6-22-73

99 cyp

UC-80

197

AI-AEC-13076, VOL I

Distr in
@-92

22,184

SELECTED COMPUTER CODES AND LIBRARIES
VOLUME I. ZIP
A TIMESHARE PROGRAM
FOR
SNAP REACTOR PARAMETRIC STUDIES

AEC Research and Development Report

Atomics International Division
Rockwell International

P.O. Box 309
Canoga Park, California 91304

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151
Price: Printed Copy \$3.00; Microfiche \$0.95

SELECTED COMPUTER CODES AND LIBRARIES

VOLUME I. ZIP

A TIMESHARE PROGRAM

FOR

SNAP REACTOR PARAMETRIC STUDIES

H. ROOD

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Atomics International Division
Rockwell International

P O Box 309
Canoga Park, California 91304

CONTRACT: AT(04-3)-701
ISSUED: JUNE 21, 1973

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISTRIBUTION

This report has been distributed according to the category "Systems for Nuclear Auxiliary Power (SNAP) Reactor – SNAP Program," as given in the Standard Distribution for Classified Scientific and Technical Reports, M-3679.

THIS IS VOLUME I OF A SERIES:
SELECTED COMPUTER CODES AND LIBRARIES

✓ VOLUME I.	ZIP – A TIMESHAPE PROGRAM FOR SNAP REACTOR PARAMETRIC STUDIES	H. Rood
VOLUME II.	APC – A MULTIGROUP TRANSPORT BUCKLING ITERATION CODE	D. S. Bost
VOLUME III.	COMPOZ – A MULTIGROUP TRANSPORT PERTURBATION CODE	V. S. Lekach
VOLUME IV.	A 28-GROUP CROSS SECTION LIBRARY FOR SNAP REACTOR ANALYSIS	J. M. Otter
VOLUME V.	TEMPO – A HEAT TRANSFER-LIFETIME CODE FOR SNAP REACTOR ANALYSIS	L. D. Felten E. Moody

BLANK

CONTENTS

	Page
Abstract	6
I. Introduction	7
II. Program Logic	9
III. The Thermal-Hydraulic Model, Overlay THERMO	13
A. Calculation of Temperature	13
B. Fuel Swelling Model	13
C. Search for N_H Resulting in All δ -Phase Fuel	14
D. Hydrogen Leakage Calculation	15
E. Check for β -Phase Fuel	16
IV. The Nuclear Model, Overlay FIZIKS	17
A. Available Reactivity	17
B. Control System Worth	19
C. Reactivity Requirements	19
D. Reactor Weight Calculation	21
E. Shield Thicknesses and Weights	21
V. Description of Input Files	25
VI. Sample Problem	31
VII. Listing of Program	37
References	66

FIGURES

1. ZIP Flow Chart	10
2. THERMO Flow Chart	11
3. 5-kwe Reactor — Reactor/Shield System	23

ABSTRACT

ZIP is a FORTRAN program written for the Honeywell 440 timeshare computer. It is a parametric survey code which applies specifically to SNAP-type nuclear reactors; i.e., compact U-ZrH-fueled, beryllium-reflected, NaK-cooled reactors. As input, the code requires information about the mission requirements (power level, operating lifetime, coolant outlet temperature, etc.) and sufficient dimensional information to describe the reactor (fuel length, cladding thickness, reflector thickness, etc.). Then, using simple equations fit to results obtained using more complex codes, ZIP determines all the significant nuclear and thermal performance characteristics of the reactor. Also included is a shield thickness calculation, and a calculation of the reactor and shield weights.

I. INTRODUCTION

ZIP is a timeshare code designed to perform parametric surveys on shadow-shielded SNAP-type reactors. It specifically applies to systems fueled with ZrH_x -uranium alloy, clad with Incoloy 800, Hastelloy N, or Hastelloy X, cooled with NaK, and radially reflected by beryllium. The shield calculation assumes a tungsten alloy gamma shield immediately below the reactor, and a LiH neutron shield below the gamma shield. In the present form, ZIP is set up for systems, similar to the 5-kwe reactor thermoelectric system,⁽¹⁾ which are controlled by sliding reflector segments.

The equations solved by ZIP are not complex; otherwise it could not be run on the timeshare computer. As an example, the basic nuclear calculation performed by ZIP uses two neutron energy groups. However, the constants used in the ZIP nuclear equations were obtained by performing a least-squares fit to a large number of calculations made with the APC⁽²⁾ neutron transport code and the SNAP 28-group cross section library.⁽³⁾ As a result, the ZIP calculation duplicates the APC results, over a wide range of core sizes and volume fractions, within about \$1 in reactivity. A similar approach was used in the heat transfer area, in which the ZIP equations are based on results obtained with the TEMPRO⁽⁴⁾ code.

Options are available that permit a variety of types of calculations to be performed. If desired, ZIP will search for the fuel element size (lattice pitch) required to give the desired end-of-life (EOL) reactivity margin. In addition, a search can be performed to find the beginning-of-life (BOL) fuel-to-cladding gap that will result in the desired EOL gap margin. Also, ZIP will, if desired, search for the BOL H/Zr ratio which results in all delta-phase fuel in the hot element.

A significant amount of effort was spent in making the ZIP calculation rapid. Through extensive use of overlays, ZIP is operable in the "RUN" mode on the currently available Minneapolis Honeywell Model 440 computer. This avoids the slower "RUNBIG" mode, and results in a considerable savings in running time.

As a result of its speed and accuracy, ZIP has resulted in a dramatic reduction in the time and money required for zirconium hydride (ZrH) reactor trade studies. A study which might require two men for two calendar weeks to complete without ZIP can now be performed by one man using ZIP on the timeshare computer in about an hour.

II. PROGRAM LOGIC

The ZIP code consists of (1) a main program, (2) an overlay called THERMO which performs the thermal-hydraulic calculation, (3) an overlay named FIZIKS which performs the core nuclear calculation, the shielding calculation, and the weight calculation, (4) the ZPRINT overlay which prints selected output data on line, and (5) the ZWRITE overlay which writes a complete output file on the disc under the name OUTPUT. Figure 1 is a flow chart showing the overall program logic, and the available options. Figure 2 shows the program flow within the THERMO overlay. Input to ZIP is principally from data files stored on the disc. The file TEMDAT contains data from the TEMPRO case used for normalization. TEMDAT is read by the THERMO overlay. Another input file is AFILE, which contains most of the constants used in the fitted equations solved by both the FIZIKS and THERMO overlays. Input data for individual cases to be analyzed by ZIP are contained in files labeled Z1, Z2, Z3, etc., up to Z40. These are read by ZIP, up to four at a time. It is intended that the data stored in TEMDAT and AFILE be more or less permanent data, not frequently changed. The data in the Z1 to Z40 files, on the other hand, represent frequently varied input data. In a typical trade study, files Z10, Z11, Z12, and Z13 might be used. Each file would be identical except for the parameter whose variation is to be studied. These four cases would be run at the same time, and a direct comparison obtained of the effects of the selected variable on reactor performance.

6531-5437

Figure 1. ZIP Flow Chart

6531-5438

Figure 2. THERMO Flow Chart

BLANK

III. THE THERMAL-HYDRAULIC MODEL, OVERLAY THERMO

A. CALCULATION OF TEMPERATURES

The thermal-hydraulic calculation performed by the THERMO overlay of ZIP is based on input temperature data calculated by the more rigorous model included in the TEMPPO code. TEMPPO data for the hot fuel element in the core is entered in the TEMDAT data file. This file contains temperature data at each of eleven axial nodes for the hot element; included are (1) the bulk NaK, (2) the cladding and glass interface, (3) the inner glass surface, (4) the fuel surface, and (5) the average fuel temperatures. Also included in this file are several single-valued parameters associated with the normalizing TEMPPO case, such as cladding ID, initial gap thickness, the number of elements, the fuel length, core thermal power, the core ΔT , and the radial power peaking factor that applies to the hot element. These parameters are used to normalize the temperature data from TEMPPO to values appropriate to the reactor being calculated by ZIP. In this manner, BOL temperatures for the hot element are obtained for each of eleven axial nodes. This calculation is performed by the TEMPS subroutine of the THERMO overlay. TEMPS also calculates hot element temperatures throughout reactor life by repeatedly calling the fuel swelling subroutine SWELLO to obtain the fuel-glass gap as a function of axial position and time. TEMPS then renormalizes the TEMPPO data to account for the reduced gap as the fuel grows. If the fuel grows more than the available gap, SWELLO holds the gap at zero, precluding a negative gap thickness or ΔT .

B. FUEL SWELLING MODEL

The hot element fuel swelling is calculated by the SWELLO subroutine using the model

$$\frac{\% \Delta V}{V} = A_{59} b + A_{60} \exp(-A_{61} / \bar{T}_{\text{fuel}}) [1 - \exp(t/A_{67})]$$

where

b = Burnup (met. at. %)

$\bar{T}_{\text{fuel}}$ = Radially averaged fuel temperature ($^{\circ}\text{R}$)

t = Time (hr)

A₆₇ = Time constant for offset fuel swelling.

For the frequently used Bonzer-Swenson swelling model,⁽⁵⁾

$$A_{59} = 3.21$$

$$A_{60} = 5.76 \times 10^6$$

$$A_{61} = 27,000.$$

The burnup at each axial node is determined from the core average burnup, the radial power peaking factor for the hot element, and the axial power profile which is obtained from an APC case and entered in the TEMDAT data file.

Diametral growth is related to volumetric growth by

$$\frac{\Delta D}{D} = \frac{\Delta V}{V} / A_{70}$$

where A₇₀ is 2.80, based on S8DR measurements of fuel swelling anisotropy.⁽⁵⁾

Included in SWELLO and TEMPS is the option of searching for the BOL gap which results in a desired value of the minimum EOL gap. If this option is desired, KGAP = X(J,12) is set equal to 1, and the desired EOL gap (in inches) is entered in X(J,16) = AMARG. Otherwise, KGAP is set equal to zero, and the BOL gap in X(J,10) is used.

C. SEARCH FOR N_H RESULTING IN ALL δ-PHASE FUEL

Because δ-phase fuel is believed to grow less, under irradiation, than ε-phase fuel, it is frequently desirable to set the N_H of the reactor so that ε-phase fuel does not exist in any significant degree at BOL. As the reactor is operated and hydrogen is lost from the fuel, the probability of ε-phase fuel is reduced, as may be seen by inspecting the ZrH phase diagram. In order to set the BOL N_H for all δ-phase fuel, KALDEL = X(J,35) = 1. Otherwise, the N_H value in X(J,23) will be used as the BOL N_H. If KALDEL = 1, Subroutine ALLDEL sets the BOL N_H to a value which results in no ε-phase fuel at the surface of the cold end of the hot element. In the other elements, at BOL, this results in a small amount of ε-phase fuel at the cold end of the rod. It appears to be impractical to exclude ε-phase fuel from all elements, since the reactivity penalty due to reduced

N_H is quite large, and the probability of encountering β -phase fuel is increased. The criterion used in ZIP is believed to be a reasonable one, in that ϵ -phase fuel is kept out of the high burnup zones of the core. S8DR experience⁽⁵⁾ appears to validate this conclusion.

D. HYDROGEN LEAKAGE CALCULATION

Hydrogen leakage from the fuel is calculated by the HLEAK subroutine of the THERMO overlay. Hot element temperatures are used to determine the hydrogen pressure in the fuel, and the leakage over a time period Δt is:

$$L = \left[A_D (A_{65}/th_{cl}) \sqrt{P} \exp(-A_{63}/T_{cl}) + (A_{62} A_{66}/th_{gl}) P \exp(-A_{64}/T_{cl}) \right] Area \Delta t ,$$

where

A_D = Barrier defect constant, the fractional area of the barrier that is defective. Leakage through this area is essentially leakage through the bare metal cladding.

P = Hydrogen pressure inside the element

th_{cl} = Cladding thickness

T_{cl} = Cladding temperature

th_{gl} = Glass barrier thickness

Area = Total cladding area.

From the above equation, performed for each of ten axial zones, the time-dependent hydrogen leakage and EOL hydrogen content of the hot element is calculated. The hydrogen loss from the core is assumed to be proportional to that of the hot element. The factor relating core reactivity loss to hot element hydrogen leakage is determined from a TEMPRO calculation, and used by ZIP to obtain the hydrogen loss reactivity at EOL.

E. CHECK FOR β -PHASE FUEL

After completing the hydrogen leakage calculation, the THERMO overlay calls the BETABN subroutine. This subroutine takes the time-dependent hydrogen pressure in the hot element and calculates the β temperature (the temperature at which β -phase fuel occurs) for each time point. Then, the calculated peak fuel temperature in the hot element is compared with the β temperature. If the calculated peak temperature exceeds the β temperature, β -phase fuel has occurred. The code then prints an on-line warning, and proceeds with the calculation. The concern about β -phase fuel is based on the massive dehydriding and shrinkage that was locally observed in S8DR.⁽⁵⁾ This potentially detrimental behavior is believed to have been initiated when the local fuel temperature exceeded the β temperature.

IV. THE NUCLEAR MODEL, OVERLAY FIZIKS

A. AVAILABLE REACTIVITY

The reactivity equations solved by the FIZIKS overlay are as follows:

$$k_{\text{eff}} = Nf \left(1 - M^2 B_R^2 - M^2 B_Z^2 \right)$$

where the migration area,

$$M^2 = 1 / (A_7 + A_8 \text{VF}_{\text{fuel}} A_9 N_H + A_{10} \text{VF}_{\text{Incoloy}} + A_{11} \text{VF}_{\text{Hastelloy-N}} + A_{13} \text{VF}_{\text{Hastelloy-X}}) ,$$

and

VF_{fuel} = Fuel volume fraction in core

N_H = Hydrogen density in fuel (10^{22} atoms/cm³)

$\text{VF}_{\text{Incoloy}}$ = Incoloy volume fraction in core

$\text{VF}_{\text{Hastelloy-N}}$ = Hastelloy-N volume fraction in core

$\text{VF}_{\text{Hastelloy-X}}$ = Hastelloy-X volume fraction in core

and where the bucklings are defined by

$$B_Z^2 = \left(\frac{A_{18}}{2.54L + A_{17}} \right)^2 ,$$

L = Active core height in inches,

and

$$B_R^2 = \left(\frac{A_{16}}{1.27 D_{\text{core}} + \delta_R} \right)^2$$

D_{core} = Active core diameter (in.)

Reflector savings,

$$\delta_R = A_{13} + A_{14} [1 - \exp(A_{15} T_R)]$$

T_R = Average reflector thickness (in.) This is calculated from the minimum reflector thickness entered in X(J,42) by the equation $T_R = T_R(\text{min}) + \text{TAN } \theta / 2L$, where θ is the cone angle and L , the core length.

The thermal multiplication factor is given by

$$k_f = A_1 + A_2 V_{F_{\text{fuel}}} (N_H + A_3) + A_4 V_{F_{\text{Incoloy}}} + A_5 V_{F_{\text{Hastelloy-N}}} + A_6 V_{F_{\text{Hastelloy-X}}},$$

and reactivity is defined as

$$\rho = \frac{k_{\text{eff}} - 1}{k_{\text{eff}}}.$$

In addition, if the reflector is tapered, the average reflector thickness is used and a taper correction factor is applied.

$$\rho_{\text{tapered}} = \rho_{\text{untapered}} - 0.025\theta - 0.0062\theta^2,$$

where

θ = Half-angle of the shield cone (it is assumed that the reflector extends out to the shielded envelope).

The above model is based on the premise that, in a compact, fully enriched, ZrH-U fueled reactor, the neutron leakage occurs at high energies, and is affected only by the fuel density, the cladding density, the hydrogen density, the core dimensions, and the reflector thickness. Radial reflector savings were fit to an exponential function which has a nonzero value for zero reflector thickness, and increases to an asymptotic limit as reflector thickness goes to very large values.

After the high energy leakage occurs, the model assumes all neutrons remaining are thermalized and captured either by the fuel or cladding.

The constants (A's) used in this model were determined by using the least-squares method to fit a large number of APC cases covering a wide range of volume fractions and reflector thicknesses. The resulting model predicts the reactivity of a typical SNAP reactor within about \$1 of an APC case on the same system.

B. CONTROL SYSTEM WORTH

In addition to calculating the BOL reactivity, the FIZIKS subroutine determines the reactivity worth of the control system. As presently set up, the model applies specifically to sliding-reflector-segment control; however, it can easily be modified for use with rotating drum control (and has been used for this purpose in the past).

The first step in determining the available control is calculation of the total reflector worth, which is accomplished by calculating reactivity with a zero-thickness reflector and subtracting that from the reflected reactivity. Then, the fraction of the total reflector worth that is available for control is defined by

$$F_{rw} = \left(\frac{D_{eg}}{360} \right) \left(0.004\theta + 1.652S_{ss} + 0.0056\theta S_{ss} - 0.664S_{ss}^2 \right)$$

where

D_{eg} = Total number of degrees subtended by the movable (sliding) part of the reflector (360° maximum)

θ = Cone half angle

S_{ss} = Fractional stroke of sliding segment; $S_{ss} = \frac{\text{stroke (in.)}}{\text{active core length (in.)}}$

The above equation is a least-squares fit to a series of more detailed calculations of control worth as a function of θ and stroke. The BOL shutdown margin is the cold, prepoisoned BOL reactivity minus the total control worth.

C. REACTIVITY REQUIREMENTS

The reactivity requirements over the system lifetime are for convenience divided into short-term (or recoverable) losses and long-term (or nonrecoverable) losses. The short-term losses include the temperature and power defects, the equilibrium Xe^{135} level, and hydrogen redistribution. The net long-term losses include burnup of U^{235} and U^{238} and the burnable poisons, buildup of U^{236} , stable fission products and Sm^{149} , and hydrogen leakage from the fuel.

From the input data, the operating power and temperature levels, and the system lifetime in years, most of the reactivity requirements are calculated.

$$\rho_{\text{TEMP-EOL}} = 0.01\alpha_{\text{iso}} \left(\frac{T_{\text{OUT}} + T_{\text{IN}}}{2} - 70^{\circ}\text{F} \right)$$

where α_{iso} , the isothermal temperature coefficient of reactivity ($^{\circ}\text{F}$) = A_{19} .

$$\rho_{\text{POWER}} = A_{20} P_{\text{sp}}$$

$$\rho_{\text{XE-135}} = A_{21} P_{\text{sp}}$$

$$\rho_{\text{hydrogen redistribution}} = A_{22} P_{\text{sp}}$$

$$\rho_{\text{short term losses}} = \rho_{\text{TEMP-EOL}} + \rho_{\text{POWER}} + \rho_{\text{Xe}} + \rho_{\text{HRD}}$$

where P_{sp} = specific power, kwt/kg U^{235} .

The long-term reactivity requirements are defined by:

$$\rho_{\text{U-235}} = A_{23} \text{Bu}$$

$$\rho_{\text{U-236}} = A_{24} \text{Bu}$$

$$\rho_{\text{U-238}} = A_{25} \text{Bu}$$

$$\text{fission products} = A_{26} \text{Bu}$$

$$\rho_{\text{FPSM}} = A_{29} [1 - \exp(\text{Bu}/A_{27})], \text{ the reactivity of fission product Sm}^{149}$$

$$\rho_{\text{Sm-149}} = \rho_{\text{o Sm-149}} \exp(\text{Bu}/A_{31})$$

$$\rho_{\text{Eu-151}} = \rho_{\text{o Eu-151}} \exp(\text{Bu}/A_{32})$$

$$\rho_{\text{Eu-152}} = (\rho_{\text{o Eu-151}} - \rho_{\text{Eu-151}}) A_{30}$$

$$\rho_{\text{Gd-155}} = \rho_{\text{o Gd-155}} \exp(\text{Bu}/A_{33})$$

$$\rho_{\text{Gd-157}} = \rho_{\text{o Gd-157}} \exp(\text{Bu}/A_{34})$$

where Bu = core average burnup in Mwd/kg U^{235} ,

and the residual prepoison at EOL is

$$\rho_{\text{prepoison}} = \rho_{\text{Sm-149}} + \rho_{\text{Eu-151}} + \rho_{\text{Gd-152}} + \rho_{\text{Gd-155}} + \rho_{\text{Gd-157}}$$

Thus, the long-term reactivity losses are:

$$\rho_{\text{long term losses}} = \rho_{\text{U-235}} + \rho_{\text{U-236}} + \rho_{\text{U-238}} + \rho_{\text{FP}} + \rho_{\text{FPSM}} + \rho_{\text{prepoison}} + \rho_{\text{HL}}$$

where ρ_{HL} is the hydrogen loss reactivity, which is calculated in the thermal-hydraulics subroutine, THERMO.

The total reactivity requirements are the sum of the long- and short-term requirements, and the EOL reactivity margin is the difference between the cold, clean BOL reactivity and the reactivity requirements.

D. REACTOR WEIGHT CALCULATION

An approximate calculation of each component of reactor weight is made in the FIZIKS subroutine. These weights are essentially the result of determining the volume of each component, and multiplying by the appropriate density. The densities in lb/in.³ are as follows:

Fuel	0.220
Cladding	0.295
Grids	0.284
NaK	0.026
Reflector	0.0628

E. SHIELD THICKNESSES AND WEIGHTS

Neutron and gamma shield thickness and weight are calculated by the SHIELD subroutine, which is called by the FIZIKS subroutine. The SHIELD subroutine calculates the thickness of a single layer tungsten gamma shield immediately below the reactor, and then calculates a single layer LiH neutron shield below that. This routine makes use of built-in attenuation factor data (attenuation vs thickness) and an interpolation routine, FUNCTI, which solves for the thicknesses required to achieve the desired dose at the dose plane.

The data required by the SHIELD subroutine is contained primarily in the input array AFILE. These are as follows:

A_{52} = Gamma dose at the dose plane, integrated over the mission lifetime
(RADS)

A_{53} = Neutron dose at the dose plane, integrated over the mission lifetime (nvt)

A_{55} = Curvature factor for top surface of neutron shield (in.), see Figure 3

A_{56} = Curvature factor for bottom surface of neutron shield (in.), see Figure 3.

The separation distance, in feet, from the reactor midplane to the dose plane, is input from the Z1 file, location X(J,44), see Section V of this report.

6531-5630

Figure 3. 5-kwe Reactor - Reactor/Shield System

BLANK

V. DESCRIPTION OF INPUT FILES

This section contains a listing of the input files TEMDAT, Z1, and AFIL.E. Explanatory comments are included in TEMDAT and Z1 (these must be deleted before the files can be used).

100C DATA FILE IFMDAT
 105C THIS INPUT FILE CONTAINS DATA TAKEN
 110C FROM THE NORMALIZING TEMPR0 CASE
 120C
 125C
 130C CLADDING I.D. (IN)
 135 0.9752,
 140C
 150C FUEL ELEMENT GAP
 160 0.0067,
 170C
 180C NUMBER OF FUEL ELEMENTS
 190 85.0,
 200C
 210C FUEL LENGTH (IN)
 220 16.0,
 230C
 240C THERMAL POWER (KW)
 250 95.0,
 260C
 270C CORE TEMPERATURE RISE (DEG F)
 280 80.0,
 290C
 300C RADIAL POWER PEAKING FACTOR
 310 1.30,
 320C
 330C
 340C THE FOLLOWING TEMPERATURE ARRAYS
 350C ARE TAKEN FROM THE HOT ELEMENT
 360C IN THE TEMPR0 CALCULATION
 370C
 380C BULK COOLANT (NAK) TEMP
 390 1120,1125,1134,1146,1161,1177,1192,1207,1219,1228,1233,
 400C
 410C TEMP AT THE CLAD I.D.
 420 1122,1129,1140,1154,1170,1186,1202,1215,1226,1232,1235,
 430C
 440C RADIALLY AVERAGED FUEL TEMP
 450 1138,1171,1204,1235,1260,1280,1293,1296,1289,1274,1251,
 460C
 470C FUEL SURFACE TEMP
 480 1135,1163,1191,1218,1241,1260,1272,1277,1275,1265,1248,
 490C
 500C TEMP AT THE GLASS BARRIER I.D.
 510 1122,1130,1143,1158,1174,1190,1206,1219,1228,1234,1235,
 520C
 530C
 540C AXIAL POWER DISTRIBUTION
 550 0.31,0.659,0.960,1.193,1.339,1.389,1.339,1.193,0.960,
 560 0.659,0.310,
 570C
 580C
 590C TIME STEP ARRAY (HOURS)
 600 0,100,200,400,800,1300,1825,10951,25500,
 610 43800,50000,
 620 1,1,1,1,1,1,1,1,1,1,
 630 1,1,1,1,1,1,1,1,1

ZI 13:13 NR T/S MAY 23, 1973

100	5 KWE	FIRST TITLE (12 CHARACTERS)
105	REACTOR	SECOND TITLE (12 CHARACTERS)
110	HAST X	CLADDING MATERIAL NAME (12 CHARACTERS)
1001	85	NUMBER OF FUEL ELEMENTS
1002	16	FUEL LENGTH (IN)
1003	1.0	LATTICE PITCH (IN)
1004	10.5	WEIGHT % URANIUM IN FUEL
1005	.025	CLADDING THICKNESS (IN)
1006	.02	FIN HEIGHT OR SPACING (IN)
1007	3	NUMBER OF FINS
1008	.07	FIN THICKNESS (IN)
1009	.0025	GLASS THICKNESS (IN)
1010	.0078	GAP THICKNESS (IN)
1011	1	KTHERM (0=N0 THERM0 CALC, 1=CALL THERM0)
1012	1	KGAP (0=GAP FROM 1010, 1=SEARCH FOR AMARG AT E0L)
1013	.2541	INTERNAL REFLECTOR THICKNESS FACTOR
1014	.50	BE VOLUME FRACTION IN INTERNAL REFLECTOR
1015	.50	SS VOLUME FRACTION IN INTERNAL REFLECTOR
1016	.004	AMARG, E0L MIN GAP TO BE SEARCHED FOR IF KGAP=1
1017	.04	VESSEL THICKNESS (IN)
1018	0	N0T USED
1019	110	POWER TO COOLANT (KWT)
1020	5	LIFETIME (YEARS)
1021	1200	COOLANT OUTLET TEMPERATURE (DEG F)
1022	90	CORE TEMPERATURE RISE (DEG F)
1023	5.6	N-SUB-H OF FUEL
1024	188	MEV PER FISSION
1025	.29	U235 ALPHA (CAPTURE/FISSION)
1026	.0075	DELAYED NEUTRON FRACTION (BETA EFFECTIVE)
1027	2.0	HYDROGEN LOSS (\$)
1028	1	ICLAD (-1=1800, 0=HASTN, 1=HASTX)
1029	0	SHIM (DELTA K INFINITY)
1030	3	PREPOISON LOADING (\$)
1031	0	PREPOISON FRACTION - SM149
1032	0	PREPOISON FRACTION - ER167
1033	.19	PREPOISON FRACTION - GD155
1034	.81	PREPOISON FRACTION - GD157
1035	1	KALDEL (0=NH FROM 1023, 1=SEARCH FOR ALDEL NH)
1036	.50	END-OF-LIFE REACTIVITY MARGIN (\$)
1037	8.5	REFLECTOR TAPER ANGLE (DEG)
1038	4	REFLECTOR SEGMENT STROKE (IN)
1039	0	N0T USED
1040	1	KFIZZ (0=PITCH FROM 1003, 1=SEARCH FOR E0L RH0 FROM 1036)
1041	263	TOTAL MOVABLE SEGMENT ANGLE (DEG)
1042	1.19	MINIMUM REFLECTOR THICKNESS (IN)
1043	0	N0T USED
1044	21.2	SEPARATION DISTANCE (FT)
1045	.0015	AD FOR COLD END OF FUEL R0D
1046	.0015	AD FOR CENTRAL PART OF FUEL R0D
1047	.0015	AD FOR HOT END OF FUEL R0D

AFILE

101 1.5493
102 .03564
103 1.85
104 -.545
105 -1.155
106 -1
107 .00657
108 .00737
109 1.245
110 .0171
111 .029
112 .029
113 9.67
114 7.36
115 -.315
116 3.083
117 4.2
118 2.595
119 .2
120 .00337
121 .0148
122 .00842
123 .0366
124 .0138
125 -.00111
126 .0413
127 -9.5
128 .37
129 1.04
130 0
131 -.08062
132 -.008482
133 -.02697
134 -.09352
135 2
136 .1
137 3
138 .0001
139 51
140 2
141 .0001
142 .5
143 .0001
144 50
145 .01
146 41.42
147 .6042
148 .0248
149 .63
150 1.25

- 2 -

AFILE CONTINUED

151 21.2
152 2.4E6
153 1.7E12
154 5.25
155 3
156 6
157 0
158 0
159 3.2
160 5.76E6
161 2.7E4
162 1
163 14750
164 20800
165 2900
166 2.4125
167 500
168 50000
169 0.933
170 2.8
171 0
172 0
173 0
174 0
175 0
176 0
177 0
178 0
179 0
180 0

BLANK

VI. SAMPLE PROBLEM

The following is the output from a four-case trade study in which the fuel length was varied from 10 to 19 in. As may be seen, the weight minimum occurs near 16 in. On the basis of a weight optimization trade study like this, the fuel length of the 5-kwe reactor was selected to be 16 in. The first page of output is the on-line print. The last three pages are written on the disc in the data file, "OUTPUT," which may be listed after the ZIP calculation is completed.

15:57 MAY 23, 1973

	10" FUEL LENGTH	13" FUEL LENGTH	5 KWE REACTOR	19" FUEL LENGTH
KFIZZ	1	1	1	1
KTHERM	1	1	1	1
KGAP	1	1	1	1
AMARG	0.0040	0.0040	0.0040	0.0040
KALDEL	1	1	1	1
LATTICE PITCH (IN)	1.3784	1.1312	1.0140	0.9439
EXTERNAL REFL TH (IN)	1.937	2.161	2.386	2.610
REACTOR ENVELOPE (IN)	18.039	15.969	15.223	14.957
GAP THICKNESS (IN)	0.0085	0.0075	0.0069	0.0065
CORE VESSEL O.D. (IN)	14.164	11.646	10.452	9.738
BOL H/ZR	1.608	1.625	1.638	1.648
PEAK-AVERAGE TFUEL (BOL)	1364	1335	1315	1300
EOL REACTIVITY MARGIN(\$)	0.50	0.50	0.50	0.50
BOL SHUTDOWN MARGIN	1.39	2.56	3.17	3.53
BOL PREPOISON LOADING	3.00	3.00	3.00	3.00
EOL RESIDUAL POISON	0.76	0.62	0.60	0.61
AVAILABLE REACTIVITY (\$)	7.03	7.46	7.62	7.66
MAX VB DRUM WORTH (\$)	5.42	7.02	7.79	8.19
HALF ANGLE (DEG)	8.50	8.50	8.50	8.50
GAMMA SHIELD TH (IN)	2.51	2.51	2.51	2.51
NEUTRON SHIELD TH (IN)	22.89	22.89	22.89	22.89
SEPARATION DISTANCE (FT)	21.20	21.20	21.20	21.20
WEIGHTS (LBS)				
FUEL	243.1	207.0	201.2	204.5
CLAD	28.6	29.7	32.1	35.1
END CAPS	16.4	11.0	8.8	7.6
GRIDS	11.1	7.5	6.0	5.2
INTERNAL REFL	29.8	26.1	25.8	26.6
CORE NAK	6.9	6.0	5.9	6.1
TOTAL CORE	335.9	287.3	279.9	285.0
VESSEL SHELL	5.8	6.0	6.5	7.1
PLENUM WALLS	7.9	6.4	5.8	5.4
PLENUM ENDS	11.1	7.5	6.0	5.2
FLANGE&SUPPORT SKIRT	10.1	8.3	7.4	6.9
PLENUM NAK	16.2	10.9	8.8	7.6
TOTAL VESSEL	51.0	39.1	34.5	32.2
REFLECTOR BE	62.5	77.9	98.8	124.0
ACTUATORS	36.6	36.6	36.6	36.6
REFL SUPPORTS	20.1	22.1	24.8	28.1
PIPING	6.3	8.2	10.1	12.0
TOTAL REFLECTOR	125.5	144.9	170.4	200.7
REACTOR TOTAL	512.4	471.2	484.7	517.9
GAMMA SHIELD WT (LBS)	265.9	189.5	157.8	140.2
NEUTRON SHIELD WT (LBS)	295.5	249.5	233.9	228.4
TOTAL SHIELD WT (LBS)	561.3	439.0	391.7	368.6
REACTOR+SHIELD WT (LBS)	1073.7	910.2	876.4	886.6

15:57 MAY 23, 1973

	10" FUEL LENGTH	13" FUEL LENGTH	5 KWE REACTOR	19" FUEL LENGTH
NUMBER OF ELEMENTS	85	85	85	85
FUEL LENGTH (IN)	10.000	13.000	16.000	19.000
LATTICE PITCH (IN)	1.0784	1.1312	1.0140	0.9439
CLAD MATERIAL	HAST X	HAST X	HAST X	HAST X
ICLAD	1	1	1	1
CLAD THICKNESS (IN)	0.0250	0.0250	0.0250	0.0250
FIN HT (ØR SPACING) (IN)	0.0200	0.0200	0.0200	0.0200
NUMBER OF FINS	3	3	3	3
FIN THICKNESS (IN)	0.0700	0.0700	0.0700	0.0700
GLASS THICKNESS (IN)	0.0025	0.0025	0.0025	0.0025
GAP THICKNESS (IN)	0.0085	0.0075	0.0069	0.0065
FUEL DIAMETER (IN)	1.2865	1.0413	0.9253	0.8560
ACTIVE CORE DIA (IN)	13.3440	10.9511	9.8169	9.1382
INTERNAL REFL TH (IN)	0.3502	0.2874	0.2577	0.2399
CORE VESSEL ID (IN)	14.084	11.566	10.372	9.658
EXTERNAL REFL TH (IN)	1.937	2.161	2.386	2.610
POWER TO COOLANT (KWT)	110	110	110	110
LIFETIME (YEARS)	5.000	5.000	5.000	5.000
OUTLET TEMP (DEG F)	1200	1200	1200	1200
CORE DELTA T (DEG F)	90	90	90	90
N-SUB-H OF FUEL	5.6833	5.7450	5.7907	5.8245
REACTOR ENVELOPE (IN)	18.039	15.969	15.223	14.957
FISSILE MASS (KG U-235)	10.634	9.057	8.802	8.946
ACTIVE CORE VOLUME (L)	22.917	20.065	19.845	20.421
SPECIFIC PWR(KWT/KGU235)	10.344	12.146	12.497	12.296
AVG PWR DENSITY (KWT/L)	4.800	5.482	5.543	5.387
AVG LINEAR POWER(KWT/FT)	1.553	1.195	0.971	0.817
AVG BURNUP(MWD/KG235)	18.892	22.181	22.824	22.457
AVG BURNUP(MET AT %)	0.086	0.101	0.104	0.102
CORE WT(LBS)	336	287	280	285
VESSEL WT(LBS)	51	39	34	32
REFLECTOR WT(LBS)	125	145	170	201
REACTOR WT(LBS)	512	471	485	518
GAMMA SHIELD WT (LBS)	266	189	158	140
NEUTRON SHIELD WT (LBS)	295	249	234	228
TOTAL SHIELD WT (LBS)	561	439	392	369
REACTOR+SHIELD WT (LBS)	1074	910	876	887
PEAK-AVERAGE TFUEL (BØL)	1364	1335	1315	1300
BØL H/ZR	1.608	1.625	1.638	1.648
EØL H/ZR	1.586	1.598	1.607	1.615
HALF ANGLE (DEG)	8.50	8.50	8.50	8.50
REFL SEGMENT STROKE (IN)	4.000	4.000	4.000	4.000
FR. REFL WØRTH IN CØNTRL	0.4439	0.3610	0.3049	0.2647
DELTA RHØ TAPER (\$)	-.66	-.66	-.66	-.66
REFL ANGLE MØVABLE SEGMT	263	263	263	263
VF FUEL	0.7900	0.7685	0.7552	0.7459
VF GAP+GLASS	0.0271	0.0297	0.0309	0.0315
VF CLAD+FINS	0.0662	0.0808	0.0902	0.0969
VF COOLANT	0.1166	0.1211	0.1238	0.1257
U-235 DENS (AT/CM-BARN)	1.188E-03	1.155E-03	1.135E-03	1.121E-03
U-238 DENS (AT/CM-BARN)	8.611E-05	8.377E-05	8.231E-05	8.130E-05
H DENS (AT/CM-BARN)	4.490E-02	4.415E-02	4.373E-02	4.344E-02
ZR DENS (AT/CM-BARN)	2.792E-02	2.716E-02	2.669E-02	2.636E-02

15:57 MAY 23, 1973

	10" FUEL LENGTH	13" FUEL LENGTH	5 KWE REACTOR	19" FUEL LENGTH
REACTIVITY REQUIREMENTS:				
DELTA TEMP	2.17	2.17	2.17	2.17
DELTA POWER	0.03	0.04	0.04	0.04
XENON-135	0.15	0.18	0.18	0.18
H REDISTRIBUTION	0.09	0.10	0.11	0.10
TOTAL RECOVERABLE LOSSES	2.45	2.49	2.50	2.50
U-235 BURNOUT	0.69	0.81	0.84	0.82
U-236 BURNIN	0.26	0.31	0.31	0.31
U-238 BURNOUT	-.02	-.02	-.03	-.02
FISSION PRODUCTS	0.78	0.92	0.94	0.93
SM-149 BURNIN	0.90	0.94	0.95	0.94
HYDROGEN LOSS	0.72	0.90	1.01	1.08
RESIDUAL GD-155	0.34	0.31	0.31	0.31
RESIDUAL GD-157	0.42	0.31	0.29	0.30
NONRECOVERABLE LOSSES	4.09	4.47	4.61	4.66
TOTAL REQUIREMENTS	6.53	6.96	7.12	7.16
AVAILABLE REACTIVITY (\$)	7.03	7.46	7.62	7.66
BOL PREPOISON LOADING	3.00	3.00	3.00	3.00
HOT POISONED REACTIVITY	1.59	1.97	2.11	2.16
EOL REACTIVITY MARGIN(\$)	0.50	0.50	0.50	0.50
MAX VB DRUM WORTH (\$)	5.42	7.02	7.79	8.19
ZERO POISON S.D. MARGIN	-1.61	-.44	0.17	0.53
BOL SHUTDOWN MARGIN	1.39	2.56	3.17	3.53
MISMATCH (NO PEAKUP)	1.09	1.47	1.61	1.66
ALLOWED MISMATCH (\$2SDM)	0.47	2.03	2.78	3.19

I	A(I)	I	A(I)	I	A(I)	I	A(I)	I	A(I)
1	1.54930	17	4.20000	33	-.02697	49	6.300E-01	65	2.900E+03
2	0.03564	18	2.59500	34	-.09352	50	1.250E+00	66	2.412E+00
3	1.85000	19	0.20000	35	2.00000	51	2.120E+01	67	5.000E+02
4	-.54500	20	0.00337	36	0.10000	52	2.400E+06	68	5.000E+04
5	-1.15500	21	0.01480	37	3.00000	53	1.700E+12	69	9.330E-01
6	-1.00000	22	0.00842	38	0.00010	54	5.250E+00	70	2.800E+00
7	0.00657	23	0.03660	39	51.00000	55	3.000E+00	71	0.000E+00
8	0.00737	24	0.01380	40	2.00000	56	6.000E+00	72	0.000E+00
9	1.24500	25	-.00111	41	0.00010	57	0.000E+00	73	0.000E+00
10	0.01710	26	0.04130	42	0.50000	58	0.000E+00	74	0.000E+00
11	0.02900	27	-9.50000	43	0.00010	59	3.200E+00	75	0.000E+00
12	0.02900	28	0.37000	44	50.00000	60	5.760E+06	76	0.000E+00
13	9.67000	29	1.04000	45	0.01000	61	2.700E+04	77	0.000E+00
14	7.36000	30	0.00000	46	41.42000	62	1.000E+00	78	0.000E+00
15	-.31500	31	-.08062	47	0.60420	63	1.475E+04	79	0.000E+00
16	3.08300	32	-.00848	48	0.02480	64	2.080E+04	80	0.000E+00

15:57 MAY 23, 1973

	10" FUEL LENGTH	13" FUEL LENGTH	5 KWE REACTOR	19" FUEL LENGTH
INPUT DATA				
1	85.0000	85.0000	85.0000	85.0000
2	10.0000	13.0000	16.0000	19.0000
3	1.0000	1.0000	1.0000	1.0000
4	10.5000	10.5000	10.5000	10.5000
5	0.0250	0.0250	0.0250	0.0250
6	0.0200	0.0200	0.0200	0.0200
7	3.0000	3.0000	3.0000	3.0000
8	0.0700	0.0700	0.0700	0.0700
9	0.0025	0.0025	0.0025	0.0025
10	0.0078	0.0078	0.0078	0.0078
11	1.0000	1.0000	1.0000	1.0000
12	1.0000	1.0000	1.0000	1.0000
13	0.2541	0.2541	0.2541	0.2541
14	0.5000	0.5000	0.5000	0.5000
15	0.5000	0.5000	0.5000	0.5000
16	0.0040	0.0040	0.0040	0.0040
17	0.0400	0.0400	0.0400	0.0400
18	0.0000	0.0000	0.0000	0.0000
19	110.0000	110.0000	110.0000	110.0000
20	5.0000	5.0000	5.0000	5.0000
21	1200.0000	1200.0000	1200.0000	1200.0000
22	90.0000	90.0000	90.0000	90.0000
23	5.6000	5.6000	5.6000	5.6000
24	188.0000	188.0000	188.0000	188.0000
25	0.2900	0.2900	0.2900	0.2900
26	0.0075	0.0075	0.0075	0.0075
27	2.0000	2.0000	2.0000	2.0000
28	1.0000	1.0000	1.0000	1.0000
29	0.0000	0.0000	0.0000	0.0000
30	3.0000	3.0000	3.0000	3.0000
31	0.0000	0.0000	0.0000	0.0000
32	0.0000	0.0000	0.0000	0.0000
33	0.1900	0.1900	0.1900	0.1900
34	0.8100	0.8100	0.8100	0.8100
35	1.0000	1.0000	1.0000	1.0000
36	0.5000	0.5000	0.5000	0.5000
37	8.5000	8.5000	8.5000	8.5000
38	4.0000	4.0000	4.0000	4.0000
39	0.0000	0.0000	0.0000	0.0000
40	1.0000	1.0000	1.0000	1.0000
41	263.0000	263.0000	263.0000	263.0000
42	1.1900	1.1900	1.1900	1.1900
43	0.0000	0.0000	0.0000	0.0000
44	21.2000	21.2000	21.2000	21.2000
45	0.0015	0.0015	0.0015	0.0015
46	0.0015	0.0015	0.0015	0.0015
47	0.0015	0.0015	0.0015	0.0015

BLANK

VII. LISTING OF PROGRAM

The following pages list the main program, ZIP, and each of the four overlay subroutines, THERMO, FIZIKS, ZPRINT, and ZWRITE.

ZIP

```

1000$   NDM
1010$   ØVR,THERMØ
1020$   ØVR,FIZIKS
1030$   ØVR,ZPRINT
1040$   ØVR,ZWRITE
1050C
1060     DIMENSION DATE(3),DNAME(40)
1070     DIMENSION ICASE(4),C1(4),C2(4),T1(4),T2(4),T3(4),T4(4)
1080C
1090$   RPC
1100     COMMON T(4,140),X(4,140),XIN(4,50),
1110&    J,A(80),XLINE
1120C
1130 DATA DNAME/"Z1","Z2","Z3","Z4","Z5","Z6","Z7","Z8","Z9",
1140&"Z10","Z11","Z12","Z13","Z14","Z15","Z16","Z17","Z18","Z19",
1150&"Z20","Z21","Z22","Z23","Z24","Z25","Z26","Z27","Z28","Z29",
1160&"Z30","Z31","Z32","Z33","Z34","Z35","Z36","Z37","Z38","Z39",
1170&"Z40"/
1180     CALL TDATA
1190     CALL ØPENF(1,"AFILE")
1200     DØ 1 I=1,80
1210     READ (1,,)A(I)
1220     1 CONTINUE
1230     CALL CLØSEF(1)
1240     WHAP=A(1)
1250     KICKS=1
1260     2 CONTINUE
1270     CALL DATIME(ITIME,TØD,DATE)
1280     NVAR=47
1290     PRINT," N,I(N) ",I*
1300     READ(50,,)NCASE,(ICASE(K),K=1,NCASE)
1310     DØ 4 I=1,NCASE
1320     KK=ICASE(I)
1330     CALL ØPENF(1,DNAME(KK))
1340     READ(1,13) TITLE1,TITLE2
1350     READ(1,13) TITLE3,TITLE4
1360     READ(1,13) CLAD1,CLAD2
1370     T1(I)=TITLE1
1380     T2(I)=TITLE2
1390     T3(I)=TITLE3
1400     T4(I)=TITLE4
1410     C1(I)=CLAD1
1420     C2(I)=CLAD2
1430     DØ 3 J=1,NVAR
1440     READ(1,,)X(I,J)
1450     XIN(I,J)=X(I,J)
1460     3 CONTINUE
1470     CALL CLØSEF(1)
1480     4 CONTINUE
1490C

```

ZIP CONTINUED

```

1500C          MAIN CALCULATIONAL LOOP
1510C
1520      DO 7 J=1,NCASE
1530      KOUNT=0
1540      KTHERM=X(J,11)
1550      KFIZZ=X(J,40)
1560C
1570      6 XPX=X(J,3)
1580      IF(KTHERM.EQ.0)GO TO 5
1590C
1600      CALL LINK(5,"OTHERM")
1610      CALL THERM0
1620      GO TO 15
1630      5 CONTINUE
1640      X(J,88)=0
1650      X(J,89)=0
1660      X(J,90)=X(J,23)/3.49
1670      X(J,91)=0
1680      15 CONTINUE
1690      YS=X(J,36)
1700      XJ3=X(J,3)
1710      DX=A(41)
1720      DXM=A(42)
1730      EPS=A(43)
1740      N=A(44)
1750      IF(KFIZZ.EQ.0)KOUNT=1
1760C
1770      CALL LINK(4,"OFIZIK")
1780      CALL FIZIKS(DX,DXM,EPS,KFIZZ,
1790&      KOUNT,N,NF,XF,XJ3,WHAP,YF,YS)
1800C
1810      X(J,3)=XF
1820      IF(KFIZZ.EQ.0)GO TO 12
1830      EPP=ABS(X(J,3)-XPX)
1840      IF(EPP.LT.A(45)) GO TO 11
1850      GO TO 6
1860      11 CONTINUE
1870      IF(KOUNT.EQ.1) GO TO 12
1880      KOUNT=1
1890      GO TO 6
1900      12 CONTINUE
1910      7 CONTINUE
1920C
1930      CALL LINK(5,"OZPRIN")
1940      CALL ZPRINT(C1,C2,NCASE,NPRINT,T1,T2,T3,T4,
1950&      ITIME,T0D,DATE)
1960C
1970      999 CONTINUE
1980      CALL LINK(2,"OZWRT")
1990      CALL ZWRITE(C1,C2,NCASE,NPRINT,NVAR,T1,T2,T3,T4,KICKS,

```

ZIP CONTINUED

```

2000& I TIME,T00,DATE)
2010C
2020      KICKS=KICKS+1
2030      G0 T0 2
2040  13 F0RMAT(2A6)
2050      END
2060C
2070C
2080C
4000 SUBROUTINE TDATA
4001 DATA T/"      NU","MBER 0","F ELEM","ENTS  ",
4002&"      "," FUEL ","LENGTH"," (IN) ",
4003&"      L","ATTICE"," PITCH"," (IN) ",
4004&"      CL","AD MAT","ERIAL ","      ",
4005&"      CL","AD THI","CKNESS"," (IN) ",
4006&"FIN HT"," (0R S","PACING","") (IN)",
4007&"      NU","MBER 0","F FINS","      ",
4008&"      F","IN THI","CKNESS"," (IN) ",
4009&"      GLA","SS THI","CKNESS"," (IN) ",
4010&"      G","AP THI","CKNESS"," (IN) ",
4011&"      F","UEL DI","AMETER"," (IN) ",
4012&"      ACT","IVE C0","RE DIA"," (IN) ",
4013&"      INTE","RNAL R","EFL TH"," (IN) ",
4014&"      INT ","REFL B","E/BE0 ","VF      ",
4015&"      INT ","REFL S","TEEL  ","VF      ",
4016&"      C0","RE VES","SEL ID"," (IN) ",
4017&"      C0","RE VES","SEL TH"," (IN) ",
4018&"      EXTE","RNAL R","EFL TH"," (IN) ",
4019&" P0WER"," T0 C0","0LANT ","(KWT) ",
4020&"      "," LIFET","IME (Y","EARS) ",
4021&"      0U","TLET T","EMP (D","EG F) ",
4022&"      C0R","E DELT","A T (D","EG F) ",
4023&"      "," N-SUB","-H 0F ","FUEL  ",
4024&" MEV/F","ISS (T","0 C00L","ANT)  ",
4025&"U-235 ","ALPHA ","(CAP/F","ISS)  ",
4026&"      "," BETA"," EFFEC","TIVE  ",
4027&"      "," VF"," FUEL ","      ",
4028&"      "," VF"," GAP+G","LASS  ",
4029&"      "," VF"," CLAD+","FINS  ",
4030&"      "," VF"," C00LA","NT  ",
4031&"U-235 ","DENS (","AT/CM-","BARN) ",
4032&"U-238 ","DENS (","AT/CM-","BARN) ",
4033&"      H ","DENS (","AT/CM-","BARN) ",
4034&"      ZR ","DENS (","AT/CM-","BARN) ",
4035&"FISSIL","E MASS"," (KG U","-235)  ",
4036&"ACTIVE"," C0RE ","V0LUME"," (L)  ",
4037&"SPECIF","IC PWR","(KWT/K","GU235)",
4038&"AVG PWR","R DENS","ITY (K","WT/L)  ",
4039&"AVG LI","NEAR P","0WER(K","WT/FT)",
4040&"      AVG"," BURNU","P(MWD/","KG235)",

```


ZIP CONTINUED

4041&" AVG"," BURNU","P(MET ","AT %) ",
4042&"WEIGHT"," % URA","NIUM I","N FUEL",
4043&"UNHYDR"," FUEL ","DENS (","GM/CC)",
4044&"AVAILA","BLE RE","ACTIVI","TY (\$)",
4045&" MAX"," VB DR","UM WØR","TH (\$)",
4046&" "," " " " " "KFIZZ ",
4047&" "," " " " " "K THERM",
4048&" "," " " " " "KGAP ",
4049&" "," " " " " "AMARG ",
4050&" "," " " " " "KALDEL",
4051&" "," " " " " "FISSION",
4052&" "," RAD","IAL BU","CKLING",
4053&" "," AX","IAL BU","CKLING",
4054&" "," " " " " "M " "SQUARE",
4055&" "," DELT","A TEMP"," " " ",
4056&" "," DELT","A PØWE","R " " ",
4057&" "," XENØ","N-135 " " " " ",
4058&" "," H RE","DISTRI","BUTION",
4059&"TØTAL " " "RECØVE","RABLE " " "LØSSES",
4060&" " " "U-23","5 BURN","ØUT " " ",
4061&" " " "U-23","6 BURN","IN " " ",
4062&" " " "U-23","8 BURN","ØUT " " ",
4063&" " " "FISS","ION PR","ØDUCTS",
4064&" " " "SM-1","49 BUR","VIN " " ",
4065&" " " "HYDR","ØGEN L","ØSS " " ",
4066&" NØN","RECØVE","RABLE " " "LØSSES",
4067&" " "TØTAL " " "REQUIR","EMENTS",
4068&"EØL RE","ACTIVI","TY MAR","GIN(\$)",
4069&" " " "ICLA","D " " " " ",
4070&"ZERØ P","ØISON " " "S.D. M","ARGIN " " ",
4071&" REA","CTOR E","NVELØP","E (IN)",
4072&"ALLØWE","D MISM","ATCH (","\$2SDM)",
4073&"SHIM (","DELTA " " "K-INFI","NITY) " " ",
4074&" BØL"," PREPØ","ISON L","ØADING",
4075&" E","ØL RES","IDUAL " " "PØISON",
4076&" B","ØL SHU","TDØWN " " "MARGIN",
4077&" MI","SMATCH"," (NØ P","EAKUP)",
4078&" HØT P","ØISØNE","D REAC","TIVITY",
4079&" " " RESI","DUAL S","M-149 " " ",
4080&" " " RESI","DUAL E","R-167 " " ",
4081&" " " RESI","DUAL E","J-152 " " ",
4082&" " " RESI","DUAL G","D-155 " " ",
4083&" " " RESI","DUAL G","D-157 " " ",
4084&"U-235 " " "DENS (","AT/CM-","BARN) " " ",
4085&"U-238 " " "DENS (","AT/CM-","BARN) " " ",
4086&" H " " "DENS (","AT/CM-","BARN) " " ",
4087&" ZR " " "DENS (","AT/CM-","BARN) " " ",
4088&"PEAK-A","VERAGE"," TFUEL"," (BØL)",
4089&"PEAK-A","VERAGE"," TFUEL"," (EØL)",
4090&" " " " "BØL H/","ZR " " "

ZIP CONTINUED

```

4091&"      ","      ","EOL H/","ZR      ",
4092&"      ","      "C","ØRE WT","(LBS) ",
4093&"      ","      "VES","SEL WT","(LBS) ",
4094&"      ","REFLEC","TØR WT","(LBS) ",
4095&"      ","      REAC","TØR WT","(LBS) ",
4096&"      ","HALF A","NGLE (","DEG)  ",
4097&"REFL S","EGMENT"," STRØK","E (IN)",
4098&"FR. RE","FL WØR","TH IN ","CØNTRL",
4099&"DELTA ","RHØ TA","PER ($","")      ",
4100&"REFL A","NGLE M","ØVABLE"," SEGMT",
4101&"      GA","MMA SH","IELD T","H (IN)",
4102&"      NEUT","RØN SH","IELD T","H (IN)",
4103&"      GAM","MA SHI","ELD WT"," (LBS)",
4104&"      NEUTR","ØN SHI","ELD WT"," (LBS)",
4105&"      TØT","AL SHI","ELD WT"," (LBS)",
4106&"      REACT","ØR+SHI","ELD WT"," (LBS)",
4107&"      CØR","E VESS","EL Ø.D",". (IN)",
4108&"      ","      RADIA","TØR WT"," (LBS)",
4109&"BUCKLI","NG ADD","-ØN WT"," (LBS)",
4110&"      BASE","      RADIA","TØR WT"," (LBS)",
4111&"      REAC","      +SHLD+","RAD WT"," (LBS)",
4112&"      RAD","IATØR ","AREA (","SQ-FT)",
4113&"SEPARA","TION D","ISTANC","E (FT)",
4114&"      ","      ","      ","      FUEL",
4115&"      ","      ","      ","      CLAD",
4116&"      ","      ","      "EN","D CAPS",
4117&"      ","      ","      ","      GRIDS",
4118&"      ","      "I","NTERNA","L REFL",
4119&"      ","      ","      "CØ","RE NAK",
4120&"      ","      ","      "TØTA","L CØRE",
4121&"      ","      ","      ","VESSEL"," SHELL",
4122&"      ","      ","      ","PLENUM"," WALLS",
4123&"      ","      ","      "PLENU","M ENDS",
4124&"      FL","ANGE&S","UPPØRT"," SKIRT",
4125&"      ","      ","      "PLEN","UM NAK",
4126&"      ","      ","      ","TØTAL ","VESSEL",
4127&"      ","      ","      ","REFLEC","TØR BE",
4128&"      ","      ","      "ACT","UATØRS",
4129&"      ","      "R","EFL SU","PPØRTS",
4130&"      ","      ","      ","PIPING",
4131&"      ","      "TØT","AL REF","LECTØR",
4132&"      ","      "R","EACTØR"," TOTAL",
4133&32*1 /
4134 RETURN
4135 END

```

THERMØ

```

10000      SUBROUTINE THERMØ
10010C
10020      DIMENSION ATFU(30),P(30),PHIA(11),TCDGP(11),TCG(11),
10030&      TF(11),TFS(11),TGS(11),TIM(30),TN(11),TPPK(30)
10037C
10038C          READ DATA ØBTAINED (MØSTLY) FROM TEMPRØ
10039C
10040      CALL ØPENF(1,"TEMDAT")
10050      READ(1,),(ØDIACL,ØGAP,ØELNØ,ØALEN,ØPØW,ØDELT,PKAVG,
10052&      TN,TCG,TF,TFS,TGS,PHIA,TIM
10060      CALL CLØSEF(1)
10070C
10080      ELNØ =X(J,1)
10090      ALEN =X(J,2)
10100      CLTH =X(J,5)*1000
10110      GTH =X(J,9)*1000
10120      GAP =X(J,10)
10130      DIACL =X(J,3)-X(J,6)-2*X(J,5)
10140      DIAFU =DIACL-2*(X(J,10)+X(J,9))
10150      KGAP =X(J,12)
10160      AMARG =X(J,16)
10170      PØW =X(J,19)
10180      ALIFE =X(J,20)
10190      DELT =X(J,22)
10200      TIN =X(J,21)-DELT
10210      AZR =X(J,23)*.2829
10220      EMEV =X(J,24)
10230      KALDEL=X(J,35)
10240      ADCØLD=X(J,45)
10250      ADTUBE=X(J,46)
10260      ADHØT =X(J,47)
10270C
10280      BU=A(46)*PØW*ALIFE/(ELNØ*ALEN*DIAFU*DIAFU*EMEVI)
10300      AKWFT=PØW*12./(ELNØ*ALEN)
10310C
10314      CALL TEMPS(AKWFT,ALIFE,AMARG,ATFU,BU,DELT,
10324&      DIACL,DIAFU,GAP,JEAN,KGAP,PHIA,TCG,TF,TFME,TFMX,TFS,
10334&      TGS,TIM,TIN,TMNF,TN,TPPK,TCDGP,
10335&      ØDIACL,ØGAP,ØELNØ,ØALEN,ØPØW,ØDELT,PKAVG)
10336C
10340      IF(KALDEL.EQ.0)GØ TØ 12
10345C
10350      CALL ALLDEL(ATFU,AZR,TMNF)
10360 12 CØNTINUE
10365C
10366      CALL HLEAK(ADCØLD,ADHØT,ADTUBE,AHL,AHLØS,
10367&      ALEN,ALIFE,ATFU,AZR,CLTH,DIACL,DIAFU,ELNØ,GTH,P,
10368&      TCDGP,TIM)
10385C
10390      CALL BETABN(JEAN,P,TIM,TPPK)

```

THERMO CONTINUED

```

10400C
10410      GGP=GAP*1000.
10420      X(J,10)=GGP/1000
10430      X(J,23)=AZR/0.2829
10440      X(J,27)=AHL0S
10450      X(J,88)=TFMX
10460      X(J,89)=TFME
10470      X(J,90)=AZR
10480      X(J,91)=AHL
10490      RETURN
10500      END

11000C
11010C
11011C      CALCULATE HOT ELEMENT TEMPERATURES
11012C      AT ELEVEN AXIAL NODES
11020C
11030      SUBROUTINE TEMPS(AKWFT,ALIFE,AMARG,ATFU,BU,DELT,
11040&      DIACL,DIAFU,GAP,JEAN,KGAP,PHIA,TCG,TF,TFME,TFMX,TFS,
11050&      TGS,TIM,TIN,TMNF,TN,TPPK,TCGDP,
11055&      QDIACL,QGAP,QELN0,GALEN,QP0W,QDELT,PKAVG)
11060C
11070      DIMENSION ATFU(30),DTGP(11),G(11),PHIA(11),TCGDP(11),
11080&      TCG(11),TF(11),TFS(11),TFUEL(11),TGS(11),TIM(30),
11090&      TN(11),TNAK(11),TPPK(30)
11100C
11110      GP=GAP
11120      ALIF=ALIFE*8766.
11130 98  CONTINUE
11140      JULIE=1
11150      GAP=GP
11160      GG=GAP
11170C
11180      D017I=1,11
11190 17  G(I)=GAP
11200 99  CONTINUE
11210      TFM=0.
11220      TNAK(1)=TIN
11230      DMP=QDIACL/DIACL
11240      GMP=G(1)*DMP/QGAP
11250      AKWMP=AKWFT*QELN0*GALEN/(QP0W*12)
11260      TCDGP(1)=TIN+(TCG(1)-TN(1))*AKWMP*DMP
11270      DTGP(1)=(TFS(1)-TGS(1))*AKWMP*GMP
11280      DTGL=(TGS(1)-TCG(1))*AKWMP*DMP
11290      TFUEL(1)=TCDGP(1)+DTGP(1)+(TF(1)-TFS(1))*AKWMP+DTGL
11300      TMNF=TCDGP(1)+DTGP(1)+DTGL
11310      DTM=DELT/QDELT
11320C
11330      D010I=2,11
11340      TNAK(I)=(TN(I)-TN(I-1))*DTM+TNAK(I-1)
11350      TCDGP(I)=TNAK(I)+(TCG(I)-TN(I))*AKWMP*DMP

```

THERMO CONTINUED

```

11360      GMP=G(I)*DMP/QGAP
11370      DTGP(I)=(TFS(I)-TGS(I))*AKWMP*GMP
11380      DTGL=(TGS(I)-TCG(I))*AKWMP*DMP
11390      TFUEL(I)=TCDGP(I)+DTGP(I)+(TF(I)-TFS(I))*AKWMP+DTGL
11400  10  CONTINUE
11410      AT=TFUEL(I)+TFUEL(11)
11420      KST=1
11430C
11440      D020I=2,10
11450      AT=AT+TFUEL(I)*2
11460      TFM=AMAX1(TFM,TFUEL(I))
11470      IF(TFUEL(I).LT.TFM)G0T020
11480      KST=KST+1
11490  20  CONTINUE
11500      TPPK(JULIE)=TFUEL(KST)+(TF(KST)-TFS(KST))*AKWMP
11510      ATFU(JULIE)=AT*0.05
11520      IF(JULIE.EQ.1)TFMX=TFM
11530C
11540      CALL SWELL0(ALIF,AMARG,BU,DIAFU,G,GG,
11550&      GP,JULIE,KGAP,PHIA,TFUEL,TIM,PKAVG)
11560      JEAN=JULIE-1
11570      IF(KGAP.LT.0)G0T016
11580      IF(TIM(JULIE).LT.ALIF)G0T099
11590      IF(GG.NE.GP)G0T098
11600  16  CONTINUE
11610      TFME=TFM
11620      RETURN
11630      END
12000C
12005C      CALCULATE FUEL SWELLING
12010C
12020      SUBROUTINE SWELL0(ALIF,AMARG,BU,DIAFU,G,GG,
12030&      GP,JULIE,KGAP,PHIA,TFUEL,TIM,PKAVG)
12040      DIMENSION A0F(11),G(11),PHIA(11),TFUEL(11),TIM(30)
12050      GMX=0.
12060      JUDY=JULIE
12070      JILL=JUDY+1
12080C
12090      D082JAN=1,11
12100      G(JAN)=GG
12110  82  CONTINUE
12120      IF(KGAP.LT.0)G0T010
12130      IF(JULIE.GT.1)G0T020
12140C
12150      D022JUDITH=1,11
12160      A0F(JUDITH)=0.0
12170  22  CONTINUE
12180  20  IF(TIM(JILL).GT.ALIF)TIM(JILL)=ALIF
12190      AXPJ=(1.-EXP(-(TIM(JILL)-TIM(JUDY))/A(67)))
12200C

```

THERMO CONTINUED

```

12210      D0 68 LE0N=1,11
12220      AT=TFUEL(LE0N)+459.7
12230      A0FF=A(60)*EXP(-A(61)/AT)
12240      DDV=(A0FF-A0F(LE0N))*AXPJ
12250      IF(DDV.LE.0.)DDV=0.
12260      A0F(LE0N)=A0F(LE0N)+DDV
12270      ABU=BU*PHIA(LE0N)*PKAVG*TIM(JILL)/ALIF
12280      BNUP=ABU*A(59)
12290      GR=(BNUP+A0F(LE0N))*DIAFU*.01/A(70)
12300      G(LE0N)=GG-GR/2.
12310      GRR=GR/2.
12320      GMX=AMAX1(GMX,GRR)
12330      IF(GRR.LT.GG)G0T081
12340      G(LE0N)=0.
12350      81 CONTINUE
12360      68 CONTINUE
12370      IF(TIM(JILL).LT.ALIF)G0T010
12380      IF(KGAP.LT.1)G0T010
12390      RG=GMX+AMARG
12400      DIF=ABS(GG-RG)
12410      IF(DIF.LT.0.00001)G0T010
12420      GP=RG
12430      10 JULIE=JILL
12440      RETURN
12450      END
13000C
13005C      DETERMINE THE N-SUB-H OF THE FUEL
13006C      WHICH RESULTS IN ALL DELTA-PHASE
13007C      FUEL IN THE HOT ELEMENT AT B0L
13010C
13020      SUBROUTINE ALLDEL(ATFU,AZR,TMNF)
13030      DIMENSION ATFU(30)
13040C
13050      FBP(Y)=1.434E-10*EXP(.01806*Y)
13060      FPRES(X1,AT)=EXP(-8.8455+88.8901*X1-78.8961*X1**2
13070&      +21.3731*X1**3)
13080&      *EXP((-12.972+9.7707*X1-2.4984*X1**2)*1E4/AT)
13090C
13100      ADD=.1
13110      AZRR=AZR
13120      3 CONTINUE
13130      AT=ATFU(1)+459.7
13140      P1=FPRES(AZRR,AT)
13150      IF(AZRR.GT.1.7)G0T06
13160      BZR=AZRR+ADD
13170      G0T07
13180      6 CONTINUE
13190      BZR=AZRR-ADD
13200      7 CONTINUE
13210      P2=FPRES(BZR,AT)

```

THERMO CONTINUED

```

13220      A1=(AZRR-BZR)/(ALOG(P1)-ALOG(P2))
13230      B=AZRR-A1*ALOG(P1)
13240      BP=FBP(TMNF)
13250      BHZR=AZRR
13260      AZRR=A1*ALOG(BP)+B
13270      DIF=BHZR-AZRR
13280      IF(DIF.LT.0.0)DIF=-DIF
13290      IF(DIF.LT.0.001)GOTO4
13300      ADD=ADD*.2
13310      GOTO3
13320      4 CONTINUE
13330      AZR=AZRR
13340      RETURN
13350      END

14000C
14005C          CALCULATE HYDROGEN LEAKAGE
14010C
14020      SUBROUTINE HLEAK(ADCOLD,ADHOT,ADTUBE,AHL,AHL0S,
14030&      ALEN,ALIFE,ATFU,AZR,CLTH,DIACL,DIAFU,ELN0,GTH,P,
14040&      TCDGP,TIM)
14050      DIMENSION AHZR(30),AM(11),ATFU(30),P(30),TC(10),
14060&      TCDGP(11),TIM(30)
14070C
14080C          RAYMOND'S PRESSURE EQUATION
14090      FPRES(X1,X2)=EXP(-8.8455+88.9801*X1-78.8961*X1**2+21.3731
14100&      *X1**3)*EXP((-12.972+9.7707*X1-2.4984*X1**2)*1.0E04/X2)
14110      AKA=A(62)*A(66)/(GTH*.0254)
14120      JUDY=1
14130      AM(1)=ADCOLD
14140      AM(10)=ADHOT
14150C
14160      D0 26,I=2,9
14170      AM(I)=ADTUBE
14180      26 CONTINUE
14190      BKD=A(65)/(CLTH*.0254)
14200      AHZR(1)=AZR
14210      AREA=ALEN*3.14159*DIACL*2.54**2*.1
14220      W0RH=A(69)/.0287
14230      CCELM=22.4E03*6.3E22*.07854*16.39*ALEN*DIAFU**2/
14240&      (2*1.81*6.023E23)
14250      D0LCC=W0RH/CCELM
14260      CC=0.0
14270      DNH=0.0
14280      AT=ATFU(1)+459.7
14290      P(1)=FPRES(AZR,AT)
14300      ALIF=ALIFE*8766.
14310C
14320      87 CONTINUE
14330      IF(TIM(JUDY+1).GT.ALIF)TIM(JUDY+1)=ALIF
14340      IF(JUDY.LE.1) G0 T0 431

```

THERMO CONTINUED

```

14350      AHZR(JUDY)=AHZR(JUDY-1)-CC/CCELM
14360 431  CONTINUE
14370      AZR=AHZR(JUDY)
14380      AT=ATFU(JUDY)+459.7
14390      P(JUDY)=FPRES(AZR,AT)
14400      TIME=TIM(JUDY+1)-TIM(JUDY)
14410      CC=0.0
14420C
14430      D057I=1,10
14440      TC(I)=0.5*(TCDGP(I)+TCDGP(I+1))+459.7
14450      CC=CC+(AM(I)*BKD*SORT(P(JUDY))*EXP(-A(63)/TC(I))+
14460&      AKA*P(JUDY)*EXP(-A(64)/TC(I))*AREA*TIME
14470 57  CONTINUE
14480      DNH=DNH+CC/CCELM
14490      DL0S=DNH*W0RH
14500      CCHR=CC/TIME
14510      IF(TIM(JUDY+1).EQ.ALIF)G0T031
14520      JUDY=JUDY+1
14530      G0T087
14540C
14550 31  CONTINUE
14560      AHZR(JUDY+1)=AHZR(JUDY)-CC/CCELM
14570      AHL0S=DNH*W0RH
14580      AZR=AHZR(1)
14590      CEL=CCHR
14600      AHL=AHZR(JUDY+1)
14610      RETURN
14620      END
15000C
15005C      CHECK TO SEE IF BETA-PHASE FUEL
15006C      HAS OCCURRED DURING LIFE
15010C
15020      SUBROUTINE BETABN(JEAN,P,TIM,TPPK)
15030      DIMENSION P(30),TIM(30),TPPK(30)
15040      FBETA(Z)=1615.97+89.9747*(AL0G(Z))+3.8810*(AL0G(Z))**2
15050&      +0.13459*(AL0G(Z))**3
15060C
15070      BTB0L=FBETA(P(1))
15080      PZ=P(JEAN)
15090      BTE0L=FBETA(PZ)
15100      IF(BTB0L.LE.TPPK(1))G0T05
15110 6  CONTINUE
15120      K=JEAN-1
15130C
15140      D014I=2,K
15150      ID=I
15160      BTP=FBETA(P(I))
15170      IF(BTP.LE.TPPK(I))G0T017
15180 14 CONTINUE
15190 26 CONTINUE

```


- 7 -

THERMO CONTINUED

```
15200      TFEL=TPPK(JEAN)
15210      IF(BTE0L.LE.TFEL)G0T09
15220      G0T02
15230      5 CONTINUE
15240      PRINT 22,TIM(1),BTB0L,TPPK(1)
15250      G0T06
15260      17 CONTINUE
15270      PRINT 22,TIM(ID),BTP,TPPK(ID)
15280      G0T026
15290      9 CONTINUE
15300      PRINT 22,TIM(JEAN),BTE0L,TPPK(JEAN)
15310      G0T02
15320      22 FORMAT(" CAUTION! BETA PHASE FUEL OCCURRED AT T=",
15330&      E12.4," HOURS." / "T BETA IS      ",E12.4, /
15340&      "T FUEL MAX IS",E12.4)
15350      2 RETURN
15360      END
```

FIZIKS

```

20000C
20010C
20020      SUBROUTINE FIZIKS(DX,DXM,EPS,KFIZZ,
20030&      KOUNT,N,NF,XF,XI,XYZ,YF,YS)
20040C
20050C          THIS SUBROUTINE CALCULATES THE
20060C          CORE NUCLEAR CHARACTERISTICS
20080C
20090C          IF KFIZZ EQUALS 1, FIZIKS
20100C          SEARCHES FOR THE PITCH REQUIRED
20110C          TO GIVE AN EOL REACTIVITY
20120C          EQUAL TO X(J,36)
20125C
20130      IF(KFIZZ.EQ.0)N=1
20140      KNT=0
20150      IF(KFIZZ.EQ.0)KNT=1
20160      X2=XI
20170      DEL=DX*X2
20180      D0204I=1,N
20190      Y2=FIZIX(X2,XYZ,KOUNT,KNT)
20200      IF(I.EQ.1)GOT0203
20210      YEP=ABS(Y2-YS)
20220      IF(YS.NE.0)YEP=YEP/ABS(YS)
20230      IF(YEP.LE.EPS)GOT0201
20240      GOT0202
20250 201 IF(KNT.EQ.1) G0 T0 206
20260      KNT=1
20270 202 CONTINUE
20280      DEL=-(Y2-YS)/(Y2-Y1)*(X2-X1)
20290      DEL=SIGN(AMINI(ABS(DEL),ABS(DXM*X2)),DEL)
20300 203 X1=X2
20310      X2=X2+DEL
20320 204 Y1=Y2
20330      IF(KFIZZ.EQ.0)G0 T0 207
20340      PRINT 205
20350 205 FORMAT(//"MAX ITERATIONS EXCEEDED IN FIZIKS
20360& SEARCH FOR PITCH")
20370      PRINT,J,"      PITCH=",X2,"      EOL RH0=",Y2
20380 207 CONTINUE
20390      I=N
20400 206 XF=X2
20410      YF=Y2
20420      NF=I
20430      RETURN
20440      END
22000C
22010C
22020      FUNCTION FIZIX(PITCH,XYZ,KOUNT,KNT)
22030$ENC
22040C          INITIALIZE VARIABLES FROM X FILE

```

FIZIKS CONTINUED

```

22050C
22060      ELN0= X(J,1)
22070      AL0NG =X(J,2)
22080      WTPCU =X(J,4)
22090      CLADTH=X(J,5)
22100      FINHT =X(J,6)
22110      FINN0 =X(J,7)
22120      FINTH =X(J,8)
22130      GLASTH=X(J,9)
22140      GAPTH =X(J,10)
22150      FACIF =X(J,13)
22160      BEVF  =X(J,14)
22170      SSVF  =X(J,15)
22180      VESTH =X(J,17)
22190      POW   =X(J,19)
22200      ALIFE =X(J,20)
22210      TOUT  =X(J,21)
22220      DELTAT=X(J,22)
22230      ENH   =X(J,23)
22240      EMEV  =X(J,24)
22250      ALPHA =X(J,25)
22260      BETA  =X(J,26)
22270      RHL   =X(J,27)
22280      ICLAD =X(J,28)
22290      SHIM  =X(J,29)
22300      PPL   =X(J,30)
22310      F149  =X(J,31)
22320      F151  =X(J,32)
22330      F155  =X(J,33)
22340      F157  =X(J,34)
22350      THETA =X(J,37)
22360      STR0KE=X(J,38)
22370      DEG   =X(J,41)
22380      TRMIN =X(J,42)
22390      AR    =X(J,43)
22400      SEPD  =X(J,44)
22410C
22420C      SET UP PRELIMINARY DATA SUCH AS DIMENSIONS,
22430C      AREAS,VOLUMES,DENSITIES,MASSSES,BURNUP,ETC.
22440C
22450      A(1)=XYZ+SHIM
22460      PI=3.141593
22470      THETAR=THETA*PI/180
22480      TANG=SIN(THETAR)/COS(THETAR)
22490      REFLTH=TRMIN+TANG*AL0NG/2
22500      DFUEL=PITCH-FINHT-2.0*(CLADTH+GLASTH+GAPTH)
22510      DGG=DFUEL+GAPTH+GLASTH
22520      DCLAD=DFUEL+2.0*(GAPTH+GLASTH)+CLADTH
22530      AFUEL=0.7854*DFUEL*DFUEL
22540      AGG=3.141593*DGG*(GLASTH+GAPTH)

```

FIZIKS CONTINUED

```

22550    ACLAD=3.141593*DCLAD*CLADTH
22560    AFINS=FINN0*FINHT*FINTH
22570    ACF=ACLAD+AFINS
22580    ACELL=0.866*PITCH*PITCH
22590    VFFUEL=AFUEL/ACELL
22600    VFGG=AGG/ACELL
22610    VFCF=ACF/ACELL
22620    VFC00L=1.0-VFFUEL-VFGG-VFCF
22630    DC0RE=SQRT(ELN0*ACELL/.7854)
22640    THIF=PITCH*FACIF
22650    DVESS=DC0RE+2.0*THIF+.04
22660    0DVESS=DVESS+2*VESTH
22670    ENV=DVESS+2*REFLTH+2*VESTH
22680    CV0L=0.7854*DC0RE*DC0RE*AL0NG*0.001*2.54**3
22690    V0LF=AFUEL*AL0NG*ELN0*2.54**3
22700    FDENS =5.63464+.0418655*WTPCU+.00037023*WTPCU*WTPCU
22710    UMASS=V0LF*FDENS*WTPCU*.9315*.982*.001
22720    UMASS=.01*UMASS
22730    SPWR=P0W/UMASS
22740    PDENS=P0W/CV0L
22750    FTKWT=12.0*P0W/(ELN0*AL0NG)
22760    BUP=SPWR*ALIFE*365.26*0.001
22770    AT0MU=UMASS*6.025E26/235.1
22780    BU=P0W*3.121E13*3.1558E07*ALIFE*200.0/EMEV
22790    BPCT=BU*100.0/AT0MU
22800    BMA0=BPCT/24.57
22810C
22820C          SET UP CLADDING MATERIAL AS PER ICLAD
22830C
22840    VFI=0.0
22850    VFHN=0.0
22860    VFHX=0.0
22870    IF(ICLAD)15,16,17
22880    15 VFI=VFCF
22890    G0 T0 18
22900    16 VFHN=VFCF
22910    G0 T0 18
22920    17 VFHX=VFCF
22930    18 CONTINUE
22940C
22950C          CALCULATE C0LD, CLEAN B0L REACTIVITY,
22960C          FIRST WITH REFLECT0R THICKNESS=0
22970C          THEN WITH REFLECT0R THICKNESS=REFLTH
22980C
22990    FINK=A(1)+A(2)*VFFUEL*(ENH+A(3))+A(4)*VFI+A(5)*VFHN+A(6)*VFHX
23000    EMS0=1.0/(A(7)+A(8)*VFFUEL*(ENH+A(9))+A(10)*VFI+
23010&    A(11)*VFHN+A(12)*VFHX)
23020    KX=-1
23030    TR=0.0
23040    12 KX=KX+1

```

FIZIKS CONTINUED

```

23050      DELR=A(13)+A(14)*(1.0-EXP(A(15)*TR))
23060      RO=1.27*DCORE+DEL R
23070      BSQR=(A(16)/RO)**2
23080      ELR=EMSQ*BSQR
23090      HO=2.54*ALONG+A(17)
23100      BSQZ=(A(18)/HO)**2
23110      ELZ=EMSQ*BSQZ
23120      ABSORP=1.0-ELR-ELZ
23130      EFFK=FINK*ABSORP
23140      FISS=EFFK/2.43
23150      RH0=(EFFK-1.0)/(EFFK*BETA)
23160      IF(KX)13,13,14
23170      13 R0E=RH0
23180      TR=REFLTH
23190      G0 T0 12
23200      14 CONTINUE
23210C
23220C          CALCULATE TAPER CORRECTION TO REACTIVITY
23230C
23240      DELRH0=-.025*THETA-.0062*THETA**2
23250      RH0=RH0+DELRH0
23260C
23270C          CALCULATE CONTROL WORTH AVAILABLE
23280C
23290      SSS=STROKE/ALONG
23300      FRW=(DEG/360)*( .004*THETA+1.652*SSS+.0056*THETA*SSS
23310&      -.664*SSS**2)
23320      DW=FRW*(RH0-R0E)
23321C
23330C          CALCULATE SHORT TERM REACTIVITY LOSSES
23332C
23350      AC0EFF=A(19)
23360      RTEMP=.01*AC0EFF*(TOUT-DELTAT/2-70)
23370      RPWR=A(20)*SPWR
23380      RXE=A(21)*SPWR
23390      RHRD=A(22)*SPWR
23400      RSTL=RTEMP+RPWR+RXE+RHRD
23410C
23420C          CALCULATE LONG TERM REACTIVITY LOSSES
23430C
23440      R235=A(23)*BUP
23450      R236=A(24)*BUP
23460      R238=A(25)*BUP
23470      RFP=A(26)*BUP
23480      RSM=A(29)*(1.0-EXP(BUP/A(27)))
23490      PPL=PPL*(F149+F151+F155+F157)
23500      R149=PPL*F149*EXP(BUP*A(31))
23510      R151=PPL*F151*EXP(BUP*A(32))
23520      R152=(F151*PPL-R151)*A(30)
23530      R155=PPL*F155*EXP(BUP*A(33))

```

FIZIKS CONTINUED

```

23540      R157=PPL*F157*EXP(BUP*A(34))
23550      RPPLR=R149+R151+R152+R155+R157
23560      RLTL=R235+R236+R238+RFP+RSM+RHL
23570      RLTL=RLTL+RPPLR
23576C
23580      RREQ=RSTL+RLTL
23590      EOLRM=RH0-RREQ
23600      ZPSDM=DW-RREQ-EOLRM
23610      AMM=DW-EOLRM-RSTL-2
23620      RHP=RH0-RSTL-PPL
23630      BSDM=DW-RH0+PPL
23640      ANPMM=RHP-EOLRM
23650C
23660C          DETERMINE THE COMPONENTS OF REACTOR WEIGHT
23670C
23680      WFUEL=ELN0*ALONG*DFUEL*DFUEL*.7854*.22
23690      WCLAD=ELN0*(ALONG+1)*(DGG+CLADTH)*CLADTH*PI*.295
23700      WECAP=ELN0*(PI/4)*((DGG+2*CLADTH)**2)*.46*.295
23710      WGRIDS=(PI/4)*(DVESS**2)*.25*.284
23720      WIR=ALONG*DVESS*THIF*A(47)
23730      WCNVAK=VFC07L*DVESS*DVESS*(ALONG+2)*A(48)
23740      WCORE=WFUEL+WCLAD+WECAP+WGRIDS+WIR+WCNVAK
23750      WSHELL=PI*DVESS*VESTH*(ALONG+1.5)*.284
23760      WPLW=PI*DVESS*.125*5.0*.284
23770      WPLE=(PI/4)*DVESS*DVESS*.125*2*.284
23780      WVSS=PI*DVESS*.2*4*.284
23790      WPNVAK=(PI/4)*DVESS*DVESS*4*.026
23800      WCVSS=WSHELL+WPLW+WPLE+WVSS+WPNVAK
23810      DD1=DVESS+2*(VESTH+REFLTH)-ALONG*TANG
23820      DD2=DD1+2*ALONG*TANG
23830      VCR=(PI/12)*ALONG*(DD1*DD1+DD2*DD2+DD1*DD2)
23840      VC=(PI/4)*ALONG*(DVESS+VESTH)*(DVESS+VESTH)
23850      WR=.0628*(VCR-VC)
23860      WACT=36.6
23870      WSE=.13*WR+12.0
23880      WPIP=ALONG*A(49)
23890      WREF=WR+WSE+WACT+WPIP
23900      WREAC=WCORE+WCVSS+WREF
23903C
23910      X(J,18)=REFLTH
23920      IF(K0JNT.EQ.0) GO TO 19
23930      IF(KNT.EQ.0) GO TO 19
23940C
23950C          SET UP VARIABLES FOR SHIELD CALCULATION
23960C
23970      SEP=SEPD
23980      DG=A(52)
23990      DV=A(53)
24000      GPV=A(54)
24010      A77=A(55)

```

FIZIKS CONTINUED

```

24020      B77=A(56)
24030      SD=SEPD
24040      CALL SHIELD(P0W,ALIFE,THETA,ALONG,ENV,0DVESS,
24050 &      TL,TG,WL,WG,WT,SEP,DG,DN,GPV,A77,B77)
24060      WT=WG+WL
24070      WRESH=WREAC+WT
24080C
24090C          SET UP OUTPUT ARRAY IN X FILE
24100C
24110      X(J,11)=DFUEL
24120      X(J,12)=DCORE
24130      X(J,13)=THIF
24140      X(J,16)=DVESS
24150      X(J,18)=REFLTH
24160      X(J,27)=VFFUEL
24170      X(J,28)=VFGG
24180      X(J,29)=VFCF
24190      X(J,30)=VFC00L
24200      X(J,35)=UMASS
24210      X(J,36)=CV0L
24220      X(J,37)=SPWR
24230      X(J,38)=PDENS
24240      X(J,39)=FTKWT
24250      X(J,40)=BUP
24260      X(J,41)=BMA0
24270      X(J,42)=WTPCU
24280      X(J,43)=FDENS
24290      X(J,44)=RH0
24300      X(J,45)=DW
24310      X(J,46)=ELR
24320      X(J,47)=ELZ
24330      X(J,48)=FINK
24340      X(J,49)=EFFK
24350      X(J,50)=ABS0RP
24360      X(J,51)=FISS
24370      X(J,52)=BSQR
24380      X(J,53)=BSQZ
24390      X(J,54)=EMSQ
24400      X(J,55)=RTEMP
24410      X(J,56)=RPWR
24420      X(J,57)=RXE
24430      X(J,58)=RHRD
24440      X(J,59)=RSTL
24450      X(J,60)=R235
24460      X(J,61)=R236
24470      X(J,62)=R238
24480      X(J,63)=RFP
24490      X(J,64)=RSM
24500      X(J,65)=RHL
24510      X(J,66)=RLTL

```

FIZIKS CONTINUED

24520	X(J,67)=RREQ
24530	X(J,68)=EOLRM
24540	X(J,69)=ICLAD
24550	X(J,70)=ZPSDM
24560	X(J,71)=ENV
24570	X(J,72)=AMM
24580	X(J,73)=SHIM
24590	X(J,74)=PPL
24600	X(J,75)=RPPLR
24610	X(J,76)=BSDM
24620	X(J,77)=ANPMM
24630	X(J,78)=RHP
24640	X(J,79)=R149
24650	X(J,80)=R151
24660	X(J,81)=R152
24670	X(J,82)=R155
24680	X(J,83)=R157
24690	X(J,84)=VFFUEL*.001504
24700	X(J,85)=VFFUEL*.000109
24710	X(J,86)=VFFUEL*ENH*.01
24720	X(J,87)=VFFUEL*.03534
24730	X(J,92)=WCORE
24740	X(J,93)=WCVESS
24750	X(J,94)=WREF
24760	X(J,95)=WREAC
24770	X(J,96)=THETA
24780	X(J,97)=STROKE
24790	X(J,98)=FRW
24800	X(J,99)=DELRH0
24810	X(J,100)=DEG
24820	X(J,101)=TG
24830	X(J,102)=TL
24840	X(J,103)=WG
24850	X(J,104)=WL
24860	X(J,105)=WT
24870	X(J,106)=WRESH
24880	X(J,107)=ODVESS
24890	X(J,113)=SEPD
24900	X(J,114)=WFUEL
24910	X(J,115)=WCLAD
24920	X(J,116)=WECAP
24930	X(J,117)=WGRIDS
24940	X(J,118)=WIR
24950	X(J,119)=WCNAK
24960	X(J,120)=WCORE
24970	X(J,121)=WSHELL
24980	X(J,122)=WPLW
24990	X(J,123)=WPLE
25000	X(J,124)=WVSS
25010	X(J,125)=WPNAK

FIZIKS CONTINUED

```

25020      X(J,126)=WC VESS
25030      X(J,127)=WR
25040      X(J,128)=WACT
25050      X(J,129)=WSE
25060      X(J,130)=WPIP
25070      X(J,131)=WREF
25080      X(J,132)=WREAC
25086C
25090      19 CONTINUE
25100      FIZIX=EOLRM
25110      RETURN
25120      END
27000C
27010C
27020      SUBROUTINE SHIELD(P0W,YRS,THETA,ALONG,ENV,0DVES,
27030&      TL,TG,WL,WG,WT,SEP,DG,DN,GPV,A,B)
27040      DIMENSION TGA(23),YA(23)
27043C
27044C          THE FOLLOWING DATA ARRAYS GIVE
27045C          GAMMA SHIELD ATTENUATION VS THICKNESS
27046C
27050      DATA YA/.030,.035,.040,.05,.06,.07,.08,.09,.1,.125,.15,
27060&      .175,.2,.25,.3,.35,.4,.5,.6,.7,.8,.9,1.0/
27070      DATA TGA/7.2,6.513,5.913,4.975,4.244,3.611,3.12,2.76,2.487,
27080&      2.062,1.811,1.615,1.45,1.20,1.015,.862,.736,.545,.404,
27090&      .273,.1745,.0818,0.0/
27100      DATA AG,RS/
27110&      3.0,13/
27115C
27120      ALIFE=YRS
27130      TL=2.61*ALOG((1.84E16*ALIFE*P0W)/(DN*SEP**2))
27140      DG1=(1.272E8*P0W/SEP**2)*EXP(-0.0756*TL)
27150      S=(SEP-7.17)*((THETA/6.56)**0.25)
27160      DNAK=4.28E5*P0W/(S**2)
27170      DG=(1.0E6-DNAK)*AG
27180      DG2=DG/ALIFE
27190      IF(DG1.LE.DG2) G0 T0 360
27200      Y=DG2/DG1
27210      NL0C=0
27220      TG=FUNCT1(YA,TGA,23,Y,NL0C,2)
27230      G0 T0 370
27240      360 TG=0
27250      370 CONTINUE
27260      R=(0DVES/2.0)+1.0
27270      VG=3.1416*TG*R**2
27280      WG=VG*0.51612
27290      C=THETA *3.1416/180.0
27300      TANG=SIN(C)/COS(C)
27310      TL=TL-0.75*TG
27320      R1=(ENV/2.0)+(RS*TANG)

```

FIZIKS

```

27330      R2=R1+(TL*TANG)
27340      P=R1+A*TANG
27350      Q=R2-B*TANG
27360      VL=3.1416*((((TL-A-B)/3.0)*(P**2+P*Q+Q**2)+
27370 &      A*(A**2+3.0*P**2)/6.0+B*(B**2+3.0*Q**2)/6.0)
27380      WL=VL*0.032
27390      WT=WG+WL
27400      RETURN
27410      END
28000C
28010C
28020C
28030 FUNCTION FUNCT1(BLAP,SPLUTT,JINGLE,SPLAT,J0J0,JUNGLE)
28040 DIMENSION BLAP(1), SPLUTT(1), ZONG0(3)
28050 EQUIVALENCE (ZONG0(1),PING), (ZONG0(2),PONG), (ZONG0(3),WHONK)
28052C
28053C          THREE POINT LAGRANGIAN INTERPOLATION ROUTINE
28054C
28060      KRASH=3
28070      IF(JINGLE.GE.3 .AND. JUNGLE.GE.2) GO TO 15
28080      KLANK=1
28090      KAB00M=0
28100      IF(JINGLE.LE.1) GO TO 38
28110      KRASH=2
28120 15  KLANK=MAX0(2,JINGLE+2-KRASH)
28130      THW0CK=SPLAT
28140      KRUNCH=2
28150      IF(J0J0.LE.1 .OR. J0J0.GE.JINGLE) GO TO 102
28160 211 KRUNCH=J0J0
28170      IF(THW0CK.LT.BLAP(KRUNCH)) GO TO 101
28180C - SEARCH UPWARD IN TABLE
28190 102 D0 20 KAB00M=KRUNCH,KLANK
28200      IF(THW0CK.LE.BLAP(KAB00M)) GO TO 10
28210 20 CONTINUE
28220      KAB00M=KLANK
28230      GO TO 10
28240 101 D0 21 JANGLE=2,KRUNCH
28250      KAB00M=KRUNCH-JANGLE+1
28260      IF(THW0CK.GT.BLAP(KAB00M)) GO TO 11
28270 21 CONTINUE
28280      KAB00M=1
28290 11 KAB00M=KAB00M+1
28300 10 SPAN=1.0E-06*THW0CK
28310      KLANK=0
28320      D0 12 JANGLE=1,KRASH
28330      KRUNCH=KAB00M+JANGLE-2
28340      ZONG0(JANGLE)=THW0CK-BLAP(KRUNCH)
28350 12 IF(ABS(ZONG0(JANGLE)).LE.SPAN) KLANK=KRUNCH
28360      IF(KLANK.EQ.0) GO TO 90
28370 38 FUNCT1=SPLUTT(KLANK)

```

FIZIKS CONTINUED

```
28380      G0 T0 80
28390    90 BLEEP=BLAP(KAB00M-1)-BLAP(KAB00M)
28400      IF(KRASH.EQ.3) G0 T0 360
28410      FUNCT1=SPLUTT(KAB00M)-(SPLUTT(KAB00M)-SPLUTT(KAB00M-1))
28415&      *PONG/BLEEP
28420      G0 T0 80
28430    360 BL00P=BLAP(KAB00M-1)-BLAP(KAB00M+1)
28440      PL0P=BLAP(KAB00M)-BLAP(KAB00M+1)
28450    36 FUNCT1=SPLUTT(KAB00M-1)*PONG*WH0NK/(BLEEP*BL00P)
28460&      -SPLUTT(KAB00M) *PING*WH0NK/(BLEEP*PL0P)
28470&      +SPLUTT(KAB00M+1)*PING*PONG/(BL00P*PL0P)
28480    80 J0J0=KAB00M
28490      RETURN
28500      END
```

ZPRINT

```

30000C
30010C      ON LINE PRINT OF SELECTED OUTPUT DATA
30020C
30030C
30040      SUBROUTINE ZPRINT(C1,C2,NCASE,NPRINT,T1,T2,T3,T4,
30050&      ITIME,T0D,DATE)
30060C
30070      COMMON T(4,140),X(4,140),XIN(4,50),
30080&      J,A(80),XLINE
30090C
30100      DIMENSION DATE(3),Z(8,140)
30110      DIMENSION ICASE(4),C1(4),C2(4),T1(4),T2(4),T3(4),T4(4)
30120C
30130      DO 302 K=1,140
30140      DO 303 I=1,NCASE
30150      J=I+4
30160      Z(J,K)=X(I,K)
30170 303 CONTINUE
30180      DO 302 I=1,4
30190      Z(I,K)=T(I,K)
30200 302 CONTINUE
30210      NPRINT=NCASE+4
30220      PRINT 85,
30230      DO 300 J=1,5
30240      PRINT 80,
30250 300 CONTINUE
30260      PRINT 63,T0D,(DATE(I),I=1,3)
30270      PRINT 70,(T1(J),T2(J),J=1,NCASE)
30280      PRINT 70,(T3(J),T4(J),J=1,NCASE)
30290      PRINT 71,(T(I,46),I=1,4),(XIN(J,40),J=1,NCASE)
30300      PRINT 71,(T(I,47),I=1,4),(XIN(J,11),J=1,NCASE)
30310      PRINT 71,(T(I,48),I=1,4),(XIN(J,12),J=1,NCASE)
30320      PRINT 72,(T(I,49),I=1,4),(XIN(J,16),J=1,NCASE)
30330      PRINT 71,(T(I,50),I=1,4),(XIN(J,35),J=1,NCASE)
30340      PRINT 72,(Z(I,3),I=1,NPRINT)
30350      PRINT 73,(Z(I,18),I=1,NPRINT)
30360      PRINT 73,(Z(I,71),I=1,NPRINT)
30370      PRINT 72,(Z(I,10),I=1,NPRINT)
30380      PRINT 73,(Z(I,107),I=1,NPRINT)
30390      PRINT 73,(Z(I,90),I=1,NPRINT)
30400      PRINT 71,(Z(I,88),I=1,NPRINT)
30410      PRINT 76,(Z(I,68),I=1,NPRINT)
30420      PRINT 76,(Z(I,76),I=1,NPRINT)
30430      PRINT 76,(Z(I,74),I=1,NPRINT)
30440      PRINT 76,(Z(I,75),I=1,NPRINT)
30450      PRINT 76,(Z(I,44),I=1,NPRINT)
30460      PRINT 76,(Z(I,45),I=1,NPRINT)
30470      PRINT 76,(Z(I,96),I=1,NPRINT)
30480      PRINT 76,(Z(I,101),I=1,NPRINT)
30490      PRINT 76,(Z(I,102),I=1,NPRINT)

```

ZPRINT CONTINUED

```
30500      PRINT 76,(Z(I,113),I=1,NPRINT)
30510      PRINT," "
30520      PRINT 86,
30530      D0 304 J=114,120
30540      PRINT 78,(Z(I,J),I=1,NPRINT)
30550 304  CONTINUE
30560      PRINT," "
30570      D0 305 J=121,126
30580      PRINT 78,(Z(I,J),I=1,NPRINT)
30590 305  CONTINUE
30600      PRINT," "
30610      D0 306 J=127,132
30620      PRINT 78,(Z(I,J),I=1,NPRINT)
30630 306  CONTINUE
30640      PRINT," "
30650      PRINT 78,(Z(I,103),I=1,NPRINT)
30660      PRINT 78,(Z(I,104),I=1,NPRINT)
30670      PRINT 78,(Z(I,105),I=1,NPRINT)
30680      PRINT," "
30690      PRINT 78,(Z(I,106),I=1,NPRINT)
30700      D0 307 I=1,8
30710      PRINT," "
30720 307  CONTINUE
30730      PRINT 85,
30740      63  FORMAT(1X,4A6)
30750      70  FORMAT(24X,8A6)
30760      71  FORMAT(4A6,I11,3I12)
30770      72  FORMAT(4A6,4F12.4)
30780      73  FORMAT(4A6,4F12.3)
30790      76  FORMAT(4A6,4F12.2)
30800      78  FORMAT(4A6,4F12.1)
30810      80  FORMAT(2X)
30820      85  FORMAT(64("-"))
30830      86  FORMAT(3X,"WEIGHTS (LBS)")
30840      RETURN
30850      END
```

ZWRITE

```

40000 SUBROUTINE ZWRITE(C1,C2,NCASE,NPRINT,NVAR,T1,T2,T3,T4,KICKS,
40010& ITIME,T0D,DATE)
40040C
40050C
40055      COMMON T(4,140),X(4,140),XIN(4,50),
40056&      J,A(80),XLINE
40060C
40070      DIMENSION DATE(3),Z(8,140)
40080      DIMENSION ICASE(4),C1(4),C2(4),T1(4),T2(4),T3(4),T4(4)
40085C
40090      IF(KICKS.EQ.1) GO TO 301
40100      CALL OPENF(1,"OUTPUT")
40110      CALL SETSCT(1,XLINE)
40120 301 CONTINUE
40130      DO 302 K=1,140
40140      DO 303 I=1,NCASE
40150      J=I+4
40160      Z(J,K)=X(I,K)
40170 303 CONTINUE
40180      DO 302 I=1,4
40190      Z(I,K)=T(I,K)
40200 302 CONTINUE
40210      NPRINT=NCASE+4
40230      IF(KICKS.GT.1) GO TO 308
40240      WRITE(1,85),
40250 308 CONTINUE
40260      DO 309,J=1,4
40270      WRITE(1,80),
40280 309 CONTINUE
40290      WRITE(1,63),T0D,(DATE(I),I=1,3)
40300      WRITE(1,70),(T1(J),T2(J),J=1,NCASE)
40310      WRITE(1,70),(T3(J),T4(J),J=1,NCASE)
40320      WRITE(1,80),
40330      WRITE(1,81),
40340      DO 310 J=55,59
40350      WRITE(1,76),(Z(I,J),I=1,NPRINT)
40360 310 CONTINUE
40370      WRITE(1,80),
40380      DO 311 J=60,65
40390      WRITE(1,76),(Z(I,J),I=1,NPRINT)
40400 311 CONTINUE
40410      DO 313 J=79,83
40420      SUMX=0.0
40430      DO 312 I=5,NPRINT
40440      SUMX=SUMX+Z(I,J)
40450 312 CONTINUE
40460      IF(SUMX.LT.0.001) GO TO 314
40470      WRITE(1,76),(Z(I,J),I=1,NPRINT)
40480 314 CONTINUE
40490 313 CONTINUE

```

ZWRITE CONTINUED

```
40500      WRITE(1,76),(Z(I,66),I=1,NPRINT)
40510      WRITE(1,80),
40520      WRITE(1,76),(Z(I,67),I=1,NPRINT)
40530      WRITE(1,80),
40540      WRITE(1,76),(Z(I,44),I=1,NPRINT)
40550      WRITE(1,76),(Z(I,74),I=1,NPRINT)
40560      WRITE(1,76),(Z(I,78),I=1,NPRINT)
40570      WRITE(1,76),(Z(I,68),I=1,NPRINT)
40580      WRITE(1,80),
40590      WRITE(1,76),(Z(I,45),I=1,NPRINT)
40600      WRITE(1,76),(Z(I,70),I=1,NPRINT)
40610      WRITE(1,76),(Z(I,76),I=1,NPRINT)
40620      WRITE(1,80),
40630      WRITE(1,76),(Z(I,77),I=1,NPRINT)
40640      WRITE(1,76),(Z(I,72),I=1,NPRINT)
40730      WRITE(1,80),
40740      WRITE(1,84),
40750      DO 317 J=1,16
40760      WRITE(1,83),(I,A(I),I=J,80,16)
40770 317 CONTINUE
40780      DO 318 J=1,9
40790      WRITE(1,80),
40800 318 CONTINUE
40810      WRITE(1,85),
40820      WRITE(1,80),
40830      WRITE(1,63),T0D,(DATE(I),I=1,3)
40840      WRITE (1,70),(T1(J),T2(J),J=1,NCASE)
40850      WRITE(1,70),(T3(J),T4(J),J=1,NCASE)
40860      WRITE(1,71),(Z(I,1),I=1,NPRINT)
40870      WRITE(1,73),(Z(I,2),I=1,NPRINT)
40880      WRITE(1,72),(Z(I,3),I=1,NPRINT)
40890      WRITE(1,75),(Z(I,4),I=1,4),(C1(I),C2(I),I=1,NCASE)
40900      WRITE(1,74),(Z(I,69),I=1,NPRINT)
40910      WRITE(1,72),(Z(I,5),I=1,NPRINT)
40920      WRITE(1,72),(Z(I,6),I=1,NPRINT)
40930      WRITE(1,74),(Z(I,7),I=1,NPRINT)
40940      DO 319 J=8,13
40950      WRITE(1,72),(Z(I,J),I=1,NPRINT)
40960 319 CONTINUE
40970      WRITE(1,73),(Z(I,16),I=1,NPRINT)
40980      WRITE(1,73),(Z(I,18),I=1,NPRINT)
40990      WRITE(1,71),(Z(I,19),I=1,NPRINT)
41000      WRITE(1,73),(Z(I,20),I=1,NPRINT)
41010      WRITE(1,71),(Z(I,21),I=1,NPRINT)
41020      WRITE(1,71),(Z(I,22),I=1,NPRINT)
41030      WRITE(1,72),(Z(I,23),I=1,NPRINT)
41040      WRITE(1,73),(Z(I,71),I=1,NPRINT)
41050      WRITE(1,80),
41060      DO 320 J=35,41
41070      WRITE(1,73),(Z(I,J),I=1,NPRINT)
```

ZWRITE CONTINUED

```
41080 320 CONTINUE
41090     WRITE(1,80),
41100     D0 321 J=92,95
41110     WRITE(1,71),(Z(I,J),I=1,NPRINT)
41120 321 CONTINUE
41130     D0 322 J=103,106
41140     WRITE(1,71),(Z(I,J),I=1,NPRINT)
41150 322 CONTINUE
41160     WRITE(1,80),
41170     WRITE(1,71),(Z(I,88),I=1,NPRINT)
41180     WRITE(1,73),(Z(I,90),I=1,NPRINT)
41190     WRITE(1,73),(Z(I,91),I=1,NPRINT)
41200     WRITE(1,80),
41210     WRITE(1,76),(Z(I,96),I=1,NPRINT)
41220     WRITE(1,73),(Z(I,97),I=1,NPRINT)
41230     WRITE(1,72),(Z(I,98),I=1,NPRINT)
41240     WRITE(1,76),(Z(I,99),I=1,NPRINT)
41250     WRITE(1,71),(Z(I,100),I=1,NPRINT)
41260     G0 T0 323
41270     WRITE(1,76),(Z(I,24),I=1,NPRINT)
41280     WRITE(1,72),(Z(I,25),I=1,NPRINT)
41290     WRITE(1,77),(Z(I,26),I=1,NPRINT)
41300     WRITE(1,73),(Z(I,42),I=1,NPRINT)
41310     WRITE(1,73),(Z(I,43),I=1,NPRINT)
41320 323 CONTINUE
41330     WRITE(1,80),
41340     D0 324 J=27,30
41350     WRITE(1,72),(Z(I,J),I=1,NPRINT)
41360 324 CONTINUE
41370     D0 325 J=84,87
41380     WRITE(1,77),(Z(I,J),I=1,NPRINT)
41390 325 CONTINUE
41400     JKLM=3
41410     D0 326 J=1,JKLM
41420     WRITE(1,80),
41430 326 CONTINUE
41440     WRITE(1,85),
41450     JKL5=5
41460     D0 327 J=1,JKL5
41470     WRITE(1,80),
41480 327 CONTINUE
41490     WRITE(1,63),T0D,(DATE(I),I=1,3)
41500     WRITE (1,70),(T1(J),T2(J),J=1,NCASE)
41510     WRITE(1,70),(T3(J),T4(J),J=1,NCASE)
41520     WRITE(1,80),
41530     WRITE(1,87),
41540     D0 328 J=1,NVAR
41550     WRITE(1,79),J,(XIN(I,J),I=1,NCASE)
41560 328 CONTINUE
41570     JKL6=11
```


ZWRITE CONTINUED

```
41580      D0 329 J=1,JKL6
41590      WRITE(1,80),
41600 329  CONTINUE
41610      WRITE(1,85),
41620 63  FORMAT(1X,4A6)
41630 68  FORMAT(A6)
41640 70  FORMAT(24X,8A6)
41650 71  FORMAT(4A6,I11,3I12)
41660 72  FORMAT(4A6,4F12.4)
41670 73  FORMAT(4A6,4F12.3)
41680 74  FORMAT(4A6,I10,3I12)
41690 75  FORMAT(12A6)
41700 76  FORMAT(4A6,4F12.2)
41710 77  FORMAT(4A6,1P4E12.4)
41720 78  FORMAT(4A6,4F12.1)
41730 79  FORMAT(124,4F12.4)
41740 80  FORMAT(2X)
41750 81  FORMAT("REACTIVITY REQUIREMENTS:")
41760 82  FORMAT(4A6,4F12.5)
41770 83  FORMAT(3(I5,F9.5),2(I4,1PE10.4))
41780 84  FORMAT(4X,"I      A(I)",5X,"I      A(I)",5X,"I      A(I)",
41790&    5X,"I      A(I)",5X,"I      A(I)")
41800 85  FORMAT(64("-"))
41810 86  FORMAT(3X,"WEIGHTS (LBS)")
41820 87  FORMAT(2X,"INPUT DATA")
41830      CALL SAVSCT(1,XLINE)
41840      IF(KICKS.GT.1) GO TO 330
41850      CALL CL0SEF(1,"OUTPUT")
41860      RETURN
41870 330  CONTINUE
41880      CALL CL0SEF(1)
41890      RETURN
41900      END
```

REFERENCES

1. H. Rood, editor, "Reactor Assembly, 5-kwe Reactor-Thermoelectric System," AI-AEC-13075, May 20, 1973
2. D. S. Bost, "Selected Computer Codes and Libraries, Volume II. APC - A Multigroup Transport Buckling Iteration Code," AI-AEC-13076, Volume II, May 2, 1973
3. J. M. Otter, "A 28-Group Cross Section Library for SNAP Reactor Analysis," AI-AEC-13076, Volume IV, May 31, 1973
4. L. D. Felten and E. Moody, "TEMPRO, A Heat Transfer-Lifetime Code for SNAP Reactor Analysis," AI-AEC-13076, Volume V, May 24, 1973
5. A. H. Lillie and V. L. Rooney, Jr., "Findings of the SNAP 8 Developmental Reactor (S8DR) Post-Test Examination," AI-AEC-13003, June 30, 1971