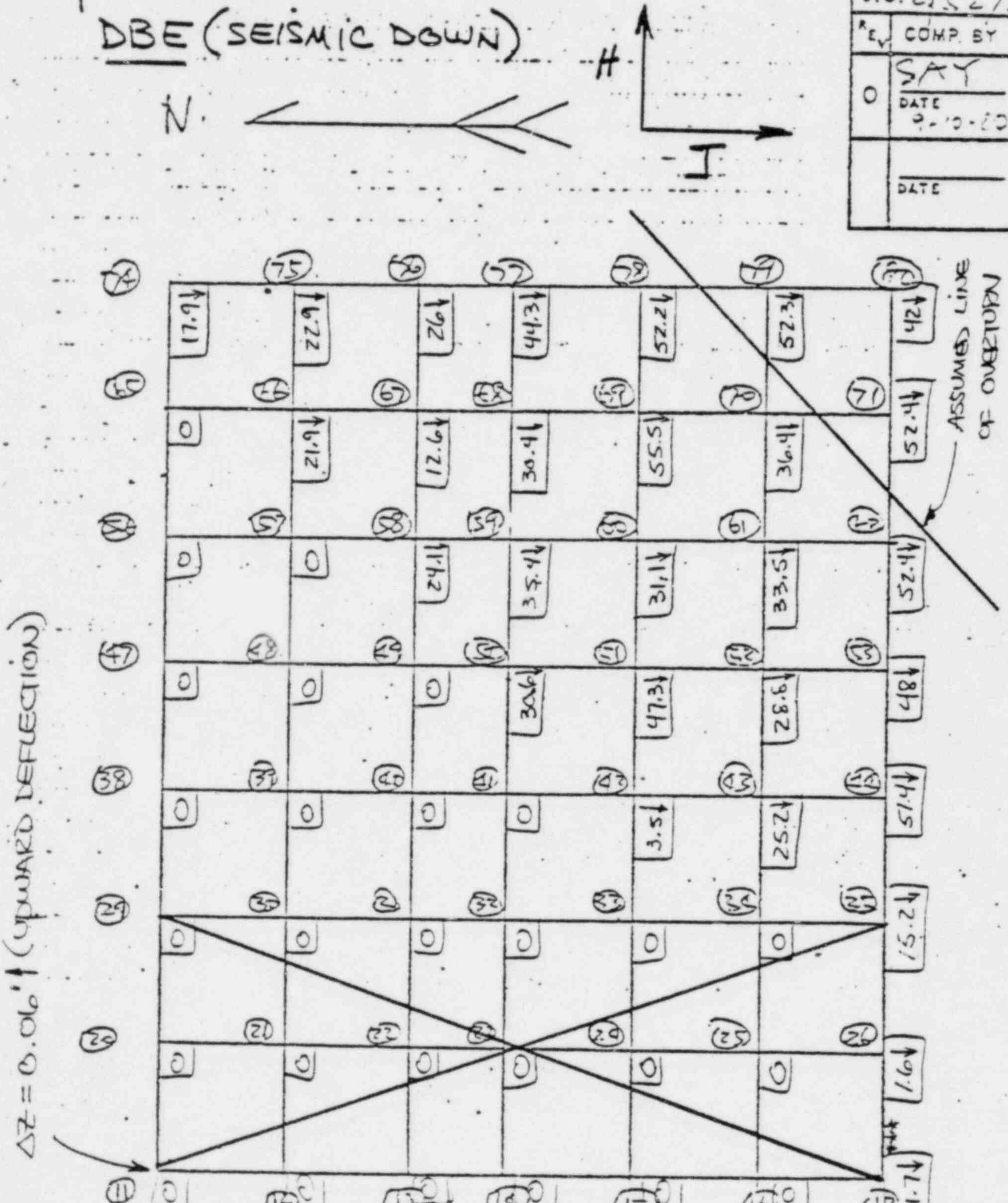
NAME OF COMPANY CP&L BSEP UNIT/S 1&2

SUBJECT Spent Fuel Storage Capacity Improvement

DBE (SEISMIC DOWN)



REACTION LOADS ON THE SLAB

LEGEND: *** – ALGEBRAIC SUMMATION OF COMPUTER OUTPUT AND RACK CORNER LOADS AT NODE POINTS.

Part 3: Finite Element Model for Fuel Pool Slab and Walls

Form 5007 Rev. 3-77

GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc.

NAME OF COMPANY CP&L BSEP UNIT/S 1&2

SUBJECT Fuel Pool Slab

CALC. SET NO.		
PRELIM.	X	9527-
FINAL	X	1-RB-FP-05
VOID		
SHEET 1 OF 36		
J.O. 9527.077		
REV	COMP. BY	CHK'D BY
0	SAY DATE 7-25-80	KC DATE 4-30-80
	DATE	DATE

THE FOLLOWING ARE DERIVED FOR THE STARDYNE INPUT

YOUNG'S MODULUS

$E = w^{1.5} 33 \sqrt{f'c}$

$= 150^{1.5} \times 33 \times \sqrt{3000}$

$= 3320000$ psi

$= 4.782 \times 10^5$ KSF

POISSON RATIO FOR CONC

$\nu = 0.15$

DENSITY

$\gamma = 150\ \#/ft^3$

$= 0.15\ K/ft^3$

Form 5007 Rev. 3-77

(DISCIPLINE)

GENERAL COMPUTATION SHEET

united engineers & constructors inc.

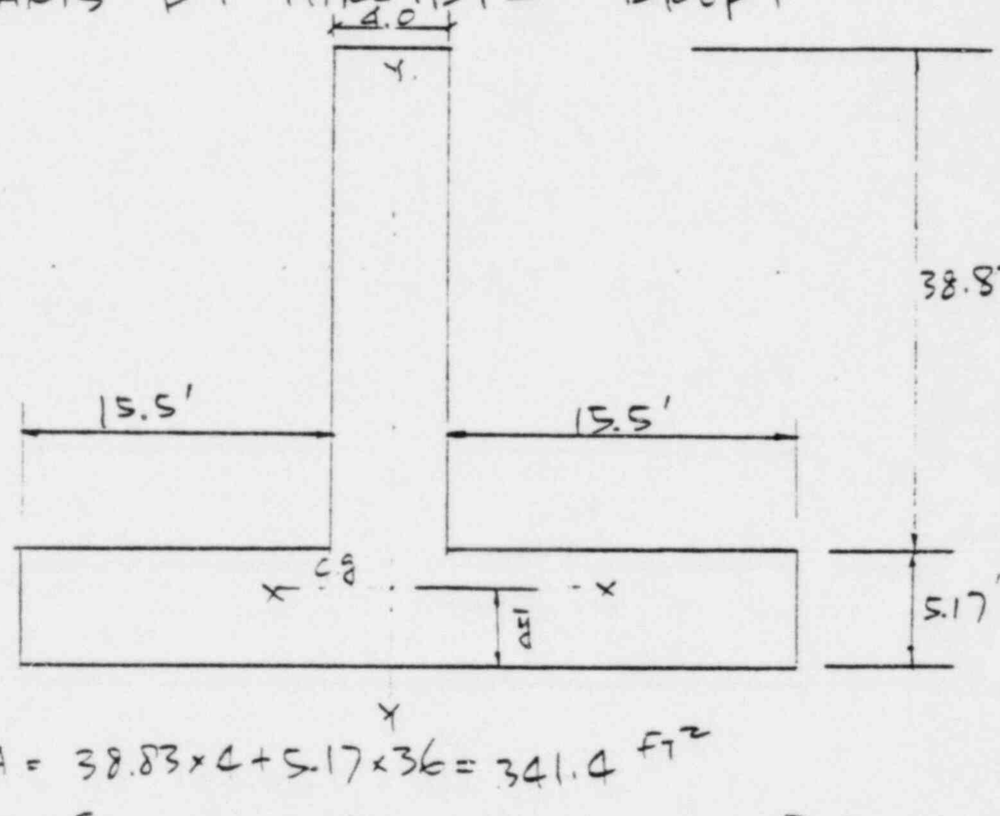
NAME OF COMPANY CP&L BSEP UNIT/S 1&2

SUBJECT Fuel pool slab.

CALC. SET NO.		
PRELIM.	X	9527-
FINAL	X	1-RB-FP-05 F
VOID		
SHEET 2 OF 36		
J.O. 9527.077		
REV	COMP. BY	CHK'D BY
0	SAY DATE 2-25-80	KC DATE 4-30-80
	DATE	DATE

TORSIONAL PROPERTIES OF THE BOUNDARY BEAMS.

BEAMS B1 THRU B12 BRGP 1



$A = 38.83 \times 4 + 5.17 \times 36 = 341.4\ FT^2$

$\bar{y} = \left[38.83 \times 4 \times \left(\frac{38.83}{2} + 5.17\right) + \frac{1}{2} \times 5.17^2 \times 35\right] / 341.4 = 12.59\ FT$

$I_{xx} = \frac{4 \times 38.83^3}{12} + \frac{35 \times 5.17^3}{12} + 38.83 \times 4 \times \left(\frac{38.83}{2} + 5.17 - 12.59\right)^2$

$+ 5.17 \times 35 \times \left(12.59 - \frac{5.17}{2}\right)^2 = 60371.0\ FT^4$

Form 5007 Rev. 3-77

GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc.

CALC. SET NO.		
PRELIM.	X	9527-
FINAL	X	1-RB-FP-05
VOID		
SHEET 3 OF 36		
J.O. 9527.077		

REV	COMP. BY	CHK'D BY
0	SAY DATE 2-25-80	KC DATE 4-30-80
	DATE	DATE

NAME OF COMPANY CP&L BSEP UNIT/S 1&2

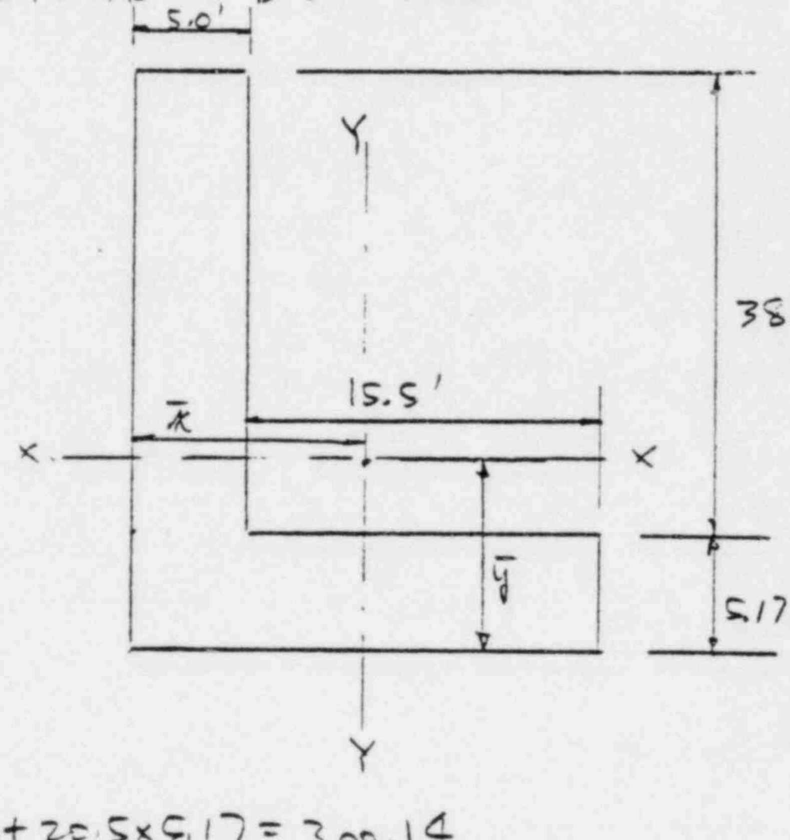
SUBJECT

$$I_{YY} = \frac{38.83 \times 4^3}{12} + \frac{5.17 \times 36^3}{12}$$

$$= 18679 \text{ FT}^4$$

$$J = I_{XX} + I_{YY} = 60371 + 18679 = 79050 \text{ FT}^4$$

BEAM B13-B18 & B21-B26



$$A = 5 \times 38.83 + 20.5 \times 5.17 = 300.14$$

$$\bar{y} = \left[5 \times 38.83 \times (38.83/2 + 5.17) + \tfrac{1}{2} \times 5.17^2 \times 20.5\right] / 300.14 = 16.82 \text{ FT}$$

$$\bar{x} = \left[5 \times 38.83 \times \frac{5}{2} + 20.5 \times 5.17 \times 20.5/2\right] / 300.14 = 5.24 \text{ FT}$$

Form 5007 Rev. 3-77

GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc.

NAME OF COMPANY .... UNIT/S ....

SUBJECT ....

CALC. SET NO.			
PRELIM.	X	9527-	
FINAL	X	1-RB-FP-05 F	
VOID			
SHEET 4 OF 36			
J.O. 9527.077			
REV	COMP. BY	CHK'D BY	
0	SAT DATE 2-25-80	KC DATE 4-30-80	
	DATE	DATE	

$$I_{xx} = 5\times 38.83^3/12 + 20.5\times 5.17^3/12 + 5\times 38.83\times(38.83/2 + 5.17 - 16.82)^2 + 20.5\times 5.17\times(16.82 - 5.17/2)^2$$

$$= 57813 \text{ FT}^4$$

$$I_{yy} = 38.83\times 5^3/12 + 5.17\times 20.5^3/12 + 5\times 38.83(5.24 - 5/2)^2 + 20.5\times 5.17\times(20.5/2 - 5.24)^2$$

$$= 8234 \text{ FT}^4$$

$$J = I_{xx} + I_{yy} = 57813 + 8234 = 66047 \text{ FT}^4$$

5

Form 5007 Rev. 3-77

(DISCIPLINE)

GENERAL COMPUTATION SHEET

united engineers & constructors inc.

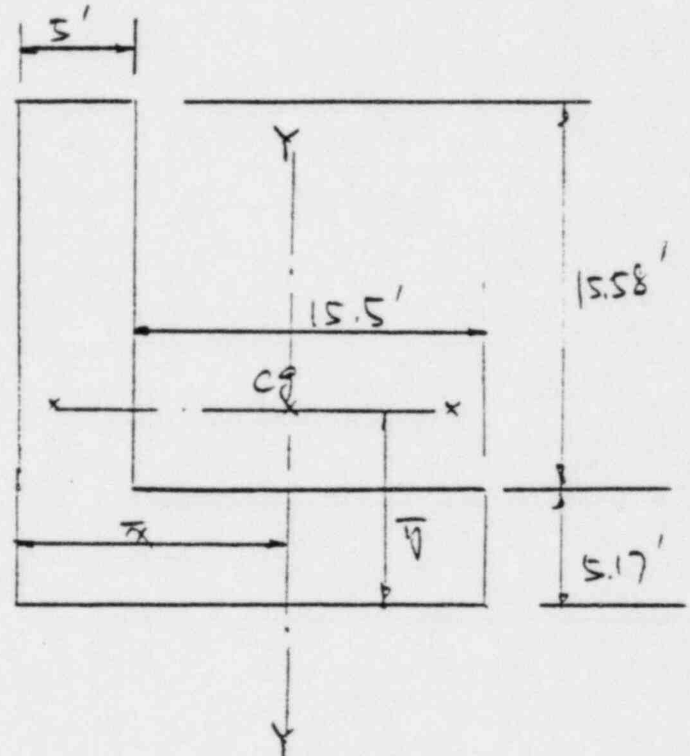
NAME OF COMPANY .... UNIT/S ....

SUBJECT ....

CALC. SET NO.		
PRELIM.	X	9527-
FINAL	X	1-RB-FP-05 F
VOID		
SHEET 5 OF 36		
J.O. 9527.077		

REV	COMP. BY	CHK'D BY
0	SAT DATE 2-25-80	KC DATE 1-30-80
	DATE	DATE

BEAMS B19 & B20



$A = 5 \times 15.58 + 20.5 \times 5.17$

$= 183.89 \text{ FT}^2$

$\bar{y} = [5 \times 15.58 \times (15.58/2 + 5.17) + 20.5 \times 5.17^2/2] / 183.99 = 6.98 \text{ FT}$

$\bar{x} = [5 \times 15.58 \times 5/2 + 5.17 \times 20.5^2/2] / 183.99 = 6.96 \text{ FT}$

$I_{xx} = 5 \times 15.58^3/12 + 20.5 \times 5.17^3/12 + 5 \times 15.58 \times (15.58/2 + 5.17 - 6.98)^2$
$+ 20.5 \times 5.17 (6.98 - 5.17/2)^2 = 6645 \text{ FT}^4$

$I_{yy} = 15.58 \times 5^3/12 + 5.17 \times 20.5^3/12 + 15.58 \times 5 \times (6.96 - 5/2)^2 + 20.5 \times 5.17 \times$
$(20.5/2 - 6.96)^2 = 6571 \text{ FT}^4$

$J = I_{xx} + I_{yy} = 6645 + 6571 = 13216 \text{ FT}^4$

Part 4: Analysis and Results

FORM 5001 REV 7/79

GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc

CALC. SET NO.		REV	COMP BY	CHK'D BY
PRELIM	X 9527-01-	0	KHD	AAM
FINAL	X RB-FP-04F		DATE 9/10/80	DATE 9/10/80
VOID				
SHEET 298 OF 327			DATE	DATE
J.O. 9527-025				

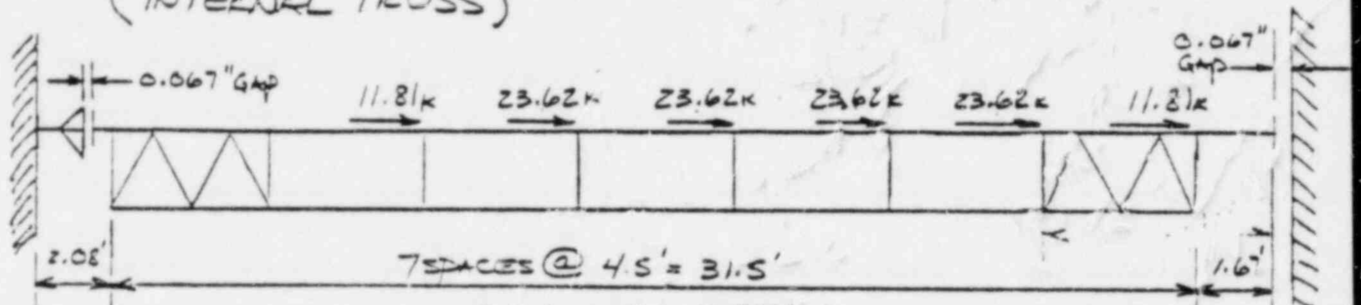
NAME OF COMPANY: CP&L (BSEP) UNIT/S: 1 & 2

SUBJECT: SPENT FUEL POOL

DBE SEISMIC SOUTH, EAST & UP (WORST CASE)

CALCULATE THERMAL & BENDING STRESSES:

(INTERNAL TRUSS)



ELEV. LKG. NORTH

BASE SHEAR FORCE (H) ALL IN SAME DIRECTION.

ASSUME ALL SHEAR FORCES ARE TAKEN BY TOP CHORD ONLY.

FOR DBE, 36-CELL RACK, BASE SHEAR (H) = 11.81k/FACE/RACK

$H = 11.81k/\text{FACE} \times 2\text{ FACES} = 23.62k$

TOTAL GAP = .067 × 2 = 0.134" = δ

TOP CHORD IS ASSUMED TO BE ONLY (2) 4"×4"×1/2" ∠'s

$T_{AMB} = 75°F$ (TOTAL GAP = 0.134")

$A = 2 \times 3.75 in^2 = 7.5 in^2$

$T_{op.} = 125°F$ (GAP CLOSES AT 107.5°F - REF. SH. 30. OF PRELIM CALC. SFSE 4, J.O. 9527-028, 8/9/76)

$T_{AB.} = 150°F$

AT 125°F: $\Delta l_{Top} = \epsilon \Delta T l = (9.2\times10^{-6})(125-107.5)(31.5+2.08+1.67)(12")$

$= \underline{0.068"}$ THERMAL EXPANSION

150°F: $\Delta l_{TAB.} = (9.2\times10^{-6})(42.5)(35.25)(12") = \underline{0.165"}$

$$\Delta l_H = \frac{H \Sigma l}{AE} = \frac{[(11.81)(24.17)+(23.62)(19.67+15.17+10.67+6.17)+(11.81)(1.67)](12")}{(7.5in^2)(29\times10^3)}$$

$= \underline{0.084"}$ SHORTENING OF TOP CHORD

FORM 5007 REV 7/79

GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc

NAME OF COMPANY: CP&L (BSEP) UNIT/S: 1&2

SUBJECT: SPENT FUEL POOL

CALC. SET NO.		REV	COMP BY	CHK'D BY
PRELIM	☒ 9527-01-	0	KHD	AAM
FINAL	☒ RB-FP-04-F		DATE 9/11/80	DATE 9/19/80
VOID				
SHEET 299 OF 327			DATE	DATE
J.O. 7527.085				

AT T_{OP}. (OPERATING TEMP.):

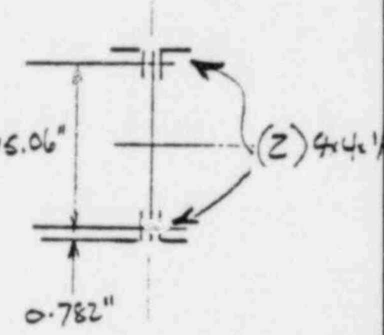
BECAUSE THE THERMAL EXPANSION AT 125°F is 0.068" > 0.134" GAP (CLOSES AT 107.5...)
COMPRESSIVE STRESSES OCCUR IN THE TOP CHORD.
— (SEE SH 2A OF 5) —
THE COMPRESSIVE FORCE (F_C) DUE TO BASE SHEAR AND MAXIMUM BENDING MOMENT IS:

$$F_C = (2 \times 11.81K) + 4(23.62K) + \frac{97.72''K}{15.06''}$$

$$= \underline{124.6K} < 196.8K_{ALLOW}$$

$$f/c = \frac{124.6}{196.8} = .63 < 1.0 \text{ OK}$$

[REF: CALC. 9527-1-RB-FP-01 SH. 43A, 3/16/77]



AT T_{AB}. (ABNORMAL TEMP.):

BECAUSE THE THERMAL EXPANSION > 0.134" GAP, THE GAP CLOSES AND THERMAL COMPRESSIVE STRESSES RESULT.

[FROM DBE SEISMIC SOUTH, EAST & UP PRINTOUT, M_{MAX} = 97.72"K ON BEAM 80]

HOWEVER, THE TOP CHORD SHORTENING OF 0.084" DUE TO THE BASE SHEARING FORCES IS GREATER THAN THE 0.031" THERMAL ELONGATION AND THEREFORE NO THERMAL COMPRESSIVE STRESSES ARE PRESENT.

FORM 5007 REV 7/79

GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc

NAME OF COMPANY CP&L (BSEP) UNIT/S 1&2

SUBJECT SPENT FUEL POOL

CALC. SET NO.		REV	COMP BY	CHK'D BY
PRELIM.	X 9527-01-	0	AAM	KHD
FINAL	X RB-FP-04-F		DATE 9/19/80	DATE 9/22/80
VOID				
SHEET 300 OF 327			DATE	DATE
J.O. 7527.005				

DBE SEISMIC SOUTH, EAST & UP CON'T

THE GAP = 0 AT T = 107.5 F°

ACTUAL AMBIENT TEMP. = 75 °F

∴ MAX. COMPRESSIVE STRESSES (σ_{MAX}) =

= STRESS DUE BASE SHEAR + BEND. MOMENT + THERMAL

$$\therefore \sigma_{Max} = \frac{2 \times 11.81 + 4(23.62)}{7.5\ in^2} + \frac{97.72\ in\text{-}k}{(7.5\ in^2)\ 15.06\ in} + \frac{(.165 - .084)(29 \times 10^3)}{35.25 \times 12}$$

$$\therefore \sigma_{Max} = 22.2\ ksi$$

$$\sigma_{Allow} = \frac{P_{Allow}}{A} = \frac{196.8\ K}{7.5} = 26.24\ ksi$$

Since $\sigma_{Max} < \sigma_{Allow}$ is ok.

Form 5007 Rev. 3-77

GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc.

NAME OF COMPANY CP&L BSEP UNIT/S 1&2

SUBJECT SPENT FUEL STORAGE CAPACITY IMPROVEMENT

CALC. SET NO.		
PRELIM.	X	9527-
FINAL	X	1-RB-FP-05 F
VOID		
SHEET 7 OF 36		
J.O. 9527.077		
REV	COMP. BY	CHK'D BY
0	SAY DATE 3-25-80	KC DATE 4-30-80
	DATE	DATE

*CHECK SHEAR CAPACITY @ EDGE OF SLAB

Shear capacity of the supporting ledge of the p.c. girder

From ACI.318-71

EQ 11-28

$$v_u = \left[6.5 - 5.1\sqrt{\frac{N_u}{V_u}}\right]\left[1 - 0.5\, a/d\right]\left\{1 + \left[64 + 160\sqrt{\left(\frac{N_u}{V_u}\right)^3}\right]\rho\right\}\sqrt{f'_c}$$

Where $f'_c = 5000$ psi

$\rho = 0.0033$

$a = 9''$ $d = .9 \times 30 = 27''$

$\frac{N_u}{V_u} = 0.2$

$$v_u = \left[6.5 - 5.1\sqrt{0.2}\right]\left[1 - 0.5\,\frac{9}{27}\right]\left\{1 + \left[64 + 160\sqrt{(0.2)^3}\right]0.0033\right\}\sqrt{5000}$$

$= 312.54$

$V_u = 0.85 \times 312.54 \times 12 \times 27 / 1000 = 86.07$ Kips (THEREFORE, REINF. HAS BEEN DESIGNED)

$A_{vf} = 3.52 - 0.86 = 2.66\ in^2$

Form 5007 Rev. 3-77

GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc.

CALC. SET NO.		
PRELIM.	X	9527
FINAL	X	1-RB-FP-05
VOID		
SHEET 8 OF 36		
J.O. 9527.077		

REV	COMP. BY	CHK'D BY
0	SAY DATE 3-25-80	KC DATE 4-30-80
	DATE	DATE

NAME OF COMPANY CP&L BSEP UNIT/S 1 & 2

SUBJECT Spent Fuel Storage Capacity Improvement

FROM EQ 11-30

$V_u = \phi f_y \mu A_{vf}$

$= 0.85 \times 60 \times 1.4 \times 2.66$

$= 189.9$ kips/ft

CONVERT TO SHEAR STRESS AS SHOWN IN STARDYNE/MRI PRINTOUT W/ t = 5.17'

TRANSVERSE SHEAR = 189.9/5.17 = 36.73 k/ft

Form 5007 Rev. 3-77

GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc

NAME OF COMPANY CP&L BSEP UNIT/S 1&2

SUBJECT Spent Fuel Storage Capacity Improvement

CALC. SET NO.		
PRELIM.	X	9527-
FINAL	X	1-RB-FP-05 F
VOID		
SHEET 9 OF 36		
J.O. 9527.077		
REV	COMP. BY	CHK'D BY
0	SAY DATE 3-25-80	KC DATE 4-30-80
	DATE	DATE

Consider ~~Shear~~ Friction

@ Slab portion

From EQ 11-28

$$v_u = \left[6.5 - 5.1\sqrt{\frac{N_u}{V_u}}\right]\left[1 - 0.5\,a/d\right]\left\{1 + \left[64 + 160\sqrt{\left(\frac{N_u}{V_u}\right)^3}\right]\rho\right\}\sqrt{f'_c}$$

Where $f'_c = 3000$ psi

$\rho = 0.0033$ $A_s = 0.0033 \times 12 \times 29 = 1.15$ in²

$a = 9''$ $d = 29''$

$N_u / V_u = 0.2$

$$v_u = \left[6.5 - 5.1\sqrt{0.2}\right]\left[1 - 0.5 \times 9/29\right]\left\{1 + \left[64 + 160\sqrt{(0.2)^3}\right] \times 0.0033\right\} \times \sqrt{3000}$$

$= 245.69$ psi

$V_u = 0.85 \times 245.69 \times 12 \times 29 / 1000 = 72.68^K$

$A_{vf} = 3.2 - 1.15 = 2.05$ in²

$V_u = 0.85 \times 60 \times 1.4 \times 2.05 = 146.37^K$

Form 3007 Rev. 3-77

GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc.

NAME OF COMPANY CP&L BSEP UNIT/S 1 & 2

SUBJECT Spent Fuel Storage Capacity Improvement

CALC. SET NO.		
PRELIM.	X	9527-
FINAL	X	1-RB-FP-05 F
VOID		
SHEET 10 OF 36		
J.O. 9527.077		
REV	COMP. BY	CHK'D BY
0	SAY DATE 3-25-80	KC DATE 4-30-80
	DATE	DATE

SHEAR @ EDGE.

$V_u = 146.37 + (1.5 + 29/12) \times 1.4 \times 3.193$

$= 163.87^{K}/FT$

CONVERT TO SHEAR STRESS FOR STARDYNE/MRI PRINTOUT

$v_u = 163.87/5.17 = 31.70^{K}/FT^2$

Form 5007 Rev. 3-77

GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc.

CALC. SET NO.		
PRELIM.	X	9527
FINAL	X	1-RB-FP-05 F
VOID		
SHEET 11 OF 36		
J.O. 9527.077		
REV	COMP. BY	CHK'D BY
0	SAY DATE 3-25-80	KC DATE 4-30-80
	DATE	DATE

NAME OF COMPANY CP&L BSEP UNIT/S 1&2

SUBJECT Spent Fuel Storage Capacity Improvement

Consider the Normal Shear Capacity of the Slab stirrup Reinforcement From A-27 of Ref 1

single leg stirrup # 6 @ 6" per 12" width

FROM EQ 11-13

$$(v_u - v_c) = \frac{A_v f_y}{b_w s}$$

WHERE $b_w = 12''$ $s = 6''$ $A_v = 0.44 \text{ in}^2$

$f_y = 60{,}000$ psi

$v_u - v_c = 366.67$ psi $< 8\sqrt{f'_c} = 8\sqrt{3000} = 438.18$

$v_c = 2\sqrt{3000} = 109.54$ psi

$v_u = 109.54 + 366.67 = 476.21$ psi

$d = 29^{in}$

$V_u = 476.21 \times 0.85 \times 12 \times 29 / 1000 = 140.86^{K}/\text{FT}$

Edge Shear $= 140.86 + 1.4 \times 1.5 \times 3.193$

$= 147.56^{K}/\text{FT}$

12

Form 5007 Rev. 3-77

GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc.

NAME OF COMPANY CP&L BSEP UNIT/S 1&2

SUBJECT SPENT FUEL STORAGE CAPACITY IMPROVEMENT

CALC. SET NO.		
PRELIM.	X	9527
FINAL	X	1-RB-FP-05
VOID		
SHEET 12 OF 36		
J.O. 9527.077		
REV	COMP. BY	CHK'D BY
0	SAY DATE 3-25-80	KC DATE 4-30-80
	DATE	DATE

CONVERT TO SHEAR STRESS

AS SHOWN IN STARDYNE/MRI PRINTOUT

W/ t = 5.17 FT

TRANSVERSE SHEAR = 147.56/5.17

= 28.54 K/FT²

(GOVERN)

Form 5007 Rev. 3-77

(DISCIPLINE)

GENERAL COMPUTATION SHEET

united engineers & constructors inc.

NAME OF COMPANY CP&L BSEP UNIT/S 1&2

SUBJECT Spent Fuel Storage Capacity Improvement

CALC. SET NO.		
PRELIM.	X	9527
FINAL	X	1-RB-FP-06
VOID		
SHEET 25 OF 93		
J.O. 9527.085		

REV	COMP. BY	CHK'D BY
0	SAY DATE 9-2-80	BG DATE 5/1/81
	DATE	DATE

F

ALTERNATE PROPOSAL No. A2

DESCRIPTION OF ARRANGEMENT

EXCEPT THE EXTREME WEST TWO BAYS, THE EXISTING RACK ARRANGEMENT STAY. THE TWO EMPTY BAYS WILL BE FILLED WITH THREE G.E. FREE-STANDING RACKS (13×17, 13×17, AND 17×15) PLUS TWO G.E. FREE-STANDING RACKS ON THE EAST SIDE OF THE POOL AND SHIPPING CASK TO BE REDUCED TO 75 TON. SAME AS ALTERNATE NO. A1.

Form 5007 Rev. 3-77

GENERAL COMPUTATION SHEET

(DISCIPLINE)

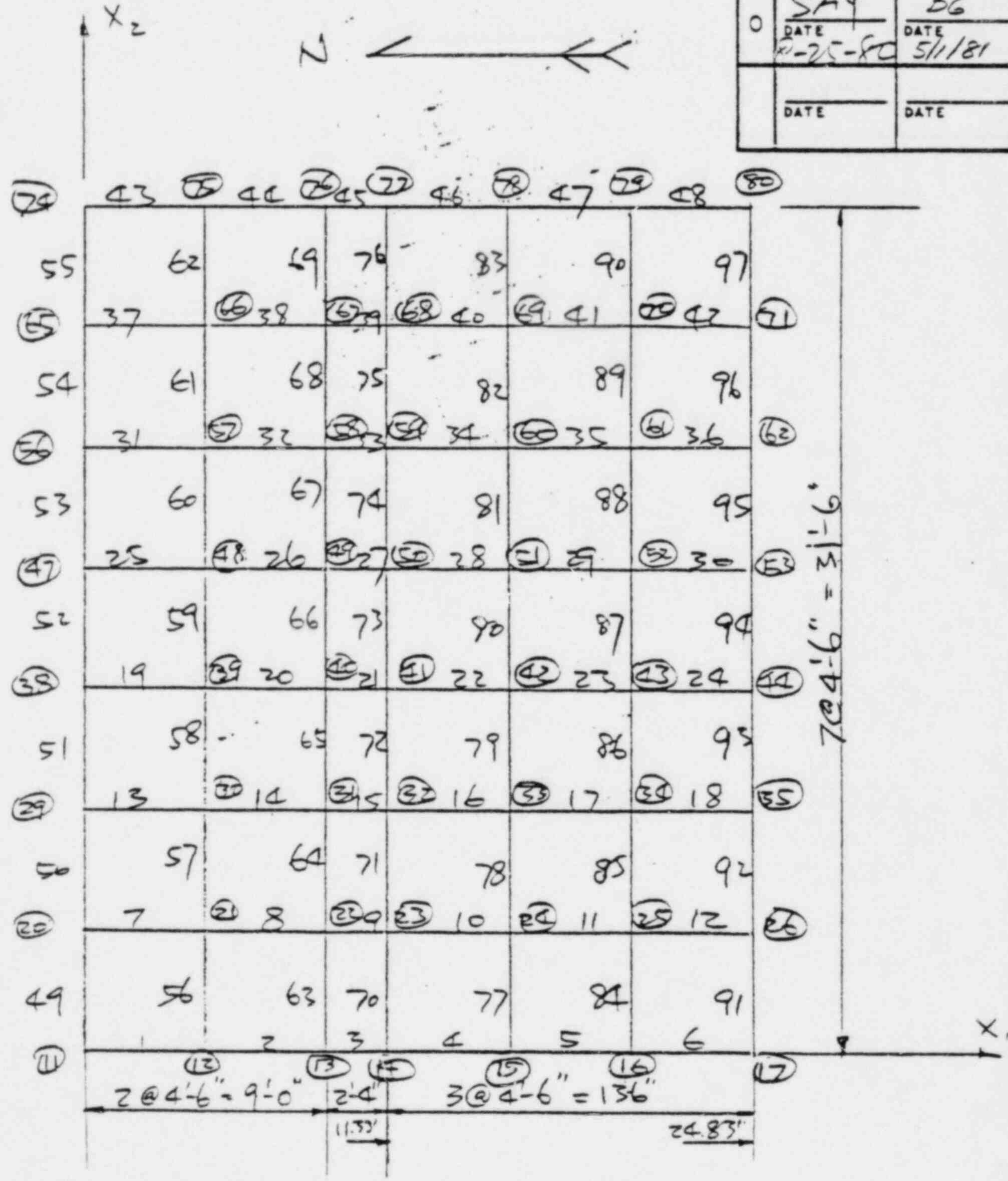
united engineers & constructors inc.

CALC. SET NO.	
PRELIM. X	9527-
FINAL X	1-RB-FP-06
VOID	
SHEET 27 OF 43	
J.O. 9527.085	

REV	COMP. BY	CHK'D BY
0	SAY DATE 12-25-80	BG DATE 5/1/81
	DATE	DATE

NAME OF COMPANY CP&L BSEP UNITS 1 & 2

SUBJECT Spent Fuel Storage Capacity Improvement



MATHEMATICAL MODEL FOR GRIDTRUSS ANALYSIS

Form F007 Rev. 3-77

GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc.

CALC. SET NO.		
PRELIM.	X	9527-
FINAL	X	1-RB-FP-06
VOID		
SHEET 38 OF 43		
J.O. 9527.085		
REV	COMP. BY	CHK'D BY
0	SAY DATE 9-9-80	BG DATE 5/4/81
	DATE	DATE

NAME OF COMPANY CP&L BSEP UNIT/S 1&2

SUBJECT Spent Fuel Storage Capacity Improvement

MAX EDGE SHEAR STRESS
IN K/FT² FROM STARDYNE/MRI
PRINTOUT

RUN NO. \ LOADING CASE NO	6	7	8	9
3	23.11 (41)*	22.20 (145)	23.92 (48)	23.02 (48)
4	14.71 (41) (145)	14.69 (41)	15.82 (48)	15.72 (48)
3-1	27.22 (145)	26.47 (145)	27.96 (122)	26.76 (122)

* INDICATE THE ELEMENT NUMBER.

Form 5015 Rev. 11/74

GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc.

NAME OF COMPANY CP&L BSEP UNIT/S 1&2

SUBJECT Spent Fuel Storage Capacity Improvement

CALC. SET NO.		
PRELIM.	X	9527
FINAL	X	1-RB-FP-c6
VOID		
SHEET 39 OF 43		
J.O. 9527.085		
REV	COMP. BY	CHK'D BY
0	SAY DATE 9-22-80	36 DATE 5/4/81
	DATE	DATE

WORST EDGE SHEAR OCCURS AT ELEMENT No. 122 BY LOADING CASE No. 8 OF LOAD RUN No. 3-1 WITH A MAGNITUDE OF 27.96 $^{K}/_{FT^2}$.

$V_{U\,MAX} = 27.96\,^{K}/_{\#} < V_{U\,ALLOWABLE} = 28.54\,^{K}/_{\#}$ O.K.

THE MARGIN $= (1 - \frac{27.96}{28.54}) \times 100\% = 2\%$

Form 6007 Rev. 3-77

(DISCIPLINE)

GENERAL COMPUTATION SHEET

united engineers & constructors inc.

CALC. SET NO.	
PRELIM. [X]	9527-
FINAL [X]	1-RB-FP-06 F
VOID	
SHEET 40 OF 43	
J.O. 9527.085	

REV	COMP. BY	CHK'D BY
0	SAY DATE 9-9-80	BG DATE 5/5/81
	DATE	DATE

NAME OF COMPANY CP&L BSEP UNIT/S 1&2

SUBJECT Spent Fuel Storage Capacity Improvement

MAX. MOMENT (M_x & M_y) IN K-FT/FT. AND ITS CORRESPONDING ELEMENT NO.

LOAD RUN NO. 3 (S1090GT)

LOADING CASE NO.	M_x MAX.	M_x MAX. ON NORTH WALL	M_x MAX. ON SOUTH WALL	M_y MAX.	M_y MAX. ON NORTH WALL	M_y MAX. ON SOUTH WALL
6	261.6	432.2	386.4	133.2	58.3	50.7
	84	145	106	137	145	89
7	235.5	409.2	339.3	133.7	55.1	46.5
	101	145	122	137	145	144
8	258.9	433.6	394.8	136.6	59.2	49.9
	101	145	89	137	145	122
9	239.5	415.2	362.7	135.6	56.6	47.9
	102	145	106	138	145	144

Form 007 Rev. 3-77

GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc.

CALC. SET NO.	
PRELIM. X	9527
FINAL X	1-RB-FP-06
VOID	
SHEET 41 OF 43	
J.O. 9527.085	

REV	COMP. BY	CHK'D BY
0	SAY DATE 9-12-80	BC DATE 5/5/81
	DATE	DATE

NAME OF COMPANY CP&L BSEP UNIT/S 1&2

SUBJECT Spent Fuel Storage Capacity Improvement

MAX. MOMENT (M_x & M_y) IN K-FT/FT AND ITS CORRESPONDING ELEMENT NO.

LOAD RUN 4

LOADING CASE NO.	M_x Max.	M_x Max. on North Wall	M_x Max. on South Wall	M_y Max.	M_y Max on North Wall	M_y Max. on South Wall
6	157.6	271.6	231.3	85.9	36.5	30.7
	76	145	89	137	145	144
7	150.3	262.5	221.3	85.3	35.2	29.6
	101	145	144	137	145	144
8	154.6	265.6	240.5	87.9	36.1	31.2
	102	145	89	138	145	144
9	147.3	265.3	226.1	88.6	36.1	30.0
	119	145	144	137	145	144

Form 3007 Rev. 3-77

GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc.

NAME OF COMPANY CP&L BSEP UNIT/S 1&2

SUBJECT Spent Fuel Storage Capacity Improvement

CALC. SET NO.		
PRELIM.	X	9527
FINAL	X	1-RB-FP-06
VOID		
SHEET 42 OF 43		
J.O. 9527.085		
REV	COMP. BY	CHK'D BY
0	SAY DATE 9-12-80	BL DATE 5/5/81
	DATE	DATE

F

Max. Moment (M_x, & M_y) in K-FT/FT and its corresponding element No.

Load Run No. 3-1

Loading Case No.	M_x			M_y		
	Max.	Max. on North Wall	Max. on South Wall	Max.	Max. on North Wall	Max. on South Wall
6	310.5	515.6	461.6	158.5	69.3	60.2
	76 & 84	145	106	137	145	89
7	285.1	492.6	418.3	159.1	66.5	55.8
	101	145	144	137	145	144
8	308.5	517.0	470.9	162.4	70.2	60.7
	101	145	89	138	145	89
9	287.9	498.6	437.9	161.6	67.6	56.1
	102	145	106	138	145	122

Form 5 Rev. 11/74

(DISCIPLINE)

GENERAL COMPUTATION SHEET

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NAME OF COMPANY CP&L BSEP UNIT/S 1&2

SUBJECT Spent Fuel Storage Capacity Improvement.

CALC. SET NO.		
PRELIM.	X	9527-
FINAL	X	1-RB-FP-06
VOID		
SHEET 43 OF 43		
J.O. 9527.088		
REV	COMP. BY	CHK'D BY
0	SAY DATE 9-15-80	BG DATE 5/5/81
	DATE	DATE

MAX. POSITIVE MOMENT @ MIDDLE OF SLAB

$M^{+}_{ux} = 310.5$ K-FT/FT (LOAD CASE 6 - LOAD RUN 3-1)

$M^{+}_{uy} = 162.4$ K-FT/FT (LOAD CASE 8 - LOAD RUN 3-1)

MAX. MOMENT @ EDGE (LOAD CASE 6 - LOAD RUN 3-1)

$M^{+}_{ux} = 515.6$ K-FT/FT (LOAD CASE 8 - LOAD RUN 3-1)

$M^{-}_{uy} = 70.2$ K-FT/FT

CAPACITY OF THE SLAB (FROM SH ~~40~~ & A-38 OF JOB NO. 9527-13 - BOOK 21R)

M^{+}_{u} CAPACITY $= 680.0$ K-FT/FT $> M^{+}_{ux} = 515.6$ K-FT/FT O.K.

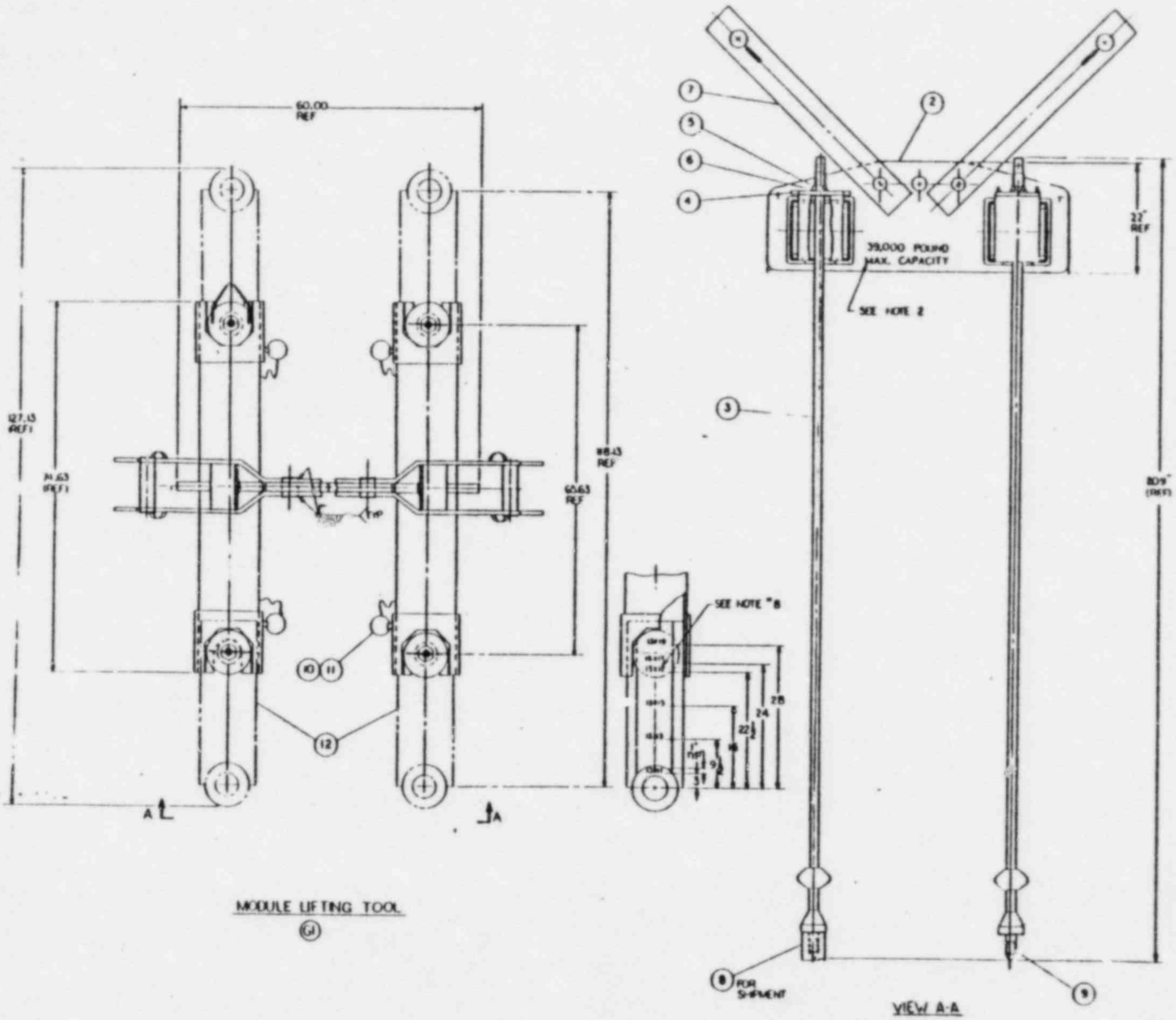
$\text{MARGIN} = (1 - \frac{515.6}{680}) \times 100\% = 24.2\%$

M^{-}_{u} CAPACITY $= 683$ K-FT/FT > 70.2 K-FT/FT O.K.

$\text{MARGIN} = (1 - \frac{70.2}{683}) \times 100\% = 89.7\%$

THE ANALYSIS RESULTS AND THE CAPACITY PROVIDED BY THE STRUCTURE AS PER ACI 318-71 HAVE BEEN COMPARED, AND FOUND ADEQUATE TO SUPPORT THE ALTERATE A2 LOADING

Attachment 4



MODULE LIFTING TOOL
(G1)

VIEW A-A

MODULE LIFTING TOOL ASSY

QTY	ITEM	NAME	DESCRIPTION
1	2	BEAM ASSY	MODULE LIFTING TOOL C5472-E-114, G1
4	3	ROD	C5472-E-115, G1
4	4	SUPPORT PLATE	C5472-E-115, G2
4	5	NUT HEX #	[illegible] ALLOY STEEL ASTM A 194 GR 7 OR A 320 GR L7
4	6	WASHER	1.75 AMERICAN STD TYPE A ASTM A-36 [illegible]
2	7	CLEVIS	C5472-E-115, G3
4	8	END CAP	C5472-E-115, ITEM 15
-	9	LUBRICANT	SEE NOTE # 6 & 7
4	10	PIN	QUICK RELEASE PIN AVIBANK # [illegible]
4	11	SCREW	SELF TAPPING SCREW 1/4 DIA x 3/4 LG
4	12	SUB ASSEMBLY	C5472-E-114, G2

* SEE NOTE 8.

NOTES:

1) TOOL ASSY SHOWN FOR LIFTING 13x11, 13x13, 13x15, 13x17, 13x19 AND 15x17.
2) NOTE TO BE PAINTED ON STRONG BACK IN RED LETTERS. PAINT NOTE ON BOTH SIDES OF LIFTING PLATE.
3) ESTIMATED WEIGHT 4300
4) REFER TO GE TECHNICAL INSTRUCTIONS NO 22A5121 FOR OPERATION INSTRUCTIONS.
5) ASSEMBLY TO BE LOAD TESTED AT 125% OF CAPACITY MARKED ON LIFTING TOOL. VISUALLY EXAMINE WELDS AND LIFT RODS AFTER TESTING.
6) COAT ALL THREADS WITH ITEM #9 "PURE NICKLE" BY NEVER-SEEZ COMPOUND CORP.
7) COAT ALL SLIDE CONTACT AREAS WITH ITEM #9 "PURE NICKLE" BY NEVER-SEEZ COMPOUND CORP.
8) PAINT AS IN NOTE #2 ON ALL FOUR SUB-ASSEMBLIES NOTED AS ITEM #12.
9) THE SECOND HEAT TREATMENT AND HARDNESS VERIFICATION PER SA 193 PARAGRAPH 7.1.5.2 IS HEREBY WAIVED.

NTED	
GEPA-	(P.O. No.)
036	(Sequence Received)
1	(Submittal No.)

P.O. NO.			DATE
INTERNAL REVIEW FOR:			
JOB NO.		RESP. ENG.	
DISCIPLINE	DATE REQUIRED	STATUS	SIGNATURE
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ELECT			
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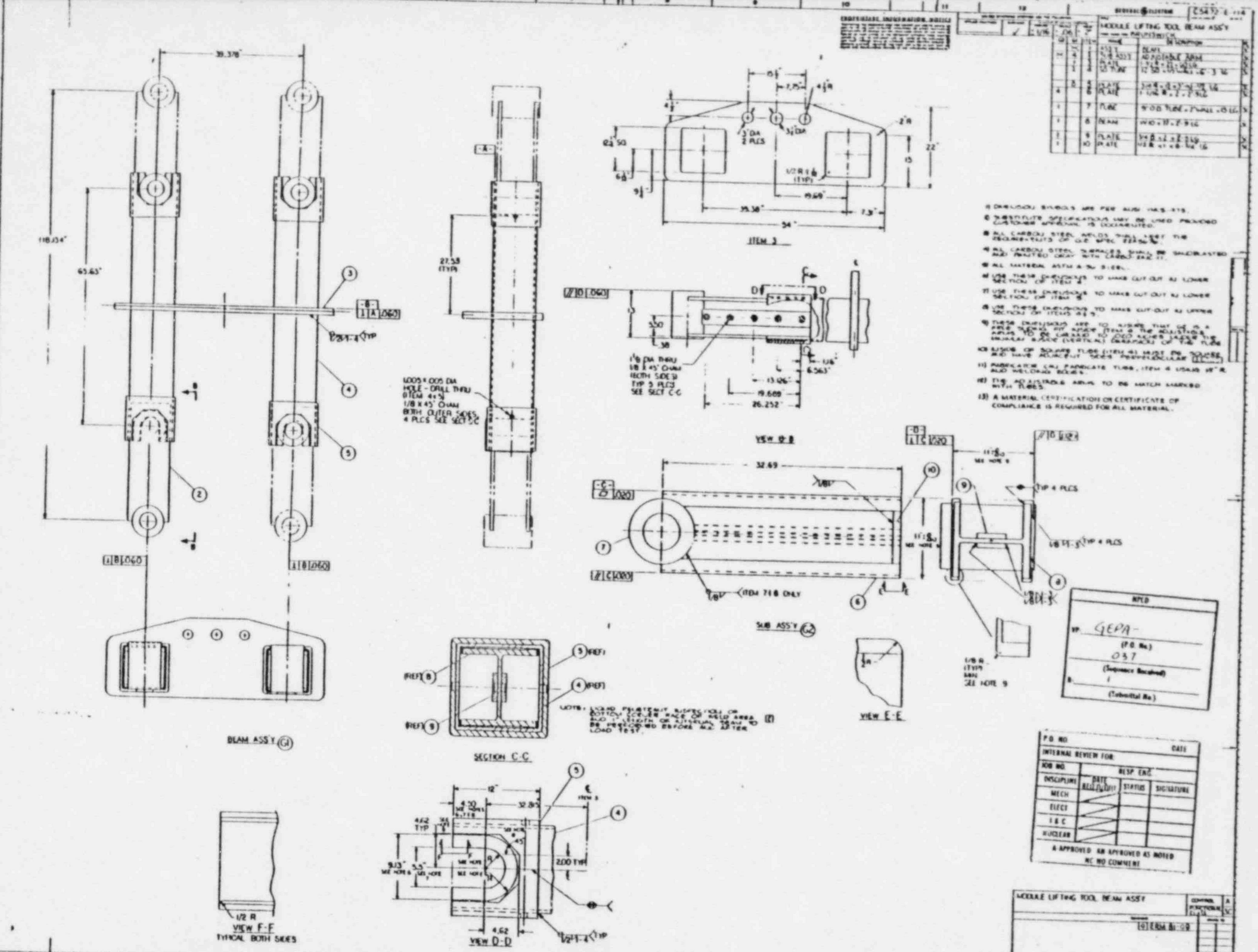
MODULE LIFTING TOOL ASS'Y

C5472-E-113


MODULE LIFTING TOOL BEAM ASS'Y
PROPRIETARY INFORMATION NOTICE
BEAM ASS'Y (G1)
SECTION C-C
VIEW F-F
TYPICAL BOTH SIDES
VIEW D-D
ITEM 3
VIEW B-B
SUB ASS'Y (G2)
VIEW E-E
1) DIMENSION SYMBOLS ARE PER ANSI Y14.5-1973.
2) SUBSTITUTE SPECIFICATIONS MAY BE USED PROVIDED CUSTOMER APPROVAL IS DOCUMENTED.
3) ALL CARBON STEEL WELDS SHALL MEET THE REQUIREMENTS OF G.E. SPEC.
4) ALL CARBON STEEL SURFACES SHALL BE SANDBLASTED AND PAINTED GRAY WITH CARBO ZINC 11.
5) ALL MATERIAL ASTM A-36 STEEL.
6) USE THESE DIMENSIONS TO MAKE CUT-OUT AT LOWER SECTION OF ITEM 4.
7) USE THESE DIMENSIONS TO MAKE CUT-OUT AT LOWER SECTION OF ITEM 5.
8) USE THESE DIMENSIONS TO MAKE CUT-OUT AT UPPER SECTION OF ITEMS 4 & 5.
9) THESE DIMENSIONS ARE TO ASSURE THAT THERE IS A FREE SLIDING FIT WHERE ITEM 8 THE ADJUSTABLE ARMS TO BE CAPABLE TO .060 INCHES LARGER THE NOMINAL SIZE (VERTICAL) DIMENSION OF THE TUBE
10) SIDES OF SQUARE TUBE (ITEM 4) MUST BE SQUARE AND HAVE ADJACENT SIDES PERPENDICULAR
11) FABRICATOR CAN FABRICATE TUBE, ITEM 4 USING 1/2" R AND WELDING BOXES.
12) THE ADJUSTABLE ARMS TO BE MATCH MARKED WITH TUBES.
13) A MATERIAL CERTIFICATION OR CERTIFICATE OF COMPLIANCE IS REQUIRED FOR ALL MATERIAL.
NOTE: LIQUID PENETRANT INSPECTION OF BOTTOM SCREEN FACE OF WELD AREA AND LENGTH OF VISUAL TO BE PERFORMED BEFORE AND AFTER LOAD TEST.
NPED
GEPA-
(P.O. No.)
037
(Sequence Received)
1
(Submittal No.)
P.O. NO.
DATE
INTERNAL REVIEW FOR
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RESP. ENG.
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SIGNATURE
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NUCLEAR
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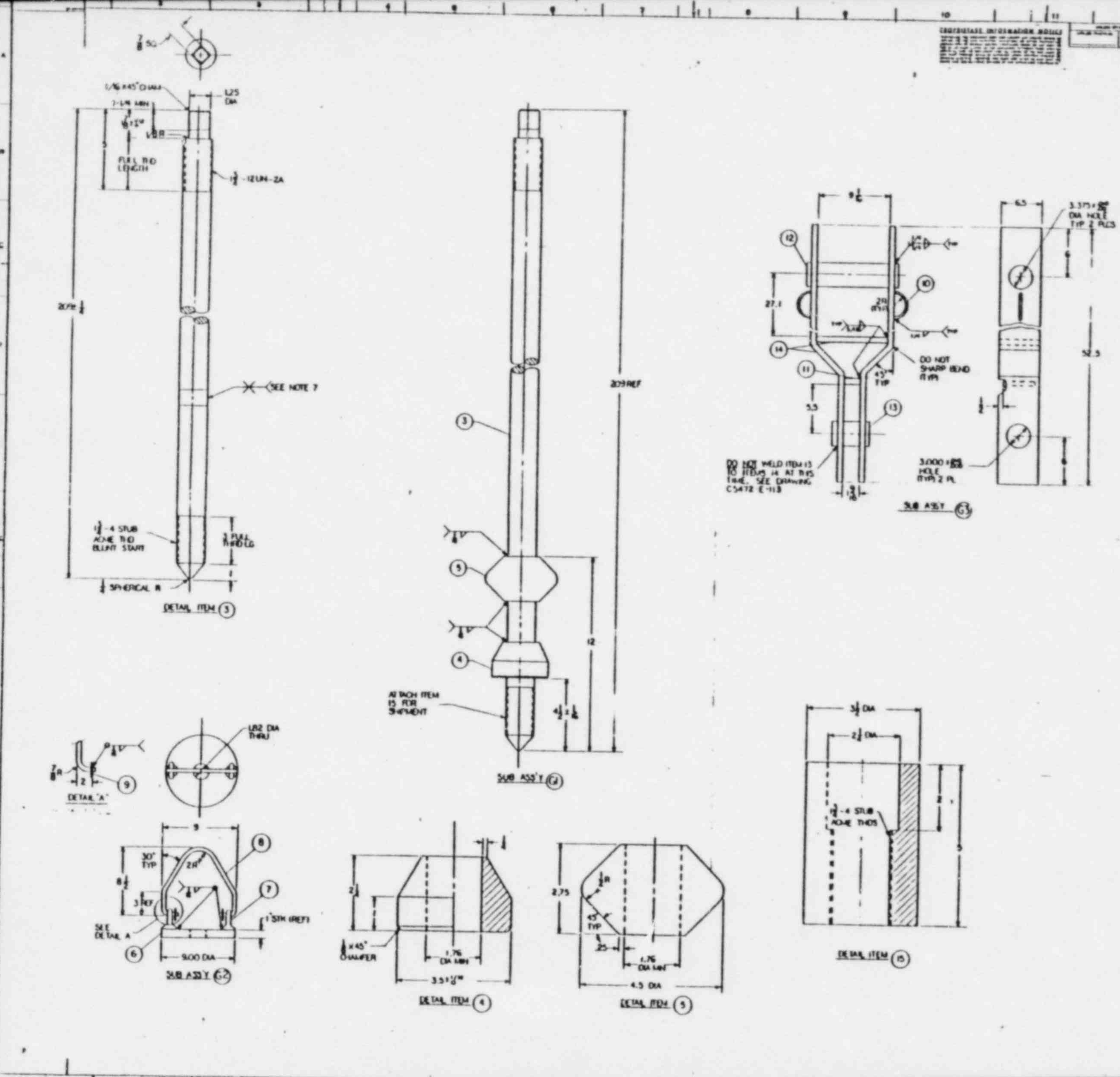
AN APPROVED AS NOTED
NC NO COMMENT
MODULE LIFTING TOOL BEAM ASS'Y
ITEM 3
BEAM
ADJUSTABLE ARM
PLATE
TUBE
BEAM
PLATE
39.378"
118.134"
65.63"
27.53 (TYP)
32.69
54"
35.38"
19.69"
15
22"
7.5"
13.126"
19.689
26.252"
6.563"
12"
4.62 TYP
2.00 TYP
1/2 R



NOTES:

1) DIMENSION SYMBOLS ARE PER ANSI Y14.5 1973.
2) SUBSTITUTE SPECIFICATIONS MAY BE USED PROVIDED CUSTOMER APPROVAL IS DOCUMENTED.
3) ALL CARBON STEEL WELDS SHALL MEET THE REQUIREMENTS OF G.E. SPEC 22A3676.
4) ALL STAINLESS STEEL WELDS SHALL MEET THE REQUIREMENTS OF G.E. SPEC 22A3672.
5) ALL CARBON STEEL SURFACES SHALL BE SANDBLASTED AND PAINTED GRAY WITH CARBO ZINC 11.
6) MATERIAL TO BE ASTM A 276 GR304.
7) ITEM 8 MAY BE MADE FROM TWO PIECES OF ROD WITH A FULL VEE WELD. WELD IS TO BE VISUALLY EXAMINED AT ROOT PASS AND ALL SUBSEQUENT PASSES.
8) A MATERIAL CERTIFICATION OR CERTIFICATE OF COMPLIANCE IS REQUIRED FOR ALL MATERIAL.

RPED

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058
(Sequence Received)
1
(Submittal No.)

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JOB NO.	RESP. ENG.		
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GENERAL ELECTRIC
C5472 E-115
MODULE LIFTING TOOL DETAILS

MODULE LIFTING TOOL DETAILS

Delete

Attachment 5

is, therefore, inconsequential so far as the 150°F pool temperature limit and pool boiling are concerned.

The pool temperature results for the various cases analyzed in Sections 8.3 and 8.4 are summarized in Table 8-8. All transient analyses performed are conservative, as no credit has been taken for cooling by evaporation from the pool surface or the thermal inertia of the steel module components or pool walls. Additional conservatism includes the high continuous power level assumed for the H. B. Robinson fuel, minimum available cooling time, and maximum service water and closed cooling water temperatures. It is therefore expected that actual pool water temperatures would be lower than those calculated.

8.5 LOCAL FUEL BUNDLE THERMAL HYDRAULICS

The bounding thermal hydraulic conditions were calculated for fuel stored in a HDFS module or basket in the BSEP pools. Bases for the calculations for typical current generation fuel were the following:

Maximum Burnup	44000 MWd/MTU
Continuous Power Level	60 KW_t/KgU
Total Core Power Level	2436 MW_t
Assemblies per Core	560
Assembly Mass	183 KgU
Transfer Time Core to Pool	15 minutes
Cooldown Time Prior to Fuel Movement	24 hours
Fuel Storage Pool Bulk Water Temperature	150°F

The methodology specified in the Auxiliary Systems Branch Technical Position ASB 9-2 was used to calculate the decay heat for the bundle defined by these bases. The result was a heat generation rate of 224,300 BTU/hour per assembly.

The maximum fuel cladding temperature will be 196°F. The maximum water temperature associated with the hottest fuel bundle will be 180°F. These temperatures and the maximum storage tube wall temperature of 165°F are low relative to structural integrity or corrosion limiting temperatures of the structural components of the storage system and fuel.

8.6 RADIOLOGICAL IMPACT OF SPENT FUEL POOL BOILING

The radiological impact of bulk boiling in the spent fuel pools of both BSEP units is most severe when the SFP cooling systems for both units are postulated to fail simultaneously following a refueling, as described in Subsection 8.4.1.

A radiological analysis has been performed to determine the thyroid dose at the site boundary/LPZ. The following assumptions were made:

1. The time to reach boiling is 13 hours for both units.

2. The boiling rate of the pool water is 1.38×10^4 lbm/hr for each unit.

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CLASS I
MAY 1981

HIGH DENSITY SPENT FUEL STORAGE MODULES FOR BRUNSWICK UNITS 1 AND 2 SUMMARY ENGINEERING CALCULATION REPORT

Y. J. LEE
F. H. SHADEL
P. C. SUN

GENERAL ELECTRIC

NEDO-24948
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Class I
May 1981

HIGH DENSITY SPENT FUEL STORAGE MODULES FOR BRUNSWICK UNITS 1 AND 2

SUMMARY ENGINEERING CALCULATION REPORT

Y. J. Lee
F. H. Shadel
P. C. Sun

Approved: [signature]
E. A. Grimm, Manager
Fuel Storage Projects

NUCLEAR FUEL AND SERVICES DIVISION • GENERAL ELECTRIC COMPANY
SAN JOSE, CALIFORNIA 95125

GENERAL ELECTRIC

CONTENTS

1. INTRODUCTION

The purpose of this report is to amplify the information given in the "NRC Docket 50-324 and 50-325, Operating Licenses DPR-62 and DPR-71, Brunswick Steam Electric Plant Units 1 and 2, Spent Fuel Pool Storage Expansion Report," dated April 16, 1981. Supporting analyses on the following four subjects were performed:

a. Seismic analysis
b. Stress analysis
c. Fuel drop analysis
d. Thermal hydraulic analysis.

In this report, the methodology of the analyses, input and output from the analyses and conclusions are summarized.

2. SEISMIC ANALYSIS

The purpose of the seismic analysis is to perform the following calculations under the design seismic loading condition:

a. To calculate the maximum seismic loads in the module. These loads will be used as input in the stress analysis.

b. To calculate the maximum sliding and stability for the module.

2.1 SEISMIC ANALYSIS INPUT

The design floor acceleration response spectra are given in Reference 1. In order to convert these design requirements into suitable form for use in the analysis, artificial earthquake time histories were generated to match the design floor acceleration response spectrum. Constant vertical acceleration equals two-thirds of maximum horizontal acceleration used in the analysis. Both the OBE and the DBE earthquakes were considered. Damping values used were 1% for OBE and 2% for DBE condition.

The time-histories were generated using SIMQK-01, a GE in-house, level-2-approved production program based on a program by Professor VanMarke of MIT (Ref. 2).

The acceleration time-histories generated are shown in Figures 2-1 and 2-2. Also shown, Figures 2-3 and 2-4, are the comparisons of the calculated response spectra with the input response spectra for each time-history. This comparison is needed to verify the acceptability of the generated earthquake time-histories per NRC Standard Review Plan, Section 3.7.1.

2.2 HYDRODYNAMIC MASS

The hydrodynamic virtual mass effects due to pool water were included in the analysis of the modules and support system. The General Electric computer program WATERMASS (Ref. 3) was used to compute the added-mass values which

represent the inertial properties of the water surrounding the submerged modules. WATERMASS is based on the finite-element method (Ref. 4), which assumes that the water is incompressible and that surface effects are negligible. Added-mass diagonal and coupling terms were computed for all modules as a single two-dimensional body. Figure 2-5 shows the plan view of the two-dimensional models of the modules and basin used in the hydrodynamic virtual mass analysis for Brunswick. The calculated hydrodynamic mass is then modified to correct for surface effect before it is added to the mass of the module for seismic analysis.

2.3 NATURAL FREQUENCIES AND SEISMIC LOADS

A two-dimensional (2D) stick model having 11 masses is considered sufficient to represent the dynamic behavior of the module. Because the interior plates represent a major portion of the module they are used as the basis for developing the 2D seismic model. This approach also provides conservative results since the interior plate has lower natural frequency that the exterior plate elements. The procedure of developing the seismic model is described below:

a. A 2D finite element model is first developed to represent the typical interior plate, assuming the two ends of the bottom edge are supported on a rigid base. See Figure 2-6a for a schematic illustration.

b. Frequencies for both horizontal and vertical modes of the 2D finite element model are computed using GE computer code SAP4G06.

c. An equivalent fixed base, 11-node stick model is then developed to represent the interior plate finite element model with the total mass of the module preserved. The equivalent sectional properties are based on the interior plate sections, and are so adjusted that the first mode horizontal and first mode vertical frequencies of the stick model match those of the finite element model. See Figure 2-6b for illustration of the fixed base stick model.

d. The fixed base stick model is modified by including the hydrodynamic mass and the effect of the flexibility of the fuel support plate. The inclusion of the latter is necessary because the module is in reality supported on the fuel support plate which in turn is supported only at the four exterior corners. The final model is shown in Figure 2-6c in which the springs K_H, H_θ and H_V represent the effect of the fuel support plate flexibility.

The GE computer code SAP4G07, (Ref. 5) was then used to compute the frequencies, mode, shapes, etc., of the flexible base stick model. Comparison of natural frequencies for the FEM and stick models for different sizes of modules are summarized in Table 2-1. Natural frequencies for modules considering proper boundary conditions and the hydrodynamic mass effect are given in Table 2-2.

Seismic response of the flexible stick model was also computed using SAP4G07. This seismic input is the 2% damping DBE or 1% damping OBE design floor spectrum as specified in Section 2.1.

Computer code SAP4G07 was used to compute the seismic responses - acceleration, shear and moment. It was found that, however, for horizontal analysis, the first mode spectrum acceleration is sufficient to represent the seismic response of the module as far as base shear and base moment are concerned. This simplifies the input preparation for the module seismic stress analysis in Section 3.

The modules are essentially "rigid" in the vertical analysis because the first mode vertical frequency, f_{1V}, always exceeds 30 Hz.

Table 2-3 summarizes the OBE and DBE seismic design acceleration.

Figure 2-7 shows the configuration of the 11-node flexible base stick model considered in the seismic analysis. Properties of the model, i.e., mass per unit length, section properties and material properties, are summarized in Table 2-4. For the 13x15, 13x17 and 13x19 modules, where applicable the properties are adopted from those previously developed for Hatch HDFSS (General Electric

Report File No. C5469-EC-152, September 28, 1980). For the 15x17 module, the corresponding properties can be extrapolated from the 13x15 and 13x17 modules.

Table 2-5 shows the equivalent spring constants, K_H, K_θ and K_V, that represent the flexibility of the fuel support plate. Spring constants for the 13x15, 13x17 and 13x19 modules are adopted from the Hatch HDFSS, and spring constants for the 15x17 module are extrapolated from those for the 13x15 and 13x17 modules.

The effect of hydrodynamic water masses are also accounted for in the seismic model. Such effect is represented by two water mass parameters. The first one, denoted by ρ', is the diagonal water mass term after the end effect correction. It is to be added to the module mass density ρ, to produce the combined module and water mass density for the seismic model. The second parameter, denoted by ρ'', represents the sum of the diagonal and all off-diagonal water mass terms. It is always a negative quantity, and its magnitude is, according to theory, equal to the cross section area of the module times the water mass density. The effect of ρ'' is equivalent to modifying the input seismic motion by a scale factor α,

$$\alpha = \frac{\rho + \rho''}{\rho + \rho'}$$

Table 2-6 summarizes the values of $\rho + \rho'$ and $\rho + \rho''$ (after correction for end effect) and α for the different modules considered.

SEISMIC RESPONSE

General Electric Computer Code SAP4G07 was used in the seismic response analysis. The input seismic motion is the 2% damping DBE floor response spectrum, which has a zero period acceleration of 0.65g.

Table 2-7 summarizes the frequencies of the first two horizontal vibration modes and the first vertical vibration mode. Because all the vertical frequencies exceed 30 Hz, the modules were treated as "rigid" for the purpose of vertical analysis.

The DBE seismic base shear is also tabulated in Table 2-8. It is the basis for the seismic stress analysis of the modules, to be described in Chapter 6.

2.4 NONLINEAR DYNAMIC ANALYSIS OF HDFSS MODULE

2.4.1 Introduction

The bottom of the HDFSS module is not anchored at the four corners. Instead, the module simply rests on the four module support pads. During earthquakes, the module may slide, or tilt, or slide and tilt in the same time. The stability of the module depends on the relative magnitudes of the seismic loads, the submerged module weight, and the friction forces between the module and support pads. For Brunswick, the friction coefficient between the module and the support pads has been determined by test to be in the range of 0.108 to 0.222.

The nonlinear stability analysis of the module is based on a 3-mass model that is a further simplification from the flexible base stick model described below. Computer code DRAIN2D, a plane structure nonlinear analysis program developed at the University of California at Berkeley, California (Ref. 6), was used to perform the stability analysis. The seismic input is the DBE synthetic floor motion time history which was generated to match the required DBE design floor spectrum.

2.4.2 Analytical Model

Figure 2-8 illustrates the 3-mass analysis model. It consists of four truss elements (springs), and five beam elements. Details of the model are as follows:

a. Mass - Because the hydrodynamic water mass varies in the two horizontal and vertical directions, values of m_4, m_5 and m_7 vary accordingly. In any given direction, however, the following relation was used:

$$m_4 = m_7 = \frac{1}{6}\left[m_{module} + \text{water mass}\right]$$

$$m_5 = \frac{2}{5}\left[m_{module} + \text{water mass}\right]$$

Such mass proportioning not only preserves the total mass of module plus hydrodynamic effect, but also preserves the mass moment of inertia of the module about either node 4 or node 7, provided that m_5 is located at a height of $H/\sqrt{2}$ above the base (H = 172.8 in. = height of module). Table 2-8 shows the values of the module and water masses.

b. Static Load - The static loads P_5 and P_6, represent the combined effect of the submerged weight of the module and a constant vertical OBE/DBE floor acceleration a_v acting upwards

$$P_5 = 2P_6 = \frac{2}{3} \text{ Submerged Module Weight } (1-a_v)$$

Table 2-8 also shows the submerged module weights.

c. Truss Elements - Truss elements 1 and 4 have the same sectional area A_1 such that $EA_1/L_1 = K_H/2$. To allow for sliding of the module whenever the seismic force in the element exceeds the specified friction force, f_R, element 1 has an elastic-plastic stress-strain relationship. The yield stress is $\pm f_R/2A_1$, where f_R = friction coefficient (0.222) times $(1-a_v)$ times the submerged module weight.

Truss elements 2 and 3 have the same section area A_2, such that $EA_2/L_2 = K_V/2$. To allow for tilting of the module, these two elements buckle whenever they are in compression.

Table 2-9 summarizes the sectional properties of the truss elements.

d. Beam Elements - Beam elements 1 and 2 represent the module base plate and were intended to be very rigid, with the following sectional properties:

Axial Area = $1\text{x}10^5$ in.^{2}
Shear Area = $1\text{x}10^4$ in.^{2}
Moment of Inertia = $1\text{x}10^7$ in.^{4}

Beam elements 3 and 4 represent the two module pads, having the following properties:

$$\text{Axial Area} = 700 \text{ in.}^2$$
$$\text{Shear Area} = 583 \text{ in.}^2$$
$$\text{Moment of Inertia} = 22{,}300 \text{ in.}^4$$

Beam element 5 represents the module. Its sectional properties are so determined that the first mode horizontal and vertical frequencies of the entire model match the corresponding fundamental mode frequencies as previously shown in Table 2-7. Table 2-10 lists the sectional properties of beam element 5. Note that the shear deformation is intentionally neglected, so as to simplify the calculation of the sectional properties of beam element 5.

e. Damping - A stiffness proportional system damping was assumed, such that the fundamental mode damping is equal to 2% of critical.

f. Input Motion Scale Factor - The scale factor, α, as previously specified in Table 2-6, was applied to the input motion in the nonlinear analysis.

2.4.3 Analysis Results

In each analysis, the horizontal synthetic floor motion was applied to the base of the model. The vertical floor motion was not applied; instead, as previously mentioned, a constant vertical upward acceleration of 0.42g was assumed.

The horizontal floor motion time history is digitized at a uniform time interval of 0.01 seconds. For accuracy in the numerical integration, however, an integration time step of 0.005 seconds was adopted.

Table 2-11 summarizes the values of the following maximum responses:

- horizontal sliding distance;
- vertical uplift of either support pad;
- rotation of module;
- support pad vertical reaction force.

The safety factor against seismic overturning is defined as the ratio of the potential energy required to overturn the module to the maximum potential energy actually attained during the seismic analysis. Referring to Figure 2-9,

$$\text{S.F. against overturning} = \frac{\theta}{\text{max. rotation in Table 2-11}}$$

Table 2-12 summarizes the safety factor calculated for the individual modules. It is concluded that there is a substantial safety margin against overturning in every case.

Table 2-1

NATURAL FREQUENCIES OF INTERIOR PLATE FEM AND EQUIVALENT FIXED BASE MODEL

		Horizontal				Vertical	
		f_{1H}		f_{2H}		f_{1V}	
Module	Direction	FEM	Stick	FEM	Stick	FEM	Stick
13x15	13-tube	15.9	15.7	49.6	56.9	46.1	45.7
13x15	15-tube	16.9	17.0	48.2	58.7	42.9	42.9
13x17	13-tube	15.9	15.7	49.5	56.9	46.1	45.7
	17-tube	17.5	18.0	46.3	60.1	39.9	39.9
13x19	13-tube	15.9	15.7	49.5	56.9	46.1	45.7
	19-tube	18.0	18.9	44.4	61.1	37.3	37.1
15x17	15-tube	16.9	17.0	48.2	58.7	42.9	42.9
	17-tube	17.5	18.0	46.3	60.1	39.9	39.9

Table 2-2

FREQUENCIES (Hz) OF THE FLEXIBLE BASE STICK MODEL INCLUDING HYDRODYNAMIC WATER MASS

Module	Direction	f_{1H}	f_{2H}	f_{1V}
13x15	13-	7.81	24.2	35.8
	15-	9.26	28.6	35.8
13x17	13-	5.89	18.2	33.3
	17-	9.13	28.0	33.3
13x19	13-	6.77	21.0	30.9
	19-	11.8	36.2	30.9
15x17	15-	7.52	23.2	34.8
	17-	8.70	27.0	34.8

Table 2-3

SEISMIC DESIGN ACCELERATION (g) FOR STRESS ANALYSIS

		OBE 1% Damping			DBE 2% Damping		
Module	Direction	Hatch 2	C_H (*)	Brunswick	Hatch 2	C_H (*)	Brunswick
13x15	13-	0.31	1.29	0.40	0.55	2.55	1.40
	15-	0.25	1.44	0.36	0.50	1.91	0.96
	Vertical	0.06	1.00	0.06	0.12	1.00	0.12
13x17	13-	0.33	1.21	0.40	0.60	3.07	1.84
	17-	0.25	1.72	0.43	0.50	2.00	1.00
	Vertical	0.06	1.00	0.06	0.12	1.00	0.12
13x19	13-	0.36	1.14	0.41	0.60	2.70	1.62
	19-	0.25	1.76	0.44	0.50	1.57	0.79
	Vertical	0.06	1.00	0.06	0.12	1.00	0.12
15x17	15-	-		0.41	-		1.59
	17-	-		0.39	-		1.11
	Vertical	-		0.06	-		0.12

---

* $$C_H = \left[\frac{V_{BRUNSWICK}}{V_{HATCH}}\right]$$

The OBE values are computed using a non-linear analyses while the DBE values are computed using a linear analysis

Table 2-4

PROPERTIES OF EQUIVALENT STICK MODELS FOR BRUNSWICK HDFSS MODULES

		Member 1				Member 2 to 10			
		ρ	A_x	A_s	I	ρ	A_x	A_s	I
Module	Direction	(lb-sec^2/in.^{2})	(in.^{2})	(in.^{2})	(in.^{4})	(lb-sec/in.^{2})	(in.^{2})	(in.^{2})	(in.^{4})
13 x 15	13 tube (NS)	0.487	6.30	60.6	1.[illegible]3 x 10^5	3.093	114.6	95.4	1.19 x 10^5
	15 tube (FW)	0.487	63.0	52.5	1.53 x 10^5	3.093	114.6	95.4	1.58 x 10^5
13 x 17	13 tube (NS)	0.552	63.0	68.7	1.50 x 10^5	3.506	129.9	108.2	1.35 x 10^5
	17 tube (EW)	0.552	63.0	52.5	1.97 x 10^5	3.506	129.9	108.1	2.30 x 10^5
13 x 19	13 tube (NS)	0.617	63.0	76.7	1.68 x 10^5	3.918	145.1	120.9	1.50 x 10^5
	19 tube (EW)	0.617	63.0	52.5	2.45 x 10^5	3.918	145.1	120.0	3.21 x 10^5
15 x 17	15 tube (NS)	0.637	63.0	68.7	1.53 x 10^5	4.045	149.8	124.7	2.07 x 10^5
	17 tube (EW)	0.637	63.0	60.6	1.97 x 10^5	4.045	149.8	124.7	2.65 x 10^5

Material Properties:
Young's Modulus = 2.8 x 10^7 psi
Poisson Ratio = 0.30

Table 2-5

SPRING CONSTANTS REPRESENTING EFFECT OF FUEL SUPPORT PLATE AND END WALL PLATES

Module	Direction	K_H (lb/in.)	K_θ* (in.-lb/rad)	K_V** (lb/in.)
13 x 15	13-	9.92×10^6	2.00×10^{11}	1.08×10^8 (1.16×10^8)
	15-	1.37×10^7	3.08×10^{11}	1.25×10^8
13 x 17	13-	9.10×10^6	1.76×10^{11}	9.56×10^7 (1.08×10^8)
	17-	1.56×10^7	3.95×10^{11}	1.25×10^8
13 x 19	13-	8.14×10^6	1.58×10^{11}	8.56×10^7 (1.05×10^8)
	19-	1.74×10^7	4.93×10^{11}	1.25×10^8
15 x 17	15-	1.05×10^7	2.62×10^{11}	1.08×10^8 (1.02×10^8)
	17-	1.35×10^7	2.98×10^{-11}	9.56×10^7

Note:

* $K_\theta = K_V B^2/4$, B = Distance between support pads

** Values shown in parentheses are average values between the two directions. The average values are used in the vertical seismic analysis.

Table 2-6

COMBINED MODULE AND WATER MASS DENSITY, AND SCALE FACTOR α FOR INPUT MOTION

		$\rho+\rho'$ ($lb\text{-}sec^2/in.^2$)		$\rho+\rho''$	
Module	Direction	Beam 1	Beam 2 to 10	Beam 2 to 10	α
13 x 15	13-(NS)	4.911	7.517	2.543	0.34
	15-(EW)	4.149	6.755	2.543	0.38
	Vertical	0.807	3.413	3.413	1.00
13 x 17	13-(NS)	10.588	13.542	2.900	0.21
	17-(EW)	5.630	8.584	2.900	0.34
	Vertical	0.914	3.868	3.868	1.00
13 x 19	13-(NS)	6.887	10.188	3.260	0.32
	19-(EW)	2.823	6.124	3.260	0.53
	Vertical	1.022	4.323	4.323	1.00
15 x 17*	15-(NS)	7.239	10.647	3.372	0.32
	17-(EW)	5.983	9.391	3.372	0.36
	Vertical	1.054	4.462	4.462	1.00

*Value shown here is the average value of ρ' between the 15 x 17 and 17 x 15 Modules.

Table 2-7

HORIZONTAL AND VERTICAL FREQUENCIES, AND DBE BASE SHEAR

Module	Direction	f_1 (H_z)	f_2 (H_z)	DBE Base Shear (Kip)
13 x 15	13-Tube	7.81	24.2	206
	15-Tube	9.26	28.6	140
	Vertical	35.8	-	-
13 x 17	13-Tube	5.89	18.2	306
	17-Tube	9.13	28.0	166
	Vertical	33.3	-	-
13 x 19	13-Tube	6.77	21.0	301
	19-Tube	11.8	36.2	146
	Vertical	30.9	-	-
15 x 17	15-Tube	7.52	23.2	309
	17-Tube	8.70	27.0	215
	Vertical	34.8	-	-

Table 2-8

SUBMERGED WEIGHTS AND COMBINED MODULE AND HYDRODYNAMIC WATER MASSES

Module	Submerged Wt (lb)	Direction	Total Module and Hydrodynamic Mass ($lb\text{-}sec^2/in.$)	
			Horiz.	Vert.
13 x 15	146,850	13-Tube	1,254	561
		15-Tube	1,153	561
13 x 17	166,200	13-Tube	2,324	632
		17-Tube	1,467	632
13 x 19	188,000	13-Tube	1,742	723
		19-Tube	1,040	723
15 x 17	191,770	15-Tube	1,821	750
		17-Tube	1,604	750

Table 2-9

PROPERTIES OF TRUSS ELEMENTS OF THE NONLINEAR ANALYSIS MODEL

Module	Direction	A_1 (in.^{2})	*$f_R/2A_1$ (psi)	A_2 (in.^{2})
13 x 15	13-Tube	1.772	5335	19.3
	15-Tube	2.447	3865	19.3
13 x 17	13-Tube	1.625	6580	17.0
	17-Tube	2.786	3840	17.0
13 x 19	13-Tube	1.454	8320	15.3
	19-Tube	3.108	3890	15.3
15 x 17	15-Tube	1.875	6585	19.3
	17-Tube	2.411	5115	19.3

*Based on a friction coefficient of 0.222.
$E = 2.8 \times 10^7$ psi

Table 2-10

SECTIONAL PROPERTIES OF BEAM ELEMENT 5

Module	Direction	Axial Area (in.^{2})	I (in.^{4})
13 x 15	13-Tube	102	70,150
	15-Tube	102	85,000
13 x 17	13-Tube	102	82,800
	17-Tube	102	107,800
13 x 19	13-Tube	104	90,400
	19-Tube	104	129,600
15 x 17	15-Tube	139	107,100
	17-Tube	139	121,400

Table 2-11

SUMMARY OF NONLINEAR ANALYSIS RESULTS

Module	Direction	Maximum Sliding (in.)	Maximum Uplift (in.)	Maximum Rotation (rad)	Maximum Reaction Per Pad (lb)
13 x 15	13-Tube	0.40	0.013	1.7×10^{-4}	113,800
	15-Tube	0.35	0.013	1.4×10^{-4}	106,300
13 x 17	13-Tube	0.31	0.005	0.7×10^{-4}	125,200
	17-Tube	0.41	0.005	0.5×10^{-4}	115,200
13 x 19	13-Tube	0.39	0.007	1.1×10^{-4}	143,200
	19-Tube	0.53	0.006	0.4×10^{-4}	121,000
15 x 17	15-Tube	0.46	0.005	0.6×10^{-4}	141,000
	17-Tube	0.45	0.005	0.4×10^{-4}	128,700

$E = 2.8 \times 10^7$ psi
Poisson Ratio = 0.30

Table 2-12

FACTOR OF SAFETY AGAINST OVERTURNING

Module	Direction	θ	Table 7-11 Maximum Rotation	S.F.
13 x 15	13-Tube	0.461 (rad)	1.7×10^{-4} (rad)	2,712
	15-Tube	0.520	1.4×10^{-4}	3,714
13 x 17	13-Tube	0.461	0.7×10^{-4}	6,586
	17-Tube	0.576	0.5×10^{-4}	11,520
13 x 19	13-Tube	0.461	1.1×10^{-4}	4,191
	19-Tube	0.628	0.4×10^{-4}	15,700
15 x 17	15-Tube	0.520	0.6×10^{-4}	8,667
	17-Tube	0.576	0.4×10^{-4}	14,400

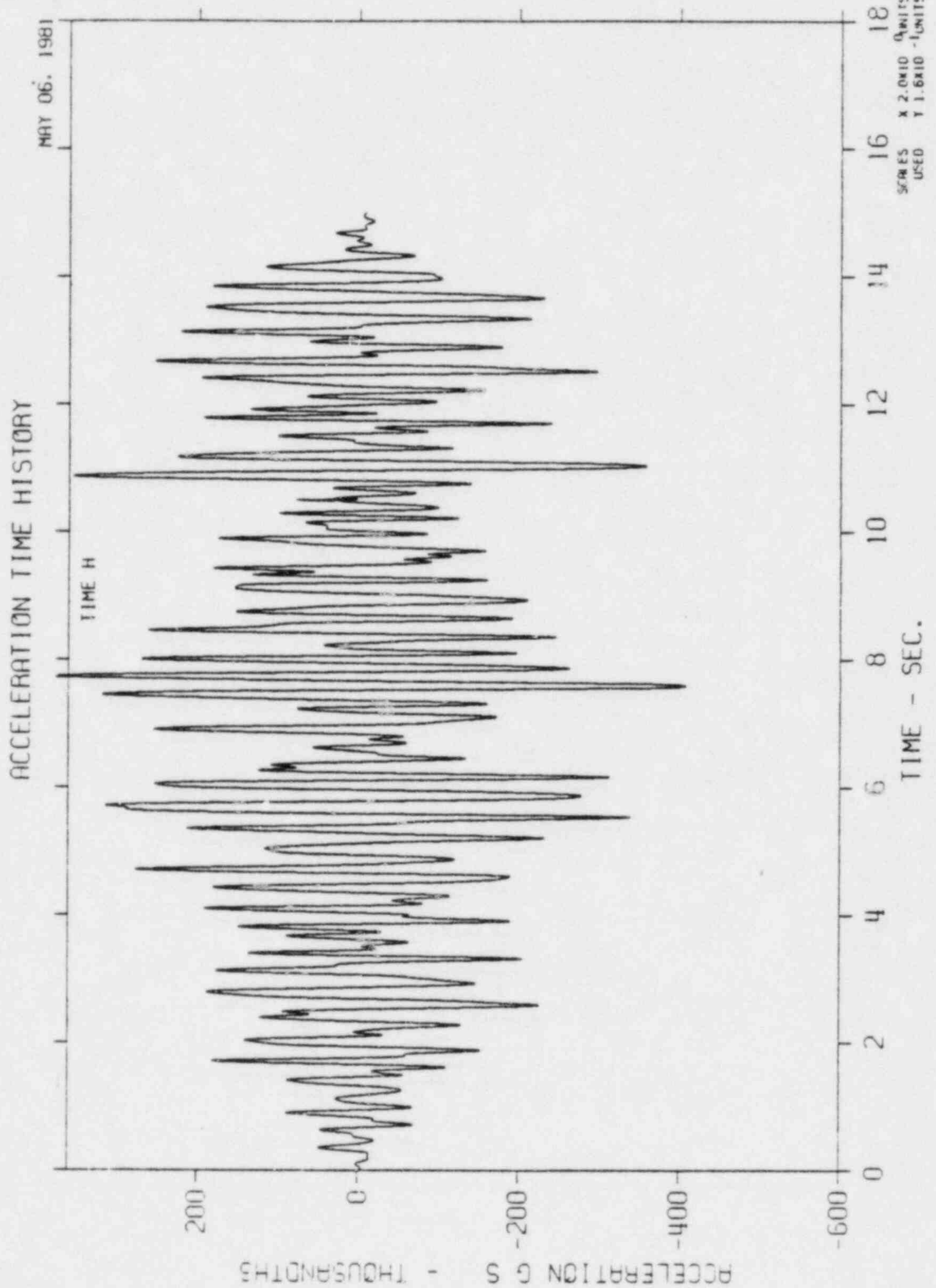


Figure 2-1. Brunswick NPP OBE Time-History 1.0% Damping

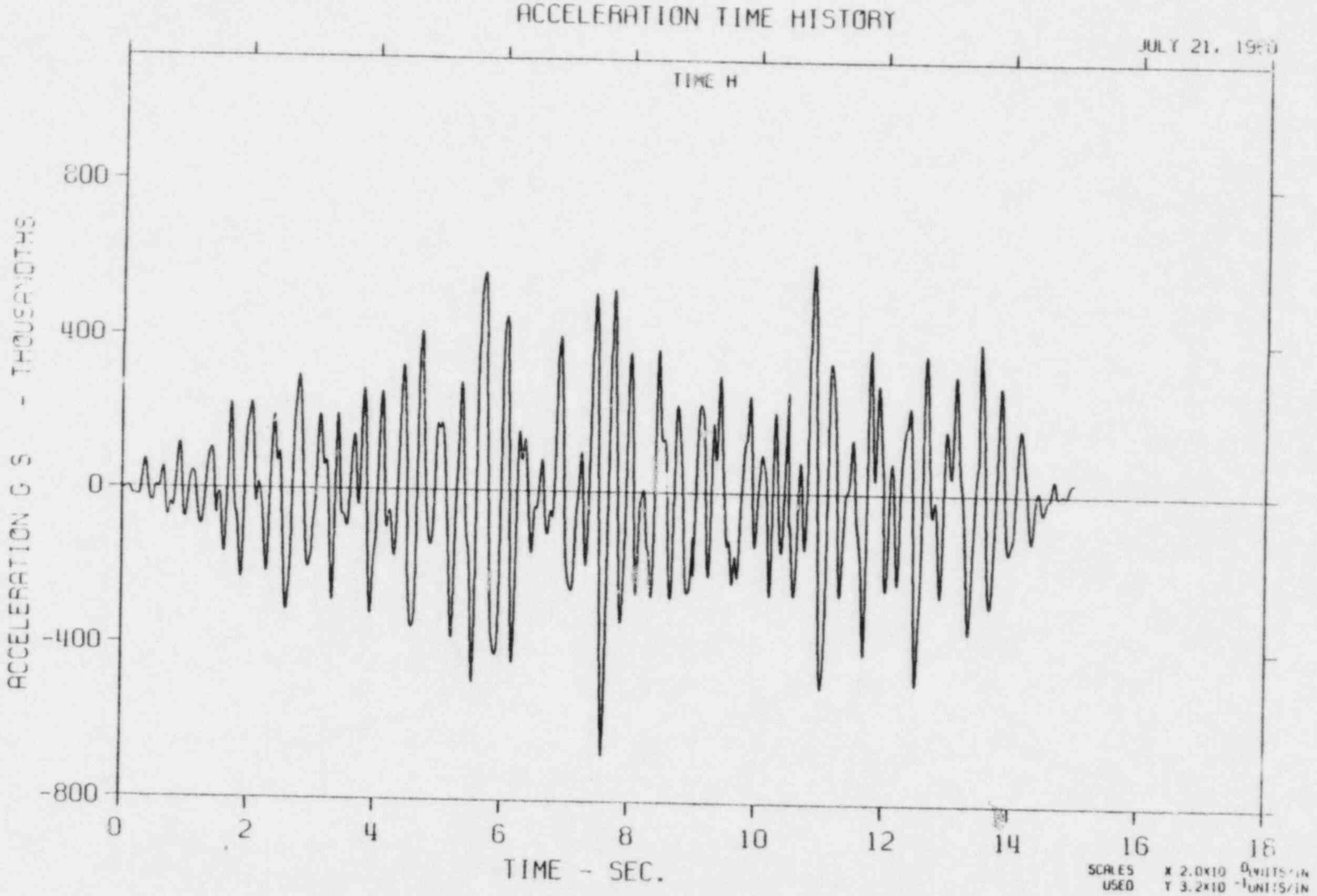


Figure 2-2. Brunswick NPP DBE Time-History 2.0% Damping

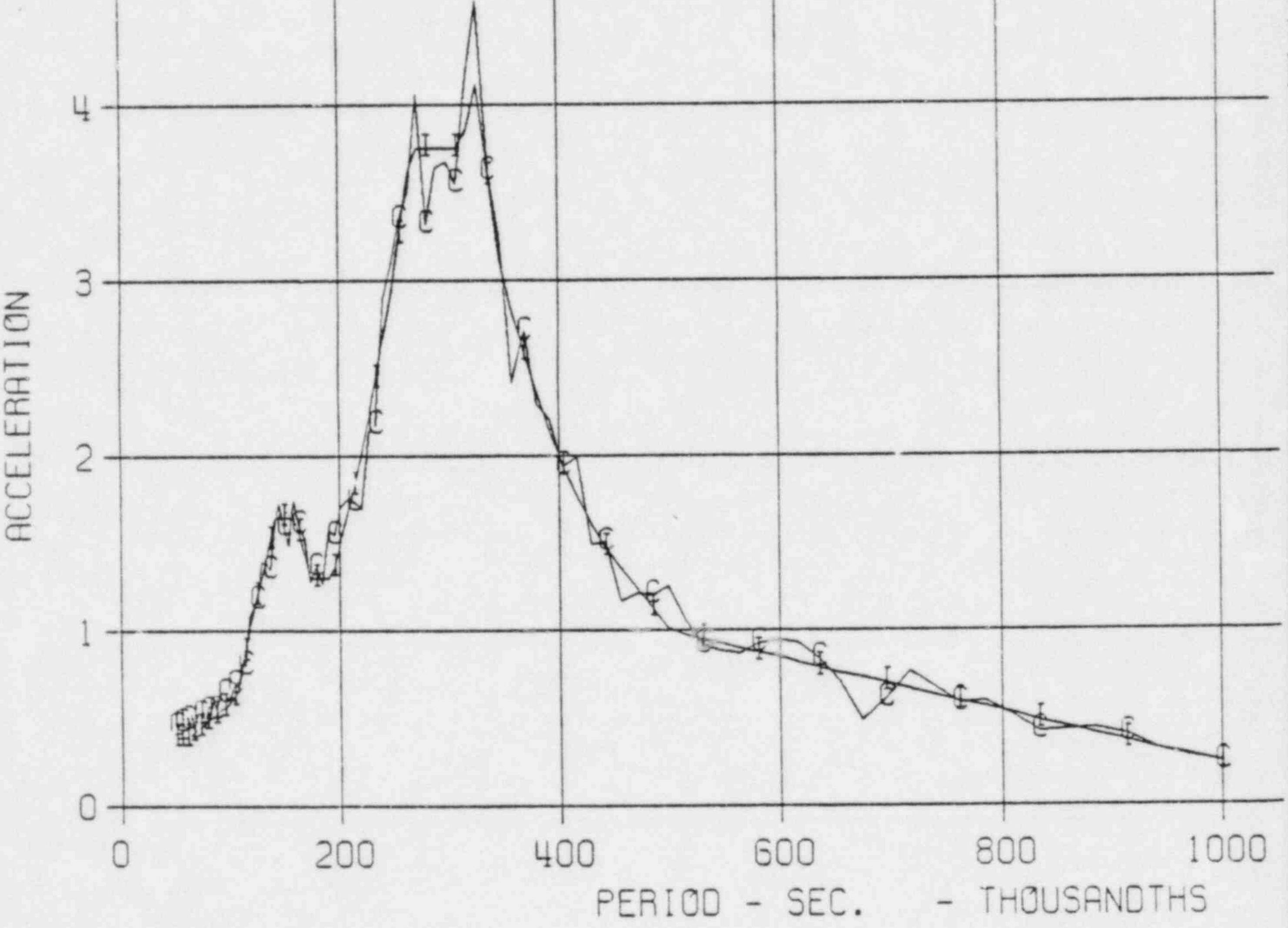


Figure 2-3. Brunswick NPP Horizontal Response Spectrum OBE 1.0% Damping

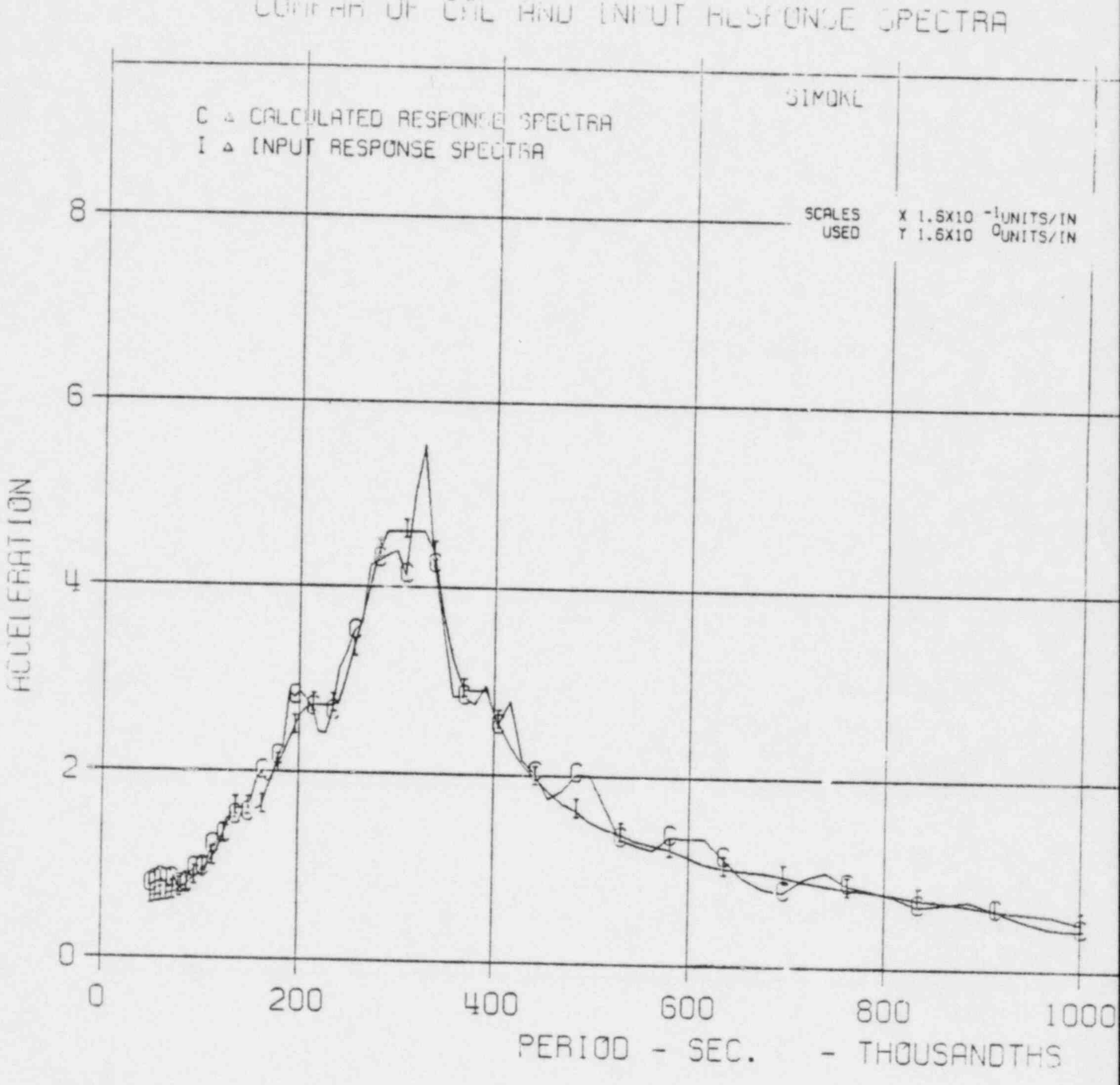


Figure 2-4. Brunswick NPP Horizontal Response Spectrum DBE 2.0% Damping

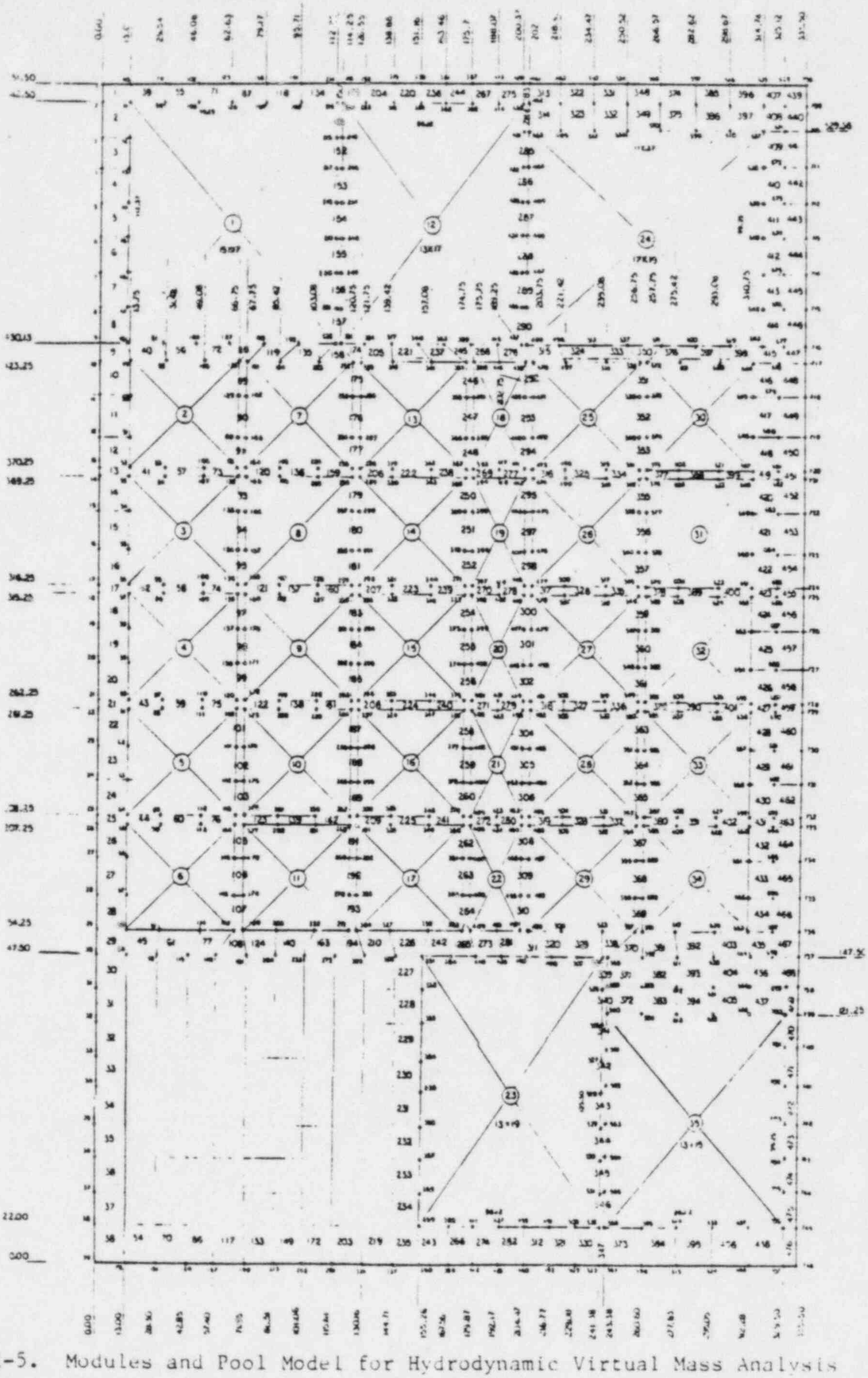


Figure 2-5. Modules and Pool Model for Hydrodynamic Virtual Mass Analysis

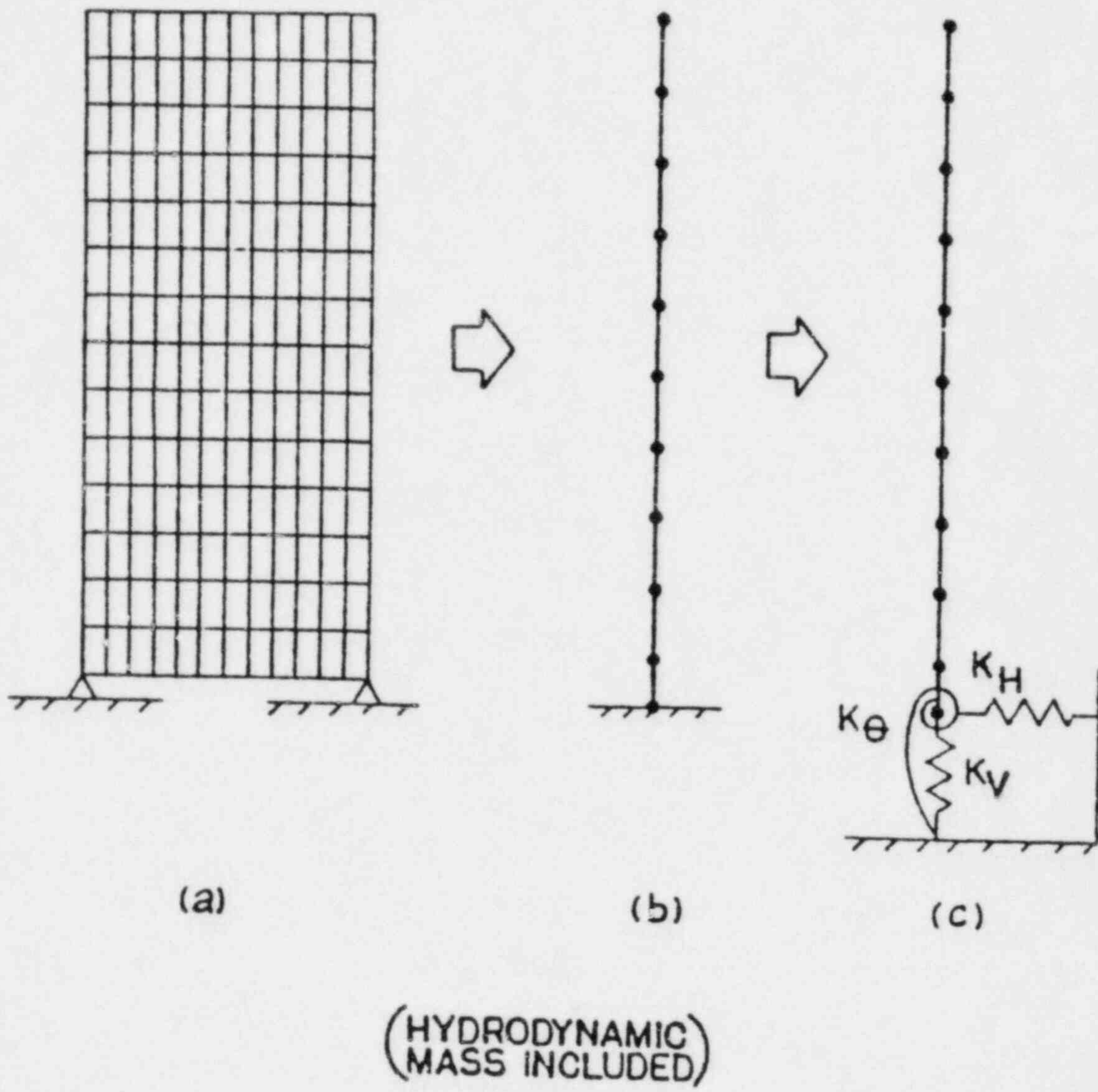


Figure 2-6. Schematic Illustration of (a) the Interior Plate FEM, (b) the Equivalent Fixed Base Stick Model, and (c) the Finalized Equivalent Stick Model for HDFSS Module.

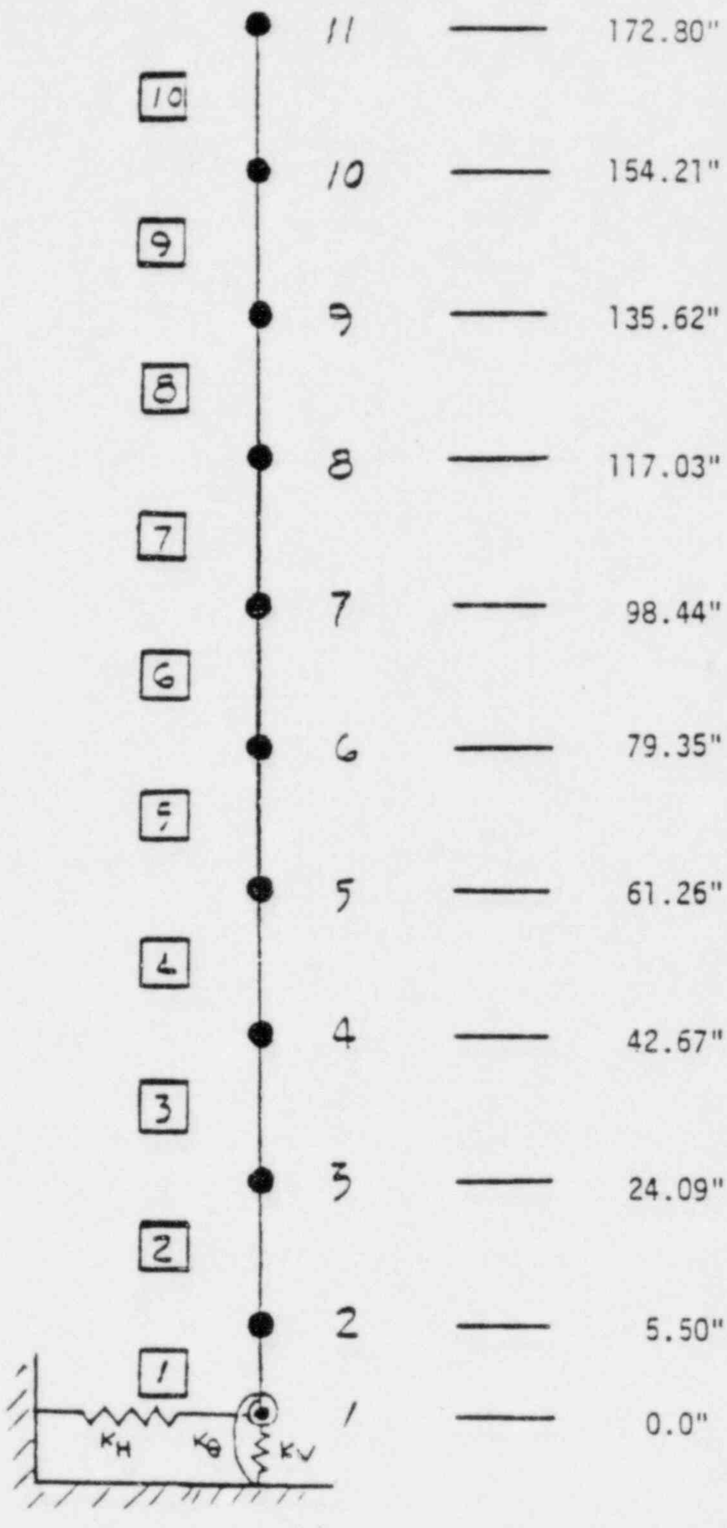
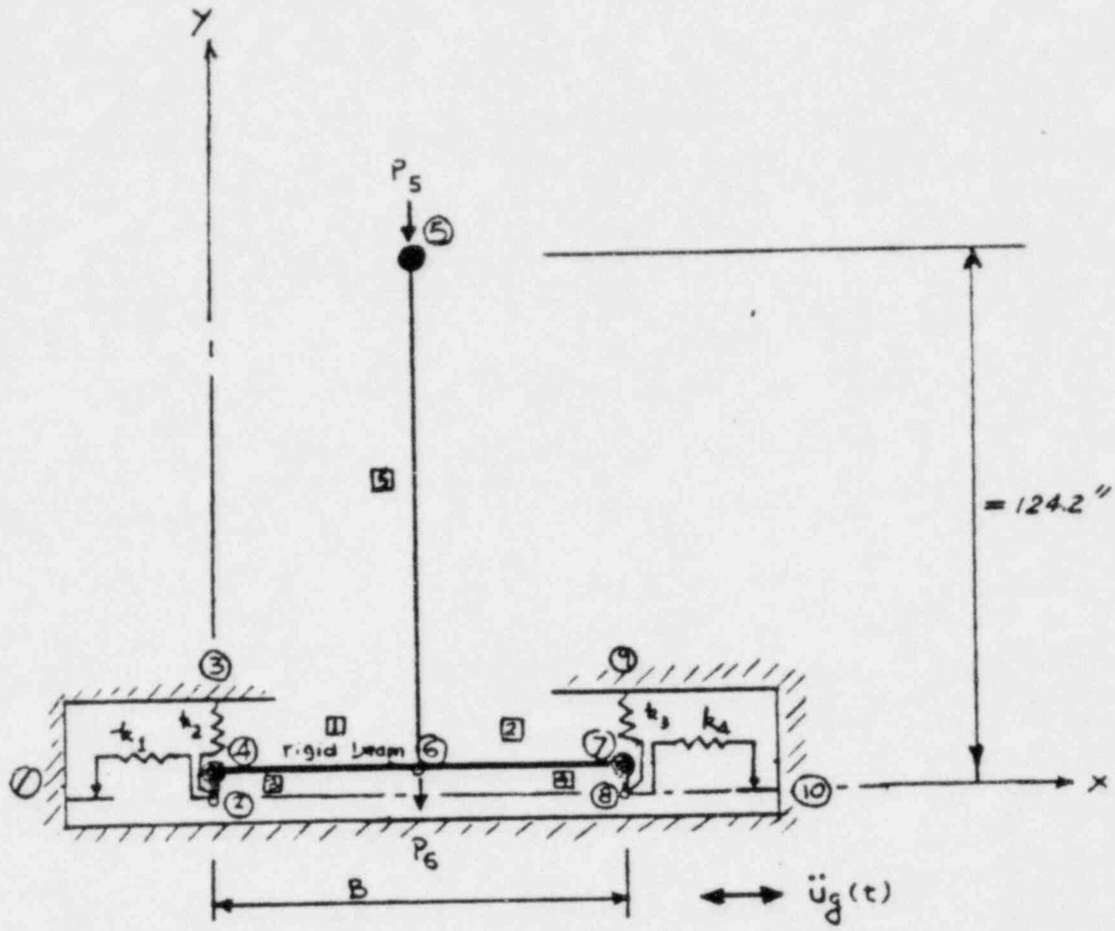


Figure 2-7. Equivalent Flexible Base Stick Model for HDFSS Module



NOTE

(i) = Node Number

[i] = Beam Element Number

(k_i) = Truss Element Number

● = Concentrated Mass

P_5, P_6 - Static Nodal Forces

Figure 2-8. Brunswick HDFSS Drained Model for Nonlinear Analysis

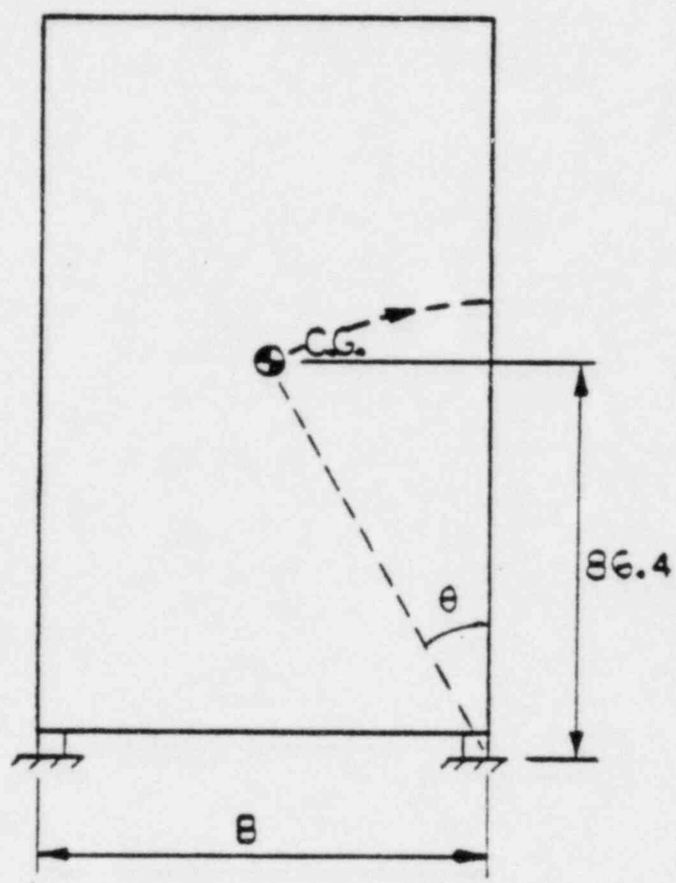


Figure 2-9. Configuration for Computation of Safety Factor Against Overturning

3. STRESS ANALYSIS MODELING AND RESULTS

3.1 INTRODUCTION

Stress analyses were performed to determine critical internal stresses in the module. General Electric's computer program SAP4G07, a modified version of SAP4 of U.C. Berkeley, was used in the stress analyses. Separate horizontal and vertical static analyses were performed first, utilizing output of dynamic analyses from Section 2 of this report, to calculate internal stresses at each critical section. Results from these structural analyses were then used to calculate maximum combined stresses in tube walls, castings, fuel support plates, closure plates and welding in the module.

3.2 STRESS ANALYSIS MODELING

An isometric view of module is shown in Figure 3-1. The force path in the module due to a horizontal earthquake is shown schematically in Figure 3-2. This figure shows the path of the horizontal earthquake induced inertial forces from the fuel elements to the module support pads. Part of the fuel element inertial forces induced by motion of the module are transferred either through the water or directly to the tube walls along the direction of motion (point 1 in Figure 3-2). These walls then transfer the forces along the side tube walls down to the casting walls and into the fuel support plates (point 2). The portion of fuel element load that is not transferred to the tube walls is transferred directly to the fuel support plate at the point where the lower end fitting of the fuel element is supported vertically (point 3). The fuel support plates, acting as a relatively rigid diaphragm, transfer the in-plane shear forces to the long casting walls, which then transfer the shear forces to the module base assembly plate (point 4). The forces are carried in the plate (point 5) until they are ultimately transferred to the module pad and to the support pad and the pool slab (point 6).

The path of the vertical forces induced by module weight and vertical earthquake motion is somewhat more complicated. The inertial forces from the fuel elements will be transferred by tube walls in both directions and the ratio of

transferred shear forces will depend on the stiffness of plates (series of tube walls or closure plates) and location of the fuel element in the module. Exterior plates and first interior plates (Figure 3-1) will carry more load than other interior plates because most of the inertial force will be transferred to module pad through exterior or first interior plates. To perform conservative stress analysis, exterior and first interior plates only are assumed to carry all of the vertical loads.

Based on symmetry of structure, only one half of exterior or first interior plate (Figure 3-3) and one quarter of base plate (combination of fuel support plate and part of casting) in horizontal direction (Figure 3-4) were used in the modeling for structural analysis. Plate/shell elements were used to represent tube walls, closure plates, castings and fuel support plates in the plane of applied forces. Beam elements were used to represent tube walls, castings, closure plates, fuel support plates and base assembly in the direction perpendicular to applied forces.

Plates with holes, such as castings or fuel support plates, were replaced by plates without holes with equivalent thickness. Equivalent mass density or weight density was used in the structural analysis to provide proper body forces to plate/shell elements. Submerged weight of module was used for calculating equivalent weight density. It was assumed that module mass was uniformly distributed throughout the module.

For the horizontal DBE stress analyses, the seismic input to the SAP4G07 Computer Code is an equivalent horizontal acceleration, a_H, in g units. This horizontal acceleration is determined as follows:

$$a_H = \text{Base Shear/Module Wt.}$$

Table 3-1 lists the values of a_H for the modules. Note that they all substantially exceed the value of friction coefficient between the module pad and the support pad, indicating sliding of the module would actually occur.

Sliding of the module will limit the acceleration of the module to the value of the friction coefficient. Therefore, stress analysis using the full value of a_H in effect neglect sliding of the module, and are very conservative. Shear force induced by horizontal earthquake effect in interior part of module will be transferred to the exterior plates and the first interior plates by the base plate. This shear force was assumed to be distributed in proportion to shear stiffness of the exterior plate and the first interior plate. Short castings contribute a negligible nodal stiffness in the analysis because they are not welded to the other castings nor the base assembly. Because of this reason, short castings were neglected and it was judged that this approach is conservative.

In calculating stresses in the long and short castings and the fuel support plates (analysis of base plate), one nodal point on the corner of the model was used to represent the friction resistance of module pad. This simplification in the analytical model is conservative to predict stresses in the aforementioned elements and shear stresses in the weld.

To calculate stresses in a perforated plate, e.g., fuel support plate, large casting and lower closure place, an equivalent solid plate with modified thickness is developed. The equivalent plate is used in the module model for structural analysis. Stresses in the perforated plate are then obtained from stresses in the equivalent plate from the structural analysis.

In the vertical stress analyses, the vertical OBE/DBE acceleration equal to 2/3 of the horizontal ground acceleration was used. This was done because the modules are, according to Section 2, rigid in vertical vibration and the module acceleration would be equal to the ground vertical acceleration.

3.3 SUMMARY OF MAXIMUM COMBINED STRESSES

The maximum horizontal and vertical DBE combined stresses are listed in Table 3-2, which also lists the allowable stresses for comparison. Most maximum stresses are found to occur in the 15x17 module. In spite of various conservative assumptions used in the analysis, the maximum stresses are well below the allowables.

Table 3-1

EQUIVALENT HORIZONTAL DBE ACCELERATION

Module	Direction	a_H (g)
13 x 15	13-Tube	1.40
	15-Tube	0.95
13 x 17	15-Tube	1.84
	17-Tube	1.00
13 x 19	13-Tube	1.62
	19-Tube	0.79
15 x 17	15-Tube	1.59
	17-Tube	1.11

Table 3-2

COMPARISON OF CALCULATED OBE AND DBE STRESSES VERSUS ALLOWABLES (psi)

Location/Type	OBE Condition		DBE Condition	
	Calc. Stress	Allowables[1]	Calc. Stress	Allowables[1]
Tube wall shear	5,520	9,260	8,230	15,400
Tube wall compression	6,210	13,900	9,380	23,100
Tube weld throat shear	5,520	9,260	8,230	15,400
Angle, weld throat shear	7,810	9,260	11,640	15,400
Casting wall shear	3,340	9,260	9,170	15,400
Casting wall compression	8,900	15,300	14,220	23,100
Casting base weld shear	3,830	9,260	10,530	15,400
Support plate weld throat shear	3,870	9,260	15,330	15,400
Upper Closure Plate				
Compression	5,820	13,900	7,880	23,100
Shear	3,060	9,260	4,010	15,400
Weld Shear	4,330	9,260	7,440	15,400
Lower Closure Plate				
Compression	3,970	13,900	4,730	23,100
Shear	5,060	9,260	8,550	15,400
Weld Shear	7,150	9,260	12,100	15,400
Corner tube local compressive stress check for local buckling	-	-	9,120	23,100

[1]Allowable stresses referenced in ASME Section III, Appendix F, Section F-1370.

NOTE: The OBE values are based on a "base shear" computed using non-linear analysis, while the DBE values are computed using a "linear-analysis-base-shear."

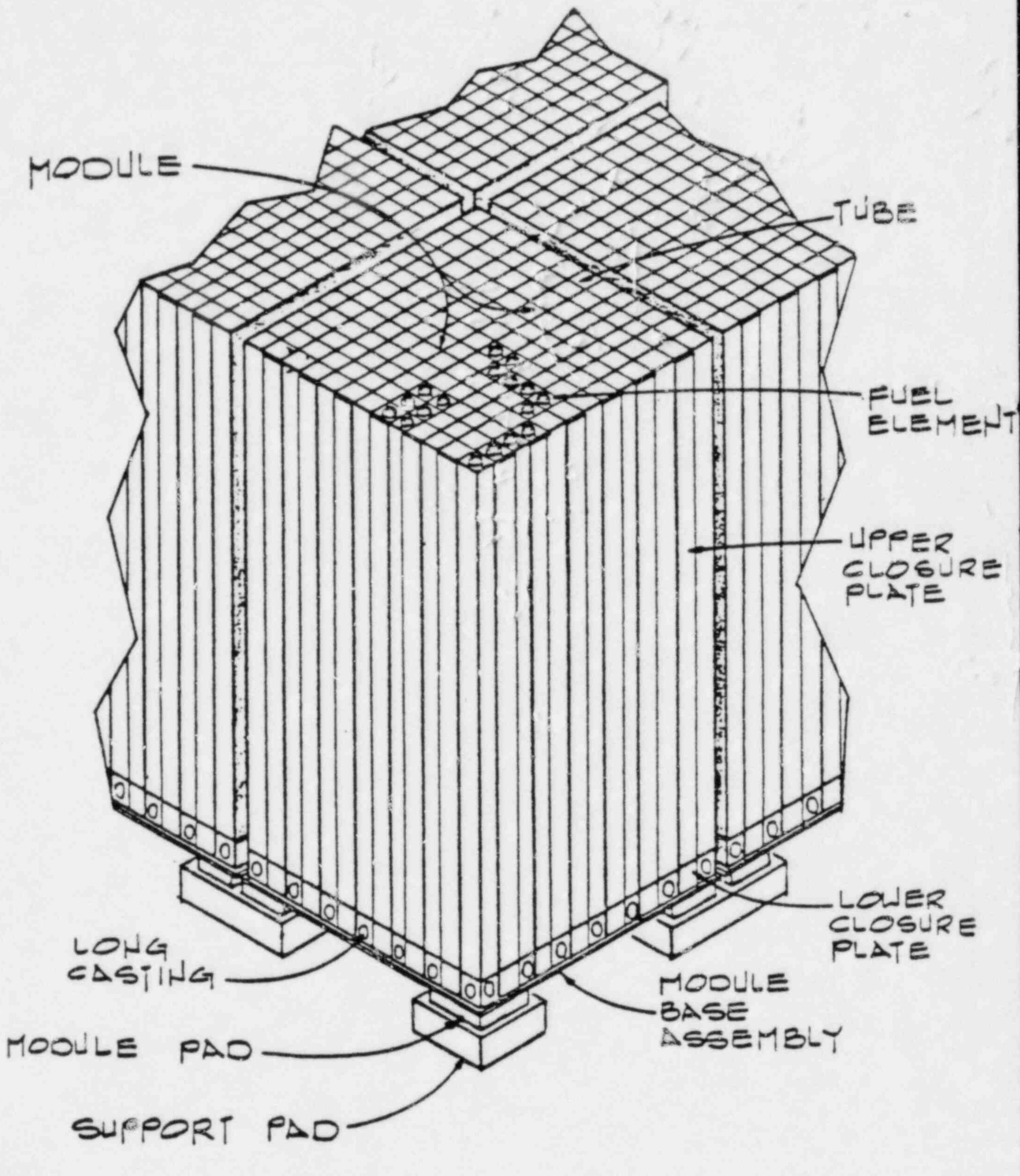


Figure 3-1. Isometric View of Modules

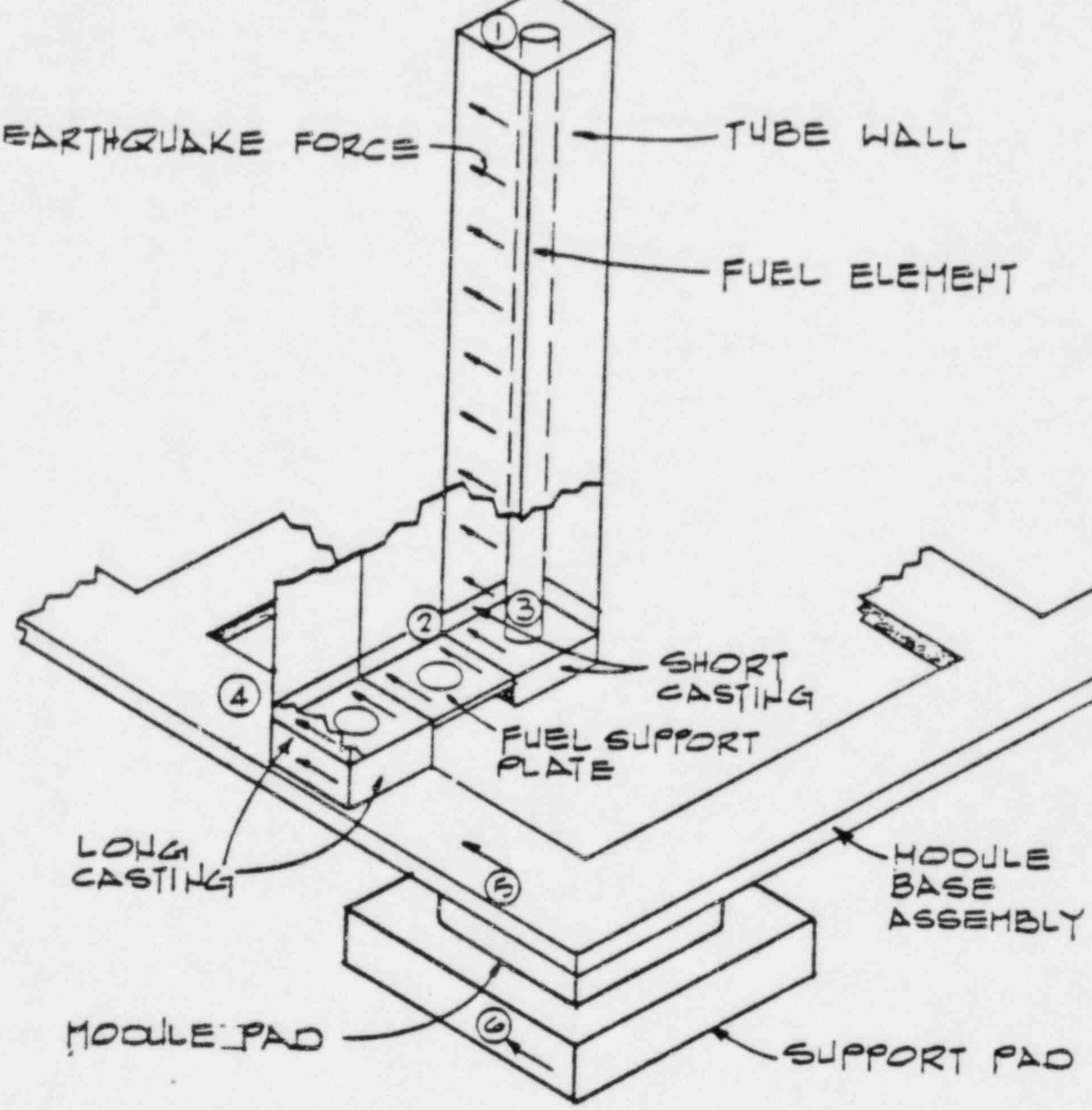


Figure 3-2. Path of Earthquake Horizontal Forces in Module

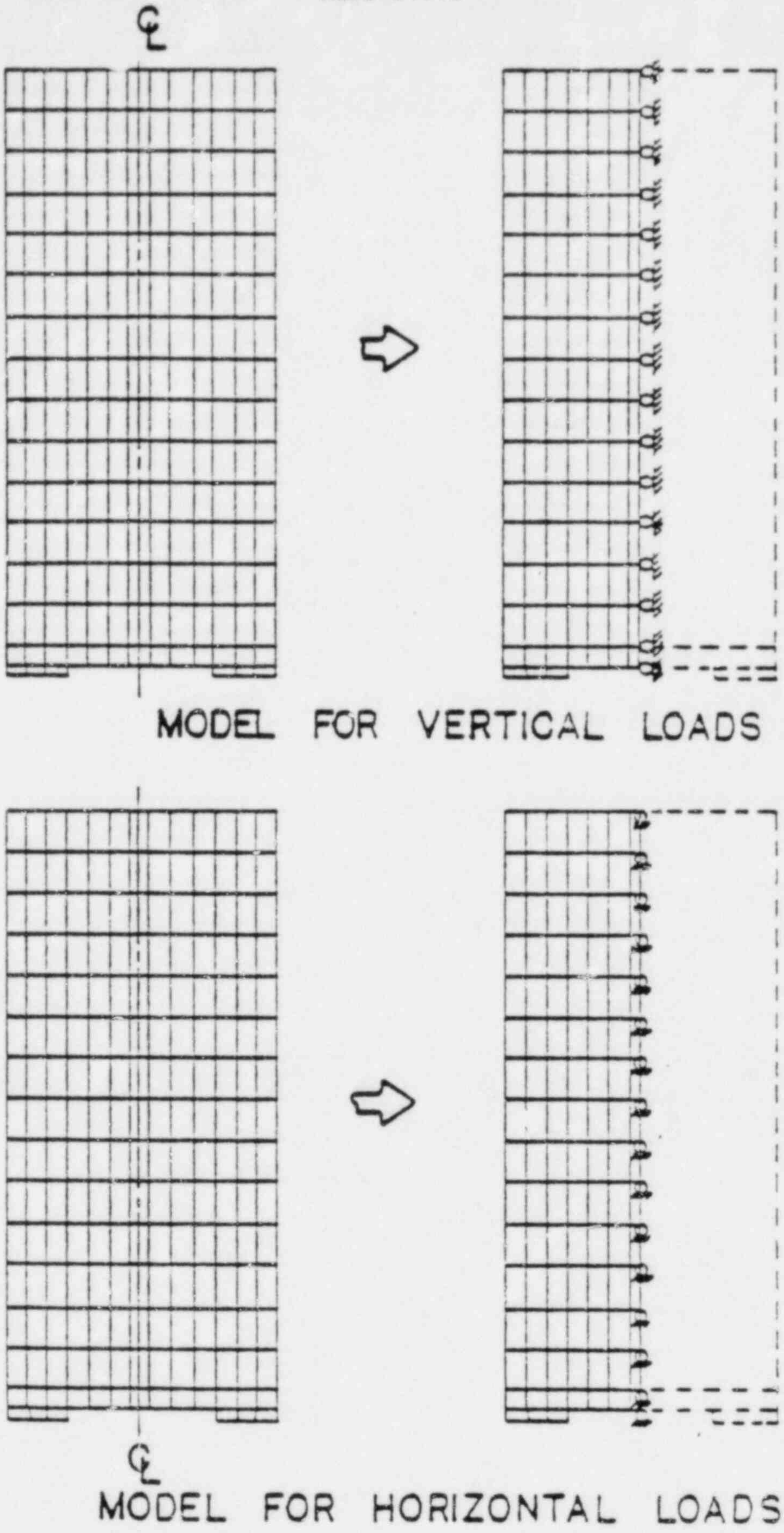


Figure 3-3. Typical Plate Model

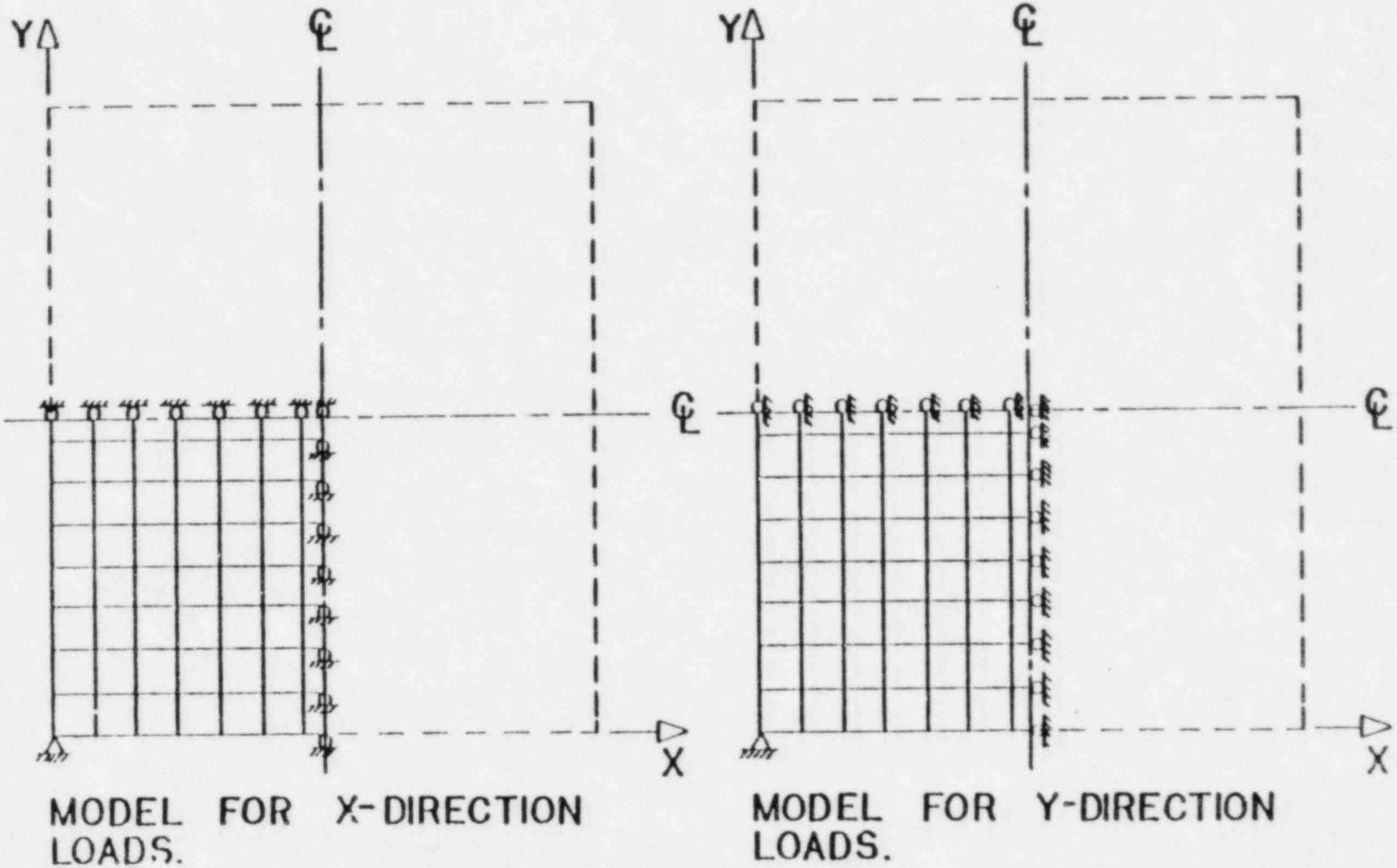


Figure 3-4. Typical Plate Model

4. FUEL DROP ACCIDENT ANALYSIS

4.1 PURPOSE OF THE ANALYSIS AND ASSUMPTIONS

The purpose of the fuel drop accident analysis is to evaluate whether there is any safety concern as a result of fuel bundle drop into and between high density fuel storage modules. Several critical configurations of fuel bundle arrays resulting from the postulated fuel bundle drops and local deformations of the module have been examined. The module design criteria requires that K_∞ remains less than 0.95 under the worst configuration.

The integrity of the pool liner due to fuel bundle drop through the storage module was not studied since the fuel impact load is less than the case of the fuel bundle drop outside the rack wheie it freely and directly impacts the liner. The latter case is not related to high density rerack activity and has been addressed elsewhere.

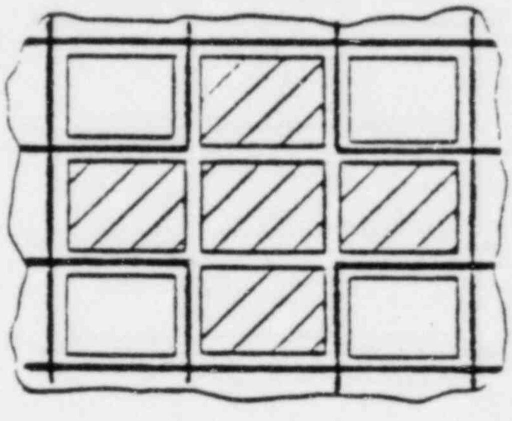
In estimating the energy absorption capability of the module and the extent of local damage as a result of fuel bundle drop, a lower bounding value established from limit analysis was used. The material is assumed to exhibit bilinear hysteresis relationship with yield stress and tensile strength as the two control points. This assumpticn is deemed conservative.

4.2 CASES CONSIDERED

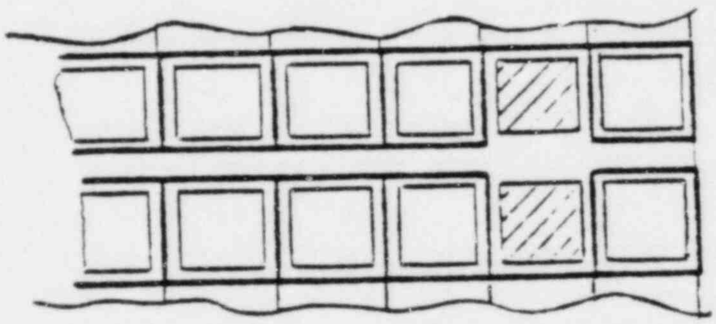
The following worst configurations of the fuel bundle array have been evaluated from a criticality point of view. K_∞ was found to be less than 0.90 in all the cases.

Four poison plates and stainless steel plates missing surrounding one fuel bundle e.g. 5 bundle stored together with no poison.

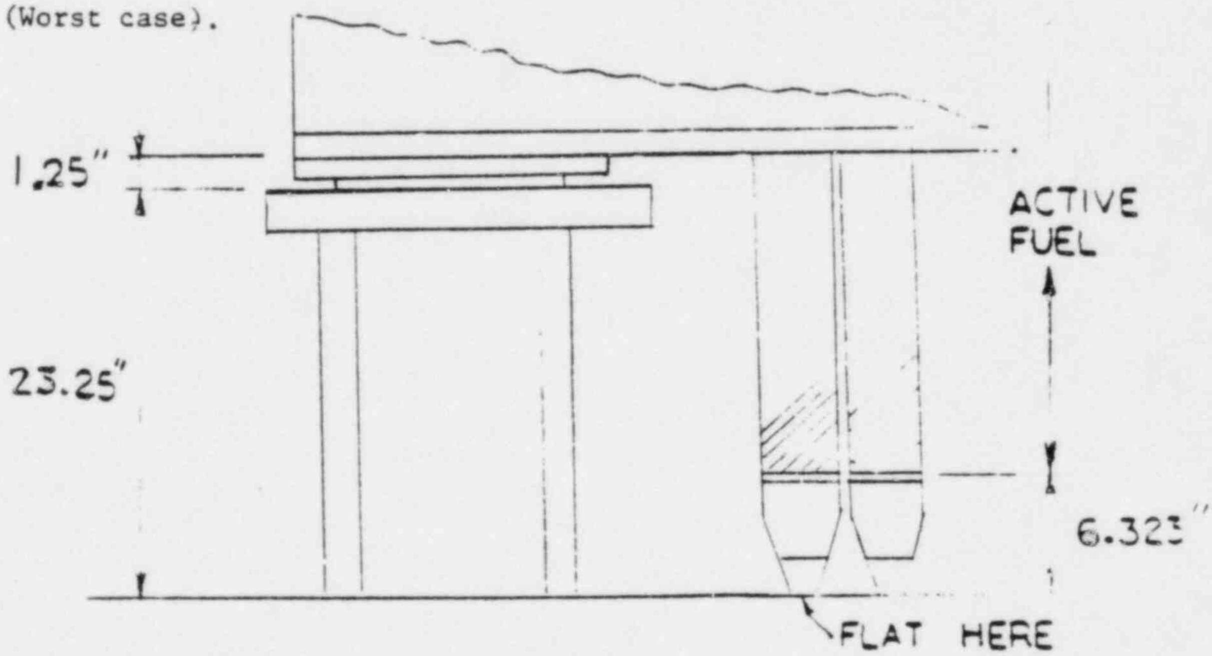
a.



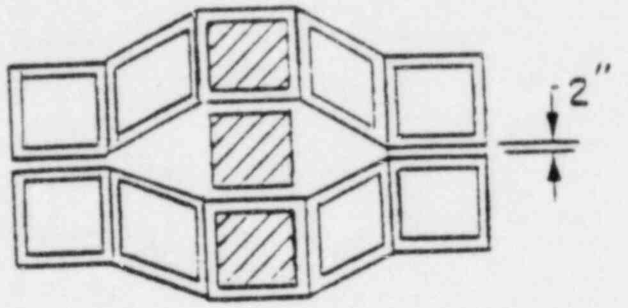
b. Two opposing fuel bundles in two separate modules with no poison in between.



c. Four fuel bundle penetrate fuel support plate and rest on liner. (Worst case).



d. One fuel bundle stuck between two modules.



4.3 CONCLUSIONS

The cases considered and results obtained are summarized in Table 4-1.

Table 4-1

HIGH DENSITY SPENT FUEL STORAGE SYSTEM ASSEMBLY DROP ACCIDENT

Case Summary

No.	Case Description	Effect on Reactivity
1.	A fuel assembly drops 27-1/2 inches vertically and impacts the top of a fully loaded HDFSS module. The dropped assembly comes to rest horizontally on top of the HDFSS.	Analysis indicates that localized tube damage or fuel support member damage will occur, but neutron absorber material will not be removed from its position between adjacent fuel assemblies. A fuel assembly resting horizontally atop the HDFSS does not increase the system reactivity because the reactivity assumes an infinite vertical length of fuel (no neutron leakage in the vertical dimension). $k_{eff} < 0.90$
2.	A fuel assembly drops from 27-1/2 inches above the HDFSS, enters an empty storage position, and falls to the bottom of the storage position.	Structural analysis indicates that localized tube damage will occur and one neutron absorber plate may be damaged. A reactivity analysis of this case, with the neutron absorber plate between two fuel assemblies totally missing, shows that k_{eff} remains less than 0.90.
3.	A fuel assembly drops from 27-1/2 inches above the HDFSS and strikes a tube wall at an oblique angle.	Same as Case 2
4.	A fuel assembly drops from 27-1/2 inches above the top of a fully loaded module and strikes the upper tie plates of 2, 3, or 4 fuel assemblies in storage.	It is not possible for a fuel assembly drop of 27-1/2 inches to drive four stored assemblies through the bottom of the module. Even so, the reactivity effect of this postulated event was calculated as a limiting value. An 18-inch section of fuel in four bundles in an unpoisoned square array was found to have a k_{eff} approximately equal to that of the system. There would be no increase in the overall reactivity $k_{eff} < 0.90$.
5.	A fuel assembly drops from 27-1/2 inches above the HDFSS, falls outside of the loaded HDFSS, and lodges adjacent and parallel to an unpoisoned, occupied fuel storage position.	This case was analyzed for normal handling conditions; $k_{eff} < 0.90$

5. THERMAL-HYDRAULICS ANALYSIS

5.1 INTRODUCTION

The analysis includes the evaluation of the maximum temperature increase of the cooling water through a fuel bundle and through a gap between fuel bundle and storage tube wall to assure that boiling will not occur in the storage pool during the normal operation. Also, the maximum water temperature inside the assembly lying horizontally in the pool has been evaluated.

5.2 FUEL BUNDLE CHARACTERISTICS

The 8x8R bundles have a 5.2662-inch-square cross-section area containing 62 fuel rods and two water rods, according to the specification for Brunswick 2, cycle 5.[7] The fuel pin is 164.3-inch overall length with 150-inch active fuel length. Each fuel bundle contains 456.4 pounds of uranium enriched maximum up to 3.16 percent. Figure 5-1 shows the bundle geometry relative to the spent fuel storage tube.

The burnup and specific power considered were provided by Carolina Power and Light as follows:[8]

Burnup - 35,000 MWD/TU
Specific Power - 4.35 MW/bundle
Full on-line time was assumed.

ORIGEN[9] was used to calculate a bundle heat load of 79,340 BTU/hour at the specified cool time of 24 hours and irradiation history given above.

5.3 MAXIMUM BUNDLE AND GAP OUTLET WATER TEMPERATURE

Evaluation of water temperature increase through the bundle is necessary to insure the bundle is adequately cooled and the water outlet temperature from the bundle is not excessive. The bulk water temperature of both pools is 150°F during the normal operation. The local water temperature will be

highest when the maximum decay heat generating fuel bundle, surrounded by the same type of fuel bundles, is located at the place where the pressure drop generated by the flow to the bottom of the bundle from the bulk pool water is largest. This situation occurs when the fresh bundle from the reactor is located at the corner of 13 x 17 module as shown in Figure 5-2. The methods of doing this are given in the following sections.

(A) Driving Force

The water circulated through the bundle to remove the decay heat is induced by the density different between pool water and water inside of the bundle. Further, it is assumed that the heat flux is uniform through the active fuel rod and the water density is a linear function of temperature for the temperature range from 150°F to 190°F. Then, the driving forces for bundle and gap become functions of the flow velocity and the heat generated by the bundle for a given geometry.

A portion of the decay heat is released as photons and is absorbed by fuel channel, boral storage tube and water in the gap. The amount of energy absorbed by each component is estimated as follows:

Fuel channel	870 BTU/hour/bundle
Gap water	2,940 BTU/hour/bundle
Boral tube	320 BTU/hour/bundle

All the energy listed above is assumed to be transferred to water in the gap. Further, the heat is transferred from the water in the bundle to the water in the gap due to higher temperatures in the bundle. The amount of heat transferred is proportional to the temperature difference between bundle and gap flow.

With the assumption of the temperature difference being 3.0°F the heat absorbed becomes

$$Q_b = 20.7 \text{ BTU/sec/bundle}$$

$$Q_g = 1.35 \text{ BTU/sec/bundle}$$

where

Q_b heat absorbed at the bundle

Q_g heat absorbed at the gap

The driving forces created in the bundle and the gap are equal to the sum of the various pressure drops generated by the water flow under the storage rack assembly, through the rack, through the fuel bundle and through the gap.

(B) Pressure Drop Under the Storage Assembly

The bulk water on the top of the storage assembly travels down through the gap between the storage wall and the storage assembly, then under the storage assembly to reach the bottom of the fuel bundle. Pressure drops under the storage assembly has been determined under the assumptions listed below:

1) All the storage spaces are filled with the fuel bundles, and the amount of water flow through the bundle and gap is the same as that through the bundle and gap with the maximum decay heat.

2) The pressure drop caused by the flow between side wall and storage assembly is negligible.

3) The main pressure drop under the assembly occurs at the entrance to the assembly due to the entrance effect. Other pressure drops are negligible.

4) The support pads with their legs are rectangular parallelepiped shaped, blocking flow completely under them.

5) The existing grid will also partially block the flow along with the support pads at the entrance near the storage wall.

6) The water flow through both sides of the entrance has the same velocity. Then, the pressure loss through the entrance near the wall is higher than that at the other side due to the existing grid. Therefore, the entrance pressure loss is evaluated based on the geometry of the entrance near the wall.

With the above assumptions, the pressure drop under the storage assembly can be expressed as a function of the flow velocity at the bundle and at the gap.

(C) Pressure Drop Through the Rack
The pressure drop occurs when the water flows through the base plate and the casting holes in the storage rack. This pressure drop, also, is a function of the velocity at the bundle and the gap.

(D) Pressure Drop Through Fuel Bundle
The pressure drop through the bundle consists of two parts; the friction pressure drop and the pressure loss through the spacers and tie-plates. The flow is laminar for calculation of the friction pressure drop through the main regions of the bundle and the pressure loss coefficient developed for the turbulent flow is used to evaluate the pressure loss through the spacers and tie-plates. Then, the pressure drop through the fuel bundle can be expressed as a function of the bundle flow velocity.

(E) Pressure Drop Through the Gap Between Fuel Bundle and Storage Tube
The pressure drop through the gap consists of two parts; the friction pressure drop through the gap itself, and the pressure loss through the support plate. The flow through the gap is laminar and the flow through the support plate is treated as turbulent. Then, the pressure drop through the gap becomes a function of the flow velocity at the gap.

(F) Overall Force Balance

Figure 5-3 shows the water from the side of the pool flows under the storage assembly, through the rack, and then is divided into the bundle flow and the gap flow. Therefore, the force balance can be described by the following two simultaneous equations:

$$H_{d,b} = H_u + H_r + H_b \qquad (1)$$

$$H_{d,g} = H_u + H_r + H_g \qquad (2)$$

where

$H_{d,b}$ Driving force through the bundle, ft of H_2O

$H_{d,g}$ Driving force through the gap, ft of H_2O

H_u Pressure drop under the storage assembly ft of H_2O

H_r Pressure drop through the rack, ft of H_2O

H_b Pressure drop through the bundle, ft of H_2O

H_g Pressure drop through the gap, ft of H_2O

Since Equations (1) and (2) are functions of the velocity at the bundle and the gap for a given geometry and bundle decay heat, the velocity at the gap and the bundle can be obtained by solving Equations (1) and (2) simultaneously. Then, the velocity at the bundle and the gap becomes

$$V_b = 0.22 \text{ ft/sec}$$

$$V_g = 0.038 \text{ ft/sec}$$

where

V_b Flow velocity at the bundle, ft/sec

V_g Flow velocity at the gap, ft/sec

(G) Bundle and Gap Water Outlet Temperature

Once the velocities of water leaving the bundle and the gap has been determined, the water outlet temperatures from the fuel bundle and the gap can be obtained from the heat balance.

$$T_{o,b} = T_p + \frac{Q_b}{\rho C_p A_b V_b} \quad (3)$$

$$T_{o,g} = T_p + \frac{Q_g}{\rho C_p A_g V_g} \quad (4)$$

where

$T_{o,b}$ Bundle outlet water temperature, °F

$T_{o,g}$ Gap outlet water temperature, °F

T_p Pool water temperature, °F

A_b Bundle flow area, ft^2

A_g Gap flow area, ft^2

C_p Heat capacity of water, BTU/°F lb

ρ Density of water at pool temperature, lb/ft^3

For the pool temperature of 150°F at the normal operating condition, the maximum bundle and gap water outlet temperatures become

$T_{o,b}$ = 164.1°F

$T_{o,g}$ = 155.3°F

The average temperature difference between bundle and gap water flow becomes

$$\frac{164.1 - 155.3}{2} = 4.4°F$$

This value agrees reasonably well with the previous assumption of 3.0°F difference.

(H) Maximum Cladding and Tube Wall Temperature

Since the flows through the fuel bundle and gap can be treated as laminar (Reynolds numbers are 2300 for the bundle and 570 for the gap), the Nusselt number becomes 6.5 for the bundle based on the rod diameter[10] and 7.4 for the gap[11] at the constant heat flux condition. From the heat balances, the maximum cladding and tube wall temperature are

$$T_c = T_{o,b} + \frac{3600 Q_b D}{A_r Nu_b k} \quad (5)$$

$$T_w = T_{o,g} + \frac{3600 Q_t D_g}{A_t Nu_g K} \quad (6)$$

where

- T_c Maximum cladding temperature, °F
- D Rod diameter, ft
- A_r Rod surface heat transfer area, ft^2
- k Conductivity of water, BTU/ft hr °F
- Nu_b Bundle Nusselt number
- T_w Maximum tube wall temperature, °F
- A_t Tube heat transfer area, ft^2
- Q Heat absorbed by tube, BTU/sec
- D_g Gap hydraulic diameter, ft
- Nu_g Gap Nusselt number

Then, the maximum cladding and tube wall temperature becomes

$$T_c = 176.4°F$$

$$T_w = 155.6°F$$

5.4 MAXIMUM WATER TEMPERATURE IN THE BUNDLE LYING HORIZONTALLY

The maximum water temperature inside the bundle lying horizontally across the top of the racks is evaluated in two steps; the natural convection heat transfer from the channel surface to the pool water and the natural convection heat transfer from the water inside the bundle to the channel surface. In this evaluation, it is assumed that both ends of the bundle are closed to the pool water in order to simplify the problem conservatively. Also, the maximum water temperature will occur in the BWR bundle fresh from the reactor which produces the highest decay heat.

(A) Heat Transfer from the Channel Surface to Pool Water

It is reasonable to treat the BWR bundle with channels like a cylinder even though its outside configuration is rectangular parrelepiped. Then, from Reference 12, the heat transfer coefficient for the natural convection from the channel surface to pool water becomes

$$h_c = 0.53 \frac{k}{D_o} \left[\frac{D_o \rho g \beta \Delta T}{\mu^2} \cdot \frac{C_p \mu}{k}\right]^{0.25} \qquad (7)$$

for

$$10^3 < N_{Pr} \cdot N_{Gr} < 10^9$$

where

h_c Heat transfer coefficient, BTU/hr ft^2

D_o Outside channel width, ft

g Acceleration owing to gravity 4.7×10^8 ft/hr^2

μ Viscosity, lb_m/ft hr

β Coefficient of volumetric expansion, 1/°F

ΔT Temperature difference, °F

N_{Pr} Prandtl number

N_{Gr} Grashof number

From the energy balance

$$Q_d = h_c A_c \Delta T \quad (8)$$

Where

Q_d Total bundle decay heat, BTU/hr bundle

A_c Channel outside surface area, ft^2

With the proper physical values, ΔT from Equations (18) and (19) becomes

$$\Delta T = 29\ °F$$

and

$$N_{Pr} \cdot N_{Gr} = 3.4 \times 10^9 \approx 10^9$$

For the pool temperature of 150°F at the normal operating condition, the channel surface temperature (T_h) becomes

$$T_h = 179°F$$

(B) Heat Transfer From the Water Inside the Bundle to the Channel Surface

Wooten and Epstein[13] have developed an equation to predict the maximum water temperature inside the cask for 17 x 17 bundles based on the experimental data and found that the correlation is similar to that for single horizontal cylinders shown in Equation (7). The geometry-dependent coefficient for 17 x 17 bundles (0.4) is smaller than the value 0.53 given for simple cylinders. For 8 x 8R bundles, it is assumed that the geometry-dependent coefficient is 0.46 which is midpoint between 0.4 and 0.53.

Then

$$Q_d = 0.46\ A_e \frac{k}{H} \left[\frac{H^3 \rho^2 \beta C_p}{k\mu}\right]^{1/4} (T_m - T_h)^{5/4} \qquad (9)$$

where

H Height of a side of the fuel elements, ft

A_e Area of the fuel elements envelope, ft^2

T_m Maximum water temperature inside bundle, °F

From Equation (9), the maximum water temperature inside bundle is

$$T_m = 211°F$$

5.5 CONCLUSIONS

Thermal-hydraulic analysis of Brunswick 1 and 2 spent fuel storage pool rerack design has been performed on the fuel data provided by Carolina Power and Light. The results indicate that boiling will not occur either in the fuel bundle or in the gap between the fuel bundle and storage tube wall. Also, it has been shown that the water inside the bundle lying horizontally across the top of the racks is close to the boiling temperature. At this temperature range, the integrity of the cladding will not be degraded.

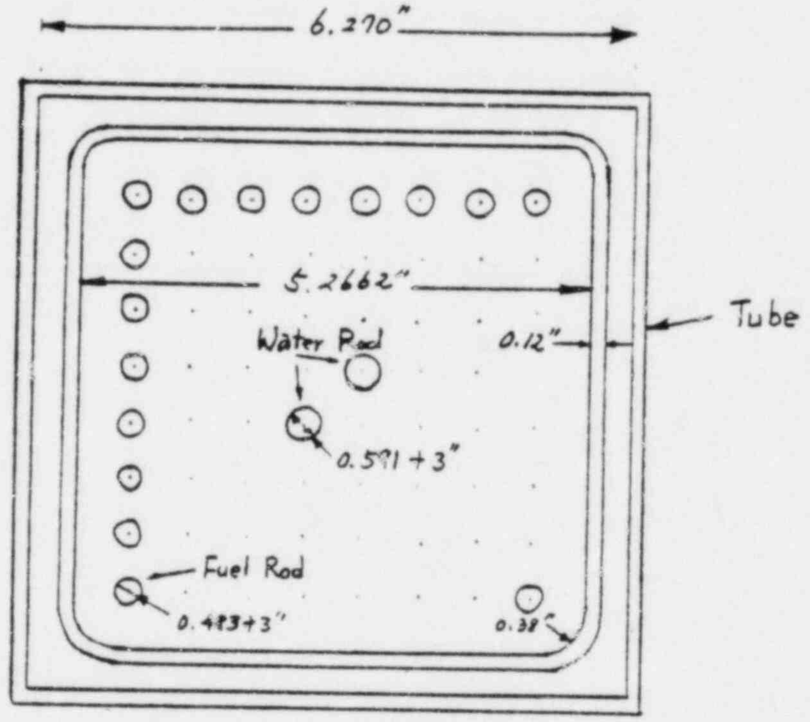


Figure 5-1. Geometry of Fuel Bundle in the Tube

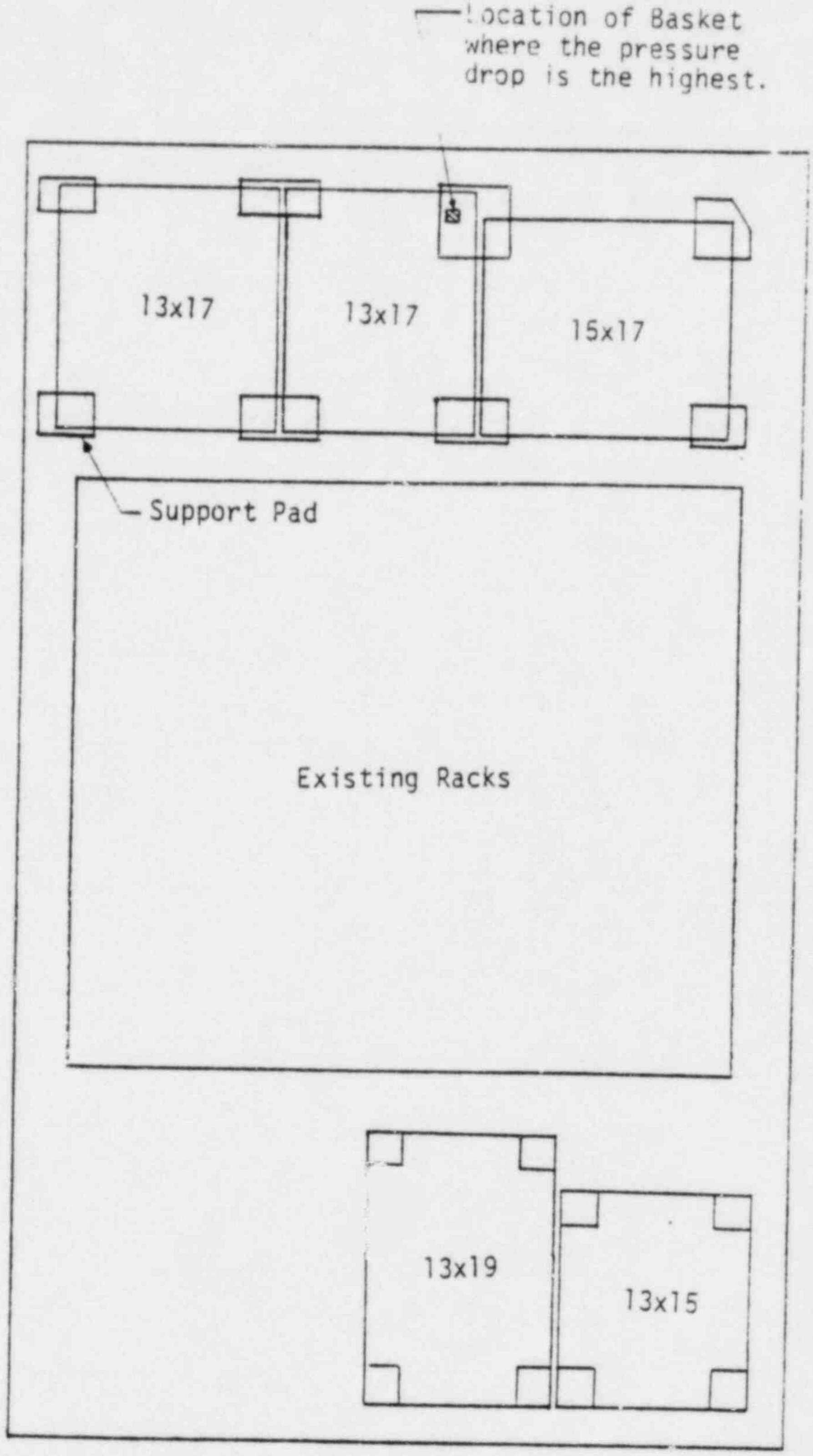


Figure 5-2. Storage Pool Configuration

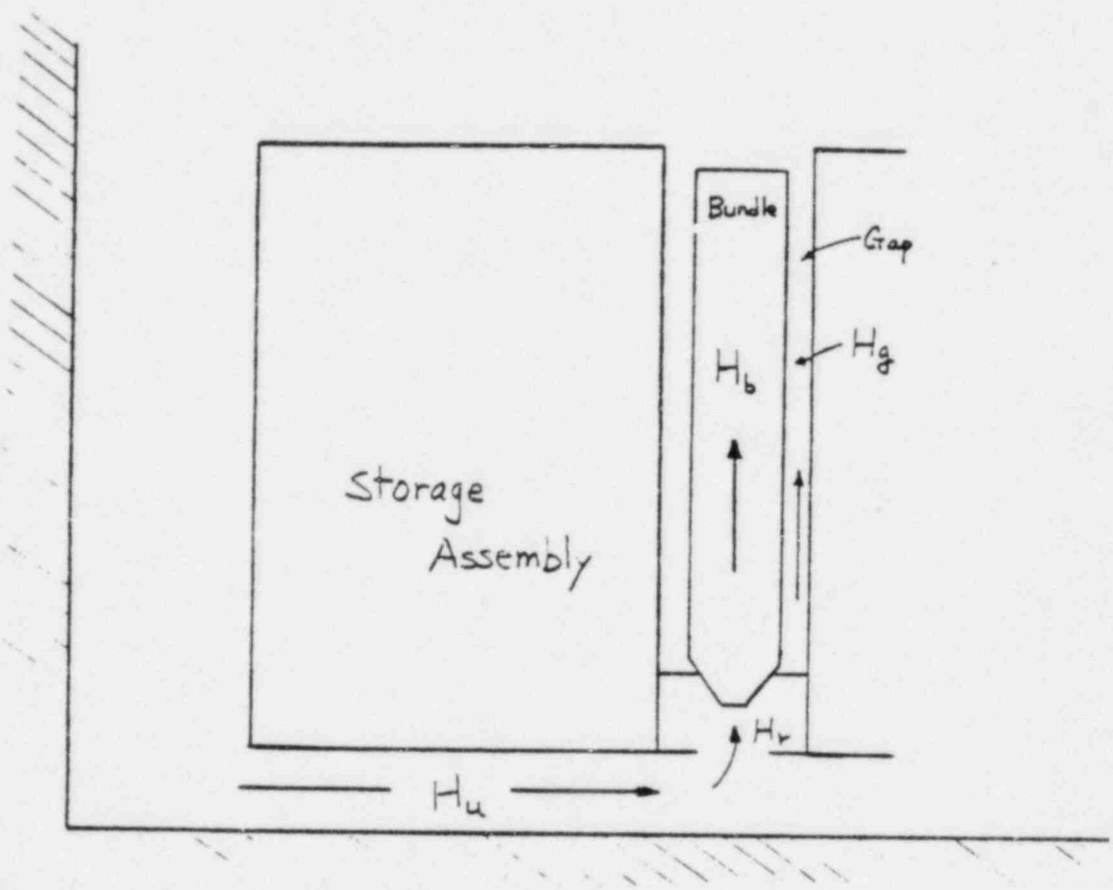


Figure 5-3. Flow Path

ATTACHMENT 5

B. J. Huselton
1149

LEAD ENGINEER: S. D. Lin MANAGER'S INITIALS KKN

PROBLEM CLASS	WORK REQUEST NUMBER	PIN NUMBER	CALCULATION SET NUMBER	JOB CHARGE
I	Speed Letter From B. J. H. To K. K. N. 11/4/80	9527.10.00-12		9527.085

PROBLEM STATEMENT:

Perform the thermal analysis and revise the draft for Chapter 8 and Section 9.5 of licensing application for BSEP-1 and BSEP-2 spent fuel pool storage expansion based on a new storage arrangement.

REVIEW & APPROVAL

RESPONSIBLE ENGINEER	S. D. Lin	DATE:	11/25/80
CHECKER	C. W. Tseng	DATE:	11/25/80
REVIEWER	K. K. Niyogi	DATE:	12.3.80
FINAL APPROVAL	K. K. Niyogi	DATE:	12.3.80

COMMENTS:

FORM 3500

MEMORANDUM

united engineers & constructors inc

JOB NO.	9527.085	OFFICE:	Philadelphia
DEPT.	Engineering-Power Division	DATE:	November 25, 1980
TO:	B. J. Huselton-11U9	COPIES:	R. M. Anzalone-11U8 w/o att. J. A. Hanlin-11U9 w/o att. Day File Chrono File SG File C. Q. Miller
FROM:	S. D. Lin-7U3		

SUBJECT: Carolina Power and Light Company
Brunswick Steam Electric Plant Units 1&2
Spent Fuel Pool Storage Expansion
Thermal Analysis

PIN: 9525.10.00-12

I. PROBLEM STATEMENT

Perform the thermal analysis and revise the draft for Chapter 8 and Section 9.5 of licensing application for BSEP-1 and BSEP-2 spent fuel pool storage expansion based on a new arrangement as shown in Attachment I.

II. RESULTS OF ANALYSIS

As in PIN: 9527.10.00-11, the analysis has been carried out for two cases: (1) Refueling Case, and (2) Core Unload Case. The projected spent fuel pool inventories for the Refueling Case are given in Tables 1 and 2 for BSEP-1 and BSEP-2, respectively. Those for the Core Unload Case are presented in Tables 3 and 4. The decay heat loads calculated on the basis of these inventories are shown in Figures 1 and 2 for the Refueling Case and Core Unload Case, respectively. It is seen that in both cases, the heat loads for the two units are practically the same.

The calculated pool bulk temperatures for the two heat load cases under various cooling modes are summarized in Table 1.

The draft for Chapter 8 (Sections 8.1 through 8.5) and Section 9.5 has been revised according to the results of this analysis and attached herewith (Attachment III).

III. CONCLUSIONS AND RECOMMENDATIONS

It is to be noted that the expansion allows BSEP-2, whose current spent fuel inventory is lower than that of BSEP-1, to continue operation without shipments offsite for about 2½ years beyond BSEP-1, if the spent fuel of each unit from future refuelings is stored in its own spent fuel pool.

To: B. J. Huselton - 11U9 November 25, 1980

From: S. D. Lin - 7U3

page: two

The heat load for the Refueling Case has been based on the projected pool inventory for the last refueling operation which would leave storage spaces enough for a full core unload but not enough for an additional refueling plus a full core unload. Refuelings thereafter would result in lower heat loads for the spent fuel pool if, during each refueling, 140 old BWR assemblies stored in the pool are removed before the 140 BWR assemblies from the core are inserted to the pool. This is primarily due to the decay of the old PWR fuel remaining in the pool. Replacing the 4x4 PWR racks with the 6x6 BWR racks to store the BWR assemblies from the core in the succeeding refuelings would also reduce the heat load, since the higher storage density of the BWR racks is not enough to offset the lower irradiation power of the BWR assemblies.

The above rationale also applies to the Core Unload Case. Therefore, refueling and reactor operation of BSEP-1 & BSEP-2 can be continued indefinitely into the future as long as the afore-mentioned restrictions are observed.

S. D. Lin, RE

Approved by:

K. K. Niyogi, Manager
Fluid Analysis Group

SDL/sr

Attachment I: Work Request and Storage Arrangement
Attachment II: Calculation Package
Attachment III: Draft for Chapter 8 and Section 9.5
Attachment IV: Computer Printout

TABLE 1

SUMMARY OF RESULTS FOR SPENT FUEL POOL BULK TEMPERATURE ANALYSIS

Case	Cooling Mode	Maximum Temperature (°F)	Time To Reach 150°F (hr)	Time To Reach 212°F (hr)
Refueling	SFP System	145.0	Never	Never
	1 SFP Hx/Pump	182.4	2.0	Never
	None	-	1.0	13
Core Unload	SFP System	197.1	46.4	Never
	RHR & SFP Systems	124.5	-	Never
	RHR System	131.7	-	Never

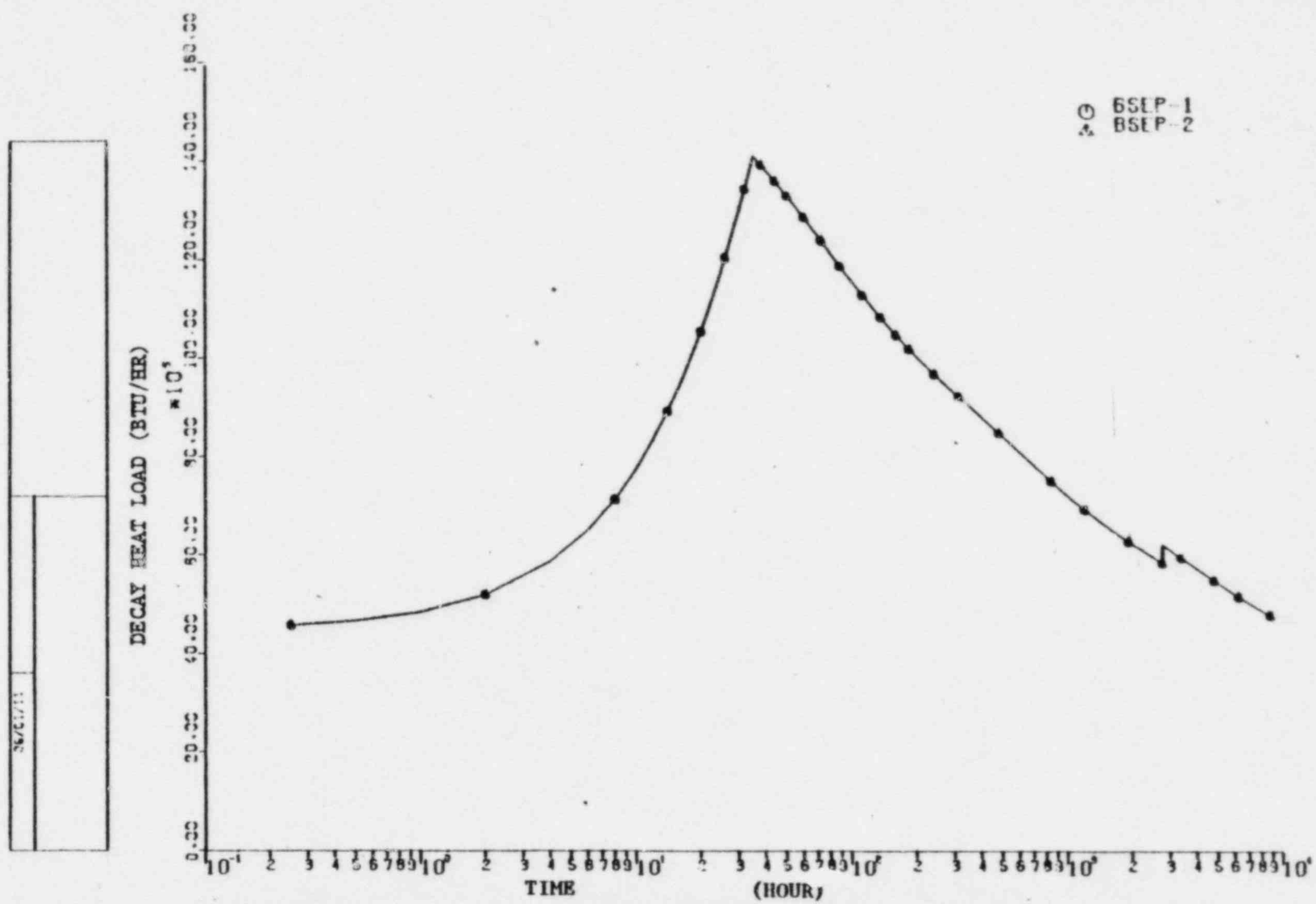


FIGURE 1 - DECAY HEAT LOADS FOR BSEP UNITS 1 & 2 FOLLOWING LAST REFUELING

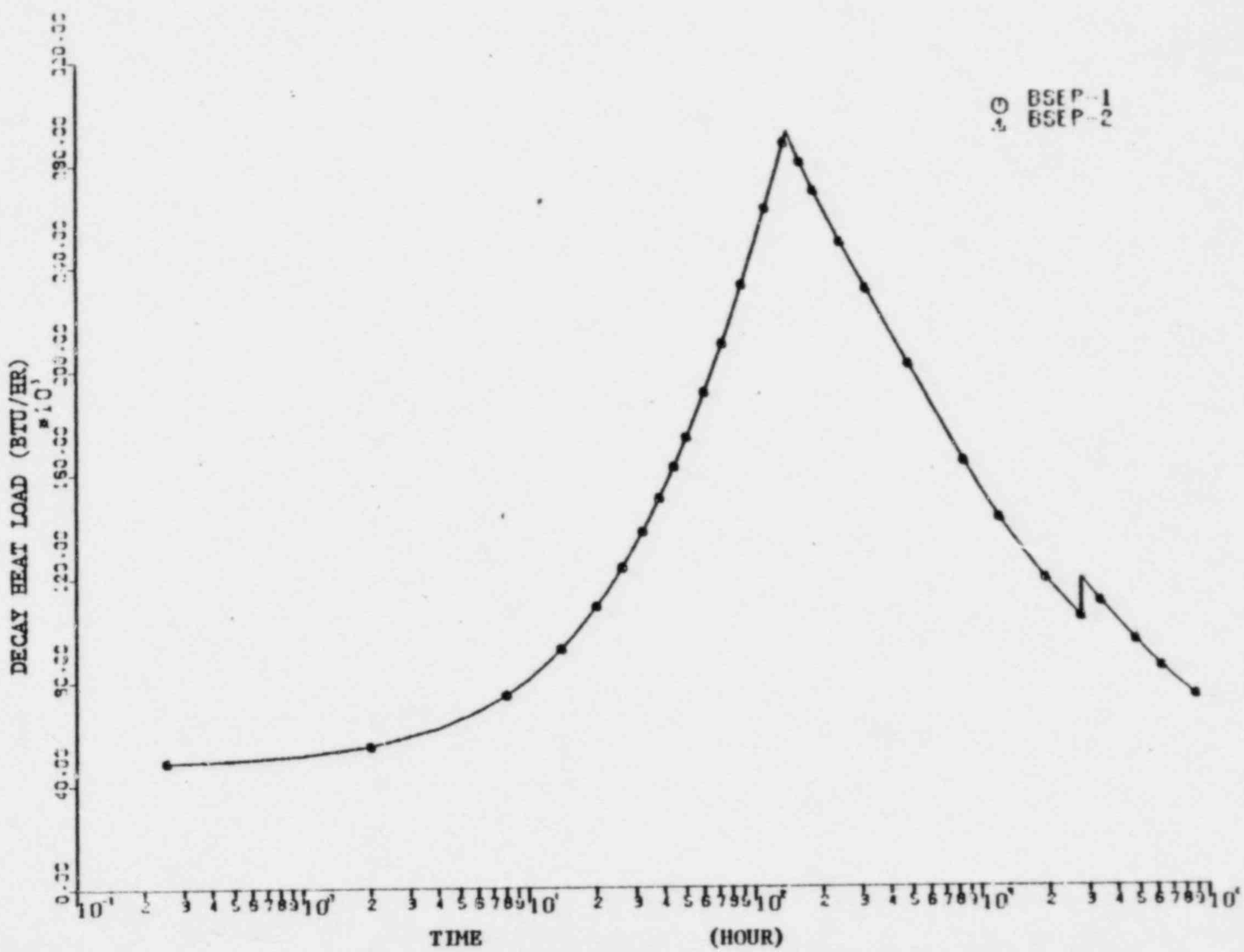


FIGURE 2 - DECAY HEAT LOADS FOLLOWING CORE UNLOAD FOR BSEP UNITS 1 & 2

ATTACHMENT I

Work Request and Storage Arrangement

Speed Letter. 44-912 GrayLine SNAP-A-WAY FORM

Speed Letter.

NOV 0 6 '80 K.K. NIYOGI

To [illegible] K.K. NIYOGI

From B.J. HUSELTON JCF

Subject CP&L BSEP UNITS 1 & 2 SPENT FUEL POOL LICENSING DOCUMENTS & RELATED ANALYSES. REVISIONS TO PREVIOUS DOCUMENTS DUE TO CHANGES IN STORAGE ARRANGEMENT

MESSAGE RE: 1. CHAPT. 8 THERMAL ANALYSIS

Date 11-4 1980

2. SECT 8.? HEAT LOADS & POOL TEMPERATURES FOR PRESENT STORAGE CAPACITY
3. ANY OTHER ANALYSES DONE BY THE MAG GROUP
4. SKETCH ATTACHED SHOWING STORAGE ARRANGEMENT

THE ABOVE WAS DISCUSSED ON 11-3-80 BY KK NIYOGI, D. LIN & J.C. FIORELLO. A PRELIMINARY EST. OF 3 CALENDAR WEEKS (WITH PREMIUM TIME) WAS ESTIMATED TO COMPLETE THE TASK. K.K. NIYOGI WAS REQUESTED TO PROCEED & COMPLETE TASK ASAP. [illegible] THIS LETTER IS THE FORMAL AUTHORIZATION TO PERFORM THE TASK.

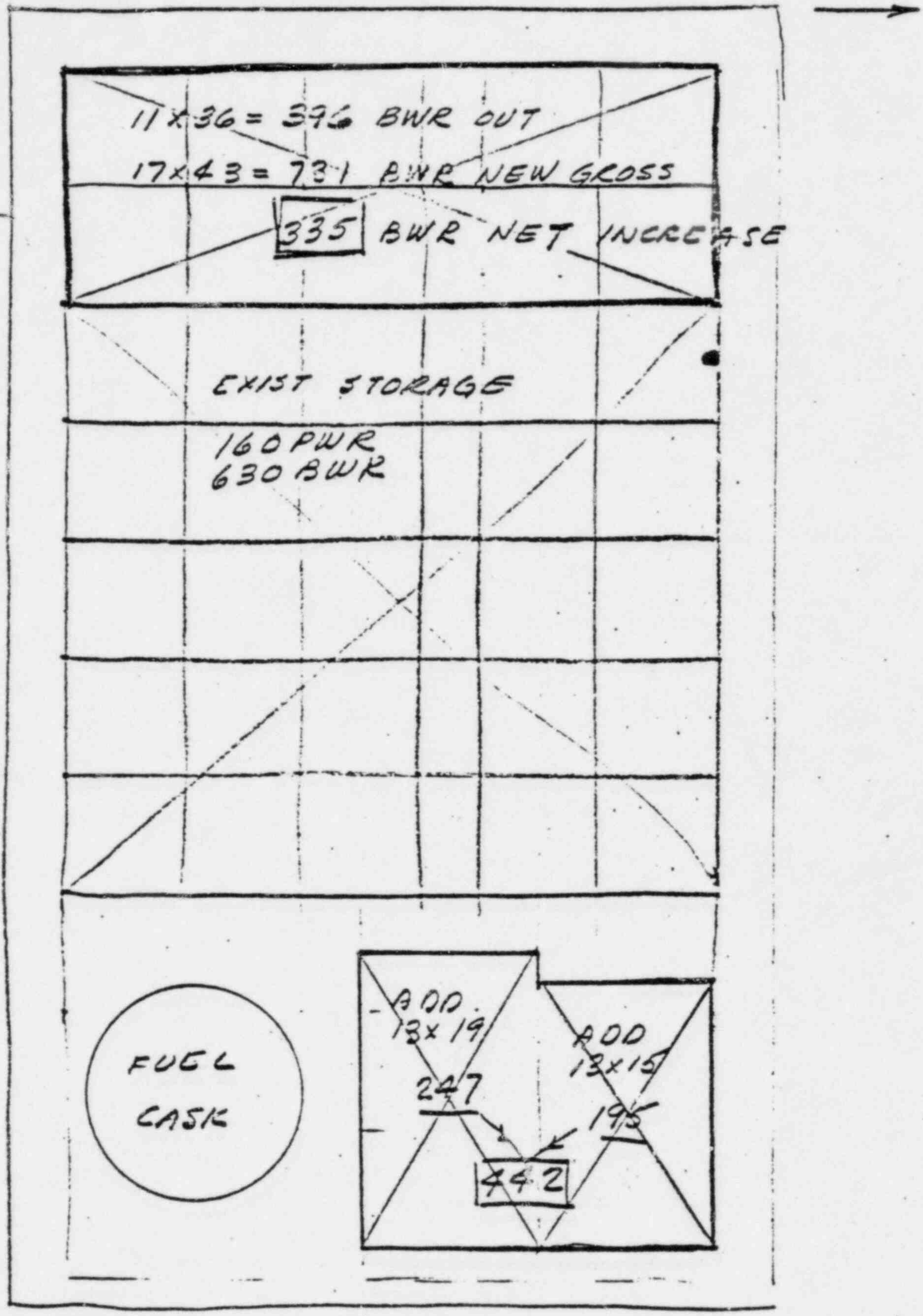
C.C.
TEF
PJH
KSS
JCF
9527.055 FILE
JAH

Signed B.J. Huselton B.J. HUSELTON JCF

REPLY

Date ______ 19__

Signed



NET INCREASE = 777 BWR STORAGE SPACES OVER 1976 EXPANSION OF (160 PWR & 1026 BWR)

SK 110480-1 JCF

CC J.A.H.

Carolina Power & Light Company

9521-083

CU-10540

File: 0011-301-704-296B

RE: 1. UC-29765 dated 8/20/80
2. UC-29752 dated 8/21/80
3. UC-29769 dated 9/3/80
4. UC-29767 dated 8/29/80

SEP 26 1980

JOB FILE 11U9
RF DUERR 4U6
BJ HUSELTON 11U9
TE FLAHERTY 11U9
RM AMALFONE 11U8
JC FIORELLO 11U8
RR CERZOSIMO 14U3
~~TE FLEMING 14U4~~
~~TG ROBERTS 2U4~~

Mr. R. F. Duerr, Project Manager
United Engineers & Constructors, Inc.
30 South 17th Street
Philadelphia, Pennsylvania 19101

CAROLINA POWER & LIGHT COMPANY J. R. BOWLING 11U8
BRUNSWICK PROJECT
1975-1977 - 1,600 MW - UNITS 1 AND 2
SPENT FUEL STORAGE EXPANSION PROJECT

DC MARR 1406

Dear Mr. Duerr:

The referenced letters provided input to CP&L for the licensing application for the subject project. These input were prepared consistent with CP&L's earlier instructions to emphasize the latch-down basket concept, which was the basis of our earlier feasibility study.

Per discussions between Messrs. J. Fiorella and B. Huselton of UE&C and C. E. Ramsey and W. M. Biggs of CP&L on September 12 and 13, 1980, the UE&C floor calculations have been completed. They have verified that the floor will support the use of freestanding racks on the two grid rows on the west side of the pool and 13x15 and 13x19 freestanding racks over the current control rod storage area. As these options offer several attractive features superior to the latch-down baskets, UE&C should revise the licensing input and referenced letters as soon as possible to reflect use of the above combination of freestanding racks.

Additionally, we believe that Reference 1 should be revised to reflect the most conservative heat-load case. Based on our previous heat-load calculations, this limiting case should be the full-core dump at the end of one-year's operations, rather than the full-core dump of a freshly refueled core.

What is the impact? JRK

CP&L's review of GE's proposal for spent fuel storage racks is nearing completion. We have scheduled a working meeting with GE to discuss their proposal on September 25 in Raleigh. Per previous discussions, we understand that Mr. J. Fiorello will be present to represent UE&C.

If you have any questions concerning the above comments, please call me or Mr. W. M. Biggs at Extension 6402.

Yours very truly,

A. B. Cutter - Manager
Nuclear Power Plant Engineering Dept.

ABC/WMB/bkp (3679)

cc: Mr. S. Bohanan
Mr. N. J. Chiangi
Mr. F. R. Coburn
Mr. A. B. Cutter
Mr. R. F. Duerr (2)
Mr. S. D. Floyd
Mr. E. Grimm
Mr. R. J. Groover
Mr. L. H. Martin
Mr. C. E. Ramsey
Mr. J. M. Rucki
Mr. A. C. Tollison
Mr. R. G. Tunell
Mr. L. V. Wagoner
Mr. J. M. Waldorf
Mr. T. H. Wyllie
BC/C-10

for Joe ...

NOV 06 '80 K.K. NIYOGI

UNIT No. 1 SPENT FUEL POOL

	BWR	PWR
NEW DESIGN CAPACITY	1803	160
RESERVED FOR CORE UNLOAD	560	
UNRESERVED CAPACITY	1243	
INVENTORY AS OF NOV. 1980	476 ?	154
AVAILABLE UNRESERVED CAPACITY	767	6
MAR. '81 REFUEL	156	6
APR '81 AVAIL. UNRES'D CAP.	611	0
ULTIMATE CAPACITY - BWR ONLY	2163	0

UNIT No. 2 SPENT FUEL POOL

	BWR	PWR
NEW DESIGN CAPACITY	1839	144
RESERVED FOR CORE UNLOAD	560	
UNRESERVED CAPACITY	1279	
INVENTORY AS OF NOV 1980	264 ?	118
AVAILABLE UNRESERVED CAPACITY	1015	26
OCT. '81 REFUEL	132	26
NOV '81 AVAIL. UNRES'D CAP	883	0
ULTIMATE CAPACITY - BWR ONLY	2163	0

ATTACHMENT II

Calculation Packages

Part A: Parameters Affected By Storage Expansion

Part B: Cooling Systems Design Parameters
(Same as in PIN: 9527.10.00-11)

PART A

Parameters Affected by Storage Expansion

Form 5604

united engineers & constructors inc.

CALCULATION CONTROL SHEET

CALC. SET NO.	
PRELIM.	
FINAL	
VOID	

PROJECT TITLE CP&L BSEP-1 & 2 DISCIPLINE 2482

SYSTEM Spent Fuel Pool Cooling System

SUBJECT Bulk Temperature Analysis (Spent Fuel Pool Storage Expansion)

DESIGN CLASSIFICATION

STARTED BY SD Lin DATE 11/6/80

AUTHORIZED BY KK Niyogi DATE 11/6/80

PROBLEM STATEMENT P.N.: 9527.10.00-12

I. Determine the spent fuel pool inventory for (a) Refueling Case, and (b) Core Unload Case for BSEP Units 1 & 2, based on the expanded storage.

II. Estimate the mass of the spent fuel pool water for use in the bulk temperature transient analyses.

III. Obtain the spent fuel pool initial conditions for calculating the pool temperature transient following a loss of SFP cooling system in the Refueling Case.

IV. Calculate the make-up water requirement with the spent fuel pool boiling after a loss of SFP cooling in the Refueling Case.

DESIGN BASIS N.A.

V. Determine the maximum pool temperatures after the RHR system is used to cool the SFP following a core unload for (a) RHR & SFP systems operating, and (b) RHR system operating alone.

TOTAL NUMBER OF SET COMPUTATION SHEETS 16

FINISHED BY SD Lin CHECKED BY C. W. Tseng

	CHECKER	DESIGN SUPER	COGNIZANT ENG'R	DESIGN REVIEW
BY	CWT	[illegible]	SD Lin	
DATE	11/21/80	12.3.80	11/12/80	

REVISION 1 STARTED DATE ________ BY ________

Form 5603

united engineers & constructors inc.

CALCULATION SUMMARY & REFERENCE SHEET

CALC. SET NO.	
PRELIM.	
FINAL	
VOID	
SHEET 1 OF 16	
J.O. 9527.1000-12	

PROJECT TITLE CP&L BSEP-1&2 DISCIPLINE 2482

REV	COMP. BY	CHK'D BY
0	JJK DATE 11/12/80	CWT DATE 11/21/80
	DATE	DATE

SYSTEM Spent Fuel Pool Cooling System

SUBJECT Spent Fuel Pool Storage Expansion — Thermal Analysis

DESIGN CLASSIFICATION ———

PIN: 9527.10.00-12

SUMMARY/CONCLUSIONS

I. The spent fuel pool inventories are given in Tables 3, 4, 5 & 6.

II. The mass of the spent fuel pool water is 2.776×10^6 lbm

III. The initial conditions for the spent fuel pool temperature transient following a loss of SFP cooling system are
$t_0 = 35$ hr, $T_0 = 145.04°F$, $Q_0 = Q(t = 35 \text{ hr})$.

IV. The make-up water requirement is 1.38×10^4 lbm/hr or about 28 gpm.

V. The maximum pool temperature is 124.5°F when RHR & SFP systems are both operating, and is 131.7°F when RHR system is operating alone.

REFERENCES: (SPECIFICATIONS, DRAWINGS, CODES, CALCULATION SETS, TEXTS, REPORTS, COMPUTER DATA PSAR ETC.)

None.

P.I.N: 9527.10.00-12

FORM 5007 REV. 7/79

GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc.

NAME OF COMPANY CP&L - BSEP UNIT/S 1&2

SUBJECT Spent Fuel Pool Storage Expansion

CALC. SET NO.		REV	COMP. BY	CHK'D BY
PRELIM.		0	SDL	CWT
FINAL			DATE 11/6/80	DATE 11/24/80
VOID				
SHEET	2 OF 16			
J.O.	9527.085		DATE	DATE

I. Pool Inventory

A. Core Unload Case

The spent fuel pool inventories for postulated core unloads on January 6, 1984 for BSEP-1 and on October 29, 1984 for BSEP-2 have previously been acquired for the analysis performed under PIN: 9527.10.00-09. They are presented here in Tables 1 & 2 for convenience.

For the new proposed modification of the spent fuel pools, the net increase of 777 BWR fuel assembly storage spaces in each pool would allow about (777-420)/140 or 2 more years of operation. The pool inventory for the Core Unload Case with this new design can therefore be obtained by modifying Tables 1 & 2 appropriately.

According to the projected plant operating schedule, the next refueling would occur in March 1981 for BSEP-1 (156 BWR assemblies to be refueled) and October 1981 for BSEP-2 (132 BWR assemblies to be refueled). For conservatism, the date of reactor shutdown will be assumed to be the first day of the month. For simplicity, it will be conservatively assumed

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GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc

CALC. SET NO.		REV	COMP. BY	CHK'D. BY
PRELIM.		0	SJL DATE 10/6/80	CWT DATE 11/21/80
FINAL				
VOID				
SHEET 3 OF 16			DATE	DATE
J.O.				

NAME OF COMPANY CP&L – BSEP UNIT/S 1 & 2

SUBJECT SPENT FUEL POOL STORAGE EXPANSION

that at each future refueling, all fuel assemblies inserted to the pool would have been irradiated for a full period of 4 cycles or 1197 days.

In contrast to PINS: 9527.10.00 – 09 and 11, the core unload will be assumed to occur at the end of the last cycle. This will give a total spent fuel decay heat that is slightly larger than what would result from a core unload 2 weeks into the last cycle.

The spent fuel pool inventories obtained with the above assumptions for the Core Unload Case are given in Tables 3 & 4 for Units 1 & 2, respectively.

FORM 5007 REV. 7/79

GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc

CALC. SET NO.		REV	COMP. BY	CHK'D. BY
PRELIM.		0	BAL	CWT
FINAL			DATE 10/27/80	DATE 11/21/80
VOID				
SHEET 4 OF 16			DATE	DATE
J.O. 9527.085				

NAME OF COMPANY CP&L BSEP UNIT/S 1&2

SUBJECT Spent Fuel Pool Storage Expansion

B. Refueling Case

The spent fuel pool inventory for the last refueling which leaves a storage space in the pool enough for a full core unload but not enough for an additional refueling plus a full core unload can be derived from those for the Core Unload Case as given in Tables 3 & 4. In fact, the time of last refueling is exactly one year before the time of postulated core unload. The inventories thus derived are given in Tables 5 & 6 for BSEP-1 and BSEP-2, respectively.

P2N: 9527.10.00-12

FORM 5007 REV. 7/79

GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc

CALC. SET NO.		REV	COMP. BY	CHK'D. BY
PRELIM		0	SJL	CWT
FINAL			DATE 11/10/80	DATE 11/21/80
VOID				
SHEET 5 OF 12			DATE	DATE
J.O. 9527.085				

NAME OF COMPANY CP&L B:ZP UNIT/S 1&2

SUBJECT Spent Fuel Pool Storage Expansion

II. Spent Fuel Pool Water Mass

Per P2N: 9527.10.00-09, the gross volume for the spent fuel pool is 48622 ft^3. Also,

volume displaced by racks = 62 ft^3

volume displaced by shipping cask = 201 ft^3

volume displaced by 10 PWR 4x4 racks = 426 ft^3

For the new modification, there will be 15 BWR 6x6 racks, 5 BWR 3x6 racks, 1 BWR 17x43 rack, 1 BWR 13x15 rack, and 1 BWR 13x19 rack. Therefore,

volume displaced by 15 BWR 6x6 racks $= 508 \times \frac{15}{10} = 762$ ft^3

volume displaced by 5 BWR 3x6 racks $= 177 \times \frac{5}{7} = 126$ ft^3

To estimate the volume displacement by the new racks, we noticed that

$$\frac{508}{10 \times 36} = 1.411 \ ft^3/\text{assembly}$$

$$\frac{177}{5 \times 18} = 1.405 \ ft^3/\text{assembly}$$

$$\frac{1382}{15 \times 64} = 1.440 \ ft^3/\text{assembly}.$$

Assuming that the new 17x43, 13x15 and 13x19 racks displace water at 1.440 ft^3/assembly, we have

volume displaced by these racks $= 1.440 \times (731 + 195 + 247)$
$= 1689$ ft^3

Thus the net pool water volume is

$$V_{pool} = 48622 - (62 + 201 + 426 + 762 + 126 + 1689) = 45356 \ ft^3$$

Assuming a minimum density corresponding to 150°F, we have

$$M_{pool} = 45356 \times 61.20 = 2.776 \times 10^6 \ lbm$$

PEN: 9527.100-12

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GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc

CALC. SET NO.		REV	COMP. BY	CHK'D. BY
PRELIM.		0	SLL	CWT
FINAL			DATE 11/18/80	DATE 11/21/80
VOID				
SHEET	6 OF 16		DATE	DATE
J.O.	9527.055			

NAME OF COMPANY CP&L BSEP UNIT/S 1&2

SUBJECT Spent Fuel Pool Storage Expansion

III Spent Fuel Pool Initial Conditions for Loss of Cooling Analysis in Refueling Case

The spent fuel pool water temperature following a loss of cooling would reach 150°F most rapidly if the initial temperature were high and the heat load were large. Clearly, the maximum heat load occurs at completion of unload. The pool temperature at that time, however, is still rising due to the thermal inertia of the pool. By the time the pool temperature is at its maximum, the heat load has decreased somewhat due to the additional cooling. The worst time for a failure in the cooling system is therefore somewhere in between these two times. For simplicity, it will be conservatively assumed that the failure occurs at the time of peak heat load and the pool temperature is also at its maximum. That is,

t_0 = 35 hrs (based on unload speed of 1 assembly/15 minutes)

and, from the pool temperature transient assuming the SFP cooling system is operating,

$T_0 = T_{max} = 145.04\ °F$.

PZN: 95249.10.0042

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(DISCIPLINE) united engineers & constructors inc

CALC. SET NO.		REV	COMP BY	CHK'D. BY
PRELIM.		0	SBL	CWT
FINAL			DATE 11/11/80	DATE 11/21/80
VOID				
SHEET 7 OF 16			DATE	DATE
J.O. 95249.085				

NAME OF COMPANY CP&L BSEP UNIT/S 1&2

SUBJECT Spent Fuel Pool Storage Expansion

IV. Make-Up Water Requirement at Pool Boiling

For a postulated loss of the spent fuel pool cooling system immediately after the reactor operation has been resumed following the last refueling, i.e., 59 hours after the reactor shutdown, the pool bulk water would reach 212°F and begin boiling in 12.9 hours.

The decay heat load at that time is

$$Q_b = 13.4 \times 10^6 \text{ Btu/hr.} \quad \text{(DEHEX output)}$$

The heat of evaporation of water at 1 atm is

$$h_{fg} = 970 \text{ Btu/lbm.}$$

Therefore, the evaporation rate is

$$W_e = \frac{13.4 \times 10^6}{970} = 1.38 \times 10^4 \text{ lbm/hr} \cong 28 \text{ gpm}$$

V Pool Temperatures for Core Unload Case with RHR System Operating

REFERRING TO PREVIOUS REPORT PIN: 9527.10.00-11 ATTACHMENT II, SECTION (5) ON SPENT FUEL POOL TEMPERATURE ANALYSIS:

(1) IN CASE OF RHR AND SFP COOLING SYSTEMS OPERATING:

*{EQ(3)}: $T_S - 0.714\,T_R = Q_S/\omega_R C_p + 25.74$ ✓ (1)

{EQ(4)}: $T_R - 0.879\,T_S = Q_R/\omega_R C_p + 12.12$ ✓ (2)

WHERE $\omega_R = 4950$ GPM

$\omega_S = 1000$ GPM

$C_p = 1.0$ BTU/LBM-F

WHEN FULL CORE-UNLOAD IS COMPLETED, IT IS FOUND THAT THE MAXIMUM HEAT LOAD OCCURS IN BSEP UNIT 2.

$Q_S = 2.9118 \times 10^7$ BTU/HR ✓

$Q_R = 0$

* {EQ(3)} INDICATE THE EQUATION NUMBER IN PREVIOUS REPORT PIN: 9527.10.00-11

Form 5007 Rev. 3-77

GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc.

NAME OF COMPANY CAROLINA P&L, BSEP UNIT/S 1/2

SUBJECT SPENT FUEL POOL TEMPERATURE CALC.

CALC. SET NO.		
PRELIM.		
FINAL		
VOID		
SHEET 9 OF 16		
J.O. 9527.085		
REV	COMP. BY	CHK'D BY
0	CWT DATE 11/11/80	SDL DATE 11/12/80
	DATE	DATE

FROM EQ(1),

$$T_S - 0.714\, T_R = \frac{2.9118 \times 10^7}{4950 \times 8.208 \times 61.5} + 25.74$$

$$= 11.93 + 25.74$$

$$= 37.67 \qquad (3)$$

FROM EQ(2),

$$T_R - 0.879\, T_S = 12.12 \qquad (4)$$

SOLVE FOR T_R AND T_S FROM EQS (3) AND (4)

$$T_S = \frac{12.12 \times 0.714 + 37.67}{1 - 0.628} = 124.5\ ^\circ F$$

$$T_R = 12.12 + 0.879 \times 124.5 = 121.6\ ^\circ F$$

Form 5007 Rev. 3-77

GENERAL COMPUTATION SHEET

united engineers & constructors inc.

(DISCIPLINE)

NAME OF COMPANY CAROLINA P&L BSEP UNIT/S 1/2

SUBJECT SPENT FUEL POOL TEMPERATURE CALC.

CALC. SET NO.		
PRELIM.		
FINAL		
VOID		
SHEET 10 OF 16		
J.O. 9527.085		
REV	COMP. BY	CHK'D BY
0	CWT DATE 11/14/80	SGL DATE 11/14/80
	DATE	DATE

2) IN CASE OF RHR COOLING SYSTEM OPERATING ALONE,

$$\omega_s = 0 \quad , \quad Q_R = 0$$

{EQ(2)}: $$\frac{Q_R}{\omega_R C_p} = T_R - \left(\frac{\omega_s}{\omega_R}\right)\eta_s T_{cs} - \left(1 - \frac{\omega_s}{\omega_R}\eta_s\right)T_s$$

$$T_R - T_s = 0$$

$$T_R = T_s \qquad (5)$$

{EQ(1)}: $$\frac{Q_s}{\omega_R C_p} = T_s - T_R(1-\eta_R) - \eta_R T_{cR}$$

WHERE $\eta_R = 0.286$

$T_{cR} = 90^\circ F$

$$T_s - 0.714\, T_R = 11.93 + 0.286\, T_{cR} \qquad (6)$$

SOLVE FOR T_R AND T_s FROM EQS (5) AND (6),

$$T_R = T_s = \frac{11.93 + 0.286 \times 90}{0.286} = 131.7^\circ F$$ ✓

TABLE 1 - Spent Fuel Pool Inventory for BSEP Unit 1 on January 6, 1984

BATCH	NO. ASSEM.	POWER (MWT)	TIRRA (DAY)	TCOOL (HOUR)
1	140	4.3500E 00	1.4000E 01	2.4000E 01
2	140	4.3500E 00	3.1300E 02	2.4000E 01
3	140	4.3500E 00	6.1200E 02	2.4000E 01
4	140	4.3500E 00	9.1100E 02	2.4000E 01
5	140	4.3500E 00	1.1970E 03	2.0400E 03
6	140	4.3500E 00	1.1970E 03	1.1472E 04
7	140	4.3500E 00	1.1970E 03	2.0352E 04
8	156	4.3500E 00	1.1970E 03	3.4152E 04
9	176	4.3500E 00	1.1970E 03	4.5384E 04
10	6	1.4650E 01	9.8500E 02	5.3808E 04
11	126	4.3500E 00	1.1970E 03	5.7144E 04
12	45	1.4650E 01	9.8500E 02	7.3464E 04
13	102	1.4650E 01	9.8500E 02	8.6544F 04
14	7	1.4650E 01	9.8500E 02	9.6480E 04

TABLE 2 - Spent Fuel Pool Inventory for BSEP Unit 2 on October 29, 1984

BATCH	NO. ASSEM.	POWER (MWT)	TIRRA (DAY)	TCOOL (HOUR)
1	140	4.3500E 00	1.4000E 01	2.4000E 01
2	140	4.3500E 00	3.1300E 02	2.4000E 01
3	140	4.3500E 00	6.1200E 02	2.4000E 01
4	140	4.3500E 00	9.1100E 02	2.4000E 01
5	140	4.3500E 00	1.1970E 03	2.0400E 03
6	140	4.3500E 00	1.1970E 03	1.0824E 04
7	140	4.3500E 00	1.1970E 03	1.9584E 04
8	140	4.3500E 00	1.1970E 03	3.1992E 04
9	132	4.3500E 00	1.1970E 03	4.3776E 04
10	132	4.3500E 00	1.1970E 03	5.1264E 04
11	38	1.4650E 01	9.8500E 02	6.0888E 04
12	14	4.3500E 00	1.1970E 03	6.4248E 04
13	4	4.3500E 00	1.1970E 03	7.7256E 04
14	52	1.4650E 01	9.8500E 02	7.1808E 04
15	7	1.4650E 01	9.8500E 02	8.0568E 04
16	1	1.4650E 01	9.8500E 02	9.3624E 04
17	46	1.4650E 01	9.8500E 02	1.0356E 05

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GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc

NAME OF COMPANY CP&L BSEP UNIT/S 1&2

SUBJECT Spent Fuel Pool Storage Expansion

CALC. SET NO.		REV	COMP. BY	CHK'D. BY
PRELIM.		0	EAL	CWS
FINAL			DATE 11/8/80	DATE 11/18/80
VOID				
SHEET 13 OF 16			DATE	DATE
J.O. 9527.085				

TABLE 3

SPENT FUEL POOL INVENTORY FOR BSEP UNIT 1 – REFUELING March 2, 1985

Batch No	No. of Assemblies		Assembly Power (MWt)	Irradiation Time (day)	Cooling Time (hr)
1	140	BWR	4.35	1197	24
2	140	BWR	4.35	1197	8,784
3	140	BWR	4.35	1197	17,568
4	140	BWR	4.35	1197	26,328
5	156	BWR	4.35	1197	35,088
6	156	BWR	4.35	1197	44,256
7	176	BWR	4.35	1197	55,488
8	6	PWR	14.65	985	63,912
9	126	BWR	4.35	1197	67,248
10	45	PWR	14.65	985	83,568
11	102	PWR	14.65	985	96,648
12	7	PWR	14.65	985	106,584

365 × 24 = 8760 hrs

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GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc.

NAME OF COMPANY CP&L BSEP UNIT/S 1 & 2

SUBJECT Spent Fuel Pool Storage Expansion

CALC. SET NO.		REV	COMP BY	CHK'D. BY
PRELIM.		0	SJL	CWT
FINAL			DATE [illegible]	DATE 11/18/80
VOID				
SHEET 14 OF 16			DATE	DATE
J.O.				

TABLE 4

SPENT FUEL POOL INVENTORY FOR BSEP UNIT 2 — REFUELING October 2, 1987

Batch No.	No. of Assemblies		Assembly Power (MWt)	Irradiation Time (days)	Cooling Time (hr)	
1	140	BWR	4.35	1197	24	
2	140	BWR	4.35	1197	8,808	8784
3	140	BWR	4.35	1197	17,568	17544
4	140	BWR	4.35	1197	26,328	26304
5	140	BWR	4.35	1197	35112	35088
6	140	BWR	4.35	1197	43,872	43848
7	132	BWR	4.35	1197	52,632	52608
8	132	BWR	4.35	1197	69,456	
9	132	BWR	4.35	1197	76,944	
10	38	PWR	14.65	985	86,568	
11	14	BWR	4.35	1197	89,928	
12	4	BWR	4.35	1197	102,936	
13	52	PWR	14.65	985	97,488	
14	7	PWR	14.65	985	106,248	
15	1	PWR	14.65	985	119,304	
16	46	PWR	14.65	985	129,240	

365×24 = 8760 hr.

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GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc

NAME OF COMPANY CP&L BSEP UNIT/S 1 & 2

SUBJECT Spent Fuel Pool Storage Expansion

CALC. SET NO.		REV	COMP. BY	CHK'D. BY
PRELIM.		0	SDL	CWT
FINAL			DATE 10/21/80	DATE 11/18/80
VOID				
SHEET	15 OF 16		DATE	DATE
J.O.	95-27.085			

TABLE 5

SPENT FUEL POOL INVENTORY FOR BSEP UNIT 1 – CORE UNLOAD March 2, 1986

Batch No.		No. of Assemblies		Assembly Power (MWt)	Irradiation Time (day)	Cooling Time (hr)
1		140	BWR	4.35	299	24
2		140	BWR	4.35	599	24
3		140	BWR	4.35	898	24
4	'85	140	BWR	4.35	1197	24
5	'85	140	BWR	4.35	1197	8,784
6	'84	140	BWR	4.35	1197	17,544
7	'83	140	BWR	4.35	1197	26,328
8	'82	160	BWR	4.35	1197	35,088
9	3/1/81	156	BWR	4.35	1197	43,848
10		156	BWR	4.35	1197	53,016
11		196	BWR	4.35	1197	64,248
12		6	PWR	14.65	985	72,672
13		126	BWR	4.35	1197	76,008
14		45	PWR	14.65	985	92,328
15		102	PWR	14.65	985	105,408
16		7	PWR	14.65	985	115,344

Total	160	PWR
	1734	BWR
Capacity	160	PWR
	1803	BWR

61+365+60 = 786 days
= 18864 hrs.

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GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc

CALC. SET NO.		REV	COMP. BY	CHK'D. BY
PRELIM.		0	SDL	CWT
FINAL			DATE 11/19/80	DATE 11/19/80
VOID				
SHEET 16 OF 16			DATE	DATE
J.O. 9527.085				

NAME OF COMPANY CP&L BSEP UNIT/S 1&2

SUBJECT Spent Fuel Pool Storage Expansion

TABLE 6

SPENT FUEL POOL INVENTORY FOR

BSEP UNIT 2 – CORE UNLOAD

October 2, 1988

Batch No.		No. of Assemblies		Assembly Power (MWt)	Irradiation Time (day)	Cooling Time (hr)
1		140	BWR	4.35	300	24
2		140	BWR	4.35	599	24
3		140	BWR	4.35	898	24
4	'88	140	BWR	4.35	1197	24.
5	'87	140	BWR	4.35	1197	8,808
6	'86	140	BWR	4.35	1197	17,568
7	'85	140	BWR	4.35	1197	26,328
8	'84	140	BWR	4.35	1197	35,088
9	'83	140	BWR	4.35	1197	43,872
10	'82	140	BWR	4.35	1197	52,632
11	10/1/81	132	BWR	4.35	1197	61,392
12		132	BWR	4.35	1197	78,216
13		132	BWR	4.35	1197	85,704
14		38	PWR	14.65	985	95,328
15		14	BWR	4.35	1197	98,688
16		4	BWR	4.35	1197	111,696
17		52	PWR	14.65	985	106,248
18		7	PWR	14.65	985	115,008
19		1	PWR	14.65	985	128,064
20		46	PWR	14.65	985	138,000
Total		144	PWR			
		1814	BWR			
Capacity		144	PWR			
		1839	BWR			

365×2 + 366×2 − 27 = 1435 day
= 34440 hr

1434

ATTACHMENT 6 9527-8-55-55-F

LEAD ENGINEER: C. W. Tseng MANAGER'S INITIALS [signature]

PROBLEM CLASS	WORK REQUEST NUMBER	PIN NUMBER	CALCULATION SET NUMBER	JOB CHARGE
I	Speed Letter (BJH to KKN)	9527.10.00-13	—	9527.085

PROBLEM STATEMENT:

Revise Previous Thermal Analysis For Spent Fuel
Pool Storage Expansion With New Fuel Unload Information

REVIEW & APPROVAL

RESPONSIBLE ENGINEER [signature: C. W. Tseng] DATE: 1/23/81
C. W. Tseng

CHECKER [signature] DATE: 2/3/81

REVIEWER [signature] DATE: 2 3 81
K. K. Niyogi

FINAL APPROVAL [signature] DATE: 2 3 81
K. K. Niyogi

COMMENTS:

FORM 3500

MEMORANDUM

united engineers & constructors inc.

JOB NO.	9527.	OFFICE:	Philadelphia
DEPT.	Engineering - Power	DATE:	January 22, 1981
TO:	B. J. Huselton 11U9	COPIES:	C. Q. Miller 7U4 R. M. Anzalone 11U8 J. C. Fiorello 11U8 J. A. Hanlin 11U8 Day File Chrono File SG File
FROM:	C. W. Tseng 7U3		

SUBJECT: Carolina Power & Light Company
Brunswick Steam Electric Plant Units 1 & 2
Spent Fuel Pool Storage Expansion
Thermal Analysis

PIN: 9527.10.00-13

I. PROBLEM STATEMENT

Revise previous thermal analysis and the draft of Chapter 8 and Section 9.5 of Licensing Application For BSEP Units 1 & 2 Spent Fuel Pool Storage Expansion using new fuel unload information as shown in Attachment I.

II. RESULTS OF ANALYSIS

As in PIN: 9527.10.00-12, the analysis has been carried out for (1) refueling case and (2) core unload case. The new projected spent fuel pool inventories for the refueling case are given in Tables 1 and 2 for BSEP Units 1 & 2, respectively. Those for the core unload case are given in Tables 3 and 4 accordingly. The decay heat loads calculated on the basis of these new inventories are shown in Figure 1 for the refueling case and Figure 2 for the core unload case. It is seen that the heat loads are higher for Unit 1 in both cases than those for Unit 2.

The calculated SFP bulk temperatures for the two cases under various cooling modes are summarized in Table 5. The draft of Chapter 8 (Section 8.1 through 8.5) and Section 9.5 has been revised according to the results of this analysis and included in Attachment III.

III. CONCLUSIONS AND RECOMMENDATIONS

It is to be noted that the SFP storage expansion allows BSEP Unit 1, whose current spent fuel inventory is higher than that of Unit 2, to continue operation without shipments off-site for about 4 months beyond Unit 2, assuming the spent fuel of each unit from future refuelings is stored in its own pool.

Although the operation of BSEP-1 is extended for two years from previous analysis (PIN: 9527.10.00-12), the increase of heat loads is only minimal compared to the results in PIN: 9527.10.00-12. This is primarily due to the decay of the old PWR fuel remaining in the pool. The operation of BSEP-2 is shortened for approximately one year. As a result, the heat loads are somewhat lower than those in PIN: 9527.10.00-12.

C. W. Tseng

C. W. Tseng

Approved By:

K. K. Niyogi

K. K. Niyogi, Manager
Fluid Analysis Group

CWT/KKN/kf

Attachments I - New Fuel Unload
II - Calculation Package
III - Draft of Chapter 8 and Section 9.5
IV - Computer Print-Out

TABLE 1

SPENT FUEL POOL INVENTORY FOR
BSEP UNIT 1 - REFUELING
MARCH 7, 1987

Batch No.	No. Of Assemblies	Assembly Power (MWT)	Irradiation Time (Day)	Cooling * Time (HR)
1	140 BWR	4.35	1197	24
2	140 BWR	4.35	1197	8784
3	140 BWR	4.35	1197	17544
4	140 BWR	4.35	1197	26304
5	140 BWR	4.35	1197	35088
6	140 BWR	4.35	1197	43848
7	245 BWR	4.35	1197	59400
8	87 BWR	4.35	1197	71424
9	6 PWR	14.65	985	79704
10	50 BWR	4.35	1197	82344
11	4 BWR	4.35	1197	96144
12	45 PWR	14.65	985	100128
13	102 PWR	14.65	985	112632
14	7 PWR	14.65	985	122592

* At beginning of fuel transfer.

TABLE 2

SPENT FUEL POOL INVENTORY FOR
BSEP UNIT 2 - REFUELING
NOVEMBER 15, 1986

Batch No.	No. Of Assemblies	Assembly Power (MWT)	Irradiation Time (Day)	Cooling* Time (HR)
1	140 BWR	4.35	1197	24
2	140 BWR	4.35	1197	8784
3	140 BWR	4.35	1197	17544
4	140 BWR	4.35	1197	26328
5	140 BWR	4.35	1197	35088
6	136 BWR	4.35	1197	43848
7	132 BWR	4.35	1197	58800
8	4 PWR	14.65	985	66600
9	132 BWR	4.35	1197	67560
10	40 PWR	14.65	985	77136
11	90 BWR	4.35	1197	79680
12	51 PWR	14.65	985	88008
13	6 PWR	14.65	985	97464
14	43 PWR	14.65	985	119880

* At beginning of fuel transfer.

K.K. NIYOGI
"NEW" FUEL UNLOAD (SPENT)-
INFORMATION FROM CP&L (1-8-81)
PLEASE REVISE THE THERMAL
ANALYSIS YOU MADE PREVIOUSLY
THE NEW ANALYSIS IS REQUIRED
ASAP. OVERTIME IS AUTHORIZED TO HELP EXPEDITE THE ANALYSIS.

Joe Fiorello
U.E&C
1-215-563-5684

3??

JAN 8 '81 C. W. TSENG

BSEP UNIT NO. 1

POOL INVENTORY ON MARCH 7, 1988 (FULL CORE UNLOAD DATE)

No. Assemblies	Type	Time in Core	Days Cooled	Reactor Power
140	BWR	299 Days	0 Yrs., 1 Day	2,436 MWt
140	BWR	599 Days	0 Yrs., 1 Day	2,436 MWt
140	BWR	898 Days	0 Yrs., 1 Day	2,436 MWt
140	BWR	1,197 Days	0 Yrs., 1 Day	2,436 MWt
140	BWR	1,197 Days	1 Yr., 1 Day	2,436 MWt
140	BWR	1 [illegible]7 Days	2 Yrs., 1 Day	2,436 MWt
140	BWR	1,197 Days	3 Yrs., 1 Day	2,436 MWt
140	BWR	1,197 Days	4 Yrs., 1 Day	2,436 MWt
140	BWR	1,197 Days	5 Yrs., 1 Day	2,436 MWt
140	BWR	1,197 Days	6 Yrs., 1 Day	2,436 MWt
245	BWR	1,197 Days	7 Yrs., 284 Days	2,436 MWt
87	BWR	1,197 Days	9 Yrs., 54 Days	2,436 MWt
6	PWR	985 Days	10 Yrs., 34 Days	2,300 MWt
50	BWR	1,197 Days	10 Yrs., 144 Days	2,436 MWt
4	BWR	1,197 Days	11 Yrs., 354 Days	2,436 MWt
45	PWR	985 Days	12 Yrs., 154 Days	2,300 MWt
102	PWR	985 Days	13 Yrs., 310 Days	2,300 MWt
7	PWR	985 Days	14 Yrs., 360 Days	2,300 MWt

1,786 BWR Assemblies

160 PWR Assemblies

TABLE 3

SPENT FUEL POOL INVENTORY FOR
BSEP UNIT 1 - CORE UNLOAD
MARCH 7, 1988

Batch No.	No. Of Assemblies	Assembly Power (MWT)	Irradiation Time (Day)	Cooling* Time (HR)
1	140 BWR	4.35	299	24
2	140 BWR	4.35	599	24
3	140 BWR	4.35	898	24
4	140 BWR	4.35	1197	24
5	140 BWR	4.35	1197	8808
6	140 BWR	4.35	1197	17568
7	140 BWR	4.35	1197	26328
8	140 BWR	4.35	1197	35088
9	140 BWR	4.35	1197	43872
10	140 BWR	4.35	1197	52632
11	245 BWR	4.35	1197	68184
12	87 BWR	4.35	1197	80208
13	6 PWR	14.65	985	88488
14	50 BWR	4.35	1197	91128
15	4 BWR	4.35	1197	104928
16	45 PWR	14.65	985	108912
17	102 PWR	14.65	985	121416
18	7 PWR	14.65	985	131376

* At beginning of fuel transfer.

TABLE 4

SPENT FUEL POOL INVENTORY FOR
BSEP UNIT 2 - CORE UNLOAD
NOVEMBER 15, 1987

Batch No.	No. Of Assemblies	Assembly Power (MWT)	Irradiation Time (Day)	Cooling* Time (HR)
1	140 BWR	4.35	299	24
2	140 BWR	4.35	599	24
3	140 BWR	4.35	898	24
4	140 BWR	4.35	1197	24
5	140 BWR	4.35	1197	8784
6	140 BWR	4.35	1197	17544
7	140 BWR	4.35	1197	26304
8	140 BWR	4.35	1197	35088
9	140 BWR	4.35	1197	43848
10	136 BWR	4.35	1197	52608
11	132 BWR	4.35	1197	67560
12	4 PWR	14.65	985	75360
13	132 BWR	4.35	1197	76320
14	40 PWR	14.65	985	85896
15	90 BWR	4.35	1197	88440
16	51 PWR	14.65	985	96768
17	6 PWR	14.65	985	106224
18	43 PWR	14.65	985	128640

* At beginning of fuel transfer.

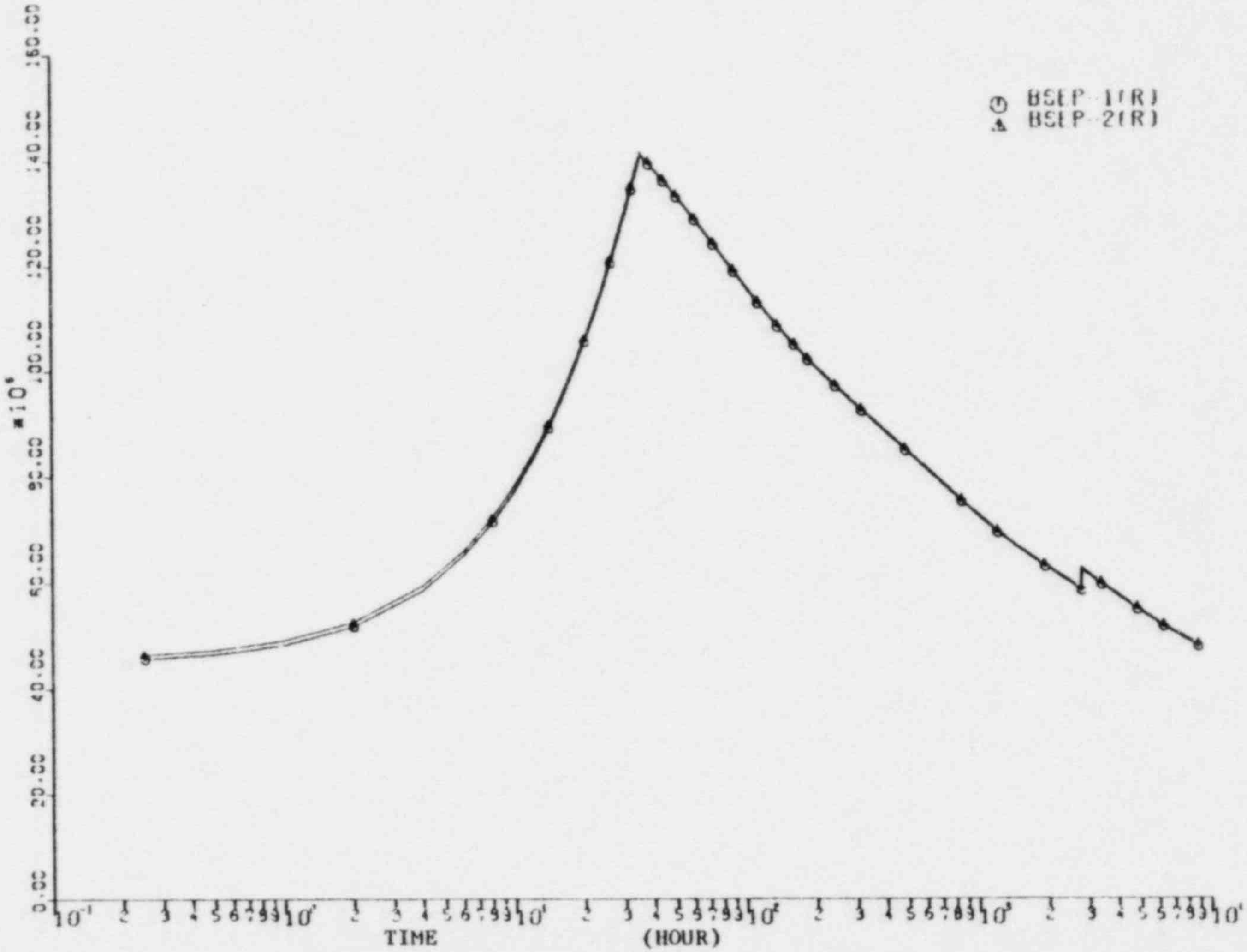

FIGURE 1 - DECAY HEAT LOADS FOR BSEP UNITS 1 & 2 FOLLOWING LAST REFUELING

TABLE 5

SUMMARY OF RESULTS FOR
SPENT FUEL POOL BULK TEMPERATURE ANALYSIS

Case	Cooling Mode	Maximum Temperature (°F)	Time To Reach 150°F (hr)	Time To Reach 212°F (hr)
Refueling	SFP System	145.2	Never	Never
	1 SFP Hx/Pump	182.6	1.9	Never
	None	-	1.0	13.5
Core Unload	SFP System	197.2	46.2	Never
	RHR & SFP Systems	124.6	-	Never
	RHR System	131.7	-	Never

ATTACHMENT I

NEW FUEL UNLOAD

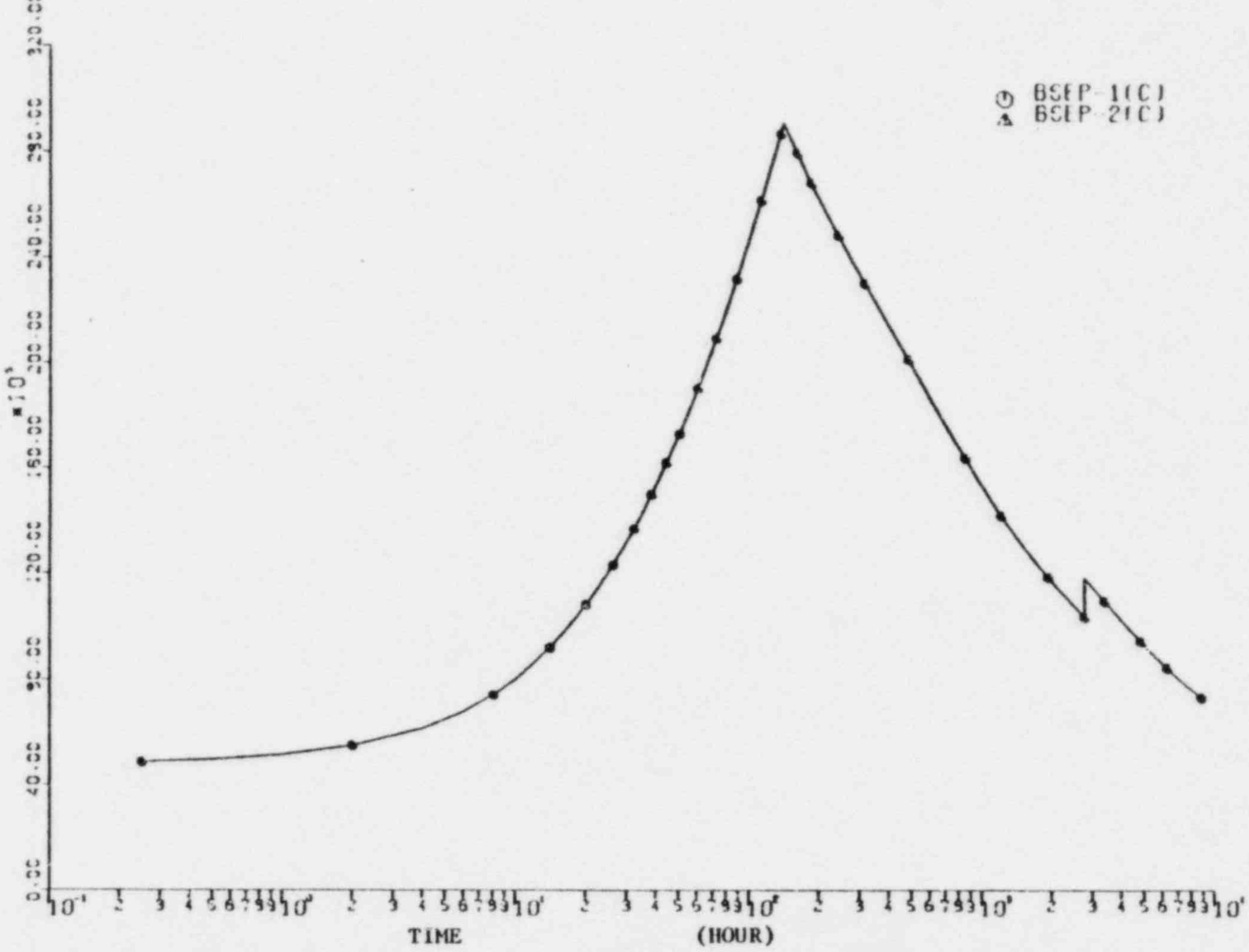

FIGURE 2 - DECAY HEAT LOADS FOLLOWING CORE UNLOAD FOR BSEP UNITS 1 & 2

BSEP UNIT NO. 2

POOL INVENTORY ON NOVEMBER 15, 1987 (FULL CORE UNLOAD DATE)

No. Assemblies	Type	Time in Core	Days Cooled	Reactor Power
140	BWR	299 Days	0 Yrs., 1 Day	2,436 MWt
140	BWR	599 Days	0 Yrs., 1 Day	2,436 MWt
140	BWR	898 Days	0 Yrs., 1 Day	2,436 MWt
140	BWR	1,197 Days	0 Yrs., 1 Day	2,436 MWt
140	BWR	1,197 Days	1 Yr., 1 Day	2,436 MWt
140	BWR	1,197 Days	2 Yrs., 1 Day	2,436 MWt
140	BWR	1,197 Days	3 Yrs., 1 Day	2,436 MWt
140	BWR	1,197 Days	4 Yrs., 1 Day	2,436 MWt
140	BWR	1,197 Days	5 Yrs., 1 Day	2,436 MWt
136	BWR	1,197 Days	6 Yrs., 1 Day	2,436 MWt
132	BWR	1,197 Days	7 Yrs., 259 Days	2,436 MWt
4	PWR	935 Days	8 Yrs., 218 Days	2,300 MWt
132	BWR	1,197 Days	8 Yrs., 258 Days	2,436 MWt
40	PWR	985 Days	9 Yrs., 292 Days	2,300 MWt
90	BWR	1,197 Days	10 Yrs., 33 Days	2,436 MWt
51	PWR	985 Days	11 Yrs., 15 Days	2,300 MWt
6	PWR	985 Days	12 Yrs., 43 Days	2,300 MWt
43	PWR	985 Days	14 Yrs., 247 Days	2,300 MWt

1,750 BWR Assemblies

144 PWR Assemblies

ATTACHMENT II

CALCULATION PACKAGE

Form 5604

9527-B-SS-55-F

united engineers & constructors inc

CALCULATION CONTROL SHEET

CALC. SET NO.	
PRELIM.	
FINAL	
VOID	

PROJECT TITLE CPEL/BSEP-1 & 2 DISCIPLINE 2482

SYSTEM SFP COOLING SYSTEM

SUBJECT BULK TEMPERATURE ANALYSIS FOR SFP STORAGE EXPANSION

DESIGN CLASSIFICATION —

STARTED BY C.W. TSENG DATE 1/10/81

AUTHORIZED BY K.K. NIYOGI DATE 1/10/81

PROBLEM STATEMENT PIN: 9527·10·00-13

I. DETERMINE THE SFP INVENTORY FOR (1) REFUELING CASE AND (2) CORE UNLOAD CASE FOR BSEP-1 & 2 USING NEW FUEL UNLOAD INFORMATION.

II DETERMINE THE SFP INITIAL CONDITIONS TO BE USED IN THE POOL TEMPERATURE TRANSIENT FOLLOWING A LOSS OF SFP COOLING SYSTEM IN REFUELING CASE.

III. DETERMINE THE MAXIMUM POOL TEMPERATURES FOLLOWING A CORE UNLOAD WITH (1) BOTH RHR AND SFP SYSTEMS OPERATING (2) RHR SYSTEM OPERATING ALONE.

DESIGN BASIS

TOTAL NUMBER OF SET COMPUTATION SHEETS 10

FINISHED BY C.W. TSENG CHECKED BY

	CHECKER	DESIGN SUPER	COGNIZANT ENG'R	DESIGN REVIEW
BY	[signature]		CWT	
DATE	2/3/81		1/22/81	

REVISION 1 STARTED DATE BY

Form 5603

9527-8-SS-55-F

united engineers & constructors inc.

CALCULATION SUMMARY & REFERENCE SHEET

CALC. SET NO.	
PRELIM.	
FINAL	
VOID	
SHEET 1 OF 10	
J.O. 9527.085	

PROJECT TITLE CPEL / BSEP-1 & 2 DISCIPLINE 2482

SYSTEM SFP COOLING SYSTEM

SUBJECT BULK TEMPERATURE ANALYSIS FOR SFP STORAGE EXPANSION

DESIGN CLASSIFICATION —

PIN: 9527.10.00-13

REV	COMP. BY	CHK'D BY
0	CWT DATE 1/22/81	[illegible] DATE 2/ /81
	DATE	DATE

SUMMARY/CONCLUSIONS

I. THE SFP INVENTORIES ARE GIVEN IN TABLES 1, 2, 3 & 4.

II. THE INITIAL CONDITIONS FOR THE SFP TEMPERATURE TRANSIENT FOLLOWING A LOSS OF SFP COOLING SYSTEM ARE $t_0 = 35$ HR, $Q_0 = 14.1 \times 10^6$ BTU/HR, $T_0 = 145.2°F$

III. THE MAXIMUM POOL TEMPERATURE IS 124.5 °F WHEN BOTH RHR AND SFP COOLING SYSTEMS ARE OPERATING FOLLOWING A CORE UNLOAD, AND IS 131.7°F WHEN RHR COOLING SYSTEM IS OPERATING ALONE.

REFERENCES: (SPECIFICATIONS, DRAWINGS, CODES, CALCULATION SETS, TEXTS, REPORTS, COMPUTER DATA PSAR ETC.)

PIN: 9527.10.00-11

PIN: 9527.10.00-12

Form 500/ Rev. 3-77

GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc.

NAME OF COMPANY CP&L/BSEP UNIT/S 1/2

SUBJECT SPENT FUEL POOL STORAGE EXPANSION

CALC. SET NO.		
PRELIM.		
FINAL		
VOID		
SHEET 2 OF 10		
J.O. 9527.085		
REV	COMP. BY	CHK'D BY
0	CWT DATE 1/21/81	AH DATE 2/5/81
	DATE	DATE

I POOL INVENTORY

A. CORE UNLOAD

ACCORDING TO THE NEW FUEL UNLOAD SCHEDULE, THE FULL CORE UNLOAD DATE IS TO OCCUR ON MARCH 7, 1988 FOR BSEP-1 AND ON NOVEMBER 15, 1987 FOR BSEP-2. THE SFP INVENTORIES FOR THE CORE UNLOAD CASE ARE PRESENTED IN TABLES 1 & 2 FOR UNITS 1 & 2 RESPECTIVELY (NEXT PAGE)

B. REFUELING CASE

THE SFP INVENTORIES FOR THE REFUELING CASE CAN BE DERIVED FROM TABLES 1 & 2. THE TIME OF LAST REFUELING IS EXACTLY ONE YEAR BEFORE THE CORE UNLOAD DATE. THE INVENTORIES THUS DERIVED ARE PRESENTED IN TABLES 3 & 4 FOR UNITS 1 & 2 RESPECTIVELY. (NEXT PAGE)

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Form 5007 Rev. 3-77

GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc.

CALC. SET NO.		
PRELIM.		
FINAL		
VOID		
SHEET 3 OF 10		
J.O. 9527.085		
REV	COMP. BY	CHK'D BY
0	CWT DATE 1/10/81	DATE
	DATE	DATE

NAME OF COMPANY CPEL/BSEP UNIT/S 1/2

SUBJECT SPENT FUEL POOL STORAGE EXPANSION

TABLE 1

SPENT FUEL POOL INVENTORY FOR

BSEP UNIT 1 - CORE UNLOAD

MARCH 7, 1988

BATCH NO.		NO. OF ASSEMBLIES	ASSEMBLY POWER (MWt)	IRRADIATION TIME (DAY)	COOLING TIME (HR)
1		140 BWR	4.35	299	24
2		140 BWR	4.35	599	24
3		140 BWR	4.35	898	24
4	3/6/88	140 BWR	4.35	1197	24
5	3/6'87	140 BWR	4.35	1197	8808
6	3/6'86	140 BWR	4.35	1197	17568
7	3/6'85	140 BWR	4.35	1197	26328
8	3/6'84	140 BWR	4.35	1197	35088
9	3/6'83	140 BWR	4.35	1197	43872
10	3/6'82	140 BWR	4.35	1197	52632
11	5'80	245 BWR	4.35	1197	68184
12	1'79	87 BWR	4.35	1197	80208
13	2'78	6 PWR	14.65	985	88488
14	10'77	50 BWR	4.35	1197	91128
15	3'76	4 BWR	4.35	1197	104928
16	10'75	45 PWR	14.65	985	108912
17	5'74	102 PWR	14.65	985	121416
18	3'73	7 PWR	14.65	985	131376

TOTAL 1786 BWR
160 PWR

9527-8-SS-SS-F

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GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc.

NAME OF COMPANY CP&L / BSEP UNIT/S 1/2

SUBJECT SPENT FUEL POOL STORAGE EXPANSION

CALC. SET NO.		
PRELIM.		
FINAL		
VOID		
SHEET 4 OF 10		
J.O. 9527.085		
REV	COMP. BY	CHK'D BY
0	CWT DATE 1/10/81	JL DATE 2/12/81
	DATE	DATE

TABLE 2

SPENT FUEL POOL INVENTORY FOR BSEP UNIT 2 - CORE UNLOAD NOVEMBER 15, 1987

BATCH NO		NO. OF ASSEMBLIES		ASSEMBLY POWER (MWT)	IRRADIATION TIME (DAY)	COOLING TIME (HR)
1		140	BWR	4.35	299	24
2		140	BWR	4.35	599	24
3		140	BWR	4.35	898	24
4	11/14/87	140	BWR	4.35	1197	24
5	11/14/86	140	BWR	4.35	1197	8784
6	11/14/85	140	BWR	4.35	1197	17544
7	11/14/84	140	BWR	4.35	1197	26304
8	11/14/83	140	BWR	4.35	1197	35088
9	11/14/82	140	BWR	4.35	1197	43848
10	11/14/81	136	BWR	4.35	1197	52608
11	3'80	132	BWR	4.35	1197	67560
12	4'79	4	PWR	14.65	985	75360
13	3'79	132	BWR	4.35	1197	76320
14	1'78	40	PWR	14.65	985	85896
15	10'77	90	BWR	4.35	1197	88440
16	11'76	51	PWR	14.65	985	96768
17	10'75	6	PWR	14.65	985	106224
18	3'73	43	PWR	14.65	985	128640

TOTAL 1750 BWR
144 PWR

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Form 5007 Rev. 3-77

GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc.

CALC. SET NO.		
PRELIM.		
FINAL		
VOID		
SHEET 5 OF 10		
J.O. 9527.085		
REV	COMP. BY	CHK'D BY
0	CWT DATE 1/10/81	DATE 2/3/81
	DATE	DATE

NAME OF COMPANY CP&L / BSEP UNIT/S 1/2

SUBJECT SPENT FUEL POOL STORAGE EXPANSION

TABLE 3

SPENT FUEL POOL INVENTORY FOR BSEP UNIT 1 - REFUELING MARCH 7, 1987

BATCH NO		NO OF ASSEMBLIES	ASSEMBLY POWER (MWT)	IRRADIATION TIME (DAY)	COOLING TIME (HR)
1	3/6/87	140 BWR	4.35	1197	24
2	3/6/86	140 BWR	4.35	1197	8784
3	3/6/85	140 BWR	4.35	1197	17544
4	3/6/84	140 BWR	4.35	1197	26304
5	3/6/83	140 BWR	4.35	1197	35088
6	3/6/82	140 BWR	4.35	1197	43848
7	5 '80	245 BWR	4.35	1197	59400
8	1 '79	87 BWR	4.35	1197	71424
9	2 '78	6 PWR	14.65	985	79704
10	10 '77	50 BWR	4.35	1197	82344
11	3 '76	4 BWR	4.35	1197	96144
12	10 '75	45 PWR	14.65	985	100128
13	5 '74	102 PWR	14.65	985	112632
14	3 '73	7 PWR	14.65	985	122592
TOTAL		1226 BWR 160 PWR			

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GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc.

CALC. SET NO.		
PRELIM.		
FINAL		
VOID		
SHEET 6 OF 10		
J.O. 9527.085		
REV	COMP. BY	CHK'D BY
0	CWJT DATE 1/1./81	[illegible] DATE 2/3/81
	DATE	DATE

NAME OF COMPANY CP&L / BSEP UNIT/S 1/2

SUBJECT SPENT FUEL POOL STORAGE EXPANSION

TABLE 4

SPENT FUEL POOL INVENTORY FOR BSEP UNIT 2 - REFUELING NOVEMBER 15, 1986

BATCH NO		NO OF ASSEMBLIES		ASSEMBLY POWER (MWT)	IRRADIATION TIME (DAY)	COOLING TIME (HR)
1	11/14/86	140	BWR	4.35	1197	24
2	11/14/85	140	BWR	4.35	1197	8784
3	11/14/84	140	BWR	4.35	1197	17544
4	11/14/83	140	BWR	4.35	1197	26328
5	11/14/82	140	BWR	4.35	1197	35088
6	11/14/81	136	BWR	4.35	1197	43848
7	3'80	132	BWR	4.35	1197	58800
8	4'79	4	PWR	14.65	985	66600
9	3'79	132	BWR	4.35	1197	67560
10	1'78	40	PWR	14.65	985	77136
11	10'77	90	BWR	4.35	1197	79680
12	11'76	51	PWR	14.65	985	88008
13	10'75	6	PWR	14.65	985	97464
14	3'73	43	PWR	14.65	985	119880

TOTAL 1190 BWR
144 PWR

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GENERAL COMPUTATION SHEET

united engineers & constructors inc.

(DISCIPLINE)

NAME OF COMPANY CP&L/BSEP UNIT/S 1/2

SUBJECT SPENT FUEL POOL STORAGE EXPANSION

CALC. SET NO.		
PRELIM.		
FINAL		
VOID		
SHEET 7 OF 10		
J.O. 9527-085		
REV	COMP. BY	CHK'D BY
0	CWT DATE 1/22/81	[illegible] DATE [illegible]
	DATE	DATE

II. INITIAL CONDITIONS FOR LOSS OF COOLING ANALYSIS IN REFUELING CASE.

DUE TO THE THERMAL INERTIA OF THE POOL, THE POOL TEMPERATURE IS STILL RISING AT THE TIME WHEN THE HEAT LOAD REACHES THE PEAK. BY THE TIME THE POOL TEMPERATURE IS AT ITS MAXIMUM, THE HEAT LOAD HAS COME DOWN SOMEWHAT DUE TO ADDITIONAL COOLING. THEREFORE THE WORST TIME FOR A FAILURE IN THE COOLING SYSTEM TO OCCUR IS SOMEWHERE IN BETWEEN THESE TWO TIMES. FOR SIMPLICITY, IT WILL BE CONSERVATIVELY ASSUMED THAT THE FAILURE OCCURS AT THE TIME OF PEAK HEAT LOAD AND THE POOL TEMPERATURE IS ALSO AT ITS MAXIMUM. FROM THE POOL TEMPERATURE TRANSIENT WITH SFP COOLING SYSTEM OPERATING, WE FIND THAT THE TIME IS 35

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GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc.

NAME OF COMPANY CP&L/BSEP UNIT/S 1/2

SUBJECT SPENT FUEL POOL STORAGE EXPANSION

CALC. SET NO.	
PRELIM.	
FINAL	
VOID	
SHEET 8 OF 10	
J.O. 9527.085	

REV	COMP. BY	CHK'D BY
0	GWT DATE 1/22/81	DATE
	DATE	DATE

HOURS, THE PEAK HEAT LOAD IS 14.1×10^6 BTU/HR (BSEP-1) AND THE MAXIMUM TEMPERATURE IS 145.2 °F

III. POOL TEMPERATURE FOR CORE UNLOAD CASE

REFERENCES: PIN: 9527.10.00-11
PIN: 9527.10.00-12

A. BOTH RHR AND SFP COOLING SYSTEMS OPERATING:

FROM PIN: 9527.10.00-11, ATTACHMENT II,

$$T_S - 0.714\,T_R = Q_S/\omega_R C_p + 25.74 \quad [EQ(3)]^*$$

$$T_R - 0.879\,T_S = Q_R/\omega_R C_p + 12.12 \quad [EQ(4)]^*$$

$\omega_R = 4950$ GPM

$\omega_S = 1000$ GPM

$C_p = 1.0$ BTU/LBM-°F

* EQUATIONS FROM PIN: 9527.10.00-11

9527-B-SS-55-F

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GENERAL COMPUTATION SHEET

(DISCIPLINE)

united engineers & constructors inc.

NAME OF COMPANY CPEL/BSEP- UNIT/S 1/2

SUBJECT Spent Fuel Pool Storage Expansion

CALC. SET NO.		
PRELIM.		
FINAL		
VOID		
SHEET 9 OF 10		
J.O. 9527.085		
REV	COMP BY	CHK'D BY
0	CWT DATE 1/22/81	[illegible] DATE
	DATE	DATE

FOR CORE UNLOAD CASE

$Q_S = 2.915 \times 10^7$ BTU/HR

$Q_R = 0$

SOLVING FOR TR AND TS, WE OBTAIN

$$T_S - 0.714\, T_R = \frac{2.915 \times 10^7}{4950 \times 8.021 \times 61.5} + 25.74$$

$$= 11.94 + 25.74$$

$$= 37.68$$

$$T_R - 0.879\, T_S = 12.12$$

$$T_S = \frac{12.12 \times 0.714 + 37.68}{1 - 0.628} = 124.6\,^\circ F$$

$$T_R = 12.12 + 0.879 \times 124.5 = 121.6\,^\circ F$$

B. RHR SYSTEM OPERATING ALONE

$\omega_S = 0$, $Q_R = 0$, $Q_S = 2.915 \times 10^7$ BTU/HR

ATTACHMENT 7

LEAD ENGINEER: Saeed A. Bokharee MANAGER'S INITIALS FB

PROBLEM CLASS	WORK REQUEST NUMBER	PIN NUMBER	CALCULATION SET NUMBER	JOB CHARGE
I		9527-1500-8001	1	9527.085

PROBLEM STATEMENT:

Carolina Power and Light Co.
BSEP units 1 & 2
Loss of Spent Fuel Pool Cooling
off-site Radiological Consequences.

REVIEW & APPROVAL

RESPONSIBLE ENGINEER	Saeed A. Bokharee (Saeed Bokharee)	DATE:	November 20, 1980
CHECKER	Dennis Zannoni D. Zannoni	DATE:	12/2/80
REVIEWER	F. Boorboor F.B.	DATE:	12/29/80
FINAL APPROVAL	F. Booboor F.B.	DATE:	12/29/80

COMMENTS:

Form 5604

9527-8-SS-54-F

united engineers & constructors inc

CALCULATION CONTROL SHEET

CALC. SET NO.	1
PRELIM.	
FINAL	
VOID	

PROJECT TITLE CP&L - BSEP 1&2 DISCIPLINE Nuclear

SYSTEM Spent Fuel Pool Cooling System

SUBJECT Radiological consequences due to loss of SFP cooling.

DESIGN CLASSIFICATION N/A

STARTED BY Saeed a Bokharee DATE Nov 13, 80

AUTHORIZED BY F. Boorboor DATE Nov 13, 80

PROBLEM STATEMENT

CP&L —— BSEP units 1&2
Loss of spent Fuel Pool cooling —
Resulting Thyroid Doses

DESIGN BASIS

Simultaneous loss of spent fuel pool cooling systems for both units 1&2 is assumed.

TOTAL NUMBER OF SET COMPUTATION SHEETS ______

FINISHED BY ______ CHECKED BY D. Zannoni

	CHECKER	DESIGN SUPER	COGNIZANT ENG'R	DESIGN REVIEW
BY	D. Zannoni		SAB	
DATE	12/2/80		NOV 13/80	

REVISION 1 STARTED DATE ______ BY ______

Form 5603

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CALCULATION SUMMARY & REFERENCE SHEET

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J.O.	9527.085

PROJECT TITLE CP&L - BSEP 1&2 DISCIPLINE Nuclear

SYSTEM Spent Fuel Pool cooling System

SUBJECT Loss of SFP cooling - offsite Doses

DESIGN CLASSIFICATION N/A

REV	COMP. BY	CHK'D BY
0	DATE	DATE
1	SAB DATE NOV 20, 80	Dan Evans DATE 12/2/80

SUMMARY/CONCLUSIONS

Off-Site Thyroid - Doses
(from both units)

	Ground-Level Releases	Releases through SGTS
EAB (0-2hrs)	282 rems	0.29 rems
LPZ (0-4days)	264 rems	1.02 rems

REFERENCES: (SPECIFICATIONS, DRAWINGS, CODES, CALCULATION SETS, TEXTS, REPORTS, COMPUTER DATA PSAR ETC.)

Computer code HDOSE

Appendix A (or memo)

attachments:

Computer outputs :—

E1642 / SBokharee
E1702 / (Saeed/2)
E1710 / (Saeed/3)
E1711 / (Saeed/4)
E1712 / (Saeed/5)

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SUBJECT Spent Fuel Accident

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When SFP cooling system for both units are postulated to fail simultaneously following a refueling, a bulk boiling in the spent fuel pools of both units will give rise to a severe radiological impact. The sequence of various events are summarized as follows:-

(1) at $t = 0$ Reactor Shut-down

(2) at $t = 24$ hrs refueling operation begins

(3) at $t = (24+35)$ hr $= 59$ hrs Refueling completed.

(4) SFP cooling is lost. It takes 12.9 hrs before the on set of boiling, i.e

at $t = (59+12.9)$ hr $= 71.9$ hrs boiling in SFP begins.

(5) at $t = (71.9 + 96)$ hr $= 167.9$ hr SFP cooling is restored.

<u>Source Terms:-</u>

Core equillibrium activity for Iodine is as follows (Memo 9527-05.2-06)

Isotope	Activity (Ci)
I-131	6.40 (7)
I-132	9.72 (7)
I-133	1.44 (8)
I-134	1.68 (8)
I-135	1.30 (8)

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As of memo, failed fuel cladding = 1%

Radial peaking factor (Ref.; R.G. 1.25) = 1.5

Leaking activity = Core equilibrium Activity × 0.01 × 1.5
($\eta'(Ci) = \eta(Ci) \times 0.01 \times 1.5$)

∴

Isotope	Leakage activity $\eta'(Ci)$
I - 131	9.60 (5)
I - 132	1.46 (6)
I - 133	2.16 (6)
I - 134	2.52 (6)
I - 135	1.95 (6)

SFP water activity (iodines) at t = 71.9 hrs (at on-set of boiling)

Calculations :-

(1) $t_1 = 0 \rightarrow 24$ hrs

leakage coefficient $\equiv L_1 = 0$ (fuel still in vessel)

(2) $t_2 = 24 \rightarrow 59$ hrs

$^*L_R = 4.60 \times 10^{-10}$/sec (Ref. memo)

$= 1.66 \times 10^{-6}$/hr

∴ $L_2 = 1.66 \times 10^{-6} \times (59-24) = 5.81 \times 10^{-5}$

(3) $t_3 = 59 \rightarrow 71.9$ hrs

Spike factor = 100 (Ref. memo)

$L_R = 1.66 \times 10^{-6}$/hr

* L_R stands for leakage coefficient Rate.

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$\therefore L_3 = 1.66 \times 10^{-6} \times 10^2 \times (71.9 - 59) = 2.1414 \times 10^{-3}$

$\therefore$ total leakage at the on-set of boiling being

$$L = L_1 + L_2 + L_3 = 0 + .0581 \times 10^{-3} + 2.1414 \times 10^{-3}$$

$$= 2.1995 \times 10^{-3}$$

To generate activities of Iodines in SFP water at t = 71.9 hrs, HDOSE Run # E1642 (S.Bokhari) was made with the following input values.

Card - 2

NT = 3
NX = 1
NCH = 5
NVIT = 3
MODE = 3
IIC = 1

Card - 3

UU = 1×10^{10}
VOLM = 8.75×10^2 (m^3)

Card - 4

RELES(I) = 0 I = 1, 2, 3, 5 and 6

RELES(4) = 1.0

Card - 5C, 5D and 5E

RELIS(1,4) = 0

RELIS(2,4) = 5.81×10^{-5}

RELIS(3,4) = 2.1995×10^{-3}

Card-6, 6E12.4

$XLI(I) = 1.0 \times 10^{-15}$ $\quad I = 1,2,3 \ (1 \rightarrow NT)$

Card-7A, B and C 3 blank cards (one for each time-step)

∵ $EPSK(I,j) = 0$ for $j = 1 \rightarrow 6$ class.

Card-8A, B, C

3 blank cards (one for each time step)

∵ $EFFCY(I,j) = 0$ $\quad j = 1 \rightarrow 6$ class

Card-11

$T(I) = 24.0, 59.0, 71.9$ (6E12.4)

Card-12A

$VIT(I) = 24.0, 59.0, 71.9$ "

Card-13

$Y(1) = 500.0$ "

Card-16

$B(I) = 2.32 \times 10^{-4}$ $\quad I = 1,2,3$

Card-17A

$PHI(I,1) = 4.6 \times 10^{-6}$ $\quad I = 1,2,3$

→ These inputs do not affect the activity in the pool water.

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SUBJECT Spent Fuel Accident

Releases of Iodines to environment :-

The releases could be categorized into two classes:-

(a) Releases from pool-water iodines

(b) Releases from fuel after boiling starts.

(a) <u>Releases of pool water iodines</u> :-

pool water mass $= 45360\ ft^3 \times 62.4\ lb/ft^3$ (memo)

$= 2830464$ lbs.

Boiling rate $= 1.38 \times 10^4$ lb/hr (memo)

$= \frac{1.38 \times 10^4}{2830464}$ Vol/hr

$= 4.8756 \times 10^{-3}$ Vol/hr

Boiled water fraction

0 — 2 hr	$= 9.7511 \times 10^{-3}$ V
0 — 4 hr	$= 1.9502 \times 10^{-2}$ V
0 — 8 hr	$= 3.9004 \times 10^{-2}$ V
0 — 24 "	$= 1.1701 \times 10^{-1}$ V
0 — 4 days	$= 4.6805 \times 10^{-1}$ V

(a) Activities at the beginning of boiling is calculated by HDOSE # E1642 as given below (SBOKHAREE)

isotope	activity of (Ci)
I-131	1.6329 (03)
I-132	1.3577 (-05)
I-133	4.4136 (02)
I-134	3.3588 (-14)
I-135	3.0510 (00)

EAB = 3000 ft = 914.4 meters FSAR

LPZ = 2 miles = 5218.7 meters FSAR

(X/Q)'s Ground-level Releases (FSAR Table 2.3-10 & Figure 14.6-4)

EAB	0 - 2 hrs	5.4×10^{-4} sec/m³
LPZ	0 - 2 hrs	1.7×10^{-4} "
	2 - 4 hrs	1.7×10^{-4} "
	4-8 hrs	1.7×10^{-4} "
	8-24 hrs	2.4×10^{-5} "
	1-4 days	8.0×10^{-6} "

HDOSE # $\frac{E1702}{SAEED12}$ was made to generate doses from Releases of pool water iodines. The input data being

Card-2 ;

NT = 5 = NVIT
NX = 2
NCH = 5
Mode = 3, ILC = 1

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Card-3, Card-4; unchanged

Cards-5 C, D, E, F, G

RELIS (1,4) = 9.7511×10^{-3}

" (2,4) = 1.9502×10^{-2}

" (3,4) = 3.9004×10^{-2} Boiled H_2O frac

" (4,4) = 1.1701×10^{-1}

" (5,4) = 4.6805×10^{-1}

Card-6

XLI (I) = 500.0 I = 1, 2, 3, 4, 5

Card-7 (A, B, C, D, E) 5 blank cards

Card-8 (A, B, C, D, E) 5 blank cards

Card-11

T(I) = 2, 4, 8, 24, 96

Card-12 VIT(I) = 2, 4, 8, 24, 96

Card-13 Y(I) = 914.4, 3218.7

Card 16 B(I) = 3.47×10^{-4}, 3.47×10^{-4}, 3.47×10^{-4}, 1.75×10^{-4}, 2.32×10^{-4}
I = 1 → 5

Card 17A PHI (I,1) = 8.4×10^{-4} ; I = 1 (EAB, χ/Q)

Card 17B PHI (I,2) = 1.7×10^{-4}, 1.7×10^{-4}, 1.7×10^{-4}, 2.4×10^{-5}, 5.0×10^{-6}

I = 1 → 5 ; (LPZ. χ/Q)

Source terms from HDOSE # E1642/Stockhouse or Page 7 of package

(b) Releases from fuel after Boiling Starts:-

$$\eta_i^{\tau} = \eta_i e^{-\lambda_i t}$$

η_i = activity in Curies for isotope-i at the reactor shutdown

η_i^{τ} = " " " " " at the time of boiling

τ = 71.9 hrs.

isotope	λ (hr^{-1})	η_i (Ci)	η_i^{τ} (Ci)
I - 131	3.59 (-3)	9.60 (5)	7.42 (5)
I - 132	3.03 (-1)	1.46 (6)	5.05 (-4)
I - 133	3.33 (-2)	2.16 (6)	1.97 (5)
I - 134	7.96 (-1)	2.52 (6)	3.51 (-19)
I - 135	1.03 (-1)	1.95 (6)	1.19 (3)

$L_R = 1.66 \times 10^{-4}\ hr^{-1}$

L ≡ Leakage fraction = L_R x time

Accumulated Leakage fraction

0 – 2 hrs	= 3.32×10^{-4}
0 - 4 hrs	= 6.64×10^{-4}
0 - 8 hrs	= 1.33×10^{-3}
0 - 24 hrs	= 3.98×10^{-3}
0 – 4 days	= 1.59×10^{-2}

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HDOSE # E1710/(Saced/3) generated the dose contributions for releases from fuel after boiling starts. The HDOSE input variations for the data are;

Card-5 C.D.E.F.G

RELIS (1,4) = 3.32 (-4)
(2,4) = 6.64 (-4)
" (3,4) = 1.33 (-3)
(4,4) = 3.98 (-3)
(5,4) = 1.59 (-2)

Cards N+1 ⟶ N+2 n 1 < 2 ≤ 5

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Venting all Releases through Standby Gas Treatment System (GTS):-

Since it takes 12.9 hrs to reach boiling after LOCA of SFP cooling, it is reasonable to assume that the SGTS is on when the releases occur. For such a release mode, the (χ/Q)'s for elevated releases are reproduced from FSAR table 2.3-10.

EAB	0 - 2 hrs	2.0×10^{-5}	sec/m³
LPZ	0 - 8 hrs	8.8×10^{-6}	"
	8 - 24 hrs	3.8×10^{-6}	"
	1 - 4 days	1.0×10^{-6}	"

SGTS filter efficiency = 95% (Reg Guide 1.52, Rev. 1)

HDOSE # E1711/(Saced14) generated dose contribution from releases from pool water iodines. The input here differs from the corresponding Run with no filters in

Cards - 8 A.B.C

Effcy (I,4) = 0.95 I = 1 → 5

Card 17A Phi (I,1) = 2.0×10^{-5} I = 1

Card 17E Phi (I,2) = 8.8×10^{-6}, 8.8×10^{-6}, 8.8×10^{-6}, 3.8×10^{-6} x 1.0×10^{-6} I = 1 → 5

Cards N+1 → N+i " 1 ≤ i ≤ 5

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SUBJECT Spent Fuel Accident

HDOSE # E1712/(Saeed/s) generated source contributions from fuel leakage after Boiling.

The variations in input to HDOSE differs from the corresponding case with no filters HDOSE input,

Cards - 8 A, B, C

Effcy (I,4) = 0.95 (I = 1 → 5)

Card - 17A Phi (I,1) = 2.0×10^{-5} (I = 1)

Card - 17B Phi (I,2) = 8.8×10^{-6}, 8.8×10^{-6}, 8.8×10^{-6} × 3.5×10^{-6} × 1.0×10^{-5}

(I = 1 → 5)

Card: N+1 - : N+2 [illegible] 1 < K ≤ 5

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Results :-

(a) Off-Site Thyroid Doses (Ground level releases — no filters) :-

(i) Contribution from boiling of SFP water;

EAB (0-2 hrs) ⟶ 7.39 rems

LPZ (0-4 days) ⟶ 8.53 "

(HDOSE # E1702 / SAEED/2)

(ii) Contribution from fuel leakage after Boiling

EAB (0-2 hrs) ⟶ 1.14×10^2 rems

LPZ (0-4 days) ⟶ 1.32×10^2 "

(HDOSE # E1710 / SAEED/3)

(iii) *Total = Contribution (i) + Contribution (ii)

EAB (0-2hrs) ⟶ 1.21×10^2 rems

LPZ (0-4days) ⟶ 1.41×10^2 "

(b) Off-Site Thyroid doses (SGTS operating)

(i) Contribution from boiling of SFP water;

EAB (0-2hrs) ⟶ 8.79×10^{-3} rems

LPZ (0-4days) ⟶ 3.28×10^{-2} "

(HDOSE # E1711 / SAEED/4)

(ii) Contribution from fuel leakage after boiling;

EAB (0-2hrs) ⟶ 0.136 rems

LPZ (0-4 days) ⟶ 0.507 "

(HDOSE # E1712 / SAEED/5)

(iii) *Total

EAB (0-2hrs) ⟶ 0.145 rems

LPZ (0-4days) ⟶ 0.540 "

* Total pertains to only one unit. For both units, total should be multiplied by a factor of 2.