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Analysis of Temperature Data from the ORR-PSF Irradiation Experiment: Methodology and Computer Software

L. F. Miller

Prepared for the U.S. Nuclear Regulatory Commission
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ANALYSIS OF TEMPERATURE DATA FROM THE ORR-PSF IRRADIATION EXPERIMENT: METHODOLOGY AND COMPUTER SOFTWARE

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ABSTRACT

The methodology of analysis and a description of applicable computer software relative to the ORR-PSF Irradiation Experiment data are presented. Items obtained from processed data include: 1) irradiation exposure time, 2) megawatt-hours of exposure, 3) average temperature of each thermocouple during normal irradiation conditions, 4) standard deviation of each thermocouple temperature, and 5) a histogram of irradiation time for several temperatures for each thermocouple.

1. INTRODUCTION

The U.S. Nuclear Regulatory Commission is conducting an extensive research effort for characterization of irradiation effects in various steels. Part of this program is conducted at Oak Ridge National Laboratory in the Oak Ridge Research Reactor Poolside Facility (ref. 1). Mechanical test specimens are irradiated in one capsule which simulates a Light Water Reactor Pressure Vessel and in another capsule which simulates a typical pressure vessel surveillance package. Specimen temperatures are maintained at approximately 288°C by an automatic control system (ref. 2).

Reactor power and specimen temperature data are recorded every hour during normal operating conditions and more frequently during transients. These data are processed in order to characterize the temperature and neutron fluence environment associated with physical property data obtained from the irradiated metallurgical test specimens.

Data selected to characterize the irradiation environment are:

1) accumulated megawatt-hours of irradiation,
2) irradiation exposure time histogram at five temperature intervals,
3) average temperature of each thermocouple, and
4) standard deviation of each thermocouple temperature.

Calculations for the above four items are not performed if the experiment is not in-place **nor** if the reactor power is below 5 MW, and they are not commenced for a particular start-up until the applicable average specimen set temperature increases above 285°C. Calculations for individual thermocouples are bypassed if their temperature decreases below 270°C.

Details regarding the methods of analysis and computer implementation of the above functional requirements are presented in the remaining sections of this report.

2. COMPUTATIONAL METHODS

Most of the four items listed in the Introduction which are selected to characterize the capsule irradiation environment require no mathematical explanations. Some mathematical descriptions are presented, however, to illustrate the calculation of average temperature and of the standard deviation for the temperature of each thermocouple. The basic algorithms for implementing the computational objectives are straightforward, but implementation of these algorithms becomes complicated because arbitrary times for insertions and retractions of the capsules, along with temperature and power software switches, must be integrated into a general calendar routine.

Three software switches are involved in calculating the irradiation time: 1) power level, set at 5 MW, 2) time of experiment insertion, and 3) time of experiment withdrawal. Time increments are determined from two successive data records. The date and time of day are established by a calendar routine and the 24-hour time base of the recorded data. Time increments are accumulated only when the experiment is inserted and the reactor power is greater than 5 MW. If these criteria are not satisfied, the time interval between the applicable data records is set to zero.

The megawatt-hours of capsule irradiation exposure are determined from a reactor power signal in conjunction with the calculation of irradiation time as described above. The trapezoidal rule is employed to obtain the integral of reactor power.

A histogram of hours at various temperature levels is computed for each thermocouple so that metallurgical specimen data may be correlated relative to irradiation time within selected temperature intervals. In particular, each time interval is accumulated in one of the following five temperature (T) intervals: 1) $0<T<270$, 2) $270<T<280$, 3) $280<T<296$, 4) $296<T<306$, and 5) $306<T$.

The average temperature and standard deviation calculations are based on two observations:

1) annealing effects are not important below approximately 270°C, and
2) characterization data should be based on essentially steady-state conditions.

In order to incorporate annealing effects into the analyses of metallurgical data, the integral exposure parameters are accumulated only when annealing is thought to be important and steady-state conditions are achieved after each start-up. Programming details are given in Appendix A.

In mathematical terms, the average temperature is defined by

$$\overline{T}(\Theta) = \frac{1}{\Gamma} \int_0^{\Theta} \chi(\tau)\ T(\tau)d\tau \tag{2.1}$$

and

$$\Gamma = \int_0^{\Theta} \chi(\tau)d\tau \tag{2.2}$$

where

τ	=	time
Θ	=	time interval over which data are processed,
$\chi(\tau)$	=	zero or unity as defined by irradiation and capsule conditions,
Γ	=	effective irradiation time,
$T(\tau)$	=	thermocouple temperature,
$\overline{T}(\Theta)$	=	average thermocouple temperature defined over Θ.

The variance, as defined over the effective irradiation time Θ, is

$$\sigma_{\Theta}^2 = \frac{1}{\Gamma} \int_0^{\Theta} \chi(\tau)[T(\tau) - \overline{T}(\Theta)]^2\ d\tau\ . \tag{2.3}$$

Determination of the variance by utilizing equation 2.3 requires that the average temperature be available from equation 2.1. This approach requires that the data be processed twice in order to obtain the variance and the average temperature. It is possible, however, to obtain both the average temperature and the variance of the temperature in a single pass through the data. Note that the average temperature at time $\Theta + \Delta$ may be written as

$$\overline{T}(\Theta + \Delta) = \frac{1}{\Gamma + \Delta} \int_{0}^{\Theta+\Delta} \chi(\tau)\, T(\tau) d\tau. \qquad (2.4)$$

It may also be written as

$$\overline{T}(\Theta + \Delta) = \frac{1}{\Gamma + \Delta} \int_{0}^{\Theta} \chi(\tau)\, T(\tau)\, d\tau + \frac{1}{\Gamma + \Delta} \int_{\Theta}^{\Theta+\Delta} \chi(\tau)\, T(\tau)\, d\tau \qquad (2.5)$$

or

$$\overline{T}(\Theta + \Delta) = \left(\frac{\Gamma}{\Gamma + \Delta}\right) \overline{T}(\Theta) + \frac{1}{\Gamma + \Delta} \int_{\Theta}^{\Theta+\Delta} \chi(\tau)\, T(\tau)\, d\tau \quad . \qquad (2.6)$$

If the integral is approximated by using the trapezoidal rule,

$$\overline{T}(\Theta + \Delta) = \left(\frac{\Gamma}{\Gamma + \Delta}\right) \overline{T}(\Theta) + \left(\frac{\Delta}{\Gamma + \Delta}\right) \left[\frac{T(\Theta) + T(\Theta + \Delta)}{2}\right] . \qquad (2.7)$$

The same approach may be employed to obtain the variance in a single pass through the data. The variance at time $\Theta + \Delta$ is given by

$$\sigma^2_{\theta+\Delta} = \frac{1}{\Gamma + \Delta} \int_0^{\theta+\Delta} \chi(\tau)[T(\tau) - \overline{T}(\theta + \Delta)]^2 d\tau \qquad (2.8)$$

or

$$\sigma^2_{\theta+\Delta} = \frac{1}{\Gamma + \Delta} \int_0^{\theta} \chi(\tau)[T(\tau) - \overline{T}(\theta + \Delta)]^2 \, dt + \frac{1}{\Gamma + \Delta} \int_{\theta}^{\theta+\Delta} \chi(\tau)[T(\tau) - \overline{T}(\theta + \Delta)]^2 d\tau \, . \qquad (2.9)$$

The first integral in equation 2.9 may be defined as

$$\int_0^{\theta} \chi(\tau)[T(\tau) - \overline{T}(\theta + \Delta)]^2 d\tau = \int_0^{\theta} \chi(\tau)[T(\tau) - \overline{T}(\theta)]^2 d\tau + C, \qquad (2.10)$$

where

$$C = \int_0^{\theta} 2\chi(\tau) \; T(\tau)[\overline{T}(\theta) - \overline{T}(\theta + \Delta)]d\tau + \Gamma[\overline{T}^2(\theta + \Delta) - \overline{T}^2(\theta)] \, . \qquad (2.11)$$

Equation 2.11 simplifies to

$$C = \Gamma[\overline{T}(\theta + \Delta) - \overline{T}(\theta)]^2 \, . \qquad (2.12)$$

Thus, equation 2.9 becomes

$$\sigma^2_{\theta+\Delta} = \frac{\Gamma}{\Gamma + \Delta} (\sigma^2_{\theta} + C) + \frac{1}{\Gamma + \Delta} \int_{\theta}^{\theta+\Delta} \chi(\tau)[T(\tau) - \overline{T}(\theta + \Delta)]^2 d\tau \, . \qquad (2.13)$$

If the integral in equation 2.13 is approximated by using the trapezoidal rule and second order effects are neglected,

$$\sigma^2_{\Theta+\Delta} = \left(\frac{\Gamma}{\Gamma + \Delta}\right)(\sigma^2_{\Theta} + C) + \left(\frac{\Delta}{\Gamma + \Delta}\right)\left[T_{\Theta+\Delta/2} - \overline{T}(\Theta + \Delta)\right]^2 \qquad (2.14)$$

where

$$T_{\Theta+\Delta/2} = [T(\Theta) + T(\Theta + \Delta)]/2 \quad . \qquad (2.15)$$

The average temperature and variance of the temperature is computed by the recursive relations defined by equations 2.7 and 2.14, respectively.

3. DATA PROCESSING CONSIDERATIONS

Capsule data are recorded on-line in a digital format by a Digital Equipment Corporation LSI-11 microcomputer on a RK05 hard disk unit. This computer operates under a single job RT-11 monitor and is dedicated to the ORR-PSF irradiation experiment. Consequently, another computer which can read RK05 hard disks is needed to process data off-line. A Digital Equipment Corporation PDP-11/60 which operates under a RSX-11M multi-user monitor is utilized for this task. This computer is located at the High Flux Isotope Reactor (HFIR).

The computer program which processes the data obtained on-line, PSFTH, is normally and most conveniently used to accumulate irradiation history over a one month interval. Another computer program, COMBO, is employed to combine monthly data into cumulative data over the duration of the experiment.

One RK05 hard disk contains about 2 1/2 months of data and is retained at the on-line process computer during this time. When a hard disk is full, it is taken to the HFIR computer facility for storage and processed into monthly characterization data. The monthly data are keypunched for permanent storage on cards and processed with COMBO on the ORNL DEC-10 computer system.

Alternative data processing and archiving scenarios are practical with existing software and hardware available, but the one outlined is quite sufficient and convenient.

4. SAMPLE RESULTS

Characterization data for the first simulated surveillance capsule (SSC-1) and for the simulated pressure vessel capsule (PVC) are given in Tables 1 and 2, respectively. The data for SSC-1 represent final conditions and those for the PVC are cumulative through Dec. 31, 1980. Note that deleted thermocouples have failed and that their output is set to the reference control temperature of 288°C. Standard deviations for these thermocouples should be zero and their average temperature should be 288°C. Relatively large standard deviations may be due to erratic thermocouples. Most standard deviations are less than 2°C, and most average temperatures are within 5°C of 288°C.

5. CONCLUSIONS AND RECOMMENDATIONS

The computer programs listed in Appendices C and D obtain the desired results from the ORR-PSF process data and provide for considerable flexibility in input data and facility operation. Further development is not considered necessary unless additional calculated data are requested from the process data.

Table 1. Cumulative Characterization Data for the Simulated Surveillance Capsule Through June 23, 1980.

Hours of Irradiation Time = 1075.29
Megawatt Hours of Irradiation = 32017.57

Thermocouple	Hours of Irradiation					Average	Standard
	***<T<270	270<T<280	280<T<296	296<T<306	306<T	Temperature	Deviation
TE 1	20.84	283.91	770.55	0.00	0.00	281.25	2.43
TE 2	15.77	4.70	1045.66	9.17	0.00	291.15	1.64
TE 3	17.82	3.12	1054.34	0.00	0.00	288.49	1.74
TE 4	7.11	9.33	364.74	694.12	0.00	295.39	3.03
TE 5	16.15	3.29	1049.00	6.83	0.00	289.70	1.87
TE 6	8.25	10.78	977.42	78.84	0.00	292.32	1.99
TE 7							
TE 8	19.50	7.78	1047.84	0.17	0.00	286.18	1.82
TE 9	10.81	8.75	702.94	352.80	0.00	295.18	1.87
TE 10							
TE 11	20.05	131.04	924.21	0.00	0.00	281.90	1.40
TE 12	19.23	106.34	949.71	0.00	0.00	283.51	2.84
TE 13	18.63	5.61	1010.84	40.21	0.00	289.42	2.70
TE 14	19.20	2.80	698.51	354.77	0.00	294.82	2.58
TE 15	19.21	5.31	1050.77	0.00	0.00	287.64	1.62
TE 16	23.64	11.49	1040.16	0.00	0.00	285.61	1.69
TE 17	19.20	9.98	1046.09	0.00	0.00	287.05	1.43
TE 18	20.65	11.53	1043.11	0.00	0.00	288.24	2.41
TE 19	19.82	15.85	1039.61	0.00	0.00	284.07	1.73
TE 20	27.85	46.31	1001.14	0.00	0.00	283.61	2.37

Table 2. Cumulative Characterization Data for the Pressure Vessel Capsule Through December 31, 1980.

Data for PSF Specimen Set OT
Hours of Irradiation = 4174.92
Megawatt Hours of Irradiation = 118294.17

Thermocouple	Hours of Irradiation					Average Temperature	Standard Deviation
	T<270	270<T<280	280<T<296	296<T<306	306<T		
TE 101	53.13	16.19	4084.22	21.38	0.00	289.64	1.84
TE 102	52.20	11.91	4068.14	42.66	0.00	291.31	1.38
TE 103	51.70	10.68	4112.54	0.00	0.00	289.13	1.03
TE 104	47.63	9.38	4109.48	8.44	0.00	291.88	0.95
TE 105	51.29	13.36	4110.30	0.00	0.00	285.58	1.15
TE 106	47.41	10.05	4117.45	0.00	0.00	288.72	1.03
TE 107	52.64	338.75	3783.55	0.00	0.00	282.06	1.44
TE 108	55.91	13.25	4096.66	9.06	0.00	289.42	1.64
TE 109	55.93	14.24	4096.95	7.78	0.00	288.96	1.66
TE 110	51.62	12.29	4098.08	12.95	0.00	290.23	1.11
TE 111							
TE 112							
TE 113	46.48	9.66	4116.72	0.04	2.00	290.42	1.64
TE 114	58.07	14.31	4102.51	0.00	0.00	288.74	1.60
TE 115							
TE 116	55.68	9.82	4109.42	0.00	0.00	289.97	0.93
TE 117	52.08	10.65	4106.39	5.29	0.50	291.35	0.95
TE 118	54.70	15.82	4104.46	0.00	0.00	286.33	1.08
TE 119	51.77	13.70	4109.45	0.00	0.00	286.64	1.05
TE 120	54.78	189.27	3930.92	0.00	0.00	282.93	1.54

Data for PSF Specimen Set 1/4 T
Hours of Irradiation Time = 4174.92
Megawatt Hours of Irradiation = 118294.17

TE 201	53.00	14.22	4105.05	2.66	0.00	290.28	1.50
TE 202	53.27	13.73	4107.74	0.17	0.00	288.89	1.05
TE 203	51.90	11.21	4111.84	0.00	0.00	288.60	1.08
TE 204	49.99	11.54	4113.08	0.33	0.00	289.40	0.87
TE 205	49.82	18.52	4106.61	0.00	0.00	286.32	1.04
TE 206	47.93	16.76	4110.24	0.00	0.00	286.84	0.94
TE 207	51.61	44.59	4078.73	0.00	0.00	282.94	1.07
TE 208	54.07	11.04	4108.97	0.83	0.00	288.12	1.44
TE 209	54.45	14.83	4105.64	0.00	0.00	288.67	1.34
TE 210	53.15	21.15	4100.64	0.00	0.00	286.73	0.83
TE 211	55.31	25.02	4094.61	0.00	0.00	284.83	0.82
TE 212	47.40	7.48	4120.04	0.00	0.00	290.84	1.05
TE 213	47.76	8.01	4119.13	0.00	0.00	289.60	1.16
TE 214	54.62	10.43	4109.85	0.00	0.00	290.47	0.99
TE 215	54.85	14.73	4105.31	0.00	0.00	287.49	0.74
TE 216	53.97	11.09	4109.88	0.00	0.00	287.85	0.79
TE 217	50.49	8.85	4115.59	0.00	0.00	289.73	0.89
TE 218	50.41	14.48	4108.07	2.00	0.00	286.76	1.07
TE 219	48.95	11.64	4114.36	0.00	0.00	286.99	0.94
TE 220	50.03	104.86	4020.05	0.00	0.00	285.00	1.36

Table 2. (Cont'd)

Data for PSF Specimen Set 1/2 T
Hours of Irradiation Time = 4174.92
Megawatt Hours of Irradiation = 118294.17

Thermocouple	Hours of Irradiation					Average Temperature	Standard Deviation
	T<270	270<T<280	280<T<296	296<T<306	306<T		
TE 301	51.66	7.32	4076.80	39.18	0.00	290.09	1.10
TE 302	53.58	11.88	4109.48	0.00	0.00	286.38	0.87
TE 303	50.65	9.51	4114.77	0.00	0.00	287.29	0.96
TE 304	47.90	9.29	4117.15	0.58	0.00	291.08	0.76
TE 305	47.59	10.03	4117.30	0.00	0.00	287.65	0.95
TE 306	49.06	14.41	4111.44	0.00	0.00	286.61	0.87
TE 307							
TE 308	53.91	7.92	4113.09	0.00	0.00	289.18	1.15
TE 309	55.29	10.46	4109.19	0.00	0.00	287.58	0.90
TE 310	55.78	24.03	4095.14	0.00	0.00	285.55	1.03
TE 311	55.95	22.99	4096.03	0.00	0.00	285.90	1.16
TE 312	48.89	7.07	4118.79	0.17	0.00	288.64	0.91
TE 313	48.84	7.08	4117.35	1.67	0.00	289.96	1.05
TE 314	56.02	10.28	4108.62	0.00	0.00	289.11	0.95
TE 315	56.74	11.20	4107.00	0.00	0.00	285.13	0.90
TE 316	55.02	4.38	4115.54	0.00	0.00	287.57	0.77
TE 317	50.94	7.68	4116.31	0.00	0.00	290.87	0.89
TE 318	50.54	7.70	4116.68	0.00	0.00	289.30	0.99
TE 319	52.62	16.36	4105.94	0.00	0.00	285.26	0.83
TE 320	50.99	12.05	4111.88	0.00	0.00	287.53	1.34

6. REFERENCES

1. W. N. McElroy, et al., LWR Pressure Vessel Surveillance Dosimetry Improvement Program, 1979 Annual Report, NUREG/CR-1291, Hanford Engineering Development Laboratory (1979).

2. L. F. Miller, A Computerized Process Control System for the ORR-PSF Irradiation Experiment, Part 2: Mathematical Basis and Computer Implementation of the Temperature Control Algorithm, NUREG/CR-1710, Vol. 2 (Nov. 1980).

APPENDIX A

USER'S MANUAL FOR PSFTH

A.1 Execution of PSFTH

There are three computers that are utilized in order to obtain the processed data; consequently, some data handling problems are encountered. Thus, procedures needed to resolve these expected situations are presented. Items in this category that are specifically addressed include: 1) compilations and links, 2) file transfers, 3) data loss from an RK05 disk, and 4) normal program execution.

Modifications to PSFTH may be accomplished with the text editor available with the RSX-11M operating system software and complete documentation located at the HFIR computer; thus, text editing considerations are not presented. There are some compiler and linkage editor non-default options that must be included for PSFTH, however. These are illustrated below through example monitor commands:

```
 1)  >RUN $F4P
 2)  F4P>PSFTH=PSFTH.FTN/CO:12
 3)  F4P>↑Z
 4)  >TKB
 5)  TKB>PSFTH/FP=PSFTH
 6)  TKB>/
 7)  ENTER OPTIONS:
 8)  TKB>MAXBUF=512
 9)  TKB>ACTFIL=7
10)  TKB>UNITS=7
11)  TKB>//
```

The user should refer to the appropriate system software documentation in the HFIR computer room prior to updating PSFTH if not very familiar with the editor, compiler, or linkage editor.

Temperature data recorded on RK05 hard disks are in RT-11 formats. Consequently, the data must first be converted to RSX format for use on the HFIR computer. This is accomplished on the PDP-11/60 with the FLX utility program available to the RSX-11M monitor. Steps for accomplishing this (after logging in) are to enter the commands:

1) >RUN $FLX
2) FLX>TI: = DK2:/RT/DI
3) FLX>DK1: = DK2: Filename.Ext/RT/IM
4) FLX> ↑ Z
5) >RUN $PIP
6) PIP>DK1:/LI
7) PIP> ↑ Z .

The RUN $FLX command, step 1, brings the file transfer utility into core memory. Step 2 obtains a directory of the RT-11 file structure data. Occasionally, actual filenames differ from those in the experiment room log; consequently, a disk directory may be useful. The actual file transfer command, step 3, requires that no file specifications be given on the output file. The ↑ Z command terminates the FLX utility. Steps 5, 6, and 7 obtain a directory listing of the user's area of DK1. Note that step 3 must be repeated for each RT-11 file to be transferred.

It is usually necessary to transfer part of the data from DK1: to the removable disk DK2: in order to obtain sufficient data storage for a single month of data records. The PIP utility is used for this transfer. Note that DK2: must be "ALLOCATED" and "MOUNTED" via software commands before using the RSX formatted removable disk.

On several occasions, data on a RK05 disk have been lost. In this case, the recovery procedure is as follows:

1) obtain a paper tape of the lost data from hard copy outputs maintained in the ORR experiment room, and
2) transfer the paper tape data to DK1: on the PDP-11/60.

The first step requires keypunching and file formatting so that the paper tape format is consistent with format "6" of PSFTH. The second step requires that the paper tape reader handler (PR:) be installed and that the data be transferred with the FLX or PIP utility.

The data analysis program PSFTH may be executed by the monitor command, "RUN PSFTH", when the appropriate disk is mounted and DK2: is the user default drive. Program control data are input from the terminal in an interactive mode so that the amount of input data required is case dependent. Data that may be required as input, however, are:

1) input data format,
2) reset interval for integration,
3) printing interval for output data,
4) option for printing intermediate data,
5) date and time the irradiation facility is inserted to the reactor face,
6) date and time the irradiation facility is retracted from the reactor face,
7) filename of temperature data,
8) number of records in temperature data file,
9) number of specimens and specimen set numbers to be analyzed,
10) filename of initialization data,
11) unit number of initialization data,
12) filename of restart file,
13) unit number of restart file,
14) elapsed time and megawatt-hours associated with initialization data,
15) time adjustment of initialization data,
16) time histogram range number for each thermocouple for the time adjustment,
17) filename of output data, and
18) unit number of output data.

All of the above data are required only if selected by the user during the interrogation. Note that the "yes" or "no" responses are not included in the above list of potential input parameters.

It may be helpful to refer to an example run shown in Table A.1 in conjunction with the following discussion of input parameters.

During the development phase of the process software, four different data storage formats were employed. These formats and applicable dates are, respectively, as follows:

1) WRITE (2'NINT) DA, IH3, IM3, IS3, IT3, IWT, TC,
2) WRITE (2'NINT) DA, IH3, IM3, IS3, IWT, TC, IPCUR (13-MAR-80 to 21-MAY-80),
3) WRITE (2'NINT) DA, IH3, IM3, IS3, IT3, PL, TC, IPCUR, (21-MAY-80 to 8-JUN-80), and
4) WRITE (2'NINT) NODAY, IH3, IM3, IS3, IT3, PL, TC, IPCUR.

All data obtained after 21-MAY-1980 that reside on a hard disk require a format "4" specification as the first terminal input. Format "5" is required for paper tape input data that does not contain reactor power, and format "6" is required for paper tape input data that does contain reactor power. Note that the primary differences between formats "1-4" are in the entries of 1) the date, DA(3) versus NODAY, 2) the watt-transducer IWT, 3) the reactor power, PL, and 4) the percent firing of the electrical heaters, IPCUR.

Three integral reset options are available: day, month, and year. Specifically, the calculated data are reset to zero at the selected frequency. The same options are available for printing. Intermediate data may also be obtained for diagnostic purposes.

If an insertion or retraction is specified, corresponding dates and times must be entered. Note that in the example shown in Table A.1, only an insertion is specified. Even though seconds are required in the time input, insertion and retraction times are actually calculated to the nearest minute with respect to the associated data record. This approximation can result in a −0.01 entry in the time histogram.

The input filename specification must be specified with the device DK1: if the input data file resides on that device. If it resides on DK2: the device does not need to be specified since DK2: is the user default. Note that the number of logical records and the file initialization date must also be specified.

Data are recorded in four sets of 20 thermocouples each. These correspond to the surveillance capsule (set 1) and three sets (OT, 1/4 T, and 1/2 T positions) in the dosimetry capsule. These data sets may be analyzed independently. Thus, the number of data sets and data set numbers must be entered. This feature is useful because the surveillance and pressure vessel capsules are not irradiated over the same time intervals.

The integral data (i.e., calculated parameters) may be initialized to zero or initialized from the output of a previous run. A "1" is entered if data are initialized from a previous run and these data reside on disk; otherwise a "0" entry is recommended. If a "1" is entered, the associated filename and logical unit number must also be input.

A restart file for subsequent initialization is always written. The example shown in Table A.1 uses "RSSE23.DAT" as the restart filename and "4" as the associated logical unit number.

The total irradiation time and accumulated megawatt-hours since the last reset must also be entered. If initialization data are read from disks, these numbers would normally be the same as those on the initialization file. However, these data frequently need to be adjusted because the actual irradiation exposure interval is inconsistent with the data recording interval. If adjustment is required and restart data are utilized, correct time and radiation exposure are entered. The computer program detects discrepancies between the two sources of input data and more detailed data from the time histogram are requested. In particular, the appropriate histogram data must be entered for each thermocouple by specifying the histogram range number for each thermocouple.

The output data filename may also be specified. If logical unit 5 is selected for the output device, the filename chosen is ignored and data are output to the terminal. This is the only option checked out.

A.2 General Comments on PSFTH

There are essentially seven primary logical categories in this computer program:

1) an interactive section which interrogates the user for input data,
2) a section which can read data in six different formats,
3) a calendar routine,
4) integration of irradiation exposure and exposure time,
5) determination of an exposure time histogram for each thermocouple,
6) calculation of the average temperature and variances of the temperature for each thermocouple, and
7) output of data.

The calendar routine determines the day, month, and year relative to the initialization date. The date is incremented each time the hour entry of the 24-hour clock decreases in magnitude.* Leap Year is detected when the year is evenly divided by four. The number of days in each month is contained in a data statement.

The determination of radiation exposure time involves keeping track of several items:

1) insertion and retraction dates and times relative to the actual date and time associated with each data entry,
2) reactor power level,
3) time difference between the 24-hour clock trip and the last data entry, and
4) integration reset specification.

There are quite a few program software switches. Hence, details are not included here to implement this calculation, but program variable definitions and comments in the listing in the appendix should be sufficient for an in-depth evaluation.

There are two factors which significantly complicate PSFTH:

1) data recording intervals from the computer are not consistent with radiation exposure intervals, and
2) the definition of normal conditions is not unique.

Some reasons that item 1 occurs are:

1) computer logging of data is usually commenced before and extends beyond the irradiation exposure interval,
2) the normal data recording interval is one hour (insertion or retraction requires only a few minutes).
3) backup, hard copy, data must be processed when computer logged data are lost, and
4) exposure intervals must be determined from reactor power and position of the irradiation facility.

---

*This will cause an error if data are obtained from hard copy output and time intervals are longer than 24 hours.

Normal conditions, as determined for computational purposes, are essentially defined relative to initiation of automatic control of temperature and to an estimate of the temperature at which annealing may be important. Computer program parameters that, if changed, could change results are:

1) the reactor power below which the reactor is considered to be shutdown,
2) the thermocouple temperature below which the average and variance of the temperatures are not computed, and
3) the average specimen set temperature which must be achieved before calculations of the average and variance of the temperatures are initiated.

The choice of 5 MW for item 1 is based on the observation that the ORR is essentially never operated for more than a few minutes, usually much less, between 300 kW and 6 MW. In this power range, it is either being started up or shut down. The high end of this range is chosen to ensure a more accurate power reading.

If the average temperature is calculated during start-up conditions, the average temperature is slightly modified, but the variance is significantly distorted. In order to avoid this problem, the average is not calculated (i.e., updated) if the thermocouple indicates a temperature of less than 270°C. Thus, the average reported is essentially the average while under automatic control of the computer and steady-state conditions. The variance, or standard deviation, is also determined under near-normal operating conditions.

The average temperature is determined recursively from Equation 2.7 with the following restrictions:

1) the average temperature of the present and previous entries must be greater than 270°C,

2) the average temperature of all thermocouples with the applicable irradiation specimen set must achieve a temperature of 285°C before the calculation is initiated,
3) the reactor power level must be greater than 5 MW,
4) the irradiation facility must be inserted, and
5) initialization is based on the first entry which satisfies the above conditions.

Calculation of the variance of the temperature for each thermocouple is accomplished with equation 2.14 and with the same restrictions as listed for the average temperature calculations except that the variance is initialized to zero. In addition to reading Appendix A carefully, the user should also study the program listing in Appendix C prior to executing PSFTH. Internal documentation of PSFTH is fairly complete.

Table A.1. Sample Execution of PSFTH. User responses are underlined.

```
 RUN PSFTH
INPUT DATA FORMAT: 1,2,3,4,5, OR 6 4
RESET CALC. BY DAY, MONTH, OR YEAR: 0,1 OR 2 1
PRINT RESULTS BY DAY, MONTH OR YEAR: 0,1, OR 2: 1
ENTER 0,1,2 OR M FOR: NO, PARTIAL ALL, OR MODULUS PRINTING OF INTERMEDIATE DATA 0
ENTER 1 IF EXP. IS INSERTED DURING DATA COLL. 1
ENTER DAY-MTH-YR OF INSERTION 23 9 80
ENTER HR-MIN-SEC OF INSERTION 13 52 0
ENTER 1 IF EXP. IS RETRACTED DURING DATA COLL. 0
INPUT FILENAME OF TEMPERATURE DATA DK1:SE23.DAT
INPUT NUMBER OF RECORDS 450
INPUT DAY-MTH-YR FILE BEGINS 23 9 80
INPUT # OF SPECIMEN SETS TO BE ANALYZED 3
INPUT SPECIMEN SET #'S TO BE ANALYZED 2 3 4
INPUT 1 IF INIT. DATA ARE TO BE INPUT FROM DISK 1
INPUT FILENAME OF INIT. DATA RSSE17.DAT
INPUT UNIT NUMBER OF INITIALIZATION FILE 3
INPUT FILENAME OF RESTART FILE RSSE23.DAT
INPUT UNIT NUMBER OF RESTART FILE 4
INPUT ELAPSED TIME AND MWH FOR INIT. DATE 449.93 13402.27
INCONSISTENT INPUT DATA
INPUT IRRADIATION TIME ADJUSTMENT 1.75
INPUT RANGE # FOR EACH TC IS SET  2
20*3
INPUT RANGE # FOR EACH TC IS SET  3
20*3
INPUT RANGE # FOR EACH TC IS SET  4
20*3
INPUT FILENAME OF OUTPUT DATA
INPUT LOGICAL UNIT NUMBER FOR OUTPUT DATA 5
  INPUT DATA FOLLOW:
 INITIALIZATION OF TIME AND MEGAWATTS   =  0.450E+03   0.134E+05
 IRRADIATION TIME ADJUSTMENT            =  0.175E+01
 LOGICAL RECORDS IN INPUT FILE          =  450
 FORMAT IDENT. OF INPUT DATA            =    4
 CALC. RESET PARAMETER                  =    1
 PRINT PARAMETER                        =    1
 FILENAME OF INPUT DATA                 = DK1:SE23.DAT
 FILENAME OF RESTART DATA               = RSSE23.DAT
 FILENAME OF OUTPUT DATA                = ***
 FILENAME OF INIT. DATA                 = RSSE17.DAT
 INSERTION DATA AND TIME ARE:  23- 9-80  13:52: 0
```

APPENDIX B

USER'S MANUAL FOR COMBO

B.1. Execution of Combo

COMBO is an ancillary computer program for PSFTH and executed on the DEC-10 at ORNL. It is used to combine output files from: 1) PSFTH, 2) COMBO, and 3) free form. The normal procedure for executing COMBO is:

1) keypunch hard copy monthly output data for PSFTH,
2) transfer this data to a DEC-10 user file, and
3) execute COMBO.

The example of executing COMBO given in Table B.1 should provide sufficient description of its execution.

B.2. General Comments on COMBO

Note that the printer output terminal width needs to be set to 132 and that the program is normally executed with an EX COMBO.FOR command. Filenames are requested for both input files and output files. An input format specification of "1" implies that the default (i.e., PSFTH or COMBO standard output) format is employed. A specification of "0" implies that the data for each thermocouple are free form and that the set, date, irradiation time, and megawatt-hour data are input consistent with FORMAT 1006 in the listing of COMBO in Appendix D. Note that the number of sets analyzed and that each set analyzed is specified in a single input string. The data associated with the output file must also be input.

Table B.1. Execution of COMBO. User Responses are Underlined.

```
.SET TTY WIDTH 132

.EX COMBO.FOR
LINK:  Loading
[LNKXCT COMBO Execution]

INPUT FILENAME OF INPUT FILE 1
*AUG31.DAT
INPUT FILENAME OF INPUT FILE 2
*SEP.DAT
INPUT FORMAT ID. FOR EACH INPUT FILE:  0 OR 1
*1 0
INPUT # OF SETS AND SET #'S COMBINED
*3 2 3 4
INPUT DAY-MTH-YR OF COMBINED FILE
*30 9 80
STOP

END OF EXECUTION
CPU TIME:  0.64  ELAPSED TIME:  1:23.23
EXIT
```

APPENDIX C

LISTING OF COMPUTER PROGRAM PSFTH

```
C************************************************************************
C***DEFINITION OF PROGRAM VARIABLES**************************************
C  XMWH(20,4,7)     = ARRAY FOR TIME HISTOGRAM, AVERAGE TEMPERATURES,
C                     AND VARIANCE OF AVERAGE TEMPERATURES FOR EACH
C                     THERMOCOUPLE
C  TC(20,4)         = ARRAY FOR THERMOCOUPLE TEMPERATURES
C  IHDTR(10,4)      = ARRAY FOR PERCENT FIRING OF HEATERS
C  MTHDS(12)        = DATA FOR NUMBER OF DAYS IN EACH MONTH
C  IA(3)            = NOT USED
C  IDAT(3)          = ARRAY FOR THE DATE FILE BEGINS
C  JPP(4)           = SPECIMEN SET NUMBERS
C  XMTH(12)         = ALPHA DATA FOR MONTHS
C  TCL(20,4)        = ARRAY FOR PREVIOUS RECORD TC TEMPERATURES
C  RXP(24)          = ARRAY FOR REACTOR POWER WHEN IDFOR=5
C  DA(3)            = ARRAY FOR THE DATE
C  TCAV(4)          = AVERAGE TEMPERATURE FOR EACH SPECIMEN SET
C  IDNSRT(3)        = DAY-MONTH-YEAR OF PSF INSERTION
C  IDRCT(3)         = DAY-MONTH-YEAR OF PSF RETRACTION
C  INTM(3)          = HOUR-MINUTE-SECOND OF PSF INSERTION
C  IOTM(3)          = HOUR-MINUTE-SECOND OF PSF RETRACTION
C  KEXIN(2)         = DAY,KEXIN(1),AND MINUTE,KEXIN(2), OF PSF INSERTION
C  KEXOT(2)         = DAY,KEXOT(1),AND MINUTE,KEXOT(2), OF PSF RETRACTION
C  IATO(4)          = FLAG-SET WHEN SPECIMEN SET TEMPS. OBTAIN 285 C
C  IAR(20)          = HISTOGRAM RANGE NUMBERS
C  NOW(2)           = DAY,NOW(1),AND MINUTE,NOW(2), OF ACTUAL DATE & TIME
C  TCID(20,4) *8    = DATA ARRAY FOR TC IDENTIFICATION
C  BLANK      *8    = 8 BLANK CHARACTERS
C  XDUM       *8    = DUMMY VARIABLE
C  XTLT(11)   *8    = DUMMY
C  TLA(7)     *8    = DATA ARRAY FOR TITLE
C  XTLA(7)    *8    = DUMMY ARRAY
C  DASH       *1    = '-'
C  XDASH      *1    = DUMMY
C  SPACE(5)   *1    = 5 BLANK CHARACTERS
C  SPCX(5)    *1    = 5 BLANK CHARACTERS
C  FILDAT(15) *1    = ARRAY FOR INITIALIZATION DATA FILENAME
C  FILSAV(15) *1    = ARRAY FOR OUTPUT DATA FILENAME
C  FILRST(15) *1    = ARRAY FOR RESTART FILENAME
C  FILNM(12)  *1    = ARRAY FOR INPUT DATA FILENAME
C  TLC(7)     *8    = DATA ARRAY FOR TITLES
C  TLD(7)     *8    = DATA ARRAY FOR TITLES
C  PCUT             = REACTOR POWER CUTOFF FOR INTEGRATING EXPOSURE TIME
C  TCUT             = TEMPERATURE CUTOFF FOR CALCULATING AVG. TMP.
C  IDFOR            = FORMAT OF INPUT DATA: 1-6
C  IRST             = RESET INTERVAL: 0-2 : DAY-MONTH-YEAR
C  IPRNT            = PRINT INTERVAL: 0-2 : DAY-MONTH-YEAR
C  NPXY             = EXTRA PRINTOUTS?: 0-2,M : NO,PART,ALL,MOD. INT. DAT
C  INSRT            = 1 IF EXP. IS INSERTED DURING DATA COLLECTION
C  IRCTR            = 1 IF EXP. IS RETRACTED DURING DATA COLLECTION
C  LRL              = # OF LOGICAL RECORDS IN INPUT DATA
C  NSET             = # OF SPECIMEN SETS ANALYZED
C  NINIT            = 1 IF INITILIZATION DATA ARE INPUT FROM DISK
C  IS1              = LOGICAL UNIT # OF INIT. FILE
C  ISET             = SPECIMEN SET # FROM INIT. DATA
C  XTLB             = DUMMY
C  TF               = RAD. EXPOSURE TIME FROM INIT. DATA
C  XF               = MEGAWATT-HOURS EXPOSURE FROM INIT. DATA
C  ISOUT            = LOGICAL UNIT # OF RESTART FILE
C  TMEXR            = SPECIFIED RAD. EXPOSURE TIME OF INIT. DATA
C  XWHS             = SPECIFIED MWH  EXPOSURE OF INIT. DATA
C  ADJ              - TIME ADJUSTMENT OF HISTOGRAM - INPUT IF TF.NE.TMEXR
```

```
C   NOUT              = LOGICAL UNIT # OF OUTPUT DATA FILE
C   IFLG              = FLAG FOR DETERMINING INITIALIZATION PASS
C   JXD               = FLAG FOR DAILY TRIPS
C   JXM               = FLAG FOR MONTHLY TRIPS
C   JXY               = FLAG FOR YEARLY TRIPS
C   IWTH              = COUNTS RECORDS AFTER EXP. WITHDRAWL
C   NPASS             = PASS COUNTER FOR FORMATS 5 AND 6
C   INN               = COUNTS RECORDS AFTER EXP. INSERTION
C   NAUX              = SWITCH FOR PRINTING INTERMEDIATE(AUXILARY) DATA
C   DTNXT             = TIME BETWEEN 24 HR. CLOCK TRIP AND LAST RECORD
C   IDAY              = DAY #
C   IMTH              = MONTH #
C   IYR               = YEAR  #
C   IH                = HOUR  #
C   IM                = MINUTE #
C   IS                = SECOND #
C   IHL               = HOUR # OF LAST RECORD
C   IML               = MINUTE # OF LAST RECORD
C   ISL               = SECOND # OF LAST RECORD
C   PL                = REACTOR POWER
C   PLL               = REACTOR POWER OF LAST RECORD
C   TMP               = TEMPERATURE OF A GIVEN TC
C   TMPL              = TEMPERATURE OF A GIVEN TC OF LAST RECORD
C   IRNG              = RANGE # FOR HISTOGRAM
C   TAV               = AVG. TC TMP. FOR PRESENT & PREVIOUS RECORD
C   ICOMP             = AVG. TMP. CALC. SWITCH
C   DELT              = TIME BETWEEN TWO RECORDS(CURRENT
C   TIME              = CURRENT RAD. EXPOSURE TIME
C   PD                = AVERAGE RX. POWER
C   XMW               = MEGAWATT-HOURS OF RADIATION EXPOSURE
```

```
      DIMENSION XMWH(20,4,7),TC(20,4),IHDTR(10,4),MTHDS(12)
     1 ,IA(3),IDAT(3),JPP(4),XMTH(12),TCL(20,4),RXP(24),DA(3)
     2 ,TCAV(4),IDNSRT(3),IDRCT(3),INTM(3),IOTM(3),KEXIN(2)
     3 ,IATO(4),IAR(20),KEXOT(2),NOW(2)
      REAL*8 TCID(20,4),BLANK
      REAL*8 XDUM,XTLT(11),TLA(7),XTLA(7)
      LOGICAL*1 DASH,XDASH,SPACE(5),SPCX(5)
      BYTE DFILE(15),FILDAT(15),FILSAV(15),FILRST(15)
      BYTE FILNM(12)
      REAL*8 TLC(7),TLD(7)
      DATA SPACE/5*' '/
      DATA DFILE/3*'*',12*00/
      DATA BLANK/'        '/
      DATA SPCX/5*' '/
      DATA TLC/'        ','        ','        ','HOURS OF',
     1 ' IRRADIA','TION TIM','E EQUALS'/
      DATA TLD/'        ','        ','        ','MEGAWATT',
     1 ' HOURS O','F IRRADI','ATION   '/
      DATA TLA/'        ','        ','        ','DATA ARE',
     1 ' FOR SPE','CIMEN SE','T NUMBER'/
      DATA TLB/' ON '/
      DATA DASH/'-'/
      DATA TCID/'TE  1','TE  2','TE  3','TE  4','TE  5','TE  6',
     1 'TE  7','TE  8','TE  9','TE 10','TE 11','TE 12',
     2 'TE 13','TE 14','TE 15','TE 16','TE 17','TE 18',
     3 'TE 19','TE 20','TE101','TE102','TE103','TE104',
     4 'TE105','TE106','TE107','TE108','TE109','TE110',
     5 'TE111','TE112','TE113','TE114','TE115','TE116','TE117',
     6 'TE118','TE119','TE120','TE201','TE202','TE203','TE204',
     7 'TE205','TE206','TE207','TE208','TE209','TE210','TE211',
     8 'TE212','TE213','TE214','TE215','TE216','TE217','TE218',
     9 'TE219','TE220','TE301','TE302','TE303','TE304','TE305',
     A 'TE306','TE307','TE308','TE309','TE310','TE311','TE312',
     B 'TE313','TE314','TE315','TE316','TE317','TE318','TE319',
     C 'TE320'/
      DATA XMTH/'JAN','FEB','MAR','APR','MAY','JUN','JUL',
     1 'AUG','SEP','OCT','NOV','DEC'/
      DATA MTHDS/31,28,31,30,31,30,31,31,30,31,30,31/
      DATA PCUT,TCUT/5.0,270.0/
C***READ INPUT DATA FROM THE TERMINAL
C**************************************************
755   CONTINUE
      CALL ASSIGN(1,'DK1:RXPR.DAT',12,'OLD','NC',1)
      DEFINE FILE 1(62,48,U,NR)
      WRITE(5,1021)
1021  FORMAT(' INPUT DATA FORMAT: 1,2,3,4,5, OR 6 ',$)
      READ(5,*)IDFOR
      WRITE(5,1023)
1023  FORMAT(' RESET CALC. BY DAY, MONTH, OR YEAR: 0,1 OR 2 ',$)
      READ(5,*)IRST
      WRITE(5,1024)
1024  FORMAT(' PRINT RESULTS BY DAY, MONTH OR YEAR: 0,1, OR 2: ',$)
      READ(5,*)IPRNT
      WRITE(5,1033)
1033  FORMAT(' ENTER 0,1,2 OR M FOR: NO, PARTIAL',
     1' ALL, OR MODULUS PRINTING OF INTERMEDIATE DATA ',$)
      READ(5,*)NPXX
      WRITE(5,1200)
1200  FORMAT(' ENTER 1 IF EXP. IS INSERTED DURING DATA COLL   ',$)
      READ(5,*)INSRT
      IF(INSRT.NE.1)GO TO 707
      WRITE(5,1201)
```

```
1201     FORMAT(' ENTER DAY-MTH-YR OF INSERTION ',$)
         READ(5,*)IDNSRT
         KEXIN(1)=IDNSRT(1)+(IDNSRT(2)-1)*31+(IDNSRT(3)-80)*1000
         WRITE(5,1202)
1202     FORMAT(' ENTER HR-MIN-SEC OF INSERTION ',$)
         READ(5,*)INTM
         KEXIN(2)=INTM(2)+INTM(1)*60
707      CONTINUE
         WRITE(5,1203)
1203     FORMAT(' ENTER 1 IF EXP. IS RETRACTED DURING DATA COLL. ',$)
         READ(5,*)IRCTR
         IF(IRCTR.NE.1)GO TO 708
         WRITE(5,1204)
1204     FORMAT(' ENTER DAY-MTH-YR OF RETRACTION ',$)
         READ(5,*)IDRCT
         KEXOT(1)=IDRCT(1)+(IDRCT(2)-1)*31+(IDRCT(3)-80)*1000
         WRITE(5,1205)
1205     FORMAT(' ENTER HR-MIN-SEC OF RECTRACTION ',$)
         READ(5,*)IOTM
         KEXOT(2)=IOTM(2)+IOTM(1)*60
708      CONTINUE
         WRITE(5,1000)
1000     FORMAT(' INPUT FILENAME OF TEMPERATURE DATA ',$)
         READ(5,1007)(FILNM(K),K=1,12)
1007     FORMAT(12A1)
         WRITE(5,1008)
1008     FORMAT(' INPUT NUMBER OF RECORDS ',$)
         READ(5,*)LRL
         IF(IDFOR.GT.4)GO TO 888
         CALL ASSIGN(2,FILNM,12,'OLD','NC',1)
         DEFINE FILE 2(LRL,256,U,NR)
         GO TO 889
888      CONTINUE
         FILNM(12)=0
         OPEN(UNIT=7,NAME=FILNM,TYPE='OLD',
       1 FORM='FORMATTED',ACCESS='SEQUENTIAL')
889      CONTINUE
         WRITE(5,1001)
1001     FORMAT(' INPUT DAY-MTH-YR FILE BEGINS ',$)
         READ(5,*)(IDAT(K),K=1,3)
         WRITE(5,1030)
1030    FORMAT(' INPUT # OF SPECIMEN SETS TO BE ANALYZED ',$)
         READ(5,*)NSET
         WRITE(5,1003)
1003     FORMAT(' INPUT SPECIMEN SET #'S TO BE ANALYZED ',$)
         READ(5,*)(JPP(K),K=1,NSET)
         WRITE(5,1015)
1015     FORMAT(' INPUT 1 IF INIT. DATA ARE TO BE INPUT FROM DISK ',$)
         READ(5,*)NINIT
         ADJ=0.0
         DO 831 K=1,15
831      FILDAT(K)=DFILE(K)
         IF(NINIT.NE.1)GO TO 4
         WRITE(5,1002)
1002     FORMAT(' INPUT FILENAME OF INIT. DATA ',$)
         READ(5,1009)FILDAT
1009     FORMAT(15A1)
         WRITE(5,1012)
1012     FORMAT(' INPUT UNIT NUMBER OF INITIALIZATION FILE ',$)
         READ(5,*)IS1
         FILDAT(15)=0
         OPEN(UNIT=IS1,NAME=FILDAT,TYPE='OLD',FORM='FORMATTED',
       1 ACCESS='SEQUENTIAL')
         DO 750 I=1,4
         IF(JPP(I).LT.1.OR.JPP(I).GT.4)GO TO 750
         READ(IS1,2000)(XTLA(K),K=1,7),ISET,XTLB,IXX,XDASH
```

```
     1    ,XTH,XDASH,IXR
          READ(IS1,2001)(XTLA(K),K=1,7),TF
          READ(IS1,2001)(XTLA(K),K=1,7),XF
          READ(IS1,2007)XDUM
          READ(IS1,2007)XDUM
          READ(IS1,2007)XDUM
          DO 700 J=1,20
          READ(IS1,2004)XDUM,(XMWH(J,ISET,IX),IX=1,7)
700       CONTINUE
750       CONTINUE
C**********************************************
4         CONTINUE
          WRITE(5,1013)
1013      FORMAT(' INPUT FILENAME OF RESTART FILE ',$)
          READ(5,1009)FILRST
          WRITE(5,1014)
1014      FORMAT(' INPUT UNIT NUMBER OF RESTART FILE ',$)
          READ(5,*)ISOUT
          FILRST(15)=0
          OPEN(UNIT=ISOUT,NAME=FILRST,TYPE='NEW',FORM='FORMATTED',
     1    ACCESS='SEQUENTIAL')
C**********************************************
          WRITE(5,1004)
1004      FORMAT(' INPUT ELAPSED TIME AND MWH FOR INIT. DATA ',$)
          READ(5,*)TMEXR,XWHS
C**********************************************
C***TEST FILE DATA IF READ*******
          IF(NINIT.NE.1)GO TO 5
          XX1=ABS(TF-TMEXR)
          XX2=ABS(XWHS-XF)
          IF(XX1+XX2.LT.0.0001)GO TO 5
          WRITE(5,1020)
1020      FORMAT(' INCONSISTENT INPUT DATA ')
          WRITE(5,3001)
3001      FORMAT(' INPUT IRRADIATION TIME ADJUSTMENT ',$)
          READ(5,*)ADJ
C***ADD ADJUSTMENT TO THE SPECIFIED HYSTRESSIS BAND
          DO 51 J=1,4
          IF(JPP(J).LT.1.OR.JPP(J).GT.4)GO TO 51
          IS=JPP(J)
          WRITE(5,3002)IS
3002      FORMAT(' INPUT RANGE # FOR EACH TC IN SET ',I2)
          READ(5,*)IAR
          DO 51 K=1,20
          L=IAR(K)
          XMWH(K,IS,L)=XMWH(K,IS,L)+ADJ
51        CONTINUE
C**********************************************
5         CONTINUE
          WRITE(5,1005)
1005      FORMAT(' INPUT FILENAME OF OUTPUT DATA ',$)
          READ(5,1009)FILSAV
          WRITE(5,1006)
1006      FORMAT(' INPUT LOGICAL UNIT NUMBER FOR OUTPUT DATA ',$)
          READ(5,*)NOUT
          IF(NOUT.NE.5)GO TO 71
          DO 63 K=1,15
63        FILSAV(K)=DFILE(K)
          GO TO 7
71        CONTINUE
          FILSAV(15)=0
          OPEN(UNIT=NOUT,NAME=FILSAV,TYPE='NEW',FORM='FORMATTED',
     1    ACCESS='SEQUENTIAL')
C*****************************************************************
7         CONTINUE
          WRITE(5,1010)TMEXR,XWHS,ADJ,LRL,IDFOR,IRST,IPRNT,FILNM,FILRST,FILSAV
```

```
     1   ,FILDAT
1010     FORMAT('    INPUT DATA FOLLOW: '/
     1   '   INITIALIZATION OF TIME AND MEGAWATTS = ',E10.3,2X,E10.3/
     2   '   IRRADIATION TIME ADJUSTMENT           = ',E10.3/
     3   '   LOGICAL RECORDS IN INPUT FILE                = ',I4/
     A   '   FORMAT IDENT. OF INPUT DATA           = ',I3/
     B   '   CALC. RESET PARAMETER                        = ',I3/
     C   '   PRINT PARAMETER                       = ',I3/
     4   '   FILENAME OF INPUT DATA                       = ',12A1/
     5   '   FILENAME OF RESTART DATA              = ',15A1/
     6   '   FILENAME OF OUTPUT DATA               = ',15A1/
     7   '   FILENAME OF INIT. DATA                       = ',15A1)
         IF(INSRT.EQ.1)WRITE(5,1230)IDNSRT,INTM
1230     FORMAT('  INSERTION DATA AND TIME ARE:  ',I2,'-',I2,'-',I2,2X,
     1 I2,':',I2,':',I2)
         IF(IRCTR.EQ.1)WRITE(5,1231)IDRCT,IOTM
1231     FORMAT('  RETRACTION DATE AND TIME ARE: ',I2,'-',I2,'-',I2,2X,
     1   I2,':',I2,':',I2)
C
C***END OF THE INPUT SECTION
C
C*******************************************************
C***INITIALIZE VARIABLES IF THE INITIALIZATION DATE DATA ARE NOT INPUT
C***AND RESET AS SPECIFIED
C*******************************************************
         IFLG=0
         JXD=0
         JXM=0
         JXY=0
         IWTH=0
         NPASS=0
         INN=0
         NAUX=0
         DTNXT=0.0
         DO 803 I=1,4
803      IATO(I)=0
         IF(NINIT.EQ.1)GO TO 3
8        NINIT=0
         IF(IFLG.EQ.0)GO TO 3
         TIME=DTNXT
         XMW=PL*DTNXT
         NREC=NREC-1
3        CONTINUE
         IF(IFLG.EQ.1)GO TO 9
         IFLG=1
C*******************************************************************
C***INITIALIZE THE READ LOOP
         TIME=TMEXR
         XMW=XWHS
         IDAY=IDAT(1)
         IMTH=IDAT(2)
         IYR=IDAT(3)
         ISTRT=0
         NREC=0
9        NRXX=0
10       NREC=NREC+1
         NRXX=NRXX+1
         KK=NREC
         IF(NREC.GT.LRL)GO TO 41
         IF(IDFOR.NE.1)GO TO 31
         READ(2'KK,END=42,ERR=45)DA,IH,IM,IS,IT,IWT,TC
         IF(DA(1).EQ.'EMPT')GO TO 40
         IEND=0
         GO TO 50
31       CONTINUE
         IF(IDFOR.NE.2)GO TO 32
```

```
      READ(2'KK,END=42,ERR=45)DA,IH,IM,IS,IT,IWT,TC,IHDTR
      IF(DA(1).EQ.'EMPT')GO TO 40
      IEND=0
      GO TO 50
32    CONTINUE
      IF(IDFOR.NE.3)GO TO 33
      READ(2'KK,END=42,ERR=45)DA,IH,IM,IS,IT,PL,TC,IHDTR
      IF(DA(1).EQ.'EMPT')GO TO 40
      IEND=0
      GO TO 50
33    CONTINUE
      IF(IDFOR.NE.4)GO TO 34
      READ(2'KK,END=42,ERR=45)NODAY,IH,IM,IS,IT,PL,TC,IHDTR
      IF(NODAY.EQ.'EM')GO TO 40
      IEND=0
      GO TO 50
34    CONTINUE
      IF(IDFOR.GT.6)GO TO 650
C  READ DATA OBTAINED FROM THE HARD COPY UNIT
      IF(NRST.EQ.1)GO TO 50
      IF(NPASS.EQ.1)GO TO 531
      NPASS=1
      READ(7,1503)TRASH
      WRITE(5,1504)TRASH
      IF(IDFOR.EQ.5)GO TO 531
      DO 201 K=1,4
      READ(7,1503)TRASH
      WRITE(5,1504)TRASH
201   CONTINUE
      NREC=0
      NRXX=0
      GO TO 10
1504  FORMAT(' ',A4)
1503  FORMAT(A4)
531   CONTINUE
      IF(IDFOR.EQ.5)READ(7,1501)(DA(K),K=1,3),IH,IM,IS,IT,IWT
      IF(IDFOR.EQ.6)READ(7,1505)(DA(K),K=1,3),IH,IM,IS,IT,IWT,PL
1505  FORMAT(3F4.0,5I3,F4.1)
1501  FORMAT(3F4.0,5I3)
      READ(7,1502,END=42)((TC(J,K),J=1,20),K=1,4)
1502  FORMAT(20F4.0)
      IEND=0
      GO TO 50
40    IEND=1
      WRITE(5,2041)NREC
2041  FORMAT(' "EMPTY RECORD" DETECTED AT NREC = ',I4)
      GO TO 400
41    IEND=1
      WRITE(5,2042)LRL
2042  FORMAT(' EXCEEDED INPUT LOGICAL RECORDS OF ',I4)
      GO TO 400
42    IEND=1
      WRITE(5,2043)NREC
2043  FORMAT(' "EOF" DETECTED   NREC = ',I4)
45    CONTINUE
      WRITE(5,2040)
2040  FORMAT('  ERROR WHILE READING DATA ')
      GO TO 650
50    CONTINUE
      IF(IDFOR.EQ.6)GO TO 56
C***READ POWER DATA
      IF(IDFOR.EQ.3.OR.IDFOR.EQ.4)GO TO 56
      IF(NRST.EQ.1)GO TO 56
      IY=80
      IMXX=IMTH
      IF(JXM.EQ.1)IMXX=IMTH+1
```

```
      ID=IDAY
      IF((IH-IHL).LT.0)ID=IDAY+1
      IF(JXD.EQ.1)ID=IDAY+1
      ITRP=0
      IF((IH-IHL).LT.0.AND.ID.GT.MTHDS(IMTH))ITRP=1
      IF(ITRP.EQ.1)ID=1
      IF(JXM.EQ.1)ID=1
      IF(ITRP.EQ.1)IMXX=IMTH+1
      IF(NREC.EQ.1)ID=IDAY
      KRX=ID+(IMXX-4)*31+(IY-80)*1000
      KRXX=KRX
      READ(1'KRXX)RXP
      PL=RXP(IH+1)
C***END POWER DATA READ SECTION
56    CONTINUE
      NPRNT=0
      NRST=0
C***CALENDAR SECTION
      IF(JXD.EQ.1)IDAY=IDAY+1
      IF(JXM.EQ.1)IDAY=1
      IF(JXM.EQ.1)IMTH=IMTH+1
      IF(JXY.EQ.1)IYR=IYR+1
      IF(JXY.EQ.1)IMTH=1
      JXM=0
      JXY=0
      JXD=0
      ID=IDAY
      IMXX=IMTH
      IY=IYR
      IF(NRXX.EQ.1)GO TO 12
      DH=IH-IHL
      DM=IM-IML
      DS=IS-ISL
      DTNXT=0.0
      IF(DH.GE.0)GO TO 11
      DH=24-IHL
      DM=0-IML
      DS=0-ISL
      DTNXT=FLOAT(IH)+FLOAT(IM)/60.+FLOAT(IS)/3600.
      JXD=1
      ID=IDAY+1
      IF(IPRNT.EQ.0)NPRNT=1
      IF(IRST.EQ.0)NRST=1
      IADD=0
      LEAP=0
      IF((IYR/4)*4.EQ.IYR)LEAP=1
      IF(IMTH.EQ.2.AND.LEAP.EQ.1)IADD=1
      IF(IDAY.LT.MTHDS(IMTH)+IADD)GO TO 11
      IF(IPRNT.EQ.1)NPRNT=1
      IF(IRST.EQ.1)NRST=1
      JXM=1
      ID=1
      IMXX=IMTH+1
      IF(IMTH.LT.12)GO TO 11
      IF(IPRNT.EQ.2)NPRNT=1
      IF(IRST.EQ.2)NRST=1
      JXY=1
      IMXX=1
      IY=IYR+1
C***END CALENDAR SECTION***
11    CONTINUE
      DELT=DH+DM/60.+DS/3600.
      IF(NRST.NE.1)DELT=DELT+DTNXT
      NOW(1)=ID+(IMXX-1)*31+(IY-80)*1000
      NOW(2)=IM+IH*60
      NSRTED=1
```

```
      IF(INSRT.NE.1)GO TO 715
      IF(NOW(1).LT.KEXIN(1))NSRTED=0
      IF(NOW(1).EQ.KEXI (1).AND.NOW(2).LT.KEXIN(2))NSRTED=0
      IF(NRST.EQ.1.AND.INN.EQ.0)DTNXT=0.0
      IF(NRST.EQ.1.AND.INN.EQ.0)NSRTED=0
      IF(NSRTED.EQ.1)INN=INN+1
      IF(INN.EQ.1)DELT=FLOAT(NOW(2)-KEXIN(2))/60.0
715   CONTINUE
      NSRTXY=1
      IF(IRCTR.NE.1)GO TO 716
      IF(NOW(1).GT.KEXOT(1))NSRTXY=0
      IF(NOW(1).EQ.KEXOT(1).AND.NOW(2).GT.KEXOT(2))NSRTXY=0
      IF(NSRTXY.EQ.0)IWTH=IWTH+1
      IF(IWTH.EQ.1)DELT=DELT-FLOAT(NOW(2)-KEXOT(2))/60.0
      IF(IWTH.EQ.1)NSRTED=1
      IF(IWTH.GT.1)NSRTED=0
716   CONTINUE
      IF(NSRTED.EQ.1)ISTRT=ISTRT+1
      IF(PL.GT.PCUT.AND.NSRTED.EQ.1)GO TO 101
      DELT=0.0
101   DMW=DELT*(PL+PLL)*0.5
      XMW=XMW+DMW
      TIME=TIME+DELT
      TRV=0.0
      IF(TIME.LE.0.01)GO TO 102
      TRV=DELT/TIME
      PD=XMW/TIME
102   CONTINUE
12    CONTINUE
      IF(NPXX.EQ.0.AND.NRXX.EQ.1)WRITE(5,1049)IDAY,DASH,XMTH
     1 (IMTH),DASH,IYR,IH,IM,IS
1049  FORMAT('0',' FIRST RECORD DATE AND TIME ARE: ',I2,A1,A3,A1,I2,
     1' AT ',I2,':',I2,':',I2)
      IF(NPXX.EQ.0)GO TO 121
C***PRINT RAW DATA AS SPECIFIED BY INPUT
      IA(1)=IDAY
      IA(2)=IMTH
      IA(3)=IYR
      IF(NAUX.EQ.1)GO TO 120
      WRITE(NOUT,1041)IDAY,DASH,XMTH(IMTH),DASH,IYR,IH,IM,IS
1041  FORMAT('0',' RECORD DATE AND TIME ARE: ',I2,A1,A3,A1,I2,
     1' AT ',I2,':',I2,':',I2)
      IF(IDFOR.LE.3)WRITE(NOUT,1042)DA
1042  FORMAT(' RECORD DATA FROM DISK IS ',3A4)
      IF(IDFOR.EQ.4)WRITE(NOUT,1043)NODAY
1043  FORMAT(' DAY NUMBER ON DISK IS ',I3)
      IF(NRXX.EQ.1)GO TO 121
      WRITE(NOUT,1044)TIME,XMW,PL,PD,TCAV
1044  FORMAT('  IRRADIATION TIME =',F10.3/
     1'   MEGAWATT HOURS OF IRRADIATION =',F10.3/
     2'   REACTOR POWER =',F10.3/
     3'   AVERAGE REACTOR POWER =',F10.3/
     4'   AVG. TMPS. OF PREV. REC. =',4F8.3)
      IF(NPXX.EQ.2)WRITE(NOUT,1032)((TC(J,I),I=1,4),J=1,20)
1032  FORMAT('0',/
     1 '      TE 1-20   TE 101-120   TE 201-220  TE 301-320 '/
     1 (4F12.1))
120   NAUX=0
      IF(NPXX.LT.3)GO TO 121
      IF((NRXX/NPXX)*NPXX.NE.NRXX)NAUX=1
121   CONTINUE
      IHL=IH
      IML=IM
      ISL=IS
      PLL=PL
      DO 200 I=1,NSET
```

```
      ICAP=JPP(I)
      IF(ICAP.LT.1.OR.ICAP.GT.4)GO TO 200
      TCAV(ICAP)=0.0
      DO 100 J=1,20
      TMP=TC(J,ICAP)
      TMPL=TCL(J,ICAP)
      TCL(J,ICAP)=TMP
      IF(NRXX.EQ.1)TMPL=TMP
      TAV=(TMP+TMPL)*0.5
      IRNG=1
      IF(TAV.GT.270.0)IRNG=2
      IF(TAV.GT.280.0)IRNG=3
      IF(TAV.GT.296.0)IRNG=4
      IF(TAV.GT.306.0)IRNG=5
      TCAV(ICAP)=TCAV(ICAP)+TAV
      IF(NRXX.NE.1)GO TO 75
      IF(NINIT.EQ.1.AND.NREC.EQ.1)GO TO 100
C***INITIALIZE VARIABLES FOR RESETS
      DO 73 K=1,5
73    XMWH(J,ICAP,K)=0.0
      XMWH(J,ICAP,IRNG)=DTNXT
      XMWH(J,ICAP,7)=0.0
      XMWH(J,ICAP,6)=TAV
      GO TO 100
75    CONTINUE
      ICOMP=1
      IF(IATO(ICAP).EQ.0)ICOMP=0
      IF(TAV.LT.TCUT)ICOMP=0
      IF(PL.LT.PCUT)ICOMP=0
      IF(NSRTED.EQ.0)ICOMP=0
      TRW=TRV
      IF(ICOMP.EQ.1)GO TO 98
      TRW=0.0
      CX1=0.0
98    CONTINUE
      TRVX=1.0-TRW
      IF(ICOMP.EQ.0)GO TO 99
      TBARL=XMWH(J,ICAP,6)
C***SET TBARL AT INITIALIZATION
      IF(TBARL.LT.TCUT)TBARL=TAV
      TBAR=TBARL*TRVX+TAV*TRW
      XMWH(J,ICAP,6)=TBAR
      TXX=(TAV-TBAR)**2
      CX1=(TBARL-TBAR)**2
99    CONTINUE
      XMWH(J,ICAP,7)=(XMWH(J,ICAP,7)+CX1)*TRVX+TXX*TRW
      XMWH(J,ICAP,IRNG)=XMWH(J,ICAP,IRNG)+DELT
100   CONTINUE
      TCAV(ICAP)=TCAV(ICAP)/20.0
      IF(TCAV(ICAP).GT.285.0)IATO(ICAP)=1
200   CONTINUE
C***BYPASS PRINTING IF NPRNT .NE. 1
      IF(NPRNT.NE.1)GO TO 620
400   CONTINUE
C****OUTPUT DATA FOR EACH IRRADIATION SET
      DO 500 I=1,NSET
      IF(JPP(I).LT.1.OR.JPP(I).GT.4)GO TO 500
      ISET=JPP(I)
      WRITE(NOUT,2000)(TLA(IT),IT=1,7),ISET,TLB,IDAY,
     1 DASH,XMTH(IMTH),DASH,IYR
      WRITE(NOUT,2001)(TLC(IT),IT=1,7),TIME
      WRITE(NOUT,2001)(TLB(IT),IT=1,7),XMW
2000  FORMAT('1',7A8,I3,A4,I3,A1,A3,A1,I2)
2001  FORMAT(' ',7A8,2X,F10.2)
      WRITE(NOUT,2002)
      WRITE(NOUT,2003)
```

```
2002    FORMAT('0',27X,'HOURS OF IRRADIATION WITH',15X,' AVERAGE ',
     1'      STANDARD')
2003    FORMAT(' ',' THERMOCOUPLE  ***<T<270 270<T<280 280<T<296',
     1  ' 296<T<306 306<T<***  TEMPERATURE  DEVIATION')
2004    FORMAT(' ',4X,A8,5F10.2,2F12.2)
        WRITE(NOUT,2007)BLANK
2007    FORMAT(' ',A8)
        DO 500 K=1,20
        STDIV=SQRT(XMWH(K,ISET,7))
        IF(IEND.EQ.2)STDIV=XMWH(K,ISET,7)
        WRITE(NOUT,2004)TCID(K,ISET),(XMWH(K,ISET,L),L=1,5),
     1  XMWH(K,ISET,6),STDIV
500     CONTINUE
620     CONTINUE
        IF(IEND.NE.0)GO TO 630
        IF(NRST.EQ.0)GO TO 10
        IF(NRST.EQ.1)GO TO 8
630     CONTINUE
C***WRITE A  RESTART FILE FOR THE NEXT INITIALIZATION
        IF(IEND.EQ.2)GO TO 650
        IEND=2
        NOUT=ISOUT
        GO TO 400
650     CONTINUE
        WRITE(5,1149)IDAY,DASH,XMTH(IMTH),DASH,IYR,IHL,IML,ISL
1149    FORMAT('0',' LAST RECORD DATE AND TIME ARE: ',I2,A1,A3,
     1 A1,I2,' AT ',I2,':',I2,':',I2)
        CALL CLOSE(1)
        CALL CLOSE(2)
        IF(NINIT.EQ.1)CALL CLOSE(IS1)
        CALL CLOSE(ISOUT)
        IF(NOUT.NE.5)CALL CLOSE(NOUT)
        WRITE(5,1025)
1025    FORMAT(' ENTER "NEXT" TO INPUT MORE DATA ',$)
        READ(5,1026)XARY
1026    FORMAT(A4)
        IF(XARY.EQ.'NEXT')GO TO 755
        STOP
        END
```

APPENDIX D

LISTING OF COMPUTER PROGRAM COMBO

```
      DIMENSION X1(20,4,7),X2(20,4,7),X3(20,4,7),ISET(4),IST1(4),IDY1(4)
     1,MTH1(4),IYR1(4),TIM1(4),XMWH1(4),IST2(4),IDY2(4),MTH2(4),IYR2(4),
     2TIM2(4),XMWH2(4),XMW(4),TIM(4),XMTH(12)
      REAL*8 TCID(20,4),BLANK,TLA(7),TLC(7),TLD(7),FIL1,
     1 FIL2,FIL3
      LOGICAL*1 DASH
      DATA BLANK/'        '/
      DATA TLC/'        ','        ','        ','HOURS OF',
     1' IRRADIA','TION TIM','E EQUALS'/
      DATA TLD/'        ','        ','        ','MEGAWATT',
     1' HOURS O','F IRRADI','ATION   '/
      DATA TLA/'        ','        ','        ','DATA ARE',
     1' FOR SPE','CIMEN SE','T NUMBER'/
      DATA TLB/' ON '/
      DATA DASH/'-'/
      DATA XMTH/'JAN','FEB','MAR','APR','MAY','JUN','JUL',
     1'AUG','SEP','OCT','NOV','DEC'/
      DATA TCID/'TE  1','TE  2','TE  3','TE  4','TE  5','TE  6',
     1'TE  7','TE  8','TE  9','TE 10','TE 11','TE 12',
     2'TE 13','TE 14','TE 15','TE 16','TE 17','TE 18',
     3'TE 19','TE 20','TE101','TE102','TE103','TE104',
     4'TE105','TE106','TE107','TE108','TE109','TE110',
     5'TE111','TE112','TE113','TE114','TE115','TE116','TE117',
     6'TE118','TE119','TE120','TE201','TE202','TE203','TE204',
     7'TE205','TE206','TE207','TE208','TE209','TE210','TE211',
     8'TE212','TE213','TE214','TE215','TE216','TE217','TE218',
     9'TE219','TE220','TE301','TE302','TE303','TE304','TE305',
     A'TE306','TE307','TE308','TE309','TE310','TE311','TE312',
     B'TE313','TE314','TE315','TE316','TE317','TE318','TE319',
     C'TE320'/
      WRITE(5,1000)
 1000 FORMAT(' INPUT FILENAME OF INPUT FILE 1 ',/,' *',$)
      READ(5,55)FIL1
 55     FORMAT(A10)
      WRITE(5,1001)
 1001 FORMAT(' INPUT FILENAME OF INPUT FILE 2 ',/,' *',$)
      READ(5,55)FIL2
      WRITE(5,1002)
 1002 FORMAT(' INPUT FILENAME OF THE OUTPUT FILE ',/,' *',$)
      READ(5,55)FIL3
      WRITE(5,1003)
 1003 FORMAT(' INPUT FORMAT ID. FOR EACH INPUT FILE: 0 OR 1 ',/,
     1    ' *',$)
      READ(5,*)IDF1,IDF2
C***OPEN INPUT AND OUTPUT FILES
      OPEN(UNIT=1,FILE=FIL1,ACCESS='SEQIN')
      OPEN(UNIT=2,FILE=FIL2,ACCESS='SEQIN')
      OPEN(UNIT=3,FILE=FIL3,ACCESS='SEQOUT')
      WRITE(5,1004)
 1004 FORMAT(' INPUT # OF SETS AND SET #'S COMBINED ',/,' *',$)
      READ(5,*)NSET,(ISET(I),I=1,NSET)
      WRITE(5,1005)
 1005 FORMAT(' INPUT DAY-MTH-YR OF COMBINED FILE ',/,' *',$)
      READ(5,*)IDAY,IMTH,IYR
C***READ THE FIRST INPUT FILE
      IF(IDF1.GT.0)GO TO 20
      DO 10 J=1,NSET
      L=ISET(J)
      READ(1,1006)IST1(L),IDY1(L),MTH1(L),IYR1(L),TIM1(L),XMWH1(L)
 1006 FORMAT(I1,1X,I2,1X,A3,1X,I2,F8.2,F10.2)
      READ(1,*)   ((X1(K,L,M),M=1,7),K=1,20)
```

```
10     CONTINUE
       GO TO 30
20     CONTINUE
       LUT=1
       CALL RDX1(NSET,ISET,TIM1,XMWH1,X1,LUT)
30     CONTINUE
C***READ THE SECOND INPUT FILE
       IF(IDF2.GT.0)GO TO 50
       DO 40 J=1,NSET
       L=ISET(J)
       READ(2,1006)IST2(L),IDY2(L),MTH2(L),IYR2(L),TIM2(L),XMWH2(L)
       READ(2,*)   ((X2(K,L,M),M=1,7),K=1,20)
40     CONTINUE
       GO TO 60
50     CONTINUE
       LUT=2
       CALL RDX1(NSET,ISET,TIM2,XMWH2,X2,LUT)
60     CONTINUE
C***COMBINE DATA FROM FILES 1 AND 2
       DO 90 I=1,NSET
       L=ISET(I)
       TIM(L)=TIM1(L)+TIM2(L)
       XMW(L)=XMWH1(L)+XMWH2(L)
       DO 80 J=1,20
       DO 70 K=1,5
70     X3(J,L,K)=X1(J,L,K)+X2(J,L,K)
       TX1=TIM1(L)/TIM(L)
       TX2=TIM2(L)/TIM(L)
         VAR1=X1(J,L,7)**2
         VAR2=X2(J,L,7)**2
       X3(J,L,6)=X1(J,L,6)*TX1+X2(J,L,6)*TX2
80     X3(J,L,7)=VAR1*TX1+VAR2*TX2
90     CONTINUE
C***OUTPUT DATA FOR EACH IRRADIATION SET
       DO 100 I=1,NSET
       L=ISET(I)
       WRITE(3,2000)(TLA(IT),IT=1,7),L,TLB,IDAY,
      1 DASH,XMTH(IMTH),DASH,IYR
       WRITE(3,2001)(TLC(IT),IT=1,7),TIM(L)
       WRITE(3,2001)(TLD(IT),IT=1,7),XMW(L)
2000   FORMAT(1H1,7A8,I3,A4,I3,A1,A3,A1,I2)
2001   FORMAT(' ',7A8,2X,F10.2)
       WRITE(3,2002)
       WRITE(3,2003)
2002   FORMAT(1H0,27X,'HOURS OF IRRADIATION WITH',15X,' AVERAGE ',
      1'     STANDARD')
2003   FORMAT(' ',' THERMOCOUPLE  ***<T<270 270<T<280 280<T<296',
      1' 296<T<306 306<T<***  TEMPERATURE  DEVIATION')
2004   FORMAT(' ',4X,A8,5F10.2,2F12.2)
       WRITE(3,2007)BLANK
2007   FORMAT(' ',A8)
       DO 100 K=1,20
       STDIV=SQRT(X3(K,L,7))
       WRITE(3,2004)TCID(K,L),(X3(K,L,M),M=1,5),
      1 X3(K,L,6),STDIV
100    CONTINUE
         CLOSE(UNIT=1,FILE=FIL1,ACCESS='SEQIN')
         CLOSE(UNIT=2,FILE=FIL2,ACCESS='SEQIN')
         CLOSE(UNIT=3,FILE=FIL3,ACCESS='SEQOUT')
       STOP
       END
C
C************** SUBROUTINE RDX1 ******************************C
C
         SUBROUTINE RDX1(NSET,ISET,TM,XMW,X,LUT)
         DIMENSION ISET(1),TM(1),XMW(1),X(20,4,7)
```

```
      REAL*8 XDUM,XTLA(7)
      LOGICAL*1 XDASH
      DO 10 I=1,NSET
      L=ISET(I)
      READ(LUT,2000)(XTLA(K),K=1,7),IST,XTLB,IXX,
     1 XDASH,XTH,XDASH,IXR
2000  FORMAT(1H1,7A8,I3,A4,I3,A1,A3,A1,I2)
      READ(LUT,2001)(XTLA(K),K=1,7),TM(L)
      READ(LUT,2001)(XTLA(K),K=1,7),XMW(L)
      READ(LUT,2007) XDUM
      READ(LUT,2007) XDUM
      READ(LUT,2007) XDUM
      DO 10 J=1,20
      READ(LUT,2004)XDUM,(X(J,IST,IX),IX=1,7)
10    CONTINUE
2001  FORMAT(' ',7A8,2X,F10.2)
2004  FORMAT(' ',4X,A8,5F10.2,2F12.2)
2007  FORMAT(' ',A8)
      RETURN
      END
```

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