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TECHNICAL DATA RECORD

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PAGE 1 OF 6

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TITLE: 1000 Mwe SGR - 90% ThO_2, 10% UO_2 Alternate Fuel - Core Thermal and Hydraulic Analysis

SECURITY CLASSIFICATION

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PROGRAM: Large SGR

SUBACCOUNT TITLE: SGR Design and Evaluation

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STATEMENT OF PROBLEM: Perform a thermal and hydraulic analysis on the 1000 Mwe SGR, substituting 90% ThO_2, 10% UO_2 fuel for the UC fuel of the reference core design (Reference 1).

ABSTRACT: The thermal and hydraulic core parameters have been determined using the SORTD I code for 90% ThO_2, 10% UO_2 fuel both for (1) a core containing 592 fuel elements corresponding to the UC reference core with a maximum UC temperature of 2000°F (Reference 1 case 11 and Reference 4), and (2) a core containing 784 fuel elements corresponding to a UC core with a maximum UC temperature of 1750°F. (Reference 1 case 10) 18 rod elements with 2.5 in.^{2} and 3.5 in.^{2} fuel areas, and 30 rod elements with 4.5 in.^{2} and 5.5 in.^{2} fuel areas are analyzed for a total of 8 cases. Complete results are given in Part IV.

FORM 701-C REV. 10-62

III. Method of Analysis

The method of analysis is described in Reference 1 for the 1000 Mwe UC core SGR. The same fuel and coolant hot channel factors are used for the present oxide core as for the UC core, i.e., $F_{\theta} = 1.14$ and $F_{\Delta T} = 1.04$. However, since there is more uncertainty associated with gas-bonded oxide fuel than with Na-bonded UC fuel, the fuel hot channel factor should be higher for the oxide fuel for the same degree of conservatism. Since the same fuel hot channel factor is used, the present analysis is somewhat less conservative than the previous UC analysis.

As explained in Reference 1, Part II, a ficticious coolant hot channel factor of

$$F_{(\Delta T \text{ code input})} = \frac{F_{(\Delta T \text{ actual})}}{\phi_e}$$

$$= \frac{1.04}{1.111 \ (h = 18 \text{ rods}),\ 1.18 \ (h = 30 \text{ rods})}$$

$$= .93693,\ .88135$$

must be used in the code input for the assumption of uniform bulk coolant temperature.

The value of the equivalent fuel-to-clad gas bond conductance has been found to range from

$$10 \leq h_{bond} \leq 5000 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F} \quad \text{(Reference 7)}$$

The value used in this analysis is $h = 2400$ Btu/hr-ft^2-°F corresponding to a 1/2 mil hot gas gap of conductivity $k_{bond} = 0.1$ Btu/hr-ft-°F.

Mass of (Th + U) per Ft

The properties of the oxides are

	mol. wt. (Ref. 6)	theoretical density, $\frac{gm}{cm^3}$ (Ref. 3)
ThO_2, natural	232.04+32 = 264.04	10.03
UO_2, 90% enriched	235.34+32 = 267.34	$10.9 \left\{\frac{267.34}{238.03+32}\right\} = 10.79$

For 90% ThO_2, 10% UO_2 fuel with an actual to theoretical density ratio of $\rho/\rho_o = .9$, the (Th + U) density (excluding the oxygen) is

$$\rho_{(Th+U)} = .9\left[.9\left(\frac{232.04}{264.04}\right)(10.03) + .1\left(\frac{235.34}{267.34}\right)(10.79)\right]$$

$$= 7.9945 \ \frac{gm\,(Th+U)}{cm^3}$$

$$= .13100 \ \frac{Kg\,(Th+U)}{IN.^3}$$

The mass of (Th + U) per ft is

$$M \cdot 1 = \frac{\pi}{4} D_4^2 (12)\,\rho_{(Th+U)}$$

$$= 3\pi D_4^2 (.13100)$$

$$= 1.235\ D_4^2 \ \frac{Kg\,(Th+U)}{ft}$$

where D_4 is the fuel slug diameter in inches.

Fuel Thermal Conductivity

The average thermal conductivity of 90% ThO_2, 10% UO_2 over the temperature range of interest is about 1.2 times that of UO_2 (Reference 2, Figure 10). UO_2 conductivity is a function of temperature (Reference 5):

$$K_{UO_2} = \frac{30}{10+T}\cdot\frac{\rho}{\rho_o} + 2.55\times10^{-12}\,T^3, \quad \frac{WATT}{cm\text{-}^oK}, \quad T \text{ IN } ^oK$$

$$= \frac{3120}{t+478}\cdot\frac{\rho}{\rho_o} + 25.3\times10^{-12}\,(t+460)^3, \quad \frac{Btu}{hr\text{-}ft\text{-}^oF}, \quad t \text{ IN } ^oF$$

The average UO_2 conductivity is

$$K_{AVG_{UO_2}} = \left\{3120\cdot\frac{\rho}{\rho_o}\ln\frac{t_2+478}{t_1+478} + 6.32\left[\left(\frac{t_2+460}{1000}\right)^4 - \left(\frac{t_1+460}{1000}\right)^4\right]\right\}\div(t_2-t_1)$$

Multiplying by 1.2 to obtain the ThO_2, UO_2 conductivity, and for $\frac{\rho}{\rho_o} = .9$

$$K_{AVG.\ 90\%\,ThO_2,\,10\%\,UO_2} = \left\{3370\ln\frac{t_2+478}{t_1+478} + 7.58\left[\left(\frac{t_2+460}{1000}\right)^4 - \left(\frac{t_1+460}{1000}\right)^4\right]\right\}\div(t_2-t_1)$$

As plotted in Figure 1 for $t_1 = 1000^oF$ and 2000^oF. After estimating the maximum fuel centerline temperature*, t_2, and the corresponding surface temperature, t_1, $k_{avg.}$ for the SORTD I code input can be obtained from Figure 1.

* In Reference 1 the nomenclature is T_{fmax} instead of t_2.

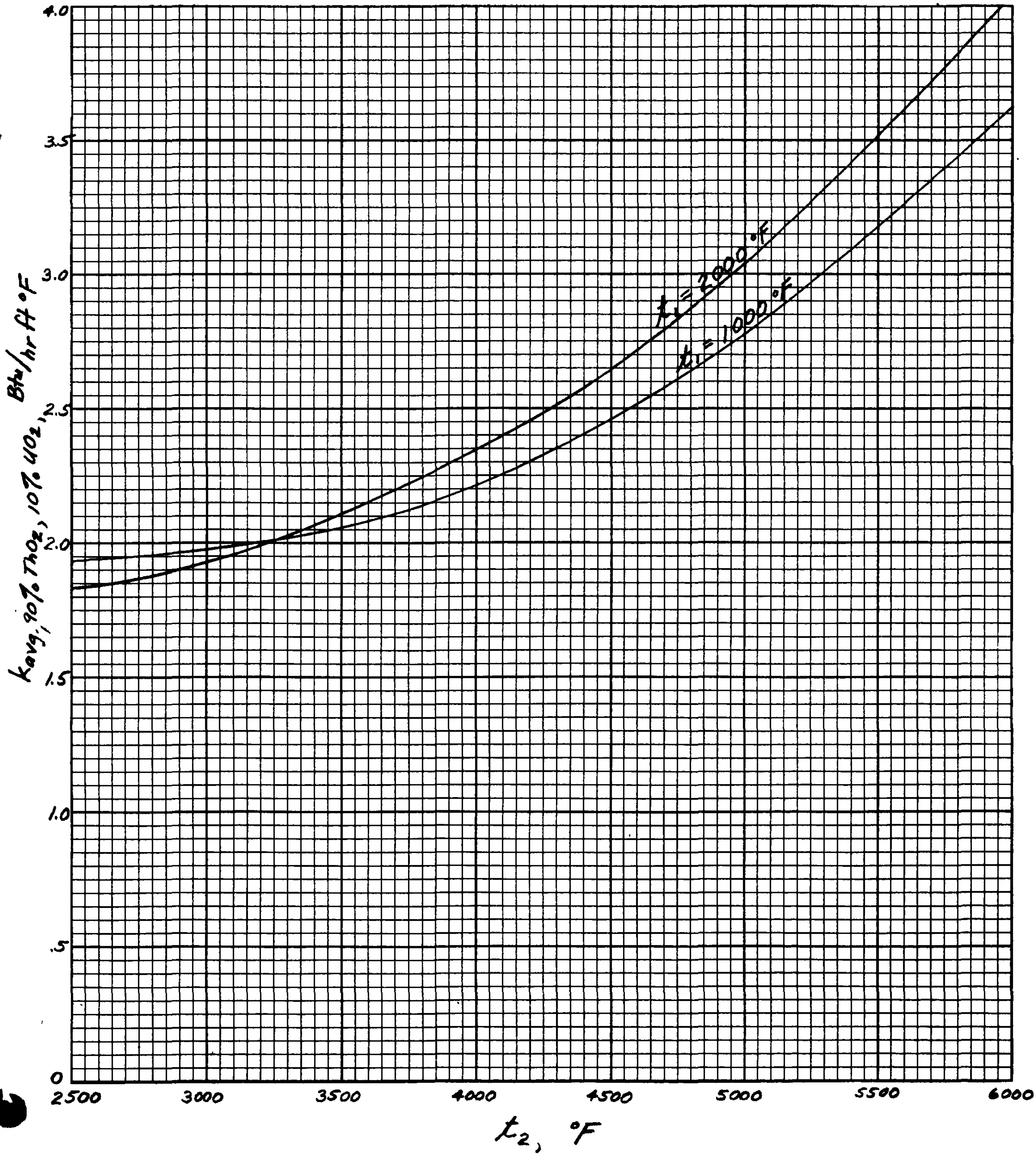

FIG. 1 Average Thermal Conductivity of 90% ThO_2, 10% UO_2
$\rho/\rho_0 = .9$ between temperatures t_1 and t_2

IV. Results

	N = 592 fuel elements				N = 784 fuel elements			
	n = 18 rods		n = 30 rods		n = 18 rods		n = 30 rods	
	fuel area = 2.5 in²	fuel area = 3.5 in²	fuel area = 4.5 in²	fuel area = 5.5 in²	fuel area = 2.5 in²	fuel area = 3.5 in²	fuel area = 4.5 in²	fuel area = 5.5 in²
	case 1	case 2	case 3	case 4	case 5	case 6	case 7	case 8
INPUT DATA								
NUMBER OF ELEMENTS	592.00000000	592.00000000	592.00000000	592.00000000	784.00000000	784.00000000	784.00000000	784.00000000
VELOCITY, FT/SEC	0.	0.	0.	0.	0.	0.	0.	0.
CONDUCTIVITY OF FUEL, BTU/HR-FT-F.	3.08999997	3.00999999	2.36999997	2.33999997	2.59999999	2.56999999	2.11999997	2.11999997
MASS OF FUEL SLUG/FT, KG U/FT.	0.21618000	0.30391999	0.23402999	0.28589000	0.21618000	0.30391999	0.23402999	0.28589000
FRACTION OF HEAT IN MODERATOR.	0.05999999	0.05999999	0.05999999	0.05999999	0.05999999	0.05999999	0.05999999	0.05999999
REACTOR THERMAL POWER, KW.	.23500000E 07	.23500000E 07	.23500000E 07	.23500000E 07	.23500000E 07	.23500000E 07	.23500000E 07	.23500000E 07
CORE TEMPERATURE RISE, F	400.00000000	400.00000000	400.00000000	400.00000000	400.00000000	400.00000000	400.00000000	400.00000000
NUMBER OF FUEL RODS PER ELEMENT.	18.00000000	18.00000000	30.00000000	30.00000000	18.00000000	18.00000000	30.00000000	30.00000000
LENGTH OF CORE, FT	14.00000000	14.00000000	14.00000000	14.00000000	14.00000000	14.00000000	14.00000000	14.00000000
LENGTH/EXTRAPOLATED LENGTH	0.82839999	0.82839999	0.82839999	0.82839999	0.82839999	0.82839999	0.82839999	0.82839999
INLET TEMPERATURE, F	750.00000000	750.00000000	750.00000000	750.00000000	750.00000000	750.00000000	750.00000000	750.00000000
NUMBER OF CONTROL RODS	74.00000000	74.00000000	74.00000000	74.00000000	98.00000000	98.00000000	98.00000000	98.00000000
NUMBER OF SOURCES.	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000
AVERAGE CORE BURNUP, MWD/MTU	40000.000000	40000.000000	40000.000000	40000.000000	40000.000000	40000.000000	40000.000000	40000.000000
PLANT FACTOR	0.80000000	0.80000000	0.80000000	0.80000000	0.80000000	0.80000000	0.80000000	0.80000000
DENSITY OF COOLANT, LB/CUBIC FT.	51.64999962	51.64999962	51.64999962	51.64999962	51.64999962	51.64999962	51.64999962	51.64999962
CONDUCTIVITY OF COOL, BTU/HR-FT-F.	38.39999962	38.39999962	38.39999962	38.39999962	38.39999962	38.39999962	38.39999962	38.39999962
VISCOSITY OF COOLANT, LB/HR-FT	0.54000000	0.54000000	0.54000000	0.54000000	0.54000000	0.54000000	0.54000000	0.54000000
SPECIFIC HEAT OF COOLANT, BTU/LB-F	0.30149999	0.30149999	0.30149999	0.30149999	0.30149999	0.30149999	0.30149999	0.30149999
RADIAL FLUX PEAKING FACTOR	1.50000000	1.50000000	1.50000000	1.50000000	1.50000000	1.50000000	1.50000000	1.50000000
AXIAL FLUX PEAKING FACTOR	1.34999999	1.34999999	1.34999999	1.34999999	1.34999999	1.34999999	1.34999999	1.34999999
ELEMENT PEAKING FACTOR	1.11099999	1.11099999	1.17999999	1.17999999	1.11099999	1.11099999	1.17999999	1.17999999
FUEL HOT CHANNEL FACTOR.	1.13999999	1.13999999	1.13999999	1.13999999	1.13999999	1.13999999	1.13999999	1.13999999
COOLANT HOT CHANNEL FACTOR	0.93692999	0.93692999	0.88135000	0.88135000	0.93692999	0.93692999	0.88135000	0.88135000
PROCESS TUBE ID, INCHES.	4.26999998	4.26999998	4.26999998	4.26999998	4.00000000	4.00000000	4.00000000	4.00000000
CENTRAL TUBE OD, INCHES.	0.50000000	0.50000000	0.50000000	0.50000000	0.50000000	0.50000000	0.50000000	0.50000000
CLAD OD, INCHES.	0.45100000	0.52900000	0.46799999	0.51400000	0.45100000	0.52900000	0.46799999	0.51400000
FUEL DIAMETER, INCHES.	0.41999999	0.49800000	0.43700000	0.48300000	0.41999999	0.49800000	0.43700000	0.48300000
CLAD ID, INCHES.	0.42100000	0.49900000	0.43799999	0.48400000	0.42100000	0.49900000	0.43799999	0.48400000
ELEMENT PITCH, INCHES.	10.25000000	10.25000000	10.25000000	10.25000000	10.25000000	10.25000000	10.25000000	10.25000000
PITCH WEIGHTING FACTOR	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000
CONDUCTIVITY OF CLAD, BTU/HR-FT-F.	12.69999993	12.69999993	12.69999993	12.69999993	12.69999993	12.69999993	12.69999993	12.69999993
CONDUCTIVITY OF BOND, BTU/HR-FT-F.	0.09999999	0.09999999	0.09999999	0.09999999	0.09999999	0.09999999	0.09999999	0.09999999
FRONTAL AREA, SQUARE INCHES.	0.	0.	0.	0.	0.	0.	0.	0.
ADDED WETTED PERIMETER, INCHES	0.	0.	0.	0.	0.	0.	0.	0.
COMPUTED RESULTS								
CORE POWER, BTU/HR	.80205499E 10	.80205499E 10	.80205499E 10	.80205499E 10	.80205499E 10	.80205499E 10	.80205499E 10	.80205499E 10
CORE FLOW RATE, LB/HR.	.66505390E 08	.66505390E 08	.66505390E 08	.66505390E 08	.66505390E 08	.66505390E 08	.66505390E 08	.66505390E 08
MAXIMUM ELEMENT COOLANT FLOW RATE,LB/SEC	.46808410E 02	.46808410E 02	.46808410E 02	.46808410E 02	.35345126E 02	.35345126E 02	.35345126E 02	.35345126E 02
NUMBER OF ELEMENTS	.59200000E 03	.59200000E 03	.59200000E 03	.59200000E 03	.78400000E 03	.78400000E 03	.78400000E 03	.78400000E 03
VELOCITY OF COOLANT, FT/SEC.	.11601980E 02	.12835078E 02	.14559871E 02	.16521779E 02	.10378850E 02	.11711870E 02	.13668572E 02	.16036008E 02
HEAT TRANSFER COEFFICIENT, BTU/HR-SQ.FT-F.	.49178938E 04	.57888202E 04	.77433083E 04	.91679947E 04	.51413351E 04	.61807989E 04	.85294562E 04	.10447255E 05
OVERALL RESISTANCE PARAMETER, HR-FT-F/BTU.	.23009107E-00	.22641250E-00	.28006021E-00	.27837231E-00	.26431971E-00	.25826700E-00	.30772594E-00	.30293954E-00
BETA - TAN FCN LOC OF FUEL HOT SPOT.	.51874780E-01	.52717599E-01	.66818178E-01	.67223328E-01	.59802706E-01	.61204235E-01	.80533447E-01	.81805864E-01
MAXIMUM LINEAR HEAT RATE, KW/FT.	.33312906E 02	.33312906E 02	.21229107E 02	.21229107E 02	.25154644E 02	.25154644E 02	.16030142E 02	.16030142E 02
MAXIMUM LINEAR HEAT RATE, BTU/HR-FT.	.11369695E 06	.11369695E 06	.72454943E 05	.72454943E 05	.85852798E 05	.85852798E 05	.54710875E 05	.54710875E 05
FLOW AREA, SQ. FT.	.78112663E-01	.70608184E-01	.62243790E-01	.54852539E-01	.65934084E-01	.58429603E-01	.50065211E-01	.42673959E-01
ACTIVE EFFECTIVE CORE DIAMETER, FT	.24892043E 02	.24892043E 02	.24892043E 02	.24892043E 02	.28640328E 02	.28640328E 02	.28640328E 02	.28640328E 02
HYDRAULIC DIAMETER, FT	.92603467E-01	.75483730E-01	.50559010E-01	.41509905E-01	.79838207E-01	.63666987E-01	.41258900E-01	.32731426E-01
SURFACE AREA OF OUTSIDE CLAD, SQ.FT./FT.	.11807153E-00	.13849188E-00	.12252212E-00	.13456489E-00	.11807153E-00	.13849188E-00	.12252212E-00	.13456489E-00
TOTAL WETTED PERIMETER, FT	.33740707E 01	.37416371E 01	.49244468E 01	.52857301E 01	.33033849E 01	.36709514E 01	.48537610E 01	.52150442E 01
VOLUME OF FUEL, CUBIC INCHES	.24802302E 06	.34870011E 06	.44751235E 06	.54668406E 06	.32846291E 06	.46179204E 06	.59265149E 06	.72398699E 06
CORE LOADING, KG. U+Th.	.32250596E 05	.45340000E 05	.58189218E 05	.71083687E 05	.42710249E 05	.60044865E 05	.77061397E 05	.94137857E 05
AVERAGE CORE SPECIFIC POWER, KW/KG.U+Th.	.72866869E 02	.51830612E 02	.40385488E 02	.33059624E 02	.55021921E 02	.39137401E 02	.30495164E 02	.24963389E 02
AVERAGE CORE POWER DENSITY, KW/CUBIC FT.	.34492824E 03	.34492824E 03	.34492824E 03	.34492824E 03	.26055168E 03	.26055168E 03	.26055168E 03	.26055168E 03
AVERAGE FUEL POWER DENSITY, KW/CUBIC IN.	.94749269E 01	.67393151E 01	.52512516E 01	.42986435E 01	.71545366E 01	.50888705E 01	.39652308E 01	.32459146E 01
FUEL IN-CORE RESIDENCE TIME, YEARS	.18799531E 01	.26429612E 01	.33919684E 01	.41436134E 01	.24896677E 01	.35001379E 01	.44920662E 01	.54874880E 01
MAX. NOMINAL ELEMENT CHANNEL POWER, KW	.59543918E 04	.59543918E 04	.59543918E 04	.59543918E 04	.44961734E 04	.44961734E 04	.44961734E 04	.44961734E 04
MAX. NOMINAL HEAT FLUX, BTU/HR-SQ.FT	.96294971E 06	.82096467E 06	.59136211E 06	.53843865E 06	.72712529E 06	.61991210E 06	.44653873E 06	.40657613E 06
AVERAGE FUEL ROD HEAT FLUX, BTU/HR-SQ.FT	.42802045E 06	.36490969E 06	.24748362E 06	.22533528E 06	.32319912E 06	.27554405E 06	.18687539E 06	.17015113E 06
HC Fuel Temperature, °F	5127.38	5060.91	4194.73	4175.31	4576.28	4493.72	3646.20	3604.66
Core Pressure Drop, psi	11.8	14.9	21.4	31.9	10.9	14.3	23.7	36.9

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