NUCLEAR ENERGY SERVICES, INC.

2500 POUND OBJECT DROP ANALYSIS

FOR NORTH ANNA POWER STATIONS UNITS 1 & 2

Prepared Under NES Project 5229

for

VIRGINIA ELECTRIC AND POWER COMPANY

Project Application	Prepared By	Date
5229	Dilip Bhagat	Oct. 1983
	APPROVALS	
TITLE/DEPT.	SIGNATURE	DATE
Mgr. Prod. Str. Des. & Anal.	[signature]	10/17/83
Project Manager	[signature]	10/17/83

RESULTS OF AN ACCIDENTAL SPENT FUEL ASSEMBLY DROP LOAD OF 2500 lbs.

Straight Drop on Top of Storage Cell	Calculated Value	Allowable Value
Weight of Fuel Assembly (kip)	2.75	--
Maximum Drop Height (in)	59.0	--
Kinetic Energy of Drop to be Absorbed (in-k)	162.25	--
Maximum Strain in Storage Cell (in/in)	0.00813	0.485[1]
Maximum Cell Axial Deformation (in)	1.37	--
Maximum Stress in Cell (ksi)	44.65	36.00[2] (103.00)[3]
Maximum Transmitted Reaction Load (kips)	142.64	--
Maximum Punching Shear Stress in Liner Plate (ksi)	13.98	23.04[4]
Maximum Local Bearing Stress on Concrete Floor (ksi)	1.07	3.57
Inclined Drop on Top of Storage Cell		
Maximum External Kinetic Energy per Storage Cell (in-k)	25.78 < 162.25	--

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1. Ultimate strain for stainless steel

2. The allowable stress value represents dynamic yield stress for stainless steel.

3. Ultimate stress for stainless steel.

4. Allowable punching shear stress = 1.6x0.4Fy
   = 1.6x0.4x.2x30 = 23.04 ksi

Straight Drop Through the Storage Cell	Calculated Value	Allowable Value
Maximum Drop Height (in.)	227.0	--
Maximum Free Fall Impact Velocity (ft/sec)	34.9	--
Maximum External Kinetic Energy (in. k)	567.5	--
Maximum Unsupported Plate Thickness That May be Perforated by Missile Free Fall Velocity, (in.)	0.25	--
BRL Formula	0.20	0.50
Maximum Transmitted Reaction Load (kips)	21.4	--

REF.

ACCIDENTAL SPENT FUEL ASSEMBLY DROP ANALYSIS

FOLLOWING IS THE ANALYSIS FOR A SPENT FUEL ASSEMBLY DROP LOAD OF 2500 lbs.

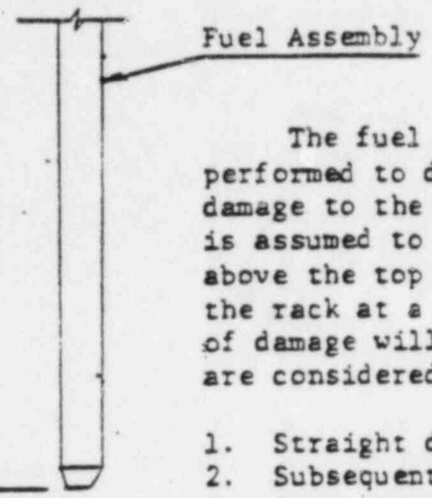
CONCLUSIONS

(i) THERE WILL BE LOCAL DEFORMATION AT THE TOP OF THE STORAGE CELLS THROUGH LOCAL BUCKLING AND CRUSHING; HOWEVER, THE STRUCTURAL INTEGRITY OF THE RACKS WILL BE MAINTAINED.

(ii) THE LINER PLATE WILL NOT BE PERFORATED AND THE LEAK TIGHT INTEGRITY OF THE POOL FLOOR WILL BE MAINTAINED.

REF.

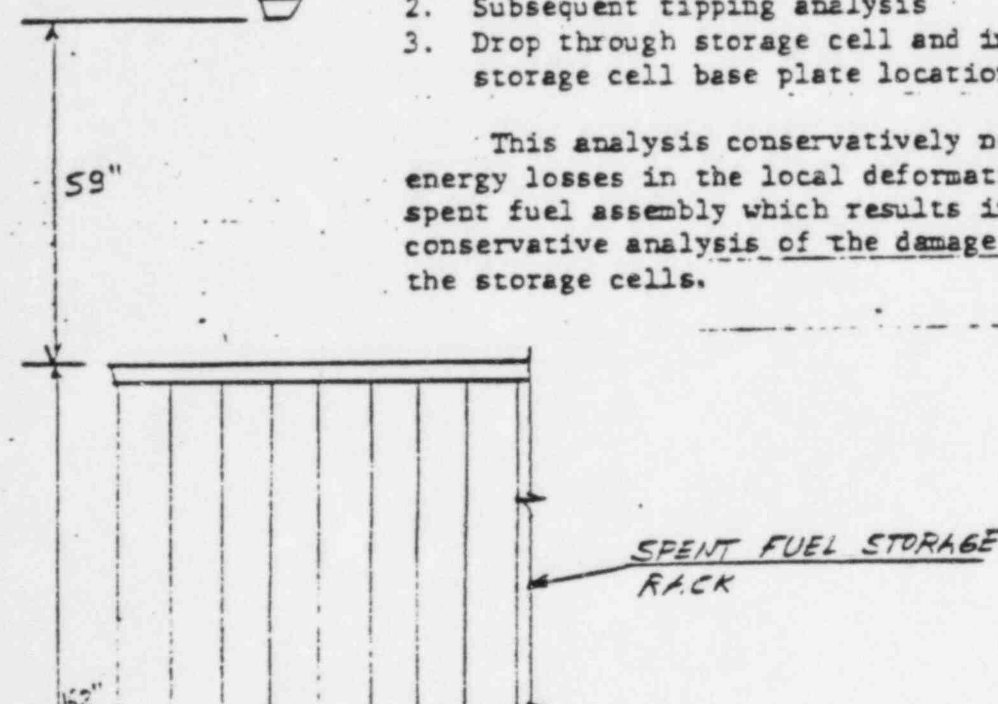
ACCIDENTAL SPENT FUEL ASSEMBLY DROP ANALYSIS



The fuel assembly drop analysis has been performed to determine the resulting structural damage to the storage racks. The fuel assembly is assumed to fall from a height of 59" above the top of this storage rack and impact the rack at a location where the critical amount of damage will result. Three fuel drop cases are considered:

1. Straight drop on top of rack
2. Subsequent tipping analysis
3. Drop through storage cell and impact at storage cell base plate location

This analysis conservatively neglects the energy losses in the local deformation of the spent fuel assembly which results in a more conservative analysis of the damage done to the storage cells.



REF.

CASE #1 STRAIGHT DROP ON TOP OF RACK

Assuming uniform storage cell compression, the external kinetic energy developed in the fall = (fall height) x (weight of fuel assembly). Neglecting any buoyant or drag forces on the falling assembly -

Drop Height = 59"
Fuel Assembly Weight = 1.1 x 2500 = 2750 K (QAPP SECTION 3.3.4 CALLS FOR 110% THE WT.)

External Kinetic Energy = 162.25 k-in

The maximum reaction loads are generated when the fuel assembly impacts a RACK at the intersection of the STORAGE cell. (stiffest region of THE RACK). The fuel assembly is assumed to impact an area equivalent to that of a storage cell, transmitting and absorbing the kinetic energy generated during the fall. During impact, the lead-in guides will collapse absorbing some percentage of the external kinetic energy. The storage cells are extremely rigid because of their configuration and therefore is conservatively assumed to transmit the reaction loads into the yielding of the base plate.

Conservatively neglect the energy losses due to the local deformation of the flare at the top of the cell. The local deformation will reduce the damage to the cell; therefore, there will be less damage to the liner plate and reinforced concrete floor under the storage cell.

LOAD FROM IMPACT ON THE CELL

Assume axial compression over one storage area. Find the force by setting the internal energy absorbed equal to the external energy of the falling fuel assembly.

External Kinetic Energy of Fuel Assembly = 162.25 K-in

Internal Strain Energy of Storage Cell (at 20% stress increase) Reference "Final structural design of a fuel storage well crash pad for the LACBWR Nuclear Power Plant", page A-18 Ref. D-1

$$E_i = \frac{116.9}{1.2} e_x^{1.20} \text{AxLxN}$$

where e_x = strain in storage cell
A = cross-sectional area of cell
= 8.875 x 4 x 0.09 = 3.195 in²
L = Length of cell
N = Number of cells = 1.0

REF.

$E_i = E_x$

$$e_x = \left[\frac{1.2\,E_x}{116.9\,ALN}\right]^{1/1.2} = \left[\frac{1.2 \times 162.25}{116.9 \times 3.195 \times 168 \times 1}\right]^{1/1.2} = 0.008125$$

Calculate % Ultimate Strain

$$\%\,e_u = \frac{e_x}{e_u} \times 100 = \frac{0.002125}{0.485} \times 100 = 1.68\,\%$$

Max Deformation of the cell = δ_x

$$\delta x = ExL = 0.008125 \times 168 = 1.37 \text{ in}$$

Max Stress in the cell

$$\sigma_x = 116.9\,e_x^{0.2} = 116.9(0.002125)^{0.2} = 44.65 \text{ KSI}$$

Using dynamic yield stress for stainless steel = 1.20% of yield
$= 1.2 \times 30^{KSI} = 36^{KSI}$ (304 SS)

Maximum transmitted reaction load

$$R_x = \sigma_x A = 142.64K$$

REF.

CASE #2 FUEL ASSEMBLY DROP AND SUBSEQUENT TIPPING

After a fuel assembly impacts the rack, it will tip over and fall onto several adjacent cells. Conservatively assume that the fuel assembly will fall diagonally impacting the minimum number of cells.

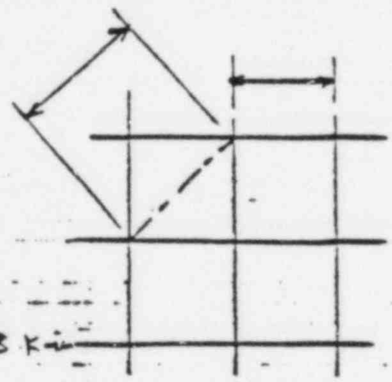
Length of fuel assembly = 160"

Number of cells on diagonal

$N = 160/10.5625 = 15.15$

Assume 15 cells max. are impacted therefore 1/15 of fuel assembly impacts the 15th cell

$$K.E. = \frac{2.5}{15}\left[160 - \frac{160}{15\times 2}\right] = 25.78 \text{ K-in}$$



Since the kinetic energy per cell 25.78 is less than the kinetic energy generated in THE straight drop 462.25, the structural damage will be less severe than the fuel assembly drop. See Case #1.

CASE #3 STRAIGHT DROP THROUGH A STORAGE CELL AND IMPACT A STORAGE CELL BASE PLATE

The fuel assembly is assumed to fall from a height 4.9 feet above the storage rack, enter into a single storage location and continue down through the storage cell impacting the storage cell base plate. The analysis conservatively neglects any drag or buoyant forces acting on the assembly.

Maximum kinetic energy at impact = $2.5\,(168+59) = 567.5$ K-in

V_S = Maximum impact velocity = $(2GH)^{1/2} = \left(2\times 32.2\times \frac{227}{12}\right)^{1/2} = 34.9$ ft/sec.

The fuel assembly is assumed to act as a missile striking the stainless steel base plate. The thickness of plate that a missile, represented by the fuel assembly, can just perforate is calculated using the Ballistic Research Laboratory (B.R.L.) equation given in reference D,2.

REF.

$$T = \frac{\left(\frac{MVs^2}{2}\right)^{2/3}}{672D}$$

Where - M = Mass of the missile = $\frac{2500}{32.2}$ = 77.64 $\frac{lb\text{-}sec^2}{ft.}$

T = Thickness just perforated (in.)

Vs = Striking velocity = 34.9 ft/sec.

D = Diameter of missile

Changing area into equivalent diameter circle $8.426^2 = \frac{\pi D^2}{4}$; D = 9.507"

Thickness = T = $\frac{\left[\frac{1}{2}(77.64 \times 34.9^2)\right]^{2/3}}{672 \times 9.507}$ = 0.20"

Recommended thickness to
Prevent Penetration = 1.25T = 0.25"

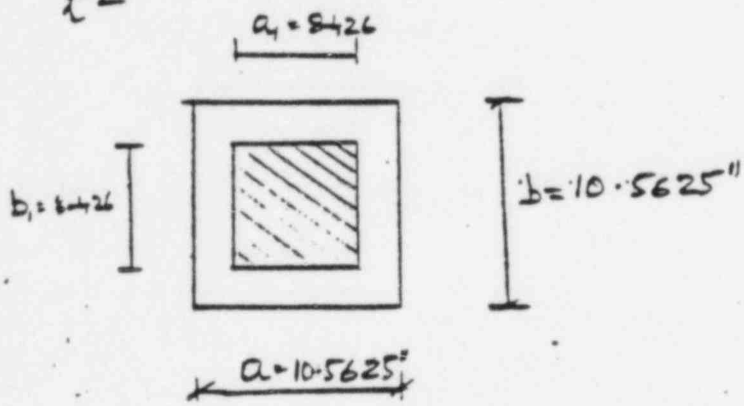
CONCLUSION: THE FUEL ASSEMBLY WILL NOT PENETRATE THE 1/2" RACK BASE PLATE.

REF.

THE MAXIMUM REACTION LOAD GENERATED BY THE FUEL ASSEMBLY IMPACT WILL BE ESTIMATED BY CALCULATING THE COLLAPSE LOAD FOR A RECTANGULAR PLATE SIMPLY SUPPORTED AT ALL FOUR EDGES.

$\sigma_{max} = 30 \times 1.2 = 36\ KSI.$

$\sigma_{max} = \frac{\beta W}{t^2}$ (REF. ROARK, P 387, sec 1C).



$\frac{a_1}{b} = 0.7977$ $\frac{b_1}{b} = 0.7977$ $\beta = 0.42$

$W = \frac{36 \times 0.5^2}{.42} = 21.42$ Kips.

THE REACTION LOAD OF 21.42^k GENERATED DURING THE FUEL ASSEMBLY DROP THROUGH THE CELL AND IMPACT ON TO THE BASE PLATE IS LOWER THAN MAXIMUM TRANSMITTED REACTION LOAD IN CASE #1. IT CAN BE CONCLUDED THAT FUEL DROP #3 CASE IS LESS SEVERE THAN #1.

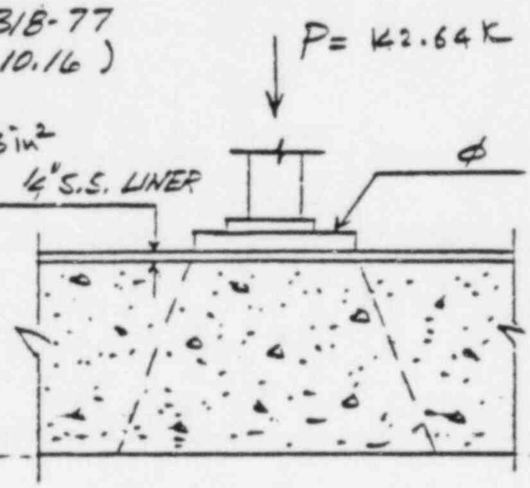
REF.

THE MAXIMUM STRESS ON THE POOL FLOOR IS CALCULATED USING THE MAXIMUM LOAD FROM CASE #1.

BEARING STRESS ON CONCRETE

$F_p = 2 \times 0.85 \times 0.70 \times f'_c$ (ACI 318-77 SEC 10.16)

$A = \frac{\pi D^2}{4} = \frac{\pi(\frac{1}{2}+13)^2}{4} = 132.73 \text{ in}^2$



$f_p = \frac{142.64}{132.73} = 1.07 \text{ KSI}$

$F_p = 2 \times 0.85 \times 0.7 \times 3^{KSI}$

$= 3.57 > 1.07 \text{ KSI}$

CONCLUSIONS:

ACCIDENTAL DROP OF THE FUEL ASSEMBLY ON THE FUEL STORAGE RACK WILL CAUSE THE FOLLOWING:

A) THERE WILL BE LOCAL DEFORMATION AT THE TOP OF THE STORAGE CELLS THROUGH LOCAL BUCKLING AND CRUSHING. HOWEVER THE STRUCTURAL INTEGRITY OF THE RACK WILL BE MAINTAINED.

B) THE LINER PLATE WILL NOT BE PERFORATED AND THE LEAK TIGHT INTEGRITY OF THE POOL FLOOR WILL BE MAINTAINED.

	REF.

References:

D.1 Nuclear Energy Services, Inc.: "Final Structural Design of a Fuel Storage Well Crash Pad for LACBWR Nuclear Power Plant. Document NES 81A0426, Rev. 1, March 31, 1976

D.2 Linderman R.B., Rotz, J.V. and Yeh G.C.K.; "Design of Structures for Missile Impact", Bechtel Power Corporation, BC-TOP-9A, Rev. 2, September, 1974.

D.3 Wood, R.H., "Plastic and Elastic Design of Slabs and Plates," the Ronald Press Company, NY, NY.

D.4 Raymond J. Roark & Warren C. Young, - "Formulas for Stress & Strain - Fifth edition, McGraw Hill Book Company - 1975.

Question B.4:

Provide a more detailed discussion of the assumptions and methodology used to calculate the decay heat loads for normal refueling and emergency fuel core offload at North Anna.

Answer:

The assumptions and methodology used in calculating the decay heat loads are listed in our report entitled "A Summary of Information In Support of Increasing the Spent Fuel Storage Capacity of North Anna Unit Nos. 1 and 2", which was attached to our letter of August 20, 1982 (Serial No. 450). In order to expand upon the information contained in this report, attached to this response is a copy of the decay heat calculations.

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CALCULATION TITLE PAGE

*SEE INSTRUCTIONS ON REVERSE SIDE

5010.64 (FRONT)

CLIENT & PROJECT: VEPCO NORTH ANNA

CALCULATION TITLE (Indicative of the Objective): FUEL POOL DECAY HEAT LOAD

QA CATEGORY (✓): ☒ I - NUCLEAR SAFETY RELATED ☐ II ☐ III ☐ ____ OTHER

CALCULATION IDENTIFICATION NUMBER

J. O. OR W.O. NO.	DIVISION & GROUP	CURRENT CALC. NO.	OPTIONAL TASK CODE	OPTIONAL WORK PACKAGE NO.
14258.13 13929.26	OSD 52	13929.26-1	00002	NA

* APPROVALS - SIGNATURE & DATE

PREPARER(S)/DATE(S)	REVIEWER(S)/DATE(S)	INDEPENDENT REVIEWER(S)/DATE(S)	REV. NO. OR NEW CALC NO.	SUPERSEDES * CALC. NO. OR REV. NO.	CONFIRMATION *REQUIRED (✓) YES	NO
Leon Stempel 5/12/82	Peter A. Liakos 5/24/82	Peter A Liakos 5/24/82	0			✓

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CALCULATION SUMMARY

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QA CATEGORY / CODE CLASS

CLIENT / PROJECT: VEPCO NORTH ANNA

SUBJECT / TITLE: FUEL POOL DECAY HEAT LOAD

OBJECTIVE OF CALCULATION

Calculate the Spent Fuel Pool Decay Heat Loads for six (6) Cases stated in the letter from Vepco attached in Appendix 1.
See pages 24-25 for the 6 Cases contents.

CALCULATION METHOD/ASSUMPTIONS

See pages 5 and 4.

SOURCES OF DATA / EQUATIONS

See page 3

CONCLUSIONS

General Results are tabulated on page 21
A summary is also shown at the end of each Case.

REVIEWER (S) COMMENTS

PREPARER	Leon Hempel	DATE 6/18/82
REVIEWER / CHECKER	C G Lenkan	DATE 6/18/82
INDEPENDENT REVIEWER	PG Liakos	DATE 6/18/82

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GRAPH AND APPENDIX

1. REFERENCES:

1. Vepco Letter NS1-507-007 of April 28, 1982
2. NRC Branch Technical Position ASB 9-2 Rev.2 - 7/81
3. FSAR section 9.1.3
4. FSAR Section 4.1.1 Core Mech. Design Parameters.
5. Calc. 11715-ES-129-0 11-25-75
6. Calc 11715-ES-144-0 8-24-76
7. Calc. 11715.27 No 313N Fuel Pool Decay Heat Temp. 10-18-76

2. Assumptions and Given Conditions:

1. 1/3 Core per Reactor Replaced Annually (Ref 1)
2. Refueling of N.A. Units is 45 days appart (Ref 1)
3. 1748 Storage locations of High Density Spent Fuel Racks. (Ref 1)
4. 157 Fuel Assemblies per Core (Ref 4)
5. Max Reactor Power is 2900 MW for North Anna and 2546 for Surry. (Ref 1)
6. 150 hrs after shutdown all Fuel is assumed to moved instantaneously to the Spent Fuel Pit. (Ref 1)
7. For full Core Discharge Case the Fuel is moved from the Reactor Core to the Fuel Pool at a rate of 20 min per assembly, starting 150 hrs after shutdown and 150 hrs + 45 days for Unit 2
8. Uranium Decay Heat is based on Ref 2 and graphed on page 23 of this calc. (Note: The graph is copied from Ref 7.)

3. Method and Approach

From Ref 5 & 6 draw graphs of P/P_0 vs time.
From graph find the Decay Power for various cases given in Ref 1.
Determine the total Decay Heat, Q in MBtu/hr. for all 6 cases.
For Region 1 Fuel (on graph) page 22 find $P|P_0$ and multiply by core full Power to obtain Decay Heat for that Region for 1/3 core.
($P|P_0$ = Decay Power as a fraction of operating Power. Ref 2).

The following equation (or with some modifications) is used in the calculation:

From Ref 7: ②

$$\text{MBtu/hr} = 2900 \text{ MW} \times 3.4127 \frac{\text{btu/hr}}{\text{watt}} \times P|P_0$$

where: 2900 MW = max Power for North Anna Unit 1 or 2
3.4127 = conversion factor for 1 watt = 3.4127 btu/hr
$P|P_0$ - described above

CALCULATION SHEET

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SUBJECT/TITLE: FUEL POOL DECAY HEAT LOAD

QA CATEGORY/CODE CLASS

4) CASE I — TABLE I. HEAT DECAY - NORTH ANNA

1/3 core = 52 or 53 assemblies.

Unit #1	P/Po	MBtu/hr	Quantity of locations
1/3 core (3 years oper) 150 hrs + 45 days = 4.43×10^6 sec	0.00037	3.66	52
1/3 core (3 years) 150 hr + 45 days + 1 year = 3.60×10^7 sec	0.000085	0.84	52
1/3 core (3 years) 150 hr + 45 days + 2 years) = 6.75×10^7 sec	0.000045	0.45	53
1/3 core (3 years) 150 + 45 days + 3 years) = 9.90×10^7	0.000034	0.33	52
subtotal	0.000534	5.28	209
Unit #2			
1/3 core (3 years) 150 hrs = 5.4×10^5 sec	0.001029	10.18	52
1/3 core (3 years) 150 hrs + 1 year = 3.21×10^7 sec	0.000095	0.94	52
1/3 core (3 yr) 150 hr + 2 years 6.36×10^7	0.000049	0.48	53
1/3 core (3 year) 150 hr + 3 years = 9.51×10^7	0.000035	0.35	52
1/3 core (3 years) 150 hr + 4 years = 1.27×10^8 sec	0.000030	0.30	52
Subtotal	0.001238	12.25	261
Total	0.001772	17.53	470

P/Po taken from Region 1.

Case 1 cont

From Ref 1: Surry Power Rating is 2546 MW.

The discharging is 124 fuel assemblies in a given time. This is $124/157 \equiv \underline{0.790}$ parts of the core.

since the Table I is based on 1/3 core the equation for Table II is to be modified as follow:

(3) $MBtu/hr = 2546 \times P/P_o \times 3.4127 \times 0.79 \times 3$

TABLE II HEAT DECAY - SURRY

SURRY STATION	P/P_o	MBtu/hr	Quantity of locations
0.79 core; 2 years = 6.31×10^7 sec	0.000049	1.01	124
0.79 core; 3 years = 9.46×10^7 sec	0.000035	0.72	124
0.79 core; 4 years = 1.26×10^8	0.000030	0.62	124
0.79 core; 5 years = 1.57×10^8	0.000027	0.56	124
TOTAL	0.000141	2.91	496

Summary:

Total Heat = 17.53 + 2.91 = 20.44 MBtu/hr

Total locations 470 + 496 = 966 sites

5. CASE 2

The pace of discharging fuel assemblies is the same as for Case 1.

Additional storage locations

1748 − 966 = 782 sites.

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SUBJECT/TITLE: FUEL POOL DECAY HEAT LOAD

QA CATEGORY / CODE CLASS:

CASE 2 (cont.)

NORTH ANNA UNITS 1 & 2

TABLE III - HEAT DECAY N.A #1

UNIT #1	P/Po	MBtu/hr	Quant. of locations
subtotal from Table I (unit #1)	0.000534	5.28	209
1/3 core (3 yr oper) 150 hr + 45 days + 4 years = 1.30×10^8 sec	0.000030	0.30	52
1/3 core (3 yr) 150 hr + 45 days + 5 yr = 1.61×10^8 sec	0.000027	0.27	52
1/3 core (3 yr) 150 hr + 45 day + 6 year = 1.94×10^8 sec	0.000026	0.26	52
1/3 core (3 yr) 150 hr + 45 days + 7 years = 2.25×10^8 sec	0.0000245	0.24	52
1/3 core (3 yr) 150 hr + 45 days + 8 yr = 2.57×10^8 sec	0.0000235	0.232	52
1/3 core (3 yr) 150 hr + 45 days + 9 yr = 2.88×10^8 sec	0.0000232	0.23	53
1/3 core (3 yr) 150 hr + 45 days + 10 years = 3.20×10^8 sec	0.000023	0.228	52
1/3 core (3 yr) 150 hr + 45 days + 11 yr = 3.51×10^8 sec	0.000022	0.218	52
TOTAL UNIT #1	[illegible]332	7.26	626

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SUBJECT/TITLE: FUEL POOL DECAY HEAT LOAD

QA CATEGO. | CODE CLASS

CASE 2 (cont)

TABLE IV N.A. #2

UNIT #2	P/P₀	MBtu/hr	Quantity of Locations
subtotal from Table I	0.001238	12.24	261
1/3 core (3yr) 150 hr + 5yr = 1.58×10^8 sec	0.0000275	0.27	52
1/3 core (3yr) 150 hr + 6 yr = 1.90×10^8 sec	0.000026	0.26	52
1/3 core (3yr) 150 hr + 7yr = 2.21×10^8 sec	0.0000245	0.24	52
1/3 core (3yr) 150 hr + 8 yr = 2.53×10^8	0.0000238	0.235	52
1/3 core (3yr) 150 hr + 9yr = 2.84×10^8 sec	0.0000233	0.23	52
1/3 core (3yr) 150 hr + 10 yrs = 3.16×10^8 sec	0.0000225	0.222	52
1/3 core (3yr) 150 hr + 11 yrs 3.47×10^8 sec	0.0000218	0.216	53
TOTAL UNIT #2	0.001407	13.91	626

Summary:

Total MBtu/hr for Units #1 & 2

N. ANNA: 7.26 + 13.91 = 21.17 MBtu/hr

Surry = 2.91 -11-

TOTAL 24.08 MBtu/hr

Total locations = 626 + 626 + 496 = 1748

6. CASE 3

Same as case 1 except last refueling is a full core discharge. (Assume for Unit #2). From Ref 1 for a full core discharge, the fuel is to be transfered to the pool at a rate of 20 min. per assembly, starting 150 hrs after shutdown.

TRANSFER OF ONE FULL CORE TO THE POOL

Time to move Fuel into Pool:

⑦ $$(1\text{ core})(157\text{ assemblies/core})\left(\frac{20\text{ minutes}}{\text{assembly}}\right)$$

$$= 3140\text{ minutes} = 188{,}400\text{ sec}$$

$$= 52.33\text{ hrs} = 2.18\text{ days}.$$

Equation ⑦ is a result of a conservative assumption that the full core is moved into the Fuel Pit at a rate of 20 minutes is given per assembly.

The Decay Heat of a full core discharge is a function of P/Po Region 1, 2 & 3. and the equation ② is modified:

⑧ $$\text{MBtu/hr} = 2900 \times 3.4127\left[(P/P_0)_{Reg1} + (P/P_0)_{Reg2} + (P/P_0)_{Reg3}\right]$$

see Graph on page 23.

CALCULATION SHEET

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L. Stempel 5/12/82	Peter A. Ziakas 5/14/82	Peter A. Ziakas 5/14/82

SUBJECT/TITLE: FUEL POOL DECAY HEAT LOAD

QA CATEGORY/CODE CLASS

CASE 3 (cont)

TABLE V - HEAT DECAY N. ANNA

UNIT # 1	P/P₀	MBtu/hr	Quantity of Locations
From Case 1 page 6 Subtotal	0.000534	5.28	209
Unit # 2			
1 full core (3 yrs) 150 hrs + 20 min/ass'y = 7.28×10^5 sec	0.00094 (1) 0.00092 (2) 0.00083 (3) 0.00269	26.62	157
1/3 core (3 yrs) 150 hrs + 1 yr = 3.21×10^7 sec	0.000095	0.94	52
1/3 core (3 yrs) 150 hrs + 2 yrs = 6.36×10^7 sec	0.000049	0.48	52
Subtotal	0.002834	28.04	261
Total	0.003368	33.32	470

Note:

Footnotes (1), (2), (3) correspond to Region 1, 2, 3

Case 3 (cont)

Total Heat for Units 1 & 2 North Anna

summary. 5.28 + 28.04 = 33.32 MBtu/hr

Surry	2.91	-"-
Total Heat	36.23	MBtu/hr

Total locations 470 + 496 = 966 assemblies.

Note: 1 full core Heat: MBtu/hr = equation ⑥

Basic Transfer time of a core = eq. ⑦

7) CASE 4

same as case 2 except last refueling is a full core discharge.
see Case 3 for assumptions and equation for discharge time determination.

TABLE VI HEAT DECAY - NORTH ANNA #1

UNIT #1	P/Po	MBtu/hr	QUANT. of LOCATIONS
Same as case 2 See Table III, pg 9			
Total Unit #1	0.0007332	7.26	626

Case 4 (cont.)

TABLE VII NORTH ANNA #2

Unit #2	P/Po	MBtu/hr	Quant. of locations
1 full core (3 years) 150 hrs + 20 min/ass'y = 7.28×10^5 sec	see Table V → 0.00269	26.62	157
1/3 core (3 yr) 150 hr + 1 yr = 3.21×10^7 sec	0.000095	0.94	52
1/3 core (3 yr) 150 hr + 2 yr = 6.36×10^7 sec	0.000049	0.48	52
1/3 core (3 yr) 150 hr + 3 yr = 9.51×10^7 sec	0.000035	0.35	52
1/3 core (3 yr) 150 hr + 4 yrs = 1.27×10^8 sec	0.000030	0.30	52
1/3 core (3 yr) 150 hr + 5 yrs = 1.58×10^8 sec	0.0000275	0.27	52
1/3 core (3 yr) 150 hr + 6 yrs = 1.90×10^8 sec	0.000026	0.26	52
1/3 core (3 yr) 150 hr + 7 yrs = 2.21×10^8 sec	0.0000245	0.24	52
1/3 core (3 yr) 150 hr + 8 yrs = 2.53×10^8 sec	0.0000238	0.23	52.
1/3 core (3 yr) 150 hr + 9 yrs = 2.84×10^8 sec	0.0000233	0.229	53
TOTAL - UNIT #2	0.00302	29.91	626

Summary: Total Heat for Units 1 & 2

North Anna: 7.26 + 29.91 = 37.17 MBtu/hr

Surry 2.91

Total 40.08 MBtu/hr

Locations: 626 × 2 + 496 = 1748

CALCULATION SHEET

A5010 61

STONE & WEBSTER ENGINEERING CORPORATION

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PREPARER/DATE	REVIEWER/CHECKER/DATE	INDEPENDENT REVIEWER/DATE
L. Stempel 5/12/82	Peter O. Zisko 5/24/82	Peter O. Zisko 5/24/82

SUBJECT/TITLE	QA CATEGORY/CODE CLASS
FUEL POOL DECAY HEAT LOAD	

8) CASE 5

Same as Case 2 with no Surry assemblies.

Approach:

Fill the Pool with North Anna Unit 1 & 2 496 assemblies. Use equation ⑤ for Decay Heat calculation.

TABLE VIII - HEAT DECAY

Unit #1.	P/Po	MBtu/hr	Quantity of locations
From Summary of Case 2	0.0007332	7.26	626
1/3 core (3 yr) 150 hr + 45 days + 12 yrs = 3.83x10⁸ sec	0.0000217	0.214	53
1/3 core (3 yr) 150 hr + 45 days + 13 yrs = 4.14x10⁸ sec	0.0000213	0.211	52
1/3 core (3 yr) 150 hr + 45 days + 14 yrs = 4.46x10⁸ sec	0.0000210	0.208	53
1/3 core (3 yr) 150 hr + 45 days + 15 yrs = 4.77x10⁸ sec	0.0000205	0.202	52
0.24 core (3 yr) 150 hr + 45 days + 16 yrs = 5.09x10⁸ sec	0.0000202	0.144	38
Total - Unit #1	0.0008379	8.24	874

For 0.24 core modified equation ③:

⑨ $MBtu/hr = 2900 \times P/P_o \times 3.4127 \times 0.24 \times 3$

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PREPARER/DATE	REVIEWER/CHECKER/DATE	INDEPENDENT REVIEWER/DATE
L. Stempel 5/12/82	Peter G Ziskon 5/24/82	Peter G Ziskon 5/24/82

SUBJECT/TITLE: FUEL POOL DECAY HEAT LOAD

QA CATEGORY/CODE CLASS:

Case 5 (cont)

TABLE IX (cont)

Unit # 2	P/Po	MBtu/hr	Quantity of locations
From Summary of Case 2	0.001407	13.91	626
1/3 core (3yr) 150 hrs + 12 years = 3.78×10^8 sec	0.000022	0.218	53
1/3 core (3yr) 150 hrs + 13 yrs = 4.10×10^8 sec	0.0000214	0.212	52
1/3 core (3yr) 150 hrs + 14 yrs = 4.42×10^8 sec	0.0000212	0.210	52
1/3 core (3yr) 150 hrs + 15 yrs = 4.74×10^8 sec	0.0000207	0.205	53
0.24 core (3yr) 150 hrs + 16 yrs = 5.05×10^8 sec	0.0000203	0.145	38
Total	0.01513	14.90	874

Summary:

Total Heat for Units 1 & 2

8.24 + 14.90 = 23.14 MBtu/hr

Total locations = 874 + 874 = 1748

Note: For 0.24 core used eq. (9), page 16

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CALCULATION SHEET

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PREPARER/DATE	REVIEWER/CHECKER/DATE	INDEPENDENT REVIEWER/DATE
L. Stempel 5/12/82	Peter A Ziaks 5/24/82	Peter A Ziaks 5/24/82

SUBJECT/TITLE	QA CATEGORY/CODE CLASS
FUEL POOL DECAY HEAT LOAD	

9. CASE 6

same as Case 4 but North Anna assemblies only.

Approach.

496 assemblies from Surry divided equal for N. Anna Unit #1 and 2.

Each Unit will have 626 + 496/2 = 874 assemblies.

Used equation ② for Heat Load calculation.

Utilized Tables VI and VII from Case 4 and recalculated the 496 units from Surry.

For 0.24 core used equation ③, page 17

Case 6 (cont).

TABLE X - HEAT DECAY N.ANNA. #1

Unit #1	P/P₀	MBtu/hr	Quant. of Locations
Total from Table VI, pg.14	0.0007332	7.26	626
1/3 core (3yr) 150hr + 45 days + 12yrs = 3.83×10^8 sec	0.0000217	0.215	53
1/3 core (3yr) 150hr + 45 days + 13 yrs = 4.14×10^8 sec	0.0000213	0.211	52
1/3 core (3yr) 150hr + 45 days + 14 yrs = 4.46×10^8 sec	0.0000210	0.208	53
1/3 core (3yr) 150hr + 45 days + 15 yrs = 4.77×10^8 sec	0.0000208	0.206	52
0.24 core (3yr) 150hr + 45 days + 16 yr - 5.09×10^8 sec	0.0000201	0.143	38
Total - Unit #1	0.000791	8.24	874

Case 6 (cont)

TABLE XI HEAT DECAY N. ANNA #2

Unit #2	P/Po	MBtu/hr	Quant. of Locations
Total from Table VII	0.00302	29.91	626
1/3 core (3 yr) 150 hrs + 10 yrs = 3.16 x 10^8 sec	0.0000225	0.223	53
1/3 core (3 yr) 150 hrs + 11 yrs = 3.47 x 10^8 sec	0.0000218	0.216	52
1/3 core (3 yrs) 150 hrs + 12 yrs = 3.78 x 10^8 sec	0.0000216	0.214	52
1/3 core (3 yrs) 150 hr + 13 yrs = 4.10 x 10^8 sec	0.0000214	0.212	53
0.24 core (3 yrs) 150 hr + 14 yrs = 4.42 x 10^8 sec	0.0000212	0.151	38
Total	0.00313	30.93	874

Summary:

Total Heat for N. A. Units 1 & 2

8.24 + 30.93 = 39.17 MBtu/hr

Total locations = 874 + 874 = 1748 sites

CALCULATION SHEET A5010.61

STONE & WEBSTER ENGINEERING CORPORATION

J.O./W.O./CALCULATION NO.	REVISION	PAGE
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PREPARER/DATE	REVIEWER/CHECKER/DATE	INDEPENDENT REVIEWER/DATE
L. Stempel 5/12/82	Peter A. Ziakas 5/24/82	Peter A. Ziakas 5/21/82

SUBJECT/TITLE: FUEL POOL DECAY HEAT LOAD

QA CATEGORY / CODE CLASS:

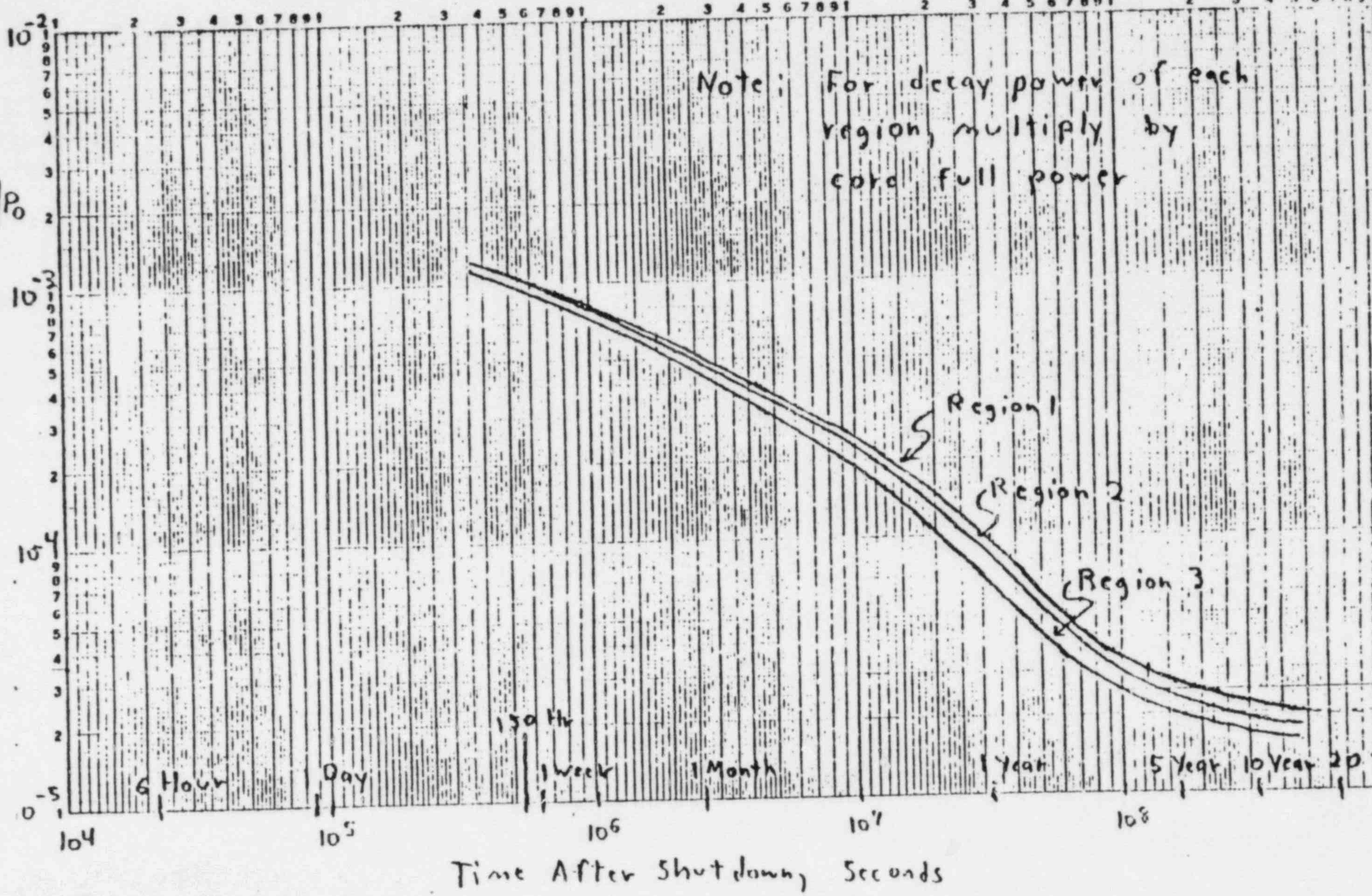
10. TABULATION OF CASES 1 THRU 6

CASE NO.	UNIT NO.	MBtu/hr	LOCATIONS	PAGE
1	N. Anna #1	5.28	209	6
1	↓ 2	12.25	261	6
1	Surry 1 & 2	2.91	496	7
Total		20.44	966	
2	N.A. #1	7.26	626	9
2	↓ 2	13.91	626	10
2	Surry #1 & 2	2.91	496	7-10
Total		24.08	1743	
3	N.A. #1	5.28	209	12
3	↓ 2	28.04	261	12
3	Surry #1 & 2	2.91	496	7-13
Total		36.23	966	
4	N.A. #1	7.26	626	14
4	↓ #2	29.91	626	15
4	Surry #1 & 2	2.91	496	7-15
Total		40.08	1748	
5	N.A. #1	8.24	874	16
5	↓ #2	14.90	874	17
Total		23.14	1748	
6	N.A. #1	8.24	874	19
6	↓ #2	30.93	874	20
Total		39.17	1748	

on Eng. Safeguards Calc. 11715 -5- 144-0 dated 8-24-76

Decay Heat from Uranium Fuel for Core Life of 2.23 years (816 days)

Based on Branch Technical Position APCSB 9-2



13929.26-1

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WES 10-8-76

Vepco

APPENDIX 1

VIRGINIA ELECTRIC AND POWER COMPANY

April 28, 1982
N51-S07-005

13929.26

Mr. C. H. Wilbur
Project Engineer
Stone & Webster Engineering Corporation
P. O. Box 2325
Boston, Massachusetts 02107

Dear Mr. Wilbur:

FUEL POOL DECAY HEAT LOADS
POISON SPENT FUEL RACK PROJECT NP-51.2
NORTH ANNA POWER STATION UNIT NOS. 1 & 2

You are herein authorized to proceed with the calculation of spent fuel pool decay heat loads and pool temperatures and an assessment of the impact on component cooling and service water systems in accordance with the scope of work contained in Attachment I. The estimate for this work, provided in your letter of April 22, 1982 (N51-V01-803), is 220 manhours.

All work associated with this task shall be charged to J. O. No. 13929.26. The current ceiling for this project is 150 manhours. The new ceiling is 370 manhours. The 1982 increment for this task is 220 manhours.

→ The required completion date for this work is May 14, 1982. Please notify us in writing in the event you should anticipate exceeding the new manhour ceiling or be unable to meet the required schedule.

If you have any questions on this matter, please contact the project engineer, Mr. H. S. McKay at (804) 771-6079.

Very truly yours,

Martin L Bowling

A. L. Parrish, III
Manager
Multiple Power Projects

HSM:cbs

Attachment

cc: Mr. G. J. Burroughs, w/attachments

bc:	G. H. Flowers	M. L. Bowling, Jr.	W. T. Davidson
	J. C. Harris, Jr.	J. M. Davis	M. L. Smith
	H. S. McKay	L. A. Taylor	PSE&C Records Management NP-51

ATTACHMENT I

SCOPE OF WORK

For cases 1 through 6 described below calculate the following:

1. Fuel Pool Decay Heat Load

2. Fuel Pool Temperatures for the following Cooling System Lineups.

   a. 1 pump 1 cooler
   b. 1 pump 2 coolers
   c. 2 pumps 2 coolers

3. Assessment of the Impact on Component Cooling Water and Service Water Systems.

ASSUMPTIONS FOR ALL CASES

1. Heat Loads to be calculated using NRC Branch Technical Position 9-2.

2. North Anna - use stretch rating of 2900 MW

3. Surry - use stretch rating of 2546 MW

4. All fuel assumed to be moved to the pool instantaneously 150 hours after shutdown except for full core discharge case when fuel is moved from the reactor core to the fuel pool at a rate of 20 mins. per assembly starting 150 hours after shutdown.

5. Service water temperature at its design max. of 100°F.

TCW 113°F ~.1

CCW = 113.2°F
FSAR section 9.1.3.1

Question B.7:

Verify that no loss of fuel pool integrity or cooling function could occur as the result of a load drop from the maximum lift height above the spent fuel pool and fuel building operating floor during rack handling and installation operations.

Answer:

An analysis has been performed to evaluate potential local damage and overall structural effects to the spent fuel storage pool due to a spent fuel rack drop accident. After the rack is raised to its highest elevation over the spent fuel pool, the rack drops straight down and strikes the pool floor. Two fuel rack drop attitudes have been considered: the rack hitting upright with its axis vertical and the rack hitting on its corner at an angle.

Based on the results of this analysis, the rack drop events could cause minor structural damage to the floor of the spent fuel pool loading area. There will be some local penetration of the floor. However, the overall structural integrity of the spent fuel pool will be maintained. A copy of the report describing the analysis and the results is attached.