CALCULATION TITLE PAGE

ICCN NO./ PRELIM. CCN NO.	PAGE __ OF __
	CCN CONVERSION: CCN NO. CCN-

Calc. No. M-DSC-330 DCP/FIDCN/FCN No. & Rev. ______

Subject THERMAL ANALYSIS OF SPENT FUEL TRANSFER TUBE Sheet 1 of 30

System Number/Primary Station System Designator / FHS SONGS Unit 2&3 Q-Class II

Tech. Spec. Affecting? ☐ NO ☐ YES, Section No. --- Equipment Tag No. ---

CONTROLLED COMPUTER PROGRAM/ DATABASE	☐ PROGRAM ☐ DATABASE ACCORDING TO SO123-XXIV-5.1	PROGRAM/DATABASE NAME(S) ☐ ALSO, LISTED BELOW	VERSION/RELEASE NO.(S)

RECORDS OF ISSUES

REV / DISC	DESCRIPTION	TOTAL SHTS / LAST SHT.	PREPARED (Print name/initial/date)	APPROVED (Signature/date)	
0		30	ORIG. P. VALANDANI 5/17/96	GS 5/28/96	Other
NEDO/ N/M		30	IRE: A. D. Sistos ANGEL SISTOS 5/24/96	DM 05/28/96	Other
			ORIG.	GS	Other
			IRE	DM	Other
			ORIG.	GS	Other
			IRE	DM	Other
			ORIG.	GS	Other
			IRE	DM	Other

Space for RPE Stamp, identify use of an alternate calc., and notes as applicable.

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This calc. was prepared for the identified DCP/FCN. DCP/FCN completion and turnover acceptance to be verified by receipt of a memorandum directing DCN Conversion. Upon receipt, this calc. represents the as-built condition. Memo date ______ by ______

CALCULATION CROSS-INDEX

ICCN NO / PRELIM. CCN NO	PAGE OF

CALCULATION NO. M-DSC-330

Sheet No. 2

CCN CONVERSION:
CCN NO. CCN--

Calc. rev. number and responsible supervisor initials and date	INPUTS: These interfacing calculations and/or documents provide input to the subject calculation, and if revised may require revision of the subject calculation		OUTPUTS: Results and conclusion of the subject calculation are used in these interfacing calculations and/or documents		Does the out-put interface calc/ document require revision?	Identify output interface calc/document CCN, DCN, TCN/Rev. or FIDCN
	Calc/Document No.	Rev. No.	Calc/Document No.	Rev. No.	YES / NO	
	DBD-SO23-TR-PL	0				
ucl 5/24/96	SO23-3-2.11					
	SD-SO23-360	3				
	DRAWINGS:					
	SO23-990-133	2				
	SO23-990-32	0				
	SO23-411-55-129	2				
	SO23-900-C-4-6	10				
	SO23-910-9	0				
	SO23-411-55-166	1				
	23065	14				

NES&L DEPARTMENT

CALCULATION SHEET

ICCN NO./	

CCN CONVERSION

Project or DCP/MMP SONGS 2&3 Calc No. M-DSC-330

Subject THERMAL ANALYSIS OF SPENT FUEL TRANSFER TUBE Sheet No. 3

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	P. VALANDANI	5/13/96	ANGEL SISTOS	5/16/96					

TABLE OF CONTENTS

PAGE

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	P. VALANDANI	5/13/96	ANGEL SISTOS	5/16/96					

1. PURPOSE:

1.1 Background- The San Onofre 2&3 FSAR Section 9.1 (Fuel Storage and Handling) contains the following statement:

> "The fuel transfer tube is sufficiently large to provide natural circulation cooling for a fuel assembly in the unlikely event that the transfer carriage should become inoperable while in the tube."

This statement implies that natural circulation cooling can be provided for only one fuel assembly, even though the transfer carriage is designed to hold two fuel assemblies. In the past, occasionally two spent fuel assemblies have been transferred simultaneously through the transfer tube. This practice has been prohibited since the discovery of the above statement in the FSAR, pending the resolution of this issue.

It is the purpose of this analysis to investigate the consequences of the transfer carriage becoming inoperable while carrying two fuel assemblies in the transfer tube, and to show that there will be no boiling and no fuel damage as a result of such an event. Should the repair of the transfer carriage system involve physical access to the transfer tube, it will be done at a much lower pool temperature and at a later time when the decay heat rate is further reduced, leading to more favorable conditions than the ones considered in this analysis.

NES&L DEPARTMENT

CALCULATION SHEET

ICCN NO. /	

CCN CONVERSION

Project or DCP/MMP SONGS 2&3 Calc No. M-DSC-330

Subject THERMAL ANALYSIS OF SPENT FUEL TRANSFER TUBE Sheet No. 5

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	P. VALANDANI	5/13/96	ANGEL SISTOS	5/16/96					

2. RESULTS/CONCLUSIONS:

The results of this analysis show that from a heat transfer point of view, the stoppage of two fuel assemblies in the transfer tube poses no danger of boiling of the water or excessive heating of the fuel rods. Using conservative values of decay heat and a minimum time between reactor shut-down and fuel off-load of only 72 hours, the maximum calculated bulk water temperature in the tube is 180 F, at least 30 degrees below the boiling point at atmospheric pressure, and more than 60 degrees below the local saturation temperature. The maximum fuel rod surface temperature is 185 F, which again rules out any boiling on the surface of the fuel rods. The maximum calculated fuel temperature is only 187 F.

The conclusion of this analysis is that from a heat transfer point of view, the simultaneous transfer of two fuel assemblies did not pose any danger of boiling or excessive fuel temperature.

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	P. VALANDANI	5/13/96	ANGEL SISTOS	5/16/96					

3. ASSUMPTIONS:

1. The decay heat rate remains constant at the value corresponding to the time of off-load (no credit taken for the exponential decay thereafter).

2. The spent fuel pool and the reactor side pool are maintained at 160, which is the maximum pool temperature.

3. The 2" diameter holes (193 total) drilled in the upper and lower cavities of the fuel carrier provide sufficient flow area for the cooling water, to avoid hot pockets. Results of the analysis show (see Tables 1 and 2) the required flow area to be less than 0.1 ft^2 compared with 1 ft^2 area of fifty 2" diameter holes.

4. The minimum time between reactor shut-down and fuel off-load is 150 hours. A conservative value of 72 hours will also be evaluated.

5. Heat transfer from the fuel rods to the water is assumed to be by natural convection only. The axial motion of the water in the transfer tube, and its effect on the rate of heat transfer is ignored, for conservatism.

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	P. VALANDANI	5/13/96	ANGEL SISTOS	5/16/96					

4. DESIGN INPUT:

1. The fuel transfer tube has an inside diameter of 35.5" and a length of 44' -8" (see Fig. 1). The centerline of the tube is at the elevation 28' 6" and the low water level in the pool is at 60'-8" elevation (Ref. 4).

2. The fuel carrier assembly consists of an upper cavity and a lower cavity, each with a cross-sectional open area of 9"x9" and a length of 15'-9 7/8" (Ref. 11)(see Fig. 2). The fuel bundle has a cross-sectional area of 8"x8" (Ref. 6), which leaves a half inch space on each side and a one inch space at the top. A large number of 2" diameter holes in the upper and lower cavities allows the cooling water to reach the fuel bundles. The lower cavity has 48 holes on the bottom surface, 16 holes on the sides, 32 holes on the top, and 4 holes at the end, for a total of 100 holes (Ref. 13). The upper cavity has 40 holes on the bottom surface, 24 holes on the sides, 25 holes on the top, and 4 holes at the end, for a total of 93 holes (Ref. 14).

3. Fuel assemblies consist of a 16x16 array of fuel rods with approximate outside dimensions of 8"x8"x177" (Ref. 6). Each assembly consists of about 1,054 pounds of UO2, 300 pounds of Zircalloy and the remainder (78 pounds) stainless steel (Ref. 3). There are 236 fuel rods (maximum) in each assembly (Ref. 1).

4. Fuel rods consist of UO2 pellets in a Zr4 tube. The inside diameter of the tube is 0.332" and the outside diameter is 0.382" (Ref. 7). The active length of the rods is approximately 150" (Ref. 7) (see Fig. 3).

NES&L DEPARTMENT

CALCULATION SHEET

ICCN NO./	

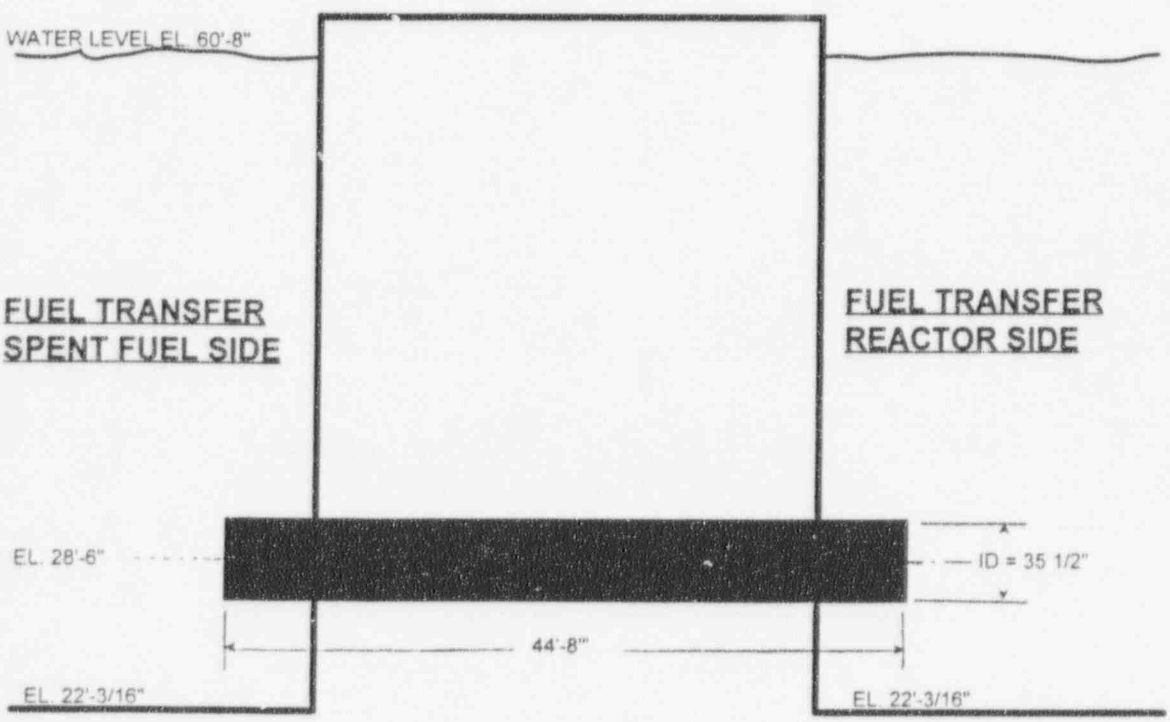
CCN CONVERSION

Project or DCP/MMP SONGS 2&3 Calc No. M-DSC-330

Subject THERMAL ANALYSIS OF SPENT FUEL TRANSFER TUBE Sheet No. 8

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	P. VALANDANI	5/13/96	ANGEL SISTOS	5/16/96					

FIG. 1- SPENT FUEL TRANSFER TUBE SCHEMATIC



NES&L DEPARTMENT

CALCULATION SHEET

ICCN NO./	

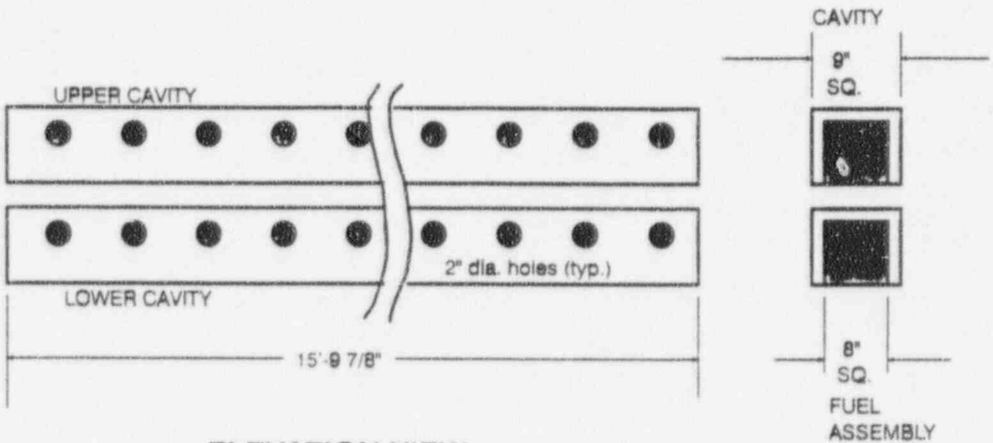
CCN CONVERSION

Project or DCP/MMP SONGS 2&3 Calc No. M-DSC-330

Subject THERMAL ANALYSIS OF SPENT FUEL TRANSFER TUBE Sheet No. 9

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	P. VALANDANI	5/13/96	ANGEL SISTOS	5/16/96					

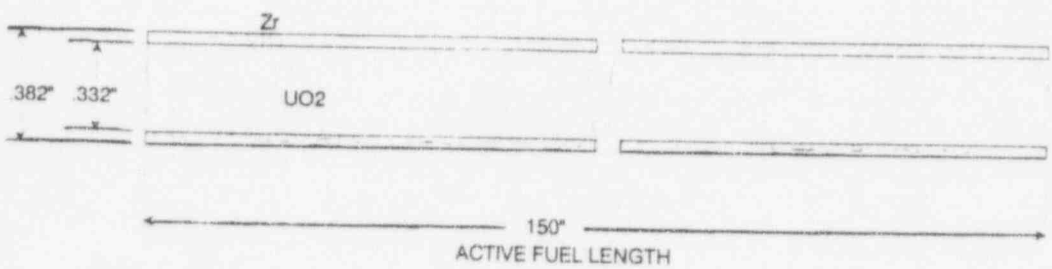
FIG. 2- DIMENSIONS OF FUEL CARRIER ASSEMBLY



ELEVATION VIEW

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	P. VALANDANI	5/13/96	ANGEL SISTOS	5/16/96					

FIG. 3- FUEL ROD DIMENSIONS



REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	P. VALANDANI	5/13/96	ANGEL SISTOS	5/16/96					

5. The maximum pool temperature is 160 F (Ref. 1, sect. 9.1.3.1)).

6. The density of UO2 pellets is 10.38 g/cu. cm (647 lb/cu. ft) (Ref. 1, p 4.2-47), their specific heat is 0.056 Btu/lb-F (Ref. 19), and their thermal conductivity is 4 Btu/hr/ft/F at 300 F(Ref. 19).

7. Thermal properties of Zr4 are (Ref. 19, p 29-15):

   Density = 412 lb/cu.ft

   Thermal conductivity = 8.4 Btu/hr/ft/F

   Specific heat = .[illegible]3 Btu/lb/F

8. The decay heat per fuel assembly is given in Ref. 2 as:

   2.29E05 Btu/hr After 72 hours

   1.68E05 Btu/hr After 150 hrs.

   These conservative values are for a fuel assembly that has been continuously irradiated for four (4) effective full power years. Peaking factors are already included in these numbers, since they are based on the maximum local decay heat rates. The values for 72 hours are included and analyzed even though SONGS 2/3 have never begun core off-load in less than 150 hours from reactor shutdown (Ref. 17).

5. METHODOLOGY:

The analysis consists of two parts:

- o A global analysis to determine the steady-state water temperature in the transfer tube, assuming a constant decay heat rate.
- o A detailed heat transfer analysis of a single fuel rod to determine the maximum temperature at the surface and on the centerline.

5.1- Global Analysis:

For a given decay heat rate (Q" per assembly), the steady state temperature in the transfer tube is calculated from the energy balance equation, assuming two fuel assemblies:

$$2Q'' = m\,C_p(T - T_p) \qquad (1)$$

where:

Q'' = Decay heat rate per assembly

m = Mass flow-rate of cooling water by natural circulation

C_p = Specific heat of water

T = Steady-state water temperature in the tube (at the top)

T_p = Pool temperature

This equation has two unknowns (m and T) which are interdependent. As the water in the transfer tube is heated, it rises to the top of the tube and moves outward until it reaches

either end of the tube. The warm water then starts to rise to the surface of the pool, forming a column of warm water, similar to the smoke in a chimney. As the warm water leaves the tube (by buoyancy), it is replaced by colder water at the pool temperature (see Fig. 4). The velocity of the water is proportional to the square root of the pressure difference between a column of water at the pool temperature and one at the temperature T (Ref. 16). The height of the column is from the top of the transfer tube to the pool surface:

$$v = C(2\Delta P/\rho)^{1/2} \qquad (2)$$

where:

v = Velocity

ρ = Density of warm water

C = A constant less than one to account for frictional losses.

and:

$$\Delta P = (\rho - \rho_p)gH \qquad (3)$$

where:

ρ_p = Density of pool water at bulk temperature

g = Acceleration of gravity

H = Distance from the top of the transfer tube to the pool surface.

Finally:

$$m = v\rho A \qquad (4)$$

NES&L DEPARTMENT

CALCULATION SHEET

ICCN NO. /	

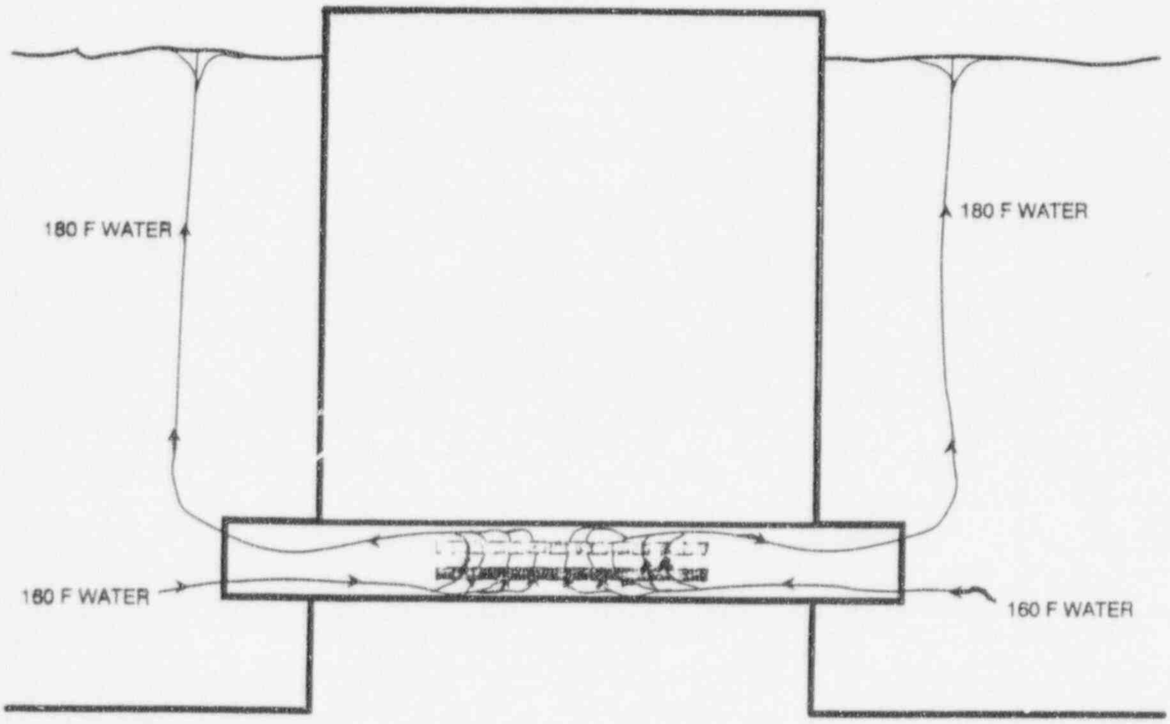
CCN CONVERSION

Project or DCP/MMP SONGS 2&3 Calc No. M-DSC-330

Subject THERMAL ANALYSIS OF SPENT FUEL TRANSFER TUBE Sheet No. 14

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	P. VALANDANI	5/13/96	ANGEL SISTOS	5/16/96					

FIG. 4- NATURAL CIRCULATION PATTERN



where:

m = Mass flow-rate

A = Flow area

The maximum value of A is one half of the cross-sectional area of the tube (hot water moving out through the upper half, and cold water coming in through the lower half of the tube). The actual required flow area is expected to be a small fraction of the available area.

5.2- Analysis of a Single Fuel Rod.

This part of the analysis involves the transfer of heat from the fuel pellets, through the cladding to the surrounding water. Let q" be the rate of decay heat per unit volume of UO2, then:

$$q" = Q"/N/(\pi d^2 L/4) \qquad (5)$$

where:

Q" = Decay heat rate per fuel assembly

N = Number of fuel rods per fuel assembly

d = diameter of fuel pellets

L = Active length of a fuel rod

The temperature distribution in a rod with internal heat generation is (Ref. 18):

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	P. VALANDANI	5/13/96	ANGEL SISTOS	5/16/96					

$$T = T_s + (q''/4k)(r_i^2 - r^2) \quad (6)$$

where:

T = Temperature at a distance r from the centerline of the rod.

T_s = Surface temperature of the rod.

r_i = Inside radius of the cladding.

K = Thermal conductivity of UO2.

The heat generated per unit length of the rod is:

$$q' = q''(\pi d^2/4) \quad (7)$$

this heat rate must be equal to the rate of heat transfer to the water. But the heat must pass through the cladding, therefore, using the combined resistance of the cladding and the surface, we have (Ref. 18):

$$q' = (2\pi r_o)(T_s - T)/(r_o Ln(r_o/r_i)/K' + 1/h) \quad (8)$$

where:

r_o = Outside radius of the cladding.

K' = Thermal conductivity of the cladding.

h = Heat transfer coefficient.

The heat transfer coefficient for free convection involving horizontal tubes can be obtained from (Ref. 18, p. 342):

NES&L DEPARTMENT

CALCULATION SHEET

ICCN NO./	

CCN CONVERSION

Project or DCP/MMP SONGS 2&3 Calc No. M-DSC-330

Subject THERMAL ANALYSIS OF SPENT FUEL TRANSFER TUBE Sheet No. 17

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	P. VALANDANI	5/13/96	ANGEL SISTOS	5/16/96					

$$N_u = 0.53(Gr_d Pr)^{1/4} \qquad (9)$$

where:

N_u = hd/K" = Nusselt number.

Gr_d = Grashoff number.

Pr = Prandtl number.

Using the above 9 equations, it is possible to calculate the following for steady-state conditions:

- o Maximum temperature in the fuel.
- o Surface temperature of the fuel.
- o Maximum water temperature in the transfer tube.
- o Rate of flow due to natural convection.

The problem is ideally suited for a spreadsheet program where various assumptions can be examined and an iterative solution be obtained.

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	P. VALANDANI	5/13/96	ANGEL SISTOS	5/16/96					

6. REFERENCES:

1. UFSAR Section 9.1, "Spent Fuel Storage", Rev. 11, 3/18/96.
2. Letter from R. Y. Chang to B. Conklin, dated August 27, 1991, Subject: "Fuel Assembly Decay Heat, San Onofre Units 2 and 3."
3. DBD-SO23-TR-PL, Rev. 0, Plant -Level Design Bases Document.
4. SO23-3-2.11, Spent Fuel Pool Operations.
5. SD-SO23-360 System Description, Reactor Coolant System.
6. Drawing SO23-990-133-2, Fuel Bundle Assembly.
7. Drawing SO23-990-32-0, Fuel Rod Assembly.
8. Drawing SO23-411-55-129-2, Install: Fuel Transfer Tube Rail Assembly Unit 3 and SO23-411-55-72-3 for Unit 2.
9. Drawing SO23-900-C-4-6, Rev. 10, Reactor Refueling Arrangement.
10. Drawing SO23-910-9, Dimension Outline 16x16 Fuel Bundle 3410 MWT.
11. Drawing SO23-411-55-166-1 Install: Fuel Carrier Assembly.
12. Drawing #23065-14, Containment Structure, Fuel Transfer Assembly.
13. SO23-939-150, Vendor drawing #AD-18895D, Lower Cavity Assembly.
14. SO23-939-148-1, Vendor drawing #AD-24424D, Upper Cavity Assembly.
15. "Handbook of Tables for Applied Engineering Science", The Chemical Rubber Company, 1970.

16. "Standard Handbook of Engineering Calculations", McGraw-Hill Book Co., 1972.

17. Decay Heat Management Practices During Refueling Outage, Doc. No: IN 95-54, Independent Safety Engineering Group Operating Experience Evaluation, March 29, 1996.

18. *Principles of Heat Transfer,* Frank Kreith, International Textbook Company, 1966.

19. *Steam/Its Generation and Use,* Babcock and Wilcox, 1975.

20. *ASME Steam Tables,* fifth edition, 1983.

NES&L DEPARTMENT

CALCULATION SHEET

ICCN NO./	

CCN CONVERSION

Project or DCP/MMP SONGS 2&3 Calc No. M-DSC-330

Subject THERMAL ANALYSIS OF SPENT FUEL TRANSFER TUBE Sheet No. 20

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	P. VALANDANI	5/13/96	ANGEL SISTOS	5/16/96					

7. NOMENCLATURE:

Symbol	Description	Units
A	Flow or heat transfer area	ft^2
C_p	Specific heat at constant P	Btu/lb/F
D	Transfer tube diameter	ft
d	Diameter of fuel pellets	ft
g	Acceleration of gravity	ft/sec^2
g_c	Conversion factor	32.2 lb/slug
Gr_d	Grashoff number	Dimensionless
H	Submergence of top of tube	ft
h	Heat transfer coefficient	Btu/hr/ft^2/F
K	Thermal conductivity of UO2	Btu/hr/ft/F
K'	Thermal conductivity of Zr4	Btu/hr/ft/F
K"	Thermal conductivity of H2O	Btu/hr/ft/F
L	Active length of fuel rod	ft
m	Mass flow rate	lb/hr
Nu	Nusselt number	Dimensionless
Pr	Prandtl number	Dimensionless
Q"	Decay heat rate per assembly	Btu/hr/assembly
q'	Decay heat per unit length	Btu/hr/ft
q"	Decay heat per unit volume	Btu/hr/ft^3
r	Distance fro the centerline of rod	ft
r_i	Inside radius of cladding	ft

Symbol	Description	Units
r_o	Outside radius of cladding	ft
ρ	Density	lb/ft^3
T	Maximum water temperature	F
T_p	Pool temperature	F
T_s	Interface temperature	F
V	Volume	ft^3
v	Velocity	ft/sec

8. CALCULATIONS:

A spreadsheet program was developed to calculate the following for any given maximum water temperature:

- o Water flow rate, and the corresponding flow area as a percentage of the transfer tube cross-sectional area.
- o Maximum temperature at the surface of the fuel rods.
- o Maximum temperature at the interface of UO2 and cladding.
- o Maximum temperature at the centerline of any fuel rod.

The results are shown in Table 1. The input quantities, including properties and design input values are listed at the top of the Table. The first quantity in the table is the number of hours since reactor shut down (150 hour) and the second one is the corresponding heat rate in Btu/hr for two assemblies. The third entry is the assumed maximum water temperature in the tube (180 F). The fourth entry is the delta density between 180 F water and 160 f water, in lb/cu. ft. The fifth entry is the delta p corresponding to a U tube with a height of H = 30.75 ft (distance between the top of the transfer tube and the pool surface), filled with water, with one side at 180 F and the other side at 160 F. This delta P is only 13.069 psf, but it is sufficient to create a velocity of 3.715 ft/sec. To be on the conservative side, we take only one fifth of that (C = .2 in the F column), or 0.743 ft/sec. Based on this

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	P. VALANDANI	5/13/96	ANGEL SISTOS	5/16/96					

A	A	B	C	D	E	F	G	H	I	J	K
1	TABLE 1- SPREAD SHEET CALCULATION OF FUEL, CLADDING AND WATER TEMPERATURES										
2	============										
3					INPUT QUANTITIES						
4					============						
5		WATER				FUEL					
6	============				============					CLADDING	
7	TP =	160	F		CP UO2=	0.056	BTU/LB/F		============		
8	CP H2O=	1	BTU/LB/F		RO UO2=	647	LB/CU.FT		CP ZR4=	0.073	BTU/LB/F
9	RO H2O=	61.01	LB/CU. FT		K UO2=	4	BTU/HR/FT/F		RO ZR4=	412	LB/CU.FT
10	K H2O=	0.39	BTU/HR/FT/F		Q150=	336000	BTU/HR (2 BNDL)		K ZR4=	8.4	B/HR/FT/F
11	H =	30.75	FT		Q72 =	458000	BTU/HR (2 BNDL)		ZR ID=	0.028	FT
12	ID TUBE=	2.96	FT		LACTIVE=	12.47	FT		ZR OD=	0.032	FT
13	LTUBE=	44.60	FT		NRODS=	236	PER				
14	PR =	2.22			Arod=	0.000601	FT^2				
15	GR/DT/d^	8.4E+08			Vfuel=	3.537504	FT^3 2 BUNDLES				
16					Vrod=	0.007495	FT^3				
17											
18	HOURS	Q	T	DRO	DP	C	v	A one side	%TOTAL	TS	TC
19		Btu/hr		lb/ft^3	psf		ft/sec	ft^2		F	F
20	============										
21	150	336000	180	0.425	13.069	0.2	0.743	0.051	0.728	184.1	185.3
22											
23											
24	T	Gr	Nu	h	Tclad						
25	============										
26	180	108647.2	11.7	143.9	184.0						

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	P. VALANDANI	5/13/96	ANGEL SISTOS	5/16/96					

velocity, we calculate a flow area needed to remove all the heat generated by the two fuel assemblies. This calculated flow area is less than 1% of the total flow area of the tube, which shows that only a thin layer of hot water needs to exit the tube and rise to the surface of the pool, in order to have sufficient cooling.

The maximum temperatures at the surface of the fuel rod, at the interface of UO2 and Zr cladding, and the centerline of the fuel are calculated for the worst case, i.e. the top fuel rods that are in contact with water at 180 F. The results are:

Maximum Fuel rod surface temperature = 184.0 F (cell E26)
Maximum interface temperature (UO2 and Zr) =184.1 F (cell j21)
Maximum temperature inside fuel = 185.3 F (cell K21)

The formulas used in this analysis were developed in Section 5 and are also listed in Table 3 for ease of reference.

Following is a step by step calculation of the quantities shown in Table 1:

1. Number of hours = 150 (Assumption, supported by Ref. 17)

2. Q = 2x1.68E05 Btu/hr (Design input)

3. T = 180 F Assumed and later verified.

4. Delta Rho, or change in density, from 180 F to 160 F is (Ref. 20) :

$$1/0.016395 - 1/0.016510 = .425 \text{ lb/ft}^3$$

5. Delta P, The pressure difference is based on the above delta Rho, the acceleration of gravity (32.2 ft/sec^2), and the submergence H = 31.25 ft:

$$\text{Delta P} = .425 * 32.2 * 31.25/32.2 \text{ (lb/slugs)} = 13.3 \text{ psf (or 0.092 psi)}$$

6. The constant C is a measure of the efficiency of the conversion of delta P to velocity A very conservative value of 0.2 (20%) is used. This value only affects the required flow area.

7. The velocity is calculated from the following equation:

$$v = C(2g_c\Delta P/\rho)^{1/2}$$
$$=0.2(2*32.2*13.3/60)^{1/2}$$
$$=0.755 \text{ ft/sec}$$

8. The required flow area (for one side) is obtained from the energy balance equation:

$$Q" = \rho v A C_p(T - T_p)$$
$$A = Q"/\rho v C_p(T - T_p)$$
$$=168000/(60*0.755*3600*1*(180-160)) = 0.0515 \text{ ft}^2$$

9. Percent total available area is:

$$100*A/(\pi D^2/4) = 100*0.0515/(3.14*8.75/4) = 0.71\% \text{ or } <1\%$$

10. The next item is Gr on line 26. Since Gr depends on the temperature difference between the fluid and the surface, it has to be calculated by trial and error. We skip the intermediate steps and start with the final answer which is a surface temperature of 184 F. The value of $Gr/(d^3(\Delta T)) = 8.42E08$ is obtained from Ref. 18 for 182 F, therefore:

$$Gr = 8.42E08*.032*.032*.032*4 = 110{,}360$$

The difference between this number and the number in Table 1 is due to rounding off the numerical value of d.

11. Using the calculated Gr and Pr = 2.22 from Ref. 18, we calculate the Nu:

$$Nu = 0.53*(Gr*Pr)^{1/4}$$
$$= 0.53*(110360*2.22)^{1/4}$$
$$= 11.792$$

12. The heat transfer coefficient is calculated from the definition of Nu:

$$Nu = hd/K"$$

h = Nu*k"/d

h = 11.792*0.39/.032 = 143.7 Btu/hr-ft^2-F

13. Now the surface temperature can be calculated and compared with the assumed value of 184 F. We need the rate of decay heat per unit length of the fuel:

q' = Q"/N/L

q' = 168000/236/12.47 = 57.1 Btu/ft

But: q' = hA(T_C - T) Where A is per unit length (πd).

or T_C = T +q'/hA = 180 + 57.1/(143.7*3.1416*0.032) =183.95 or 184 F

14. Now we can go back to line 21 and calculate the interface temperature between UO2 and Zr4:

T_s = T + q' (r_oLn(r_o/r_i)/K' + 1/h)/πd

= 180 + 57.1(.5*.032Ln(.032/.028)/8.4 + 1/143.7) /(3.1416*.032)

= 184.1 F

15. Finally the temperature at the center of the fuel rod is calculated:

T = T_s + (q"/4k)r_i^2

Where:

q" =q'/ (πd^2 /4) = 57.1/(3.1416*.028*.028/4) = 92732 Btu/hr/ft^3

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
0	P. VALANDANI	5/13/96	ANGEL SISTOS	5/16/96					

T = 184.1 + (S2732/4/4)*.028*.028/4 = 185.24 F

Since these results show a comfortable margin of more than 30 degrees from boiling, it was decided to run a case where the off-load takes place only 72 hours after shutdown (see Table 2). The only difference in this case is the heat load, which is about 30% higher. The results are not significantly different from the standard case. The flow area is about 30% higher (as expected) but still less than 1% of the transfer tube flow area. The calculated temperatures are one or two degrees higher than before, but the margin is still about 30 degrees, and if the saturation temperature corresponding to the local pressure is used, the margin is more than 60 degrees.

The above results correspond to steady-state conditions and show that a small delta T of a few degrees is needed to remove the decay heat. If the fuel assembly is initially at a higher temperature, the heat loss to the water will exceed the decay heat rate, and the fuel assembly will cool off until the steady-state temperature is reached. At that point the rate of decay heat is balanced with the rate of heat removal.

The results show that the system is capable of handling two fuel assemblies simultaneously and to remove the decay heat, without boiling, should the assemblies become stuck in the transfer tube for an extended period of time.

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
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A	A	B	C	D	E	F	G	H	I	J	K
1	TABLE 2- SPREAD SHEET CALCULATION OF FUEL, CLADDING AND WATER TEMPERATURES (72 HOURS)										
2	==										
3	==										
4					INPUT QUANTITIES						
5		WATER			================						
6	===========================				FUEL					CLADDING	
7	TP =	160	F		CP UO2=	0.056	BTU/LB/F		CP ZR4=	0.073	BTU/LB/F
8	CP H2O=	1	BTU/LB/F		RO UO2=	647	LB/CU.FT		RO ZR4=	412	LB/CU.FT
9	RO H2O=	61.01	LB/CU. FT		K UO2=	4	BTU/HR/FT/F		K ZR4=	8.4	B/HR/FT/F
10	K H2O=	0.39	BTU/HR/FT.F		Q150=	336000	BTU/HR (2 BNDL)		ZR ID=	0.028	FT
11	H =	30.75	FT		Q72 =	458000	BTU/HR (2 BNDL)		ZR OD=	0.032	FT
12	ID TUBE=	2.96	FT		LACTIVE=	12.47	FT				
13	LTUBE=	44.60	FT		NRODS=	236	PER				
14	PR =	2.22			Arod=	0.000601	FT^2				
15	GR/DT/d^	8.4E+08			Vfuel=	3.537504	FT^3 2 BUNDLES				
16					Vrod=	0.007495	FT^3				
17											
18	HOURS	Q	T	DRO	DP	C	v	A one side	%TOTAL	TS	TC
19		Btu/hr		lb/ft^3	psf		ft/sec	ft^2		F	F
20	==										
21	72	458000	180	0.425	13.069	0.2	0.743	0.070	0.993	185.3	186.9
22											
23											
24	T	Gr	Nu	h	Tclad						
25	==										
26	180	135809	12.4	152.2	185.1						

NES&L DEPARTMENT

CALCULATION SHEET

ICCN NO./	

CCN CONVERSION

Project or DCP/MMP SONGS 2&3 Calc No. M-DSC-330

Subject THERMAL ANALYSIS OF SPENT FUEL TRANSFER TUBE Sheet No. 30

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE
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Table 3- Formulas used in the Spreadsheet Program

```
A:A21:   150
A:B21:   +F10
A:C21:   180
A:D21:   +0.425*(C21-$B$7)/20
A:E21:   +D21*$B$11
A:F21:   0.2
A:G21:   +F21*@SQRT(2*32.2*E21/$B$9)
A:H21:   +B21/(2*3600*$B$9*G21*$B$8*(C21-$B$7))
A:I21:   +100*H21/(9*3.1416/4)
A:J21:   +C21+(B21*$F$14/$F$15)*(0.5*$J$11*@LN($J$11/$J$10)/$J$9+1/D26)/(3.1416*$J$11)
A:K21:   +J21+(B21/$F$15)*($J$10*$J$10/4)/(4*$F$9)
A:A26:   +C21
A:B26:   +$B$15*$J$11*$J$11*$J$11*4
A:C26:   +0.53*(B26*$B$14)^0.25
A:D26:   +C26*$B$10/$J$11
A:E26:   +A26+($B$21*$F$14/$F$15)/D26/(3.1416*$J$11)
```