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TIMH--A COMPUTER PROGRAM
FOR THE DETERMINATION OF FLUENCE
WITH A TIME-VARYING FLUX

R. D. Bourquin

August 1970

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TIMH--A COMPUTER PROGRAM
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WITH A TIME-VARYING FLUX

By

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ABSTRACT

This report presents a method for calculating flux and fluence from activities induced in neutron-activated foils from irradiations with varying reactor power. The FORTRAN V program that performs calculations according to this method is described, along with input instructions, a complete listing, and an illustrative test case.

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TIMH--A COMPUTER PROGRAM
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INTRODUCTION

Historically, flux and fluence have been calculated assuming a constant reactor power level for an irradiation. No reactor operates continuously, so calculations of flux and fluence would be more precise if the effects of reactor cycling were considered. Since activity saturates at a level that depends on the flux and at a rate that depends on the daughter half-life, the flux calculated for a short half-life monitor assuming a constant power level would be significantly in error if the power level had fluctuated.

This document describes a method for calculating flux and fluence for variable reactor power levels. Three assumptions are made: (1) the reactor power history may be represented by a histogram of flux levels constant for each day, (2) spectral shift caused by fuel burnup is negligible, and (3) no burnout of daughter nuclide occurs.* This method forms the basis for TIMH, a FORTRAN V program. A test case (Appendix A) and listing (Appendix B) are included.

* This means that ^{58}Ni analysis in a thermal reactor would be inadequate. For a fast reactor, however, the ^{58}Co absorption cross section is very low, and the effects of burnout are negligible.

METHOD

For a flux-fluence monitor, without burnup, the time behavior of target product atoms with a time-varying flux level is

$$\frac{dN}{dt} = \bar{\sigma} \phi(t) - \lambda N, \quad (1)$$

where N is the total number of radioactive product atoms at time t , λ is the decay constant in sec^{-1} ($\ln 2/t_{1/2}$), $\bar{\sigma}$ is the spectral-averaged cross section in cm^2 calculated by SAND-2⁽¹⁾ (or a comparable method), and $\phi(t)$ is the time-varying flux.

Solve Equation (1) to obtain

$$N = \bar{\sigma} e^{-\lambda T} \int_0^T \phi(t) e^{\lambda t} dt, \quad (2)$$

where T is the irradiation time.

To solve Equation (2) for $\int_0^T \phi(t) dt$, assume that $\phi(t)$ may be represented by a histogram of constant power level operations of L cycles as in Figure 1 and ϕ_i is the power level for the i^{th} cycle.

Now represent Equation (2) as

$$N = \bar{\sigma} e^{-\lambda T} \sum_{i=1}^L \phi_i \int_{t_i}^{t_{i+1}} e^{\lambda t} dt.$$

Evaluating the integral gives

$$N = \bar{\sigma} e^{-\lambda T} \sum_{i=1}^L \frac{\phi_i}{\lambda} (e^{\lambda t_{i+1}} - e^{\lambda t_i}). \quad (3)$$

FIGURE 1. Power History for a Typical Test Facility

Let ϕ = flux level for maximum reactor power at the position of the flux-fluence monitor during the irradiation.

P_i = fraction of maximum power for the i^{th} cycle ($P_i = \frac{\phi_i}{\phi}$).

Rewriting Equation (3) as

$$N = \frac{\bar{\sigma}}{\lambda} e^{-\lambda T} \phi \sum_{i=1}^L P_i (e^{\lambda t_{i+1}} - e^{\lambda t_i}),$$

solving for ϕ and letting $A = \lambda N$ (activity of the foil) gives

$$\phi = \frac{A}{\bar{\sigma} e^{-\lambda T} \sum_{i=1}^L P_i (e^{\lambda t_{i+1}} - e^{\lambda t_i})}. \quad (4)$$

The total fluence is now calculated from the relationship

$$\phi t = \int_0^T \phi(t) dt = \sum_{i=1}^L \phi_i (t_{i+1} - t_i)$$

or

$$\phi t = \phi \sum_{i=1}^L P_i (t_{i+1} - t_i). \quad (5)$$

TIMH uses Equations (4) and (5) for the calculation of flux and fluence. One may calculate the saturated activity of a monitor by setting $\bar{\sigma} = 1$ in Equation (4). This feature is especially convenient for the preparation of input to SAND-2 iteration runs.

In Equation (4) a potential trouble-spot in the term

$$\sum_{i=1}^L P_i (e^{\lambda t_{i+1}} - e^{\lambda t_i})$$

is $e^{\lambda t}$, which becomes excessively large for irradiations longer than about 20 half-lives. To keep the computer from overflowing its number size limit ($0 \leq |x| < \sim 10^{38}$) and to avoid round-off errors arising from the addition and subtraction of large numbers differing by small amounts, only the last 20 half-lives of any foil are considered for an irradiation. If this is less than the total irradiation time, a message is printed giving the number of days actually considered in the calculation of the maximum flux level. The arithmetic error introduced in the flux calculations is less than 0.0001%, but the fluences calculated by such a monitor may not be accurate, since the activity becomes saturated at a level that depends on the flux during the end of the irradiation.

PROGRAM DESCRIPTION

TIMH is written in FORTRAN V⁽²⁾ (FORTRAN IV, level H) and was first used on a UNIVAC 1108 computer. Local software options used include the subroutines "SETEOF" (transfers control to a statement number designated in its call list when an end-of-file is reached), "SETEND" (transfers control to the designated statement number when illegal input characters are encountered), and "NTRAN" (an I/o routine permitting parallel processing).

The subroutine "DAYS" is used to find the number of days between two dates in the same century. It is called by TIMH to find the number of days from reactor startup to irradiation start (NSTT) and the length of the irradiation in days (NDAY). TIMH then uses these data and the tabulated power factors (P_i) to calculate the sums:

$$QP = \sum_{i=1}^{NDAY} P_i (e^{\lambda t_{i+1}} - e^{\lambda t_i})$$

$$TPINT = \sum_{i=1}^{NDAY} P_i (t_{i+1} - t_i).$$

Using these sums, TIMH then processes the data for the foils having the same λ . Equations (4) and (5) reduce to:

$$\phi = \frac{A}{(\bar{\sigma})(e^{-\lambda T})(QP)} \quad (4a)$$

$$\text{FLUENCE} = (\phi)(\text{TPINT}) \quad (5a)$$

Figure 2 shows the logical flow in TIMH.

FIGURE 2. Logical Flow for TIMH

ACKNOWLEDGEMENT

The author wishes to express his appreciation to Dr. W. N. McElroy for suggesting the writing of this program.

The EBR-II time history data used in the test case were obtained from the EBR-II project, Argonne National Laboratory, which has also prepared a computer program (EBR-II History Program) which can be used to handle the time varying flux problem for EBR-II.*

* D. Rossin, Argonne National Laboratory, Chicago, Ill.
Private Communication (1969)

APPENDIX A

TIMH INPUT INSTRUCTIONS AND TEST CASE

APPENDIX A

TIMH INPUT INSTRUCTIONS AND TEST CASEINPUT INSTRUCTIONS

Input consists of the following:

- (1) A reactor power history (by days) of either (a) a tape generated by THIST (Appendix C) or (b) cards in the format for input to THIST.
- (2) Two title cards containing 13 six-character words of alphanumeric run identification.
- (3) One card containing

	<u>Column</u>	<u>Data</u>	<u>Data Type</u>
Irradiation Start Time	{ 1-3	Month	Integer
	{ 4-6	Day	Integer
	{ 7-9	Year	Integer
	{ 10-12	Hour (24- hour clock)	Integer
	{ 13-15	Minute	Integer
Irradiation Stop Time	{ 21-23	Month	Integer
	{ 24-26	Day	Integer
	{ 27-29	Year	Integer
	{ 30-32	Hour (24- hour clock)	Integer
	{ 33-35	Minute	Integer
	36-40	Number of Monitors	Integer

Leave the rest of the card blank unless the irradiation was interrupted. If it was, add the following

	50	Was irradiation interrupted by removal from reactor?	Logical (TorF)
Beginning of Interruption	{ 51-53	Month	Integer
	{ 54-56	Day	Integer
	{ 57-59	Year	Integer
Date of Replacement in Reactor	{ 61-63	Month	Integer
	{ 64-66	Day	Integer
	{ 67-69	Year	Integer

- (4) One card for each Monitor [card type (3)--see columns 36-40 under No. (3) above] containing

<u>Column</u>	<u>Data</u>	<u>Data Type</u>	<u>Unit</u>
1-5	Number of Foils	Integer	-
6-15	λ for this Monitor	Floating Point	sec ⁻¹

- (5) One card for each foil [card type (4)--see columns 1-5 under No. (4) above] containing

1-12	Foil Ident.	Alphanumeric	-
13-24	A	Floating Point	dps/ nucleus
23-36	$\bar{\sigma}$	Floating Point	cm ²
37-48	Estimated flux/MW	Floating Point	n/cm ² - sec-MW)

To calculate fluxes and fluences from different irradiations in the same reactor, repeat card types (2) through (5).

TEST CASE

Sample output for TIMH appears on page A-4. The irradiation considered is an assembly which was in EBR-II during Run 31F.⁽³⁾ The activity data used for the calculation of flux and fluence came from the reactions $^{58}\text{Fe}(n,\gamma)^{59}\text{Fe}$ and

$^{54}\text{Fe}(n,p)^{54}\text{Mn}$ (which were counted from the same foil),
 $^{63}\text{Cu}(n,\gamma)^{64}\text{Cu}$, and $^{235}\text{U}(n,f)^{140}\text{Ba}$. Flux per megawatt predic-
tions were obtained from 2DB diffusion theory calculations.⁽⁴⁾

PROGRAM LISTING

The FORTRAN V listings for TIMH and subroutine DAYS
appear in Appendix B.

TIME TEST CASE FOR EBR-II RUN 31-F DOSIMETRY STUDY

DATE AND TIME IN : 11/ 5/68 AT 23:51 EXPOSURE: MW SEC. MW HOURS MW DAYS
 DATE AND TIME OUT: 11/14/68 AT 4: 0 3.5719+07 9.9220+03 4.1342+02

FOIL NUMBER: 1 DECAY CONSTANT (LAMBDA): 6.2676-07

CASE NUMBER	FOIL IDENTIFICATION	CROSS SECTION (SQ.CM)	ACTIVITY (DPS/NUCLEUS)	FLUX/MW (CALCULATED)	FLUENCE (CALCULATED)	MAXIMUM FLUX (MEASURED)	FLUENCE (MEASURED)	RATIO OF FLUENCES (CALC. TO MEASURED)
1	RCW 2--U235	1.3470-24	1.0290-09	4.16000+13	1.48592+21	2.10603+15	1.56451+21	.9876418

TIME TEST CASE FOR EBR-II RUN 31-F DOSIMETRY STUDY

DATE AND TIME IN : 11/ 5/68 AT 23:51 EXPOSURE: MW SEC. MW HOURS MW DAYS
 DATE AND TIME OUT: 11/14/68 AT 4: 0 3.5719+07 9.9220+03 4.1342+02

FOIL NUMBER: 2 DECAY CONSTANT (LAMBDA): 2.5590-08

CASE NUMBER	FOIL IDENTIFICATION	CROSS SECTION (SQ.CM)	ACTIVITY (DPS/NUCLEUS)	FLUX/MW (CALCULATED)	FLUENCE (CALCULATED)	MAXIMUM FLUX (MEASURED)	FLUENCE (MEASURED)	RATIO OF FLUENCES (CALC. TO MEASURED)
1	RCW 2--FE54	1.7760-26	6.7394-13	4.16000+13	1.48592+21	2.08766+15	1.49139+21	.9963293

TIME TEST CASE FOR EBR-II RUN 31-F DOSIMETRY STUDY

DATE AND TIME IN : 11/ 5/68 AT 23:51 EXPOSURE: MW SEC. MW HOURS MW DAYS
 DATE AND TIME OUT: 11/14/68 AT 4: 0 3.5719+07 9.9220+03 4.1342+02

FOIL NUMBER: 3 DECAY CONSTANT (LAMBDA): 1.8028-07

CASE NUMBER	FOIL IDENTIFICATION	CROSS SECTION (SQ.CM)	ACTIVITY (DPS/NUCLEUS)	FLUX/MW (CALCULATED)	FLUENCE (CALCULATED)	MAXIMUM FLUX (MEASURED)	FLUENCE (MEASURED)	RATIO OF FLUENCES (CALC. TO MEASURED)
1	RCW 2--FE58	4.0670-27	1.0235-12	4.16000+13	1.48592+21	2.07471+15	1.48214+21	1.0025491

TIME TEST CASE FOR EBR-II RUN 31-F DOSIMETRY STUDY

DATE AND TIME IN : 11/ 5/68 AT 23:51 EXPOSURE: MW SEC. MW HOURS MW DAYS
 DATE AND TIME OUT: 11/14/68 AT 4: 0 3.5719+07 9.9220+03 4.1342+02

FOIL NUMBER: 4 DECAY CONSTANT (LAMBDA): 1.4995-05

CASE NUMBER	FOIL IDENTIFICATION	CROSS SECTION (SQ.CM)	ACTIVITY (DPS/NUCLEUS)	FLUX/MW (CALCULATED)	FLUENCE (CALCULATED)	MAXIMUM FLUX (MEASURED)	FLUENCE (MEASURED)	RATIO OF FLUENCES (CALC. TO MEASURED)
1	RCW 2--CU63	2.2900-26	6.1054-11	4.16000+13	1.48592+21	2.08236+15	1.48760+21	.9988682

APPENDIX B

LISTINGS OF TIMH AND DAYS


```

1.      C      TIMH WILL TAKE ACTIVITIES IN DPS/NUCLEUS, CROSS SECTIONS IN CM**2,
2.      C      DATES IN AND OUT IN THE FORM OF MONTH NUMBER, DAY OF THE MONTH, AND THE
3.      C      LAST TWO DIGITS OF THE YEAR, TIMES IN AND OUT IN 24-HOUR CLOCK NOTATION,
4.      C      DECAY CONSTANT IN SEC**-1, AND FOIL IDENTIFICATION. FROM THIS INPUT
5.      C      AND A TIME-VARYING POWER HISTORY OF THE REACTOR (FROM A TAPE PREPARED
6.      C      PRIOR TO THIS RUN OR FROM CARDS IN THE FORMAT USED TO PREPARE THE TAPE
7.      C      (SEE DOCUMENTATION ON TIMH AND THIST FOR PARTICULARS)), TIMH WILL
8.      C      CALCULATE A FLUX AT THE MAXIMUM POWER LEVEL, TOTAL FLUENCE, AND A RATIO
9.      C      OF CALCULATED (PREDICTED) TO MEASURED (FROM FOIL ACTIVATION) FLUENCES.
10.     C
11.     C      ALL VARIABLES BEGINNING WITH THE LETTER 'L' ARE AUTOMATICALLY TYPED LOGICAL
12.     C
13.     C      IMPLICIT LOGICAL (L)
14.     C
15.     C      DIMENSION ID(3), JD(3), ISD(3), IDOUT(3), IDIN(3), IDENT(26),
16.     C      1 ACT(100), SIG(100), FPMW(100), FLUX(100), FLCH(100), FLUEN(100),
17.     C      2 IDF(2,100), RATC(100), PF(3000), PFN(1500), TD(1500), ED(1500),
18.     C      3 IRN(2)
19.     C
20.     C      COMMON PF, PFN
21.     C
22.     C      DATA IBLNK /'      '/
23.     C
24.     C      120 FORMAT('OFOIL NUMBER:', 1I4, 5X, 'DECAY CONSTANT (LAMBDA):',
25.     C      1 1PE12.4)
26.     C      121 FORMAT('ONTRAN HIT A SNAG. BELOW ARE LISTED (IN ORDER) THE STATUS
27.     C      1 VARIABLE AND THE NUMBER IT SHOULD BE (IST AND NPF). ' //, 2I15)
28.     C      122 FORMAT('O CASE      FOIL      CROSS SECTION      ACTIVITY
29.     C      1FLUX/MW      FLUENCE      MAXIMUM FLUX      FLUENCE      RATIO OF FL
30.     C      2UENCES' / ' NUMBER IDENTIFICATION      (SQ.CM)      (DPS/NUCLEUS)
31.     C      3(CALCULATED) (CALCULATED)      (MEASURED)      (MEASURED)      (CALC. TO
32.     C      4 MEASURED)' //, ((1X, 1I4, 5X, 2A6, 1PE14.4, E15.4, E15.5, E14.5,
33.     C      5 E16.5, E13.5, OPF19.7)))
34.     C      123 FORMAT('OCONGRATULATIONS! YOU HAVE JUST ENTERED THE TWILIGHT ZONE
35.     C      1 OF', T75, 'YOU WANT DATA PAST THE LAST AVAILABLE INFORMATION.',
36.     C      1 T62, 2A6, /
37.     C      2'O MAXIMUM INDEX FOR DATA DESIRED      =', I7, /
38.     C      3'O MAXIMUM INDEX FOR DATA AVAILABLE =', I7, /
39.     C      124 FORMAT('1', 19X, 13A6, /, 20X, 13A6, /,
40.     C      1      'ODATE AND TIME IN :', 1I5, '/', 1I2, '/', 1I2, ' AT ', 1I2, ':',
41.     C      2 1I2, 24X, 'EXPOSURE:  MW SEC.      MW HOURS      MW DAYS' /'ODATE
42.     C      3 AND TIME OUT:', 1I5, '/', 1I2, '/', 1I2, ' AT ', 1I2, ':', 1I2, 31X,
43.     C      4 1P3E13.4/)
44.     C      125 FORMAT(13A6)
45.     C      126 FORMAT(2A6, 3E12.0)

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46.      127 FORMAT('0THIS TEST ASSEMBLY WAS OUT OF THE REACTOR FROM ', I2, '/')
47.      1, I2, '/', I2, ' UNTIL ', I2, '/', I2, '/', I2, '/')
48.      128 FORMAT(5I3, 5X, 5I3, 1I5, 1L10, 3I3, 1X, 3I3)
49.      129 FORMAT(1I5, 1E10.0)
50.      130 FORMAT('0THIS FOIL HAS A SHORTENED EXPOSURE BECAUSE OF ITS SHORT H
51.      1ALF-LIFE. EXPOSURE LONGER THAN TWENTY TIMES THE HALF-LIFE'/' CON
52.      2TRIBUTES LESS THAN 1 PART PER MILLION OF THE ACTIVITY. ACTUAL DAY
53.      3S CONSIDERED:', I6)
54.      131 FORMAT(2A6, 3I3, E14.0)
55.      132 FORMAT(6E12.0)
56.      C
57.      C
58.      C WHEN AN END-OF-FILE CONDITION IS REACHED, GO TO STATEMENT NUMBER 200 (EXIT)
59.      CALL SETEOF($200)
60.      C
61.      C
62.      C DETERMINE WHETHER POWER HISTORY IS TO BE READ FROM CARDS OR TAPE
63.      C
64.      READ(5,125) (IDENT(I), I=1,13)
65.      IF(IDENT(8).NE.IBLNK) GO TO 15
66.      C
67.      C READ POWER HISTORY FROM CARDS
68.      C
69.      ILU = -4
70.      READ(ILU,131) IRN, ISD, FCT
71.      CALL SETEND(3HIC, $5)
72.      DO 2 II=1,500
73.      K = II * 6
74.      J = K - 5
75.      READ(5,132) (PF(I), I=J,K)
76.      2 CONTINUE
77.      5 NPF = K - 6
78.      READ(ILU,125) (IDENT(I), I=1,13)
79.      DO 7 I=1,NPF
80.      PF(I) = PF(I) * FCT
81.      7 CONTINUE
82.      GO TO 17
83.      C
84.      C READ THE POWER HISTORY FROM TAPE
85.      C
86.      15 READ(1) NPF, ISD, IRN
87.      CALL NTRAN(1,2,NPF,PF,IST)
88.      IST = IST
89.      16 IF(IST.EQ.-1) GO TO 16
90.      IF(IST.LT.NPF) GO TO 201
91.      CALL NTRAN(1,11)
92.      17 READ(5,125) (IDENT(I), I=14,26)
93.      GO TO 19
94.      C

```

```

193.      32 CONTINUE
194.      DO 33 I=1,NDAY
195.      J = I + 1
196.      GP = PFN(I) * (ED(J) - ED(I)) + GP
197.      33 CONTINUE
198.      C
199.      C CALCULATE FLUXES AND FLUENCES AND COMPARE THE FLUENCES OBTAINED WITH THE
200.      C PREDICTED (CALCULATED) FLUENCE.
201.      C
202.      DO 34 I=1,NCAS
203.      FLUX(I) = ACT(I) / (GP * SIG(I) * EINTT)
204.      FLUEN(I) = FLUX(I) * TPINT
205.      FLCH(I) = FPMW(I) * TBU
206.      RATO(I) = FLCH(I) / FLUEN(I)
207.      34 CONTINUE
208.      C
209.      C WRITE ALL OUTPUT FOR THIS FOIL AND PICK UP THE NEXT FOIL.
210.      C
211.      WRITE(6,120) KK, AMDA
212.      WRITE(6,122) (I, IDF(1,I), IDF(2,I), SIG(I), ACT(I), FPMW(I), FLCH(I),
213.      1 FLUX(I), FLUEN(I), RATO(I), I=1, NCAS)
214.      35 CONTINUE
215.      C
216.      C RETURN TO THE FIRST TO PICK UP THE NEXT IRRADIATION.
217.      C
218.      GO TO 150
219.      C
220.      200 WRITE(6,124) IBLNK
221.      CALL EXIT
222.      C
223.      C
224.      C IF ERRORS ARE ENCOUNTERED, WRITE ERROR FLAGS AND CALL EXIT.
225.      C
226.      201 WRITE(6,121) IST, NPF
227.      GO TO 200
228.      202 WRITE(6,123) IRN, M, NPF
229.      GO TO 150
230.      END

```

```

95.      C BEGIN THE FIRST CASE.
96.      C
97.      150 READ(5,125) IDENT
98.      19 READ(5,128) ID, IF, IM, JD, JH, JM, NFOIL, LOUT, IDOUT, IDIN
99.      C
100.     C FIND THE NUMBER OF DAYS FROM THE IN TIME TO OUT TIME AND FROM THE REACTOR
101.     C START-UP DATE TO THE IN TIME.
102.     C
103.         CALL DAYS(NSTT, ISD, ID)
104.         CALL DAYS(NDY, ID, JD)
105.         M = NSTT + NDY
106.         IF(M.GT.NPF) GO TO 202
107.     C
108.     C IF THE EXPERIMENTAL ASSEMBLY WAS REMOVED FROM THE REACTOR AT ANY TIME
109.     C DURING THE IRRADIATION, FIND THE CYCLES
110.     C
111.         IF(.NOT.LOUT) GO TO 20
112.         CALL DAYS(NSOT, ISD, IDOUT)
113.         CALL DAYS(NBIN, IDOUT, IDIN)
114.     C
115.     C READ IN THE PERTINENT VARIABLES FOR THE FOILS, 1 THROUGH NFOIL. (MANY CASES
116.     C PER FOIL)
117.     C
118.     20 DO 35 KK=1,NFOIL
119.         READ(5,129) NCAS, AMDA
120.         READ(5,126) ((IDF(M,N), M=1,2),ACT(N),SIG(N),FPMW(N), N=1,NCAS)
121.         NDAY = NDY
122.         N = M - NDY
123.         LJUMP = .FALSE.
124.         LSHORT = .FALSE.
125.     C
126.     C IF MORE THAN 20 HALF-LIVES ARE INCLUDED IN THE COMPUTATION, CONSIDER
127.     C ONLY THE LAST 20 HALF-LIVES IN THE CALCULATION OF THE FLUX (PRINT MESSAGE)
128.     C
129.         I20HL = 1.6045074E-4 / AMDA + .9999
130.         IF(I20HL.GE.NDY) GO TO 21
131.         LSHORT = .TRUE.
132.         N = M - I20HL
133.         NDAY = I20HL
134.         IF(.NOT.LOUT) GO TO 21
135.         MMM = NSOT + NBIN
136.         IF(MMM.LT.N) LJUMP = .TRUE.
137.         MMM = MMM - N
138.         NNN = NSOT - N
139.         IF(NNN.LT.0) NNN = 1
140.     21 GP = 0.0
141.         PMX = PF(N)
142.         DO 25 K=N,M
143.             PMX = MAX(PMX,PF(K))

```

```

144.      25 CONTINUE
145.      PMX = 1. / PMX
146.      DO 26 K=N,M
147.      J = K - N + 1
148.      PFN(J) = PF(K) * PMX
149.      26 CONTINUE
150.      IF(.NOT.LOUT.OR.LJUMP) GO TO 28
151.      DO 27 K=NNN,MMM
152.      PFN(K) = 0.
153.      27 CONTINUE
154.      C
155.      28 NHR = IH - JH + 23
156.      NMN = IM - JM + 60
157.      VAR1 = NDAY * 86400 - NHR * 3600 - NMN * 60
158.      ED(0) = 1.
159.      TJ = (23-IH) * 3600 + (60-IM) * 60
160.      IF(LSHORT) TJ = 8.64E4
161.      TK = JH * 3600 + JM * 60
162.      NDAY1 = NDAY + 1
163.      PFN(NDAY1) = 0.
164.      TPINT = PFN(1) * 8.64E4
165.      DO 31 I=2,NDAY
166.      J = I - 2
167.      TD(I) = J * 8.64E4 + TJ
168.      TPINT = PFN(I) * 8.64E4 + TPINT
169.      31 CONTINUE
170.      TD(1) = 0.
171.      TD(NDAY1) = (NDAY-1) * 8.64E4 + TJ + TK
172.      JJ = N - 1
173.      JK = M + 1
174.      IF(PF(JJ).LT.1.E-5) PFN(1) = PFN(1) * 8.64E4 / TJ
175.      IF(PF(JK).LT.1.E-5) PFN(NDAY) = PFN(NDAY) * 8.64E4 / TK
176.      C
177.      TBU = 0.
178.      DO 29 K=N,M
179.      J = K - N + 1
180.      IF(PFN(J).LT..00001) GO TO 29
181.      TBU = TBU + PF(K)
182.      29 CONTINUE
183.      TMWH = TBU / 3600.
184.      TMWD = TMWH / 24.
185.      WRITE(6,124) IDENT, ID, IH, IM, JD, JH, JM, TBU, TMWH, TMWD
186.      IF(LOUT) WRITE(6,127) IDOUT, IDIN
187.      IF(LSHORT) WRITE(6,130) I20HL
188.      C
189.      C
190.      EINTT = EXP(-AMDA * VAR1)
191.      DO 32 I=1,NDAY1
192.      ED(I) = EXP(AMDA * TD(I))

```

```

1.      SUBROUTINE DAYS(NDAY, ID, JD)
2.      C
3.      IMPLICIT LOGICAL (L)
4.      C
5.      DIMENSION ID(3), JD(3), LY(100), LJ(12)
6.      C
7.      I = ID(3)
8.      J = JD(3)
9.      NDAY = -ID(2) + 1
10.     NN = JD(1)
11.     MN = ID(1)
12.     DO 14 K=1,12
13.     LJ(K) = .FALSE.
14. CONTINUE
15.     C
16.     DO 20 K=I,J
17.     LY(K) = .FALSE.
18.     IF(MOD(K,4).EQ.0) LY(K) = .TRUE.
19.     IF(K.EQ.J) LJ(NN) = .TRUE.
20.     IF(K.EQ.I) GO TO (1,2,3,4,5,6,7,8,9,10,11,12), MN
21.     IF(LJ(NN)) GO TO 1
22.     NDAY = NDAY + 365
23.     IF(LY(K)) NDAY = NDAY + 1
24.     GO TO 20
25.     1 IF(LJ(1)) GO TO 18
26.     NDAY = NDAY + 31
27.     2 IF(LJ(2)) GO TO 18
28.     NDAY = NDAY + 28
29.     IF(LY(K)) NDAY = NDAY + 1
30.     3 IF(LJ(3)) GO TO 18
31.     NDAY = NDAY + 31
32.     4 IF(LJ(4)) GO TO 18
33.     NDAY = NDAY + 30
34.     5 IF(LJ(5)) GO TO 18
35.     NDAY = NDAY + 31
36.     6 IF(LJ(6)) GO TO 18
37.     NDAY = NDAY + 30
38.     7 IF(LJ(7)) GO TO 18
39.     NDAY = NDAY + 31
40.     8 IF(LJ(8)) GO TO 18
41.     NDAY = NDAY + 31
42.     9 IF(LJ(9)) GO TO 18
43.     NDAY = NDAY + 30
44.     10 IF(LJ(10)) GO TO 18
45.     NDAY = NDAY + 31
46.     11 IF(LJ(11)) GO TO 18
47.     NDAY = NDAY + 30
48.     12 IF(LJ(12)) GO TO 18
49.     NDAY = NDAY + 31
50.     GO TO 20
51.     18 NDAY = NDAY + JD(2)
52.     GO TO 21
53.     20 CONTINUE
54.     C
55.     21 RETURN
56.     C
57.     END

```

BNWL-1492

APPENDIX C

THIST

APPENDIX C

THIST

THIST is a program for reading cards containing the power history of a reactor, converting the power factors to megawatt seconds per day, and writing a binary tape of this information for use with TIMH. The reactor power history is listed by months from the startup date through the date of the last available data.

INPUT FORMATCard 1

<u>Column</u>	<u>Data</u>	<u>Data Type</u>
1-12	Reactor Identification	Alphanumeric
13-15	Month } Date on which power history begins	Integer
16-18		Integer
19-21		Integer
22-35	Factor needed to convert power data to megawatt seconds per day	Floating Point
36-40	Do you want a listing only? (No tape produced if true.)	Logical

Cards 2 through N

These contain the reactor power history in 6E12.0 format. (Six days per card; units must be consistent with the factor given on Card 1, columns 22-35, above.)

TEST CASE

The test case output for THIST appears on page C-2. The input is a power history listing in megawatt seconds per day beginning on September 6, 1968, and continuing through March 31, 1969.

PROGRAM LISTING

The FORTRAN V listing of THIST appears on page C-3.

THIS IS A REACTOR POWER HISTORY FOR EBR-II BEGINNING ON SEPT. 6, 1968

SEPT., 1968									
0.00000	1.49040+06	4.32000+06	4.32000+06	4.24800+06	1.80000+04	0.00000	5.43600+05	2.48400+06	1.45800+06
0.00000	0.00000	2.95200+05	2.59200+06	2.59200+06	1.33200+06	2.70000+05	2.59200+06	2.59200+06	1.35000+06
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000				
OCT. , 1968									
1.46160+06	2.59200+06	2.59200+06	1.07280+06	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
7.70400+05	2.23920+06	2.35080+06	1.22400+05	2.06280+06	2.59200+06	2.59200+06	1.00800+06	4.03200+05	2.59200+06
2.59200+06	1.62000+06	0.00000	0.00000	0.00000	1.80360+06	2.70000+06	2.67120+06	4.29840+06	4.32000+06
4.32000+06									
NOV. , 1968									
4.32000+06	4.32000+06	3.37320+06	0.00000	4.39200+05	4.32000+06	4.32000+06	4.32000+06	4.32000+06	4.32000+06
4.32000+06	4.32000+06	4.32000+06	7.20000+05	1.94040+06	4.32000+06	3.31200+06	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	7.20000+03	1.89360+06	3.34080+06	4.32000+06
DEC. , 1968									
3.45960+06	4.32000+06	4.32000+06	4.32000+06	4.32000+06	4.32000+06	4.32000+06	3.79800+06	4.03200+06	4.32000+06
4.32000+06	3.63960+06	4.23000+06	4.32000+06	4.30560+06	1.24560+06	4.86000+05	3.24000+05	4.13280+06	4.32000+06
4.32000+06	4.32000+06	2.49120+06	1.62000+06	2.00160+06	3.60000+06	6.30000+05	1.30680+06	4.14000+06	4.32000+06
4.32000+06									
JAN. , 1969									
3.29400+06	1.96560+06	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000									
FEB. , 1969									
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	9.21600+05	3.40560+06		
MARCH, 1969									
1.90800+06	4.32000+06	1.26720+06	2.66040+06	1.00080+06	3.24720+06	4.32000+06	4.14000+06	9.25200+05	4.32000+06
3.29400+06	1.17000+06	2.44800+05	2.45160+06	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	1.15200+05	3.85920+06	4.30200+06	3.82320+06	0.00000	0.00000
0.00000									

```

1.      IMPLICIT LOGICAL (L)
2.      DIMENSION PF(4000), MO(12)/' JAN. FEB. MARCH APRIL MAY JUNE J
3.      JULY AUG. SEPT. OCT. NOV. DEC.'/, IYR(20), ISTART(3), IRN(2),
4.      2 NDAY(12)/31,28,31,30,31,30,31,31,30,31,30,31/
5.      51 FORMAT(6E12.0)
6.      52 FORMAT('1 THIS IS A REACTOR POWER HISTORY FOR', T51, 'BEGINNING O
7.      1N', T73, ' ', T39, 2A6, T64, A6, I3, T75, I4 /)
8.      53 FORMAT('0', 40X, 1A6, ' ', 115 /)
9.      54 FORMAT(1P10E13.5)
10.     55 FORMAT(2A6, 3I3, E14.0, L5)
11.     56 FORMAT(1P6E12.5)
12.     102 FORMAT('UNTRAN HAS HIT A SNAG!!  IST =', T35, ' ', NPF =', T31, I4,
13.           1 T42, I4)
14.           CALL SETEOF($2)
15.           READ(5,55) IRN, ISTART, FACTOR, LIST
16.           DO 1 I=1,1500
17.             J = (I-1) * 6 + 1
18.             K = J + 5
19.             READ(5,51) (PF(KK), KK=J,K)
20.           1 CONTINUE
21.           2 NPF = K - 6
22.           DO 5 J=1,NPF
23.             PF(J) = PF(J) * FACTOR
24.           5 CONTINUE
25.           IF(LIST) GO TO 11
26.           WRITE(1) NPF, ISTART, IRN
27.           CALL NTRAN(1,1,NPF, PF, IST)
28.           IST = IST
29.           11 CONTINUE
30.           NY = NPF / 365 + 2
31.           IYR(1) = 1900 + ISTART(3)
32.           DO 3 I=2,NY
33.             J = I - 1
34.             IYR(I) = IYR(J) + 1
35.           3 CONTINUE
36.           I1 = ISTART(1)
37.           I1 = ISTART(1)
38.           I1 = MO(I1)
39.           I2 = ISTART(2)
40.           I3 = IYR(1)
41.           WRITE(6,52) IRN, I1, I2, I3
42.           IF(LIST) GO TO 12
43.           15 IF(IST.EQ.-1) GO TO 15
44.           IF(IST.LT.NPF) GO TO 101
45.           12 CONTINUE
46.           N1 = 1
47.           NN = NDAY(I1) - ISTART(2) + 1
48.           IF(MOD(ISTART(3),4).EQ.0.AND.I1.EQ.2) NN = NN + 1
49.           DO 10 I=1,NY
50.             II = 1
51.             IF(I.EQ.1) II = ISTART(1)
52.             DO 8 J=II,12
53.               IF(N1.GT.NPF) GO TO 10
54.               WRITE(6,53) MO(J), IYR(I)
55.               WRITE(6,54) (PF(K), K=N1,NN)
56.               IF(J.EQ.12) GO TO 9
57.               JJ = J + 1
58.               N1 = NN + 1
59.               NN = NN + NDAY(JJ)
60.               IF(MOD(IYR(I), 4).EQ.0.AND.JJ.EQ.2) NN = NN + 1
61.             8 CONTINUE
62.             9 N1 = NN + 1
63.             NN = NN + NDAY(1)
64.           10 CONTINUE
65.           IF(LIST) GO TO 20
66.           CALL NTRAN(1,9)
67.           CALL NTRAN(1,11)
68.           20 CALL EXIT
69.           101 WRITE(6,102) IST, NPF
70.           GO TO 20
71.           END

```


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