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10-27-76

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LA-NUREG-6563-MS
Informal Report
NRC-8

los alamos
scientific laboratory
of the University of California
LOS ALAMOS, NEW MEXICO 87545

LARC-1: A Los Alamos Release Calculation Program for Fission Product Transport in HTGRs During the LOFC Accident

by

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Manuscript completed: October 1976
Issued: November 1976

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Prepared for the US Nuclear Regulatory Commission
Office of Nuclear Regulatory Research

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LARC-1: A LOS ALAMOS RELEASE CALCULATION PROGRAM FOR FISSION PRODUCT TRANSPORT IN HTGRs DURING THE LOFC ACCIDENT

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ABSTRACT

The theoretical and numerical data base development of the LARC-1 code is described. Four analytical models of fission product release from an HTGR core during the LOFC accident are developed. Effects of diffusion, adsorption and evaporation of the metallics and precursors are neglected in this first LARC model. Comparison of the analytic models indicates that the constant release-renormalized model is adequate to describe the processes involved.

The numerical data base for release constants, temperature modeling, fission product release rates, coated fuel particle failure fraction and aged coated fuel particle failure fractions is discussed. Analytic fits and graphic displays for these data are given for the Ft. St. Vrain and GASSAR models.

I. INTRODUCTION

In early 1975, a simplified model of fission product release from an HTGR (High-Temperature Gas-Cooled Reactor) core during the LOFC (Loss of Forced Circulation) accident was proposed by John E. Foley.[1] This simplified model was based on the following assumptions:

1. The entire core is at a uniform temperature.
2. All coated particles fail at the same time.
3. Fission products are released only from failed particles (no release from intact particles).

4. The release rate of an isotope from the failed particles is given by the release constant from the SORS report[2].
5. There is no buildup of the isotope from precursor decay.

In December 1975 we began developing the LARC code (Los Alamos Release Calculation) with the goal of calculating analytically the fission product transport of noble gases and metallics in an HTGR during the LOFC accident. We have systematically removed the assumptions of the simplified model. We have also studied the simple analytical models relative to more complex analytical models so as to judge the relative accuracy of the simple models used as a basis for extending the theory.

In this report we review the models developed to the present time, discuss the data base as developed thus far, and illustrate the workings of the LARC code with preliminary results. The current version, LARC-1, neglects the effects of diffusion, adsorption and evaporation of the metallics, and precursors.

The effects of precursors have been solved theoretically. A one-dimensional analytical diffusion model has been derived, but not implemented into this program. These topics will be addressed in subsequent reports.

In Section II we derive and discuss the analytical models: the Simplified Model, the Constant Release-Renormalized Model, the Linear Release Renormalized Model, and the Linear Failure Self-Consistent Model.

In Section III we review and discuss the data base used for the temperature modeling of the core, the fission product release rates for BISO and TRISO fuels from SORS and GASSAR, particle coating failure fraction, and the algorithm for computing the aged fuel failure fraction.

Section IV discusses and compares the results of release calculations for different isotopes. The relative accuracy of the models is compared with the conclusion that the Constant Release-Renormalized Model is justified for further theory extensions, for example for precursors and diffusion processes.

The results presented here are the culmination of about 700 short computer runs. The LARC-1 code runs on either the CDC-7600 in the BATCH mode or on the CDC-6600 in NOS (formally KRONOS) time-sharing system.

We would also like to acknowledge the usage of MACSYMA,* Version 258 (Project MAC's Symbolic Manipulation System for symbolic integration, differentiation, limiting and pattern recognition) that was of great help in the verification of many of the results presented in Appendices A and B.

The programs LARC-1 and PLOTS are discussed and listed in Appendices C and D.

II. ANALYTICAL MODELS

A. Simplified Model Equations - A Review

Using assumptions 1-5, the four Simplified model equations are given by

$$\frac{dN(t)}{dt} = -\Lambda_1(t)N(t), \quad 0 \leq t \leq \tau, \tag{1}$$

$$R(\tau) = \int_0^\tau r_1(s)N(s)ds, \tag{2}$$

$$\frac{dN'(t)}{dt} = S(t) - \Lambda^*(t)N'(t), \quad 0 \leq t \leq \tau, \tag{3}$$

$$R'(\tau) = \int_0^\tau L(s)N'(s)ds, \tag{4}$$

where

$N(t)$ is the number of atoms of the isotope in the core at time t in the interval $0 \leq t \leq \tau$,

$\Lambda_1(t) = \lambda + r_1(t)$, and λ is the isotope decay constant,

$r_1(t)$ is the release constant for failed particles,

*Supported by the Defense Advanced Research Projects Agency work order #2095, under Office of Naval Research Contract N00014-75C-0661.

$R(\tau)$ is the amount of isotope released in the core during the time interval τ,

$N'(t)$ is the number of atoms of the isotope in the containment building at time t,

$R'(\tau)$ is the amount of the isotope released from the containment building during the time interval τ,

$\Lambda^*(t)$ $= \lambda + V(t) + L(t)$ is the total decay constant for the containment building,

$V(t)$ is the containment building cleanup rate,

$L(t)$ is the containment building leakage rate, and

$S(t)$ is the source rate to the containment building from the core.

In the Simplified model we assume that $r_1(t)$, $V(t)$, and $L(t)$ are constant in the time interval $0 \leq t \leq \tau$. We further assume that the source rate can be taken as a constant average, namely

$$S(t) = \frac{R(t)}{t}, \qquad 0 \leq t \leq \tau \tag{5}$$

which is valid if all the time steps are equal <u>and</u> small. In the other models we use

$$S(t) = \frac{dR(t)}{dt}, \tag{6}$$

which avoids that assumption.

The solutions to Eqs. (1-4), using Eq. (5), are given by

$$N(\tau) = N(0)e^{-\Lambda_1 \tau}, \tag{7}$$

$$R(\tau) = \frac{r_1 N(0)}{\Lambda_1}(1-e^{-\Lambda_1 \tau}), \tag{8}$$

$$N'(\tau) = N'(0)e^{-\Lambda^* \tau} + \frac{R(\tau)}{\tau\Lambda^*}(1 - e^{-\Lambda^* \tau}), \text{ and} \tag{9}$$

$$R'(\tau) = \frac{L}{\Lambda^*} N'(0)(1-e^{-\Lambda^*\tau}) + \frac{LR(\tau)}{\tau\Lambda^{*2}} [e^{-\Lambda^*\tau} - (1+\Lambda^*\tau)]. \quad (10)$$

In order to find the release after a number of time steps $k\tau$, the activity is accumulated according to

$$A(k\tau) = A[(k-1)\tau]e^{-\lambda\tau} + R(\tau) \text{ and} \quad (11)$$

$$A'(k\tau) = A[(k-1)\tau]e^{-\lambda\tau} + R'(\tau) \quad . \quad (12)$$

In addition, the values of $N(\tau)$ and $N'(\tau)$ at the end of a time step become the initial values $N(0)$, $N'(0)$, respectively, for the next time step.

The release rate, $\bar{r}_1$, the leakage rate, $\bar{L}$, and the clean-up rate, $\bar{V}$, are determined by

$$\bar{r}_1 = \frac{1}{2} [r(0) + r(\tau)], \quad (13)$$

$$\bar{L} = \frac{1}{2} [L(0) + L(\tau)], \text{ and} \quad (14)$$

$$\bar{V} = \frac{1}{2} [V(0) + V(\tau)] \quad . \quad (15)$$

Currently we use the values $\bar{L}$ and $\bar{V}$ for all time intervals. The decay constant is an input quantity.

B. Constant Release - Renormalized Model

Whereas in the Simplified model we treated only failed particle release, we now assume a constant release r_i for failed (i=1) and intact (i=2) particles. In addition we calculate the release from BISO and TRISO particles separately and sum the releases using $X_{TOTAL} = a \cdot X_{BISO} + (1-a) \cdot X_{TRISO}$ where a = 0.6 and X is a release, either R or R'. Then the differential equations corresponding to Eqs. (1-4) and (6) are

$$\frac{dN_i(t)}{dt} = -\Lambda_i(t)N_i(t), \tag{16}$$

$$R_i(\tau) = \int_0^\tau r_i(s)N_i(s)ds, \tag{17}$$

$$\frac{dN_i'(t)}{dt} = S_i(t) - \Lambda^* N_i'(t), \tag{18}$$

$$R_i'(\tau) = \int_0^\tau L(s)N_i'(s)ds, \text{and} \tag{19}$$

$$S_i(t) = \frac{dR_i(t)}{dt} = r_i(t)N_i(t). \tag{20}$$

Integrating Eqs. (16-17), using Eqs. (2) and (13-15) we find

$$N_i(\tau) = e^{-\Lambda_i\tau} N_i(0), \tag{21}$$

$$R_i(\tau) = \frac{\bar{r}_i}{\Lambda_i}(1-e^{-\Lambda_i\tau})N_i(0), \tag{22}$$

$$N_i'(\tau) = \begin{cases} e^{-\Lambda^*\tau} N_i'(0) + \dfrac{\bar{r}_i}{\Lambda^*-\Lambda_i}(e^{-\Lambda_i\tau} - e^{-\Lambda^*\tau})N_i(0) & \text{if } \Lambda^* \neq \Lambda_i, \\ e^{-\Lambda^*\tau} N_i'(0) + \bar{r}_i\tau e^{-\Lambda^*\tau} N_i(0) & \text{if } \Lambda^* = \Lambda_i, \end{cases} \tag{23}$$

$$R_i'(\tau) = \begin{cases} \dfrac{\bar{L}}{\Lambda^*}(1-e^{-\Lambda^*\tau})N_i'(0) + \dfrac{\bar{L}\bar{r}_i}{\Lambda^*-\Lambda_i}\dfrac{1}{\Lambda_i}\left[(1-e^{-\Lambda_i\tau}) - \dfrac{1}{\Lambda^*}(1-e^{-\Lambda^*\tau})\right]N_i(0) & \text{if } \Lambda^* \neq \Lambda_i, \\ \dfrac{\bar{L}}{\Lambda^*}(1-e^{-\Lambda^*\tau})N_i'(0) + \dfrac{\bar{L}\bar{r}_i}{\Lambda^{*2}}\left[1-(1+\Lambda^*\tau)e^{-\Lambda^*\tau}\right]N_i(0) & \text{if } \Lambda^* = \Lambda_i, \end{cases} \tag{24}$$

where $\Lambda_i \equiv \lambda + \bar{r}_i$ and $\Lambda^* = \lambda + \bar{L} + \bar{V}$. Since $\bar{r}_i$ is given as a function of temperature and implicitly as a function of time, the limiting cases $\Lambda^* = \Lambda_i$ are distinctly possible and must be accounted for.

In the Simplified model where we treated the release only from failed particles, using the final value for $N(\tau)$ of a time step as the initial value, $N(0)$, for the next time step was justified. However, from a study of the intact-failed transition (Section D) it became clear that matching the failed fraction (for BISO and TRISO) as a function of time is crucial. The failed fraction is defined as

$$F(t) = \frac{N_1(t)}{N_1(t) + N_2(t)} \quad . \tag{25}$$

Assuming that we know $F(t)$, which we do, then we want to adjust the ratio N_1/N_2 while maintaining the constancy of the sum $N_1 + N_2$. This renormalization of $N_i(\tau)$ at the end of a time step to $N_i(0)$ at the beginning of the next time step is accomplished by the transformation

$$F(\tau)[N_1(\tau) + N_2(\tau)] \rightarrow N_1(0)$$

$$[1 - F(\tau)][N_1(\tau) + N_2(\tau)] \rightarrow N_2(0), \tag{26}$$

for both BISO and TRISO particles using the $F(\tau)$ specific to each type. The failed fraction is a function of temperature which is a function of time and of core volume fraction. Thus $F(t)$ is implicitly a function of time.

The quantities $N_i(t)$, $R_i(\tau)$, $N_i'(t)$, $R_i'(\tau)$ are calculated separately and then summed for BISO and TRISO particles, failed (1) and intact (2) particle coating release, and various core volume fractions.

Although we use the averaging given by Eq. (13) for the $\bar{r}_i$, we also tried time centering $\bar{r}_i$ defined by

$$\bar{r}_i = r_i[T(\tau/2)]. \tag{27}$$

Those results were not in as good agreement as using Eq. (13) in parameter studies involving time steps and core volume fraction.

C. Linear Release - Renormalized Model

In the Constant Release-Renormalized model we assumed that the release rate for failed and intact particles was given by

$$\bar{r}_i = \frac{1}{2}[r_i(0) + r_i(\tau)] \quad i=1,2 \ , \tag{28}$$

over the time interval τ.

Now we approximate the release function of time over the time interval τ, given by suppressing the subscript i)

$$r(t) = \sum_{k=1} [a_k + b_k(t-t_k)][\theta(t-t_k) - \theta(t-t_{k+1})], \tag{29}$$

where $\theta(x)$ is the Heaviside step-function defined by

$$\theta(x) = \begin{cases} 1, & x > 0 \\ 0, & x \leq 0 \ . \end{cases} \tag{30}$$

Denoting

$$\begin{aligned} r_k &= r[T(t_k)] \\ \tau &= t_{k+1} - t_k \end{aligned} \tag{31}$$

we solve for the a_k and b_k in Eq. (29) to obtain

$$a_k = r_k \quad \text{and}$$
$$b_k = (r_{k+1} - r_k)/\tau \ . \tag{32}$$

Note that using Eq. (32) in (29), we obtain

$$r(t_k + \frac{1}{2}\tau) = \frac{1}{2}(r_k + r_{k+1}) \ , \tag{33}$$

which is equivalent to Eq. (28).

The same remarks concerning BISO and TRISO particles preceding Eq. (16) in the constant release model apply for the linear release model. The differential equations for the Linear Release-Renormalized model are

$$\frac{dN_i(t)}{dt} = -\Lambda_i(t)N_i(t) \ , \tag{34}$$

$$R_i(\tau) = \int_0^\tau r_i(s)N_i(s)ds \ , \tag{35}$$

$$\frac{dN_i'(t)}{dt} = S_i(t) - \Lambda^* N_i'(t), \tag{36}$$

$$R_i'(\tau) = \int_0^\tau L(s)N_i(s)ds, \tag{37}$$

$$S_i(t) = \frac{dR_i(t)}{dt} = r_i(t)N_i(t) \ , \tag{38}$$

$$\Lambda_i(t) = \lambda + r_i(t), \tag{39}$$

$$r_i(s) = a_i + b_i s \ , \quad i = 1,2 \tag{40}$$

where a_i and b_i are determined for $i = 1,2$ (that is, failed and intact particles) over the time interval τ using Eq. (32) as

$$a_i = r_i(0) \quad \text{and}$$

$$b_i = [r_i(\tau) - r_i(0)]/\tau . \tag{41}$$

After solving Eqs. (34-38) we apply the same renormalization as discussed in the Constant Release-Renormalized model, namely Eq. (26).

The integration of Eqs. (34-38) is straightforward, using the methods developed in Appendices A and B, with the results that

$$N_i(\tau) = e^{-\bar{\Lambda}_i \tau} N_i(0), \tag{42}$$

$$R_i(\tau) = [1-e^{-\bar{\Lambda}_i \tau} - \lambda P_o(\Lambda_i,\beta,\tau)]N_i(0), \tag{43}$$

$$N'_i(\tau) = e^{-\Lambda^* \tau} N'_i(0) + [(\bar{V} + \bar{L})P_o(\Lambda_i-\Lambda^*,\beta,\tau) + 1-e^{-(\Lambda_i-\Lambda^*)\tau}]e^{-\Lambda^* \tau} N_i(0), \tag{44}$$

$$R'_i(\tau) = \frac{\bar{L}}{\Lambda^*}(1-e^{-\Lambda^* \tau})N'_i(0) + \frac{\bar{L}}{\Lambda^*}[1-e^{-\Lambda^* \tau} - \lambda P_o(\Lambda_i,\beta,\tau) + (\bar{V}+\bar{L})e^{-\Lambda^* \tau}P_o(\Lambda_i-\Lambda^*,\beta,\tau)]N_i(0), \tag{45}$$

where

$$\bar{\Lambda}_i = \lambda + a_i + \frac{b_i \tau}{2},$$

$$\Lambda_i = \lambda + a_i, \tag{46}$$

$$\beta = \frac{b_i}{2},$$

and

$$P_k(\gamma,\beta,\tau) = \int_o^\tau ds\, s^k e^{-\gamma s-\beta s^2} = (-\frac{\partial}{\partial\gamma})^k P_o(\gamma,\beta,\tau) \tag{47}$$

with

$$P_o(\gamma,\beta,\tau) = \frac{1}{2}\sqrt{\frac{\pi}{\beta}}\ e^{\gamma^2/4\beta}\ [\mathrm{erf}(\sqrt{\beta}\tau + \frac{\gamma}{2\sqrt{\beta}}) - \mathrm{erf}\ (\frac{\gamma}{2\sqrt{\beta}})]\ . \tag{48}$$

Various limiting forms of $P_o(\gamma,\beta,\tau)$ are derived in Appendix A where it is shown that

$$P_o(0,\beta,\tau) = \frac{1}{2}\sqrt{\frac{\pi}{\beta}}\ \mathrm{erf}\ (\sqrt{\beta}\tau) \text{ if } \gamma = 0,\ \beta \neq 0 \tag{49}$$

$$P_o(\gamma,0,\tau) = \frac{1}{\gamma}(1-e^{-\gamma\tau}) \quad \text{if } \gamma \neq 0,\ \beta = 0 \tag{50}$$

and

$$P_o(0,0,\tau) = \tau \quad \text{if } \gamma = \beta = 0\ . \tag{51}$$

Also involved in the integration of Eqs. (34-38), and derived in Appendices A and B, are the integrals

$$P_1(\gamma,\beta,\tau) = \int_o^\tau ds\ s\ e^{-\gamma s-\beta s^2} = -\frac{\gamma}{2\beta}\ P_o(\gamma,\beta,\tau) + \frac{1}{2\beta}\ (1-e^{-\gamma\tau-\beta\tau^2}), \tag{52}$$

$$\int_o^\tau ds\ e^{-\Lambda^* s}\ P_o(\gamma,\beta,s) = \frac{1}{\Lambda^*}\ [P_o(\Lambda^* + \gamma,\beta,\tau) - e^{-\Lambda^*\tau}P_o(\gamma,\beta,\tau)], \tag{53}$$

and

$$\int_0^\tau ds\, e^{-\Lambda^* s} P_1(\gamma,\beta,s) = \frac{1}{2\beta\Lambda^*}\,[-(\Lambda^*+\gamma)P_o(\Lambda^*+\gamma,\beta,\tau)$$

$$+\,\gamma e^{-\Lambda^*\tau}P_o(\gamma,\beta,\tau) + 1-e^{-\Lambda^*\tau}]\,. \qquad (54)$$

Using Eqs.(48-51), the various limiting forms may be written explicitly as

<u>$\gamma = \Lambda_i - \Lambda^*,\ \beta \neq 0$:</u>

$$N_i'(\tau) = e^{-\Lambda^*\tau}\, N_i'(0) + e^{-\Lambda^*\tau}[a_i P_o(0,\beta,\tau) + 1-e^{-\beta\tau^2}]N_i(0) \qquad (55)$$

$$R_i'(\tau) = \bar{L}\,\{\frac{1-e^{-\Lambda^*\tau}}{\Lambda^*}\, N_i'(0) + \frac{1}{\Lambda^*}\,[(a_i-\Lambda^*)P_o(\Lambda^*,\beta,\tau)$$

$$-a_i P_o(0,\beta,\tau) + 1-e^{-\Lambda^*\tau}]N_i(0)\}\ . \qquad (56)$$

<u>$\gamma = \Lambda_i - \Lambda^* \neq 0,\ \beta = 0$:</u>

$$N_i'(\tau) = e^{-\Lambda^*\tau}N_i'(0) + \frac{a_i}{\bar{\Lambda}_i}\,[1-e^{-(\Lambda_i-\Lambda^*)\tau}]\ e^{-\Lambda^*\tau}N_i(0) \qquad (57)$$

$$R_i'(\tau) = \bar{L}\left\{\frac{1-e^{-\Lambda^*\tau}}{\Lambda^*}\, N_i'(0) + \frac{a_i}{\bar{\Lambda}_i}\left[\frac{1}{\Lambda^*}\,(1-e^{-\Lambda^*\tau}) - \frac{1}{\Lambda_i}\,(1-e^{-\Lambda_i\tau})\right]N_i(0)\right\}. \qquad (58)$$

<u>$\gamma = \Lambda_i - \Lambda^* = 0,\ \beta = 0$:</u>

$$N_i'(\tau) = e^{-\Lambda^*\tau}N_i'(0) + a_i\tau e^{-\Lambda^*\tau}N_i(0) \qquad (59)$$

$$R_i'(\tau) = \bar{L}\ \{ \frac{1-e^{-\Lambda^*\tau}}{\Lambda^*}\ N_i'(0) + \frac{a_i}{\Lambda^{*2}}\ [1-(1+\Lambda^*\tau)e^{-\Lambda^*\tau}]N_i(0)\}. \quad (60)$$

In the $\beta = 0$ limit, $a_i \rightarrow \bar{r}_i$ using Eq. (41), and Eq. (57) and Eq. (59) for $N_i'(\tau)$ and Eq. (58) and Eq. (60) for $R_i'(\tau)$ are seen to be identical with Eq. (23) and Eq. (24), respectively, for the Constant Release model described previously, as they should.

In terms of numerical evaluation it suffices to use the limiting forms for $P_o(\gamma,\beta,\tau)$ given in Eqs. (48-51) in Eqs. (42-45) since there are no singularities.

D. Intact - Failed Self-Consistent Fuel Transition

In order to investigate the accuracy of the simple renormalized intact-failed models, we now develop a self-consistent model for reference comparisons. We assume that the release rate, $r(t)$, the containment building clean-up system removal rate, $V(t)$, and the containment building leak rate, $L(t)$, are constant over the time interval τ. We assume that the failed fraction, $F(t)$, is a linear function of time over the time interval τ.

The transition of intact to failed fuel, including decay and release from failed (Eq.61) and intact (Eq.62) fuel particles can be represented by

$$\frac{dN_1}{dt} = -(\lambda+\bar{r}_1)N_1 + \dot{G}N_2 \quad \text{(failed)}, \quad (61)$$

$$\frac{dN_2}{dt} = -(\lambda+\bar{r}_2)N_2 - \dot{G}N_2 \quad \text{(intact)}, \quad (62)$$

where λ is the isotope decay constant and the $\bar{r}_i$ are the release constants. We assume that the release constants are averaged

over the time interval τ and are given by

$$\bar{r}_i \equiv \frac{1}{2}\,[r_i(0) + r_i(\tau)], \quad i = 1,2 . \tag{63}$$

The transition rate, $\dot{G}$, in Eqs. (61) and (62), is determined from the definition of the failed fraction

$$F(t) \equiv \frac{N_1(t)}{N_1(t) + N_2(t)} \quad . \tag{64}$$

Differentiating ($\dot{} \equiv \frac{d}{dt}$) Eq. (64), we obtain

$$\dot{F}(t) = [1 - F(t)]\,\frac{\dot{N}_1(t)}{N_1(t) + N_2(t)} - F(t)\,\frac{\dot{N}_2(t)}{N_1(t) + N_2(t)} , \tag{65}$$

where we have used Eq.(64). Defining

$$\Lambda_i = \lambda + \bar{r}_i \ , \ i = 1,2 \tag{66}$$

and substituting Eqs.(61) and (62) for $\dot{N}_1(t)$ and $\dot{N}_2(t)$ into Eq. (65), we find

$$\dot{F}(t) = F(t)\ [1-F(t)](\Lambda_2-\Lambda_1) + [1-F(t)]\dot{G} . \tag{67}$$

Solving for $\dot{G}(t)$ we obtain

$$\dot{G}(t) = \frac{\dot{F}(t)}{1-F(t)} + (\Lambda_1-\Lambda_2)F(t) . \tag{68}$$

Assuming that the failed fraction, $F(t)$, is approximated as a linear function in the time interval τ,

$$F(t) = a + bt \ , \ 0 \leq F(t) \leq 1 \tag{69}$$

then

$$a = F(0)$$
$$b = \frac{F(\tau) - F(0)}{\tau} \tag{70}$$

and Eqs. (61) and (62) can be integrated, using Eq. (68) to give

$$N_1(\tau) = \sum_{k=o}^{3} A_k \, M_k(\tau)$$

and (71)

$$N_2(\tau) = \sum_{k=4}^{5} A_k \, M_k(\tau),$$

where the functions $M_k(\tau)$ are defined as

$$M_o(\tau) = e^{-\Lambda_1 \tau},$$

$$M_k(\tau) = e^{-\Lambda_1 \tau} \int_o^{\tau} ds \; s^{k-1} \; e^{\alpha s - \beta s^2} \;, \; 1 \leq k \leq 3,$$

$$M_4(\tau) = e^{-\gamma\tau - \beta\tau^2} \;, \text{ and}$$

$$M_5(\tau) = \tau e^{-\gamma\tau - \beta\tau^2} \;. \tag{72}$$

The constants (in the time interval τ) α, β, γ, and A_k are given by

$$\alpha = (\Lambda_1 - \Lambda_2)(1-a) \,,$$

$$\beta = (\Lambda_1 - \Lambda_2) \; b/2 \,,$$

$$\gamma = \Lambda_1 a + \Lambda_2 (1-a) = \Lambda_1 - \alpha \,, \tag{73}$$

and

$$A_o = N_1(0) ,$$

$$A_1 = [b + (\Lambda_1-\Lambda_2)(1-a)] \frac{N_2(0)}{1-a} ,$$

$$A_2 = (\Lambda_1-\Lambda_2)[b(1-a)-ab] \frac{N_2(0)}{1-a} , \tag{74}$$

$$A_3 = -(\Lambda_1-\Lambda_2) \frac{b^2 N_2(0)}{1-a} ,$$

$$A_4 = N_2(0) , \text{ and}$$

$$A_5 = - \frac{bN_2(0)}{1-a} .$$

The release from intact and failed particles is given by

$$R_i(\tau) = \int_o^\tau ds\ r_i\ N_i(s),\ i = 1,2 \tag{75}$$

or

$$R_1(\tau) = \sum_{R=o}^{3} B_k\ \hat{P}_k\ (\tau)$$

$$R_2(\tau) = \sum_{R=4}^{5} B_k\ \hat{P}_k(\tau) , \tag{76}$$

where the functions $\hat{P}_k(\tau)$ are defined by

$$\hat{P}_k(\tau) = \int_o^\tau ds\ M_k(s) \tag{77}$$

and the constants B_k are related to the A_k's by

$$B_k = \bar{r}_1\ A_k \quad 0 \leq k \leq 3$$

$$B_k = \bar{r}_2\ A_k \quad k = 4,5 . \tag{78}$$

The functions $M_k(\tau)$ and $\hat{P}_k(\tau)$ are derived explicitly in Appendix A. They are all expressible in terms of exponentials and combinations of exponentials with error functions. If we define the function $P_o(\gamma,\beta,\tau)$, c.f. Eq. (A-8), by

$$P_o(\gamma,\beta,\tau) = \int_o^\tau ds\ e^{-\gamma s-\beta s^2}$$

$$= \frac{1}{2}\sqrt{\frac{\pi}{\beta}}\, e^{\gamma^2/2\beta}\left[\mathrm{erf}(\sqrt{\beta}\tau + \frac{\gamma}{2\sqrt{\beta}}) - \mathrm{erf}\ (\frac{\gamma}{2\sqrt{\beta}})\right], \qquad (79)$$

then by integration and differentiation [with respect to the parameters of $P_o(\gamma,\beta,\tau)$], the $M_k(\tau)$ functions for $\beta \neq 0$ are given by

$$M_o(\Lambda_1,\tau) = e^{-\Lambda_1\tau},$$

$$M_1(\Lambda_1,\alpha,\beta,\tau) = e^{-\Lambda_1\tau} P_o(-\alpha,\beta,\tau),$$

$$M_2(\Lambda_1,\alpha,\beta,\tau) = \frac{e^{-\Lambda_1\tau}}{2\beta}\left[\alpha P_o(-\alpha,\beta,\tau) + 1-e^{\alpha\tau-\beta\tau^2}\right],$$

$$M_3(\Lambda_1,\alpha,\beta,\tau) = \frac{e^{-\Lambda_1\tau}}{4\beta^2}\left[\begin{array}{l}(\alpha^2+2\beta)P_o(-\alpha,\beta,\tau) + \alpha(1-e^{\alpha\tau-\beta\tau^2}) \\ -(\alpha-2\beta\tau)e^{\alpha\tau-\beta\tau^2}\end{array}\right],$$

$$M_4(\gamma,\beta,\tau) = e^{-\gamma\tau-\beta\tau^2},$$

and

$$M_5(\gamma,\beta,\tau) = \tau e^{-\gamma\tau-\beta\tau^2}. \qquad (80)$$

The functions $M_2(\tau)$ and $M_3(\tau)$ are expressible as

$$M_2(\Lambda_1,\alpha,\beta,\tau) = \frac{M_o(\Lambda_1,\tau) - M_4(\Lambda_1-\alpha,\beta,\tau) + \alpha M_1(\Lambda_1,\alpha,\beta,\tau)}{2\beta} \qquad (81)$$

and

$$M_3(\Lambda_1,\alpha,\beta,\tau) = \frac{M_1(\Lambda_1,\alpha,\beta,\tau) - M_5(\Lambda_1-\alpha,\beta,\tau) + \alpha M_2(\Lambda_1,\alpha,\beta,\tau)}{2\beta} . \quad (82)$$

The limiting forms are given in Appendix A. In particular we note that the integrals for $M_2(\tau)$ and $M_3(\tau)$ in the $\beta = 0$ limit are finite and independent of β. The contribution from $A_k M_k(\tau)$, $k = 2,3$, is therefore zero since A_2 and A_3 have a factor of β in them.

Similarly, integration of Eq. (77), using Eq. (80), as derived in Appendix A, yields for the $\hat{P}_k(\tau)$ functions the results

$$\hat{P}_o(\Lambda_1,\tau) = \frac{1}{\Lambda_1}(1-e^{-\Lambda_1\tau}) ,$$

$$\hat{P}_1(\Lambda_1,\alpha,\beta,\tau) = \frac{1}{\Lambda_1}[P_o(\Lambda_1-\alpha,\beta,\tau)-e^{-\Lambda_1\tau} P_o(-\alpha,\beta,\tau)] ,$$

$$\hat{P}_2(\Lambda_1,\alpha,\beta,\tau) = \frac{1}{2\beta\Lambda_1}\left[(\Lambda_1-\alpha)P_o(\Lambda_1-\alpha,\beta,\tau)+\alpha e^{-\Lambda_1\tau} P_o(-\alpha,\beta,\tau) - (1-e^{-\Lambda_1\tau})\right] ,$$

$$\hat{P}_3(\Lambda_1,\alpha,\beta,\tau) = \frac{1}{4\beta^2}\left\{-\frac{[2\beta+(\Lambda_1-\alpha)^2]}{\Lambda_1} P_o(\Lambda_1-\alpha,\beta,\tau) + \frac{(-2\beta+\Lambda_1^2)}{\Lambda_1} e^{-\Lambda_1\tau} x \; P_o(-\alpha,\beta,\tau)+(1-e^{-\beta\tau^2-(\Lambda_1-\alpha)\tau})- \frac{\alpha}{\Lambda_1}(1-e^{-\Lambda_1\tau})\right\} ,$$

$$\hat{P}_4(\gamma,\beta,\tau) = P_o(\gamma,\beta,\tau) , \quad \text{and}$$

$$\hat{P}_5(\gamma,\beta,\tau) = -\frac{\gamma}{2\beta} P_o(\gamma,\beta,\tau) + \frac{1}{2\beta}(1-e^{-\gamma\tau-\beta\tau^2}) , \quad (83)$$

where the limiting forms for $\hat{P}_k(\tau)$ are given in Appendix A.

The functions $\hat{P}_k(\tau)$ are expressible as

$$\hat{P}_o(\Lambda_1,\tau) = \frac{1-M_o(\Lambda_1,\tau)}{\Lambda_1} ,$$

$$\hat{P}_1(\Lambda_1,\alpha,\beta,\tau) = \frac{\hat{P}_4(\Lambda_1-\alpha,\beta,\tau) - M_1(\Lambda_1,\alpha,\beta,\tau)}{\Lambda_1} ,$$

$$\hat{P}_2(\Lambda_1,\alpha,\beta,\tau) = \frac{\hat{P}_o(\Lambda_1,\tau) - \hat{P}_4(\Lambda_1-\alpha,\beta,\tau) + \alpha\hat{P}_1(\Lambda_1,\alpha,\beta,\tau)}{2\beta} ,$$

$$\hat{P}_3(\Lambda_1,\alpha,\beta,\tau) = \frac{\hat{P}_1(\Lambda_1,\alpha,\beta,\tau) - \hat{P}_5(\Lambda_1-\alpha,\beta,\tau) + \alpha P_2(\Lambda_1,\alpha,\beta,\tau)}{2\beta} ,$$

$$\hat{P}_4(\gamma,\beta,\tau) = P_o(\gamma,\beta,\tau) \text{ , and}$$

$$\hat{P}_5(\gamma,\beta,\tau) = \frac{1 - \gamma\hat{P}_4(\gamma,\beta,\tau) - M_4(\gamma,\beta,\tau)}{2\beta} . \tag{84}$$

In particular we note that the integrals for $\hat{P}_2(\tau)$, $\hat{P}_3(\tau)$, and $\hat{P}_5(\tau)$ in the $\beta = 0$ limit are finite and independent of β. The contribution from $A_k\hat{P}_k(\tau)$ for $k = 2,3$, and 5 therefore vanishes for $\beta = 0$. The other limiting forms are automatically accounted for using Eq. (84) and the limiting forms for $P_o(\gamma,\beta,\tau)$ given in Appendix A.

The number of isotope particles, $N_i'(t)$, from failed or intact particles released in the containment building is governed by

$$\frac{dN_i'}{dt} = S_i(t) - \Lambda^* N_i'(t) , \tag{85}$$

where the source, $S_i(t)$, is taken as the release rate from failed or intact particles,

$$S_i(t) = \frac{dR_i}{dt} = r_i N_i(t) . \tag{86}$$

The decay constant, Λ^*, is defined as

$$\Lambda^* = \lambda + \bar{V} + \bar{L} , \tag{87}$$

where $V(\tau)$ represents the containment building cleanup system removal rate and $L(\tau)$ represents the containment building leakage rate. We assume averaged values over the time interval τ and define

$$\bar{V} \equiv \frac{1}{2} [V(0) + V(\tau)] \quad \text{and}$$

$$\bar{L} \equiv \frac{1}{2} [L(0) + L(\tau)] . \tag{88}$$

The release from the containment building is given by

$$R_i'(\tau) = \int_0^\tau ds\, L(s) N_i'(s) . \tag{89}$$

Integrating Eqs. (85) and (89), using Eq. (86), we may express the solutions in the form

$$N_i'(\tau) = e^{-\Lambda^*\tau} N_i'(0) + \bar{r}_i e^{-\Lambda^*\tau} \int_0^\tau ds\, e^{\Lambda^* s} N_i(s)$$

and (90)

$$R_i'(\tau) = \bar{L} \left[\frac{(1-e^{-\Lambda^*\tau})}{\Lambda^*} N_i'(0) + \bar{r}_i \int_0^\tau ds\, e^{-\Lambda^* s} \int_0^s ds'\, e^{\Lambda^* s'} N_i(s') \right] ,$$

where $\bar{r}_i$, Λ^*, and $\bar{L}$ are given by Eqs. (63), (87), and (88), respectively.

Substituting Eq. (71) and (78) into Eq. (90), we may express the solutions as

$$N_1'(\tau) = e^{-\Lambda^*\tau} N_1'(0) + e^{-\Lambda^*\tau} \sum_{R=0}^{3} B_k Q_k(\tau),$$

$$N_2'(\tau) = e^{-\Lambda^*\tau} N_2'(0) + e^{-\Lambda^*\tau} \sum_{R=4}^{5} B_k Q_k(\tau), \tag{91}$$

and

$$\frac{R_1'(\tau)}{L} = \frac{1-e^{-\Lambda^*\tau}}{\Lambda^*} N_1'(0) + \sum_{k=0}^{3} B_k V_k(\tau),$$

$$\frac{R_2'(\tau)}{L} = \frac{1-e^{-\Lambda^*\tau}}{\Lambda^*} N_2'(0) + \sum_{k=4}^{5} B_k V_k(\tau), \tag{92}$$

where the functions $Q_k(\tau)$ and $V_k(\tau)$ are defined by

$$Q_k(\tau) = \int_0^\tau ds\, e^{\Lambda^* s} M_k(s),$$

$$V_k(\tau) = \int_0^\tau ds\, e^{-\Lambda^* s} Q_k(s). \tag{93}$$

The $Q_k(\tau)$ and $V_k(\tau)$ functions are derived explicitly in Appendix B.

For the general case of $Q_k(\tau)$ we obtain the results that

$$Q_o(\Lambda^*, \Lambda_1, \tau) = \frac{1}{\Lambda_1 - \Lambda^*} [1 - e^{-(\Lambda_1 - \Lambda^*)\tau}],$$

$$Q_1(\Lambda^*,\Lambda_1,\alpha,\beta,\tau) = \frac{1}{\Lambda_1-\Lambda^*}\,[P_o(\Lambda_1-\Lambda^*-\alpha,\beta,\tau) - e^{-(\Lambda_1-\Lambda^*)\tau}P_o(-\alpha,\beta,\tau)],$$

$$Q_2(\Lambda^*,\Lambda_1,\alpha,\beta,\tau) = \frac{1}{2\beta(\Lambda_1-\Lambda^*)}\left[\begin{array}{l}(\Lambda_1-\Lambda^*-\alpha)P_o(\Lambda_1-\Lambda^*-\alpha,\beta,\tau)\\ \\ +\ \alpha e^{-(\Lambda_1-\Lambda^*)\tau}P_o(-\alpha,\beta,\tau)\\ \\ -(1-e^{-(\Lambda_1-\Lambda^*)\tau}\end{array}\right],$$

$$Q_3(\Lambda^*,\Lambda_1,\alpha,\beta,\tau) = \frac{1}{4\beta^2}\left\{\begin{array}{l}\dfrac{[2\beta+(\Lambda_1-\Lambda^*-\alpha)^2]}{\Lambda_1-\Lambda^*}P_o(\Lambda_1-\Lambda^*-\alpha,\beta,\tau)\\ \\ -\ \dfrac{(2\beta+\alpha^2)}{\Lambda_1-\Lambda^*}e^{-(\Lambda_1-\Lambda^*)\tau}P_o(-\alpha,\beta,\tau)\\ \\ -[1-e^{-\beta\tau^2-(\Lambda_1-\Lambda^*-\alpha)\tau}]\\ \\ +\ \dfrac{\alpha}{\Lambda_1-\Lambda^*}[1-e^{-(\Lambda_1-\Lambda^*)\tau}]\end{array}\right\},$$

$Q_4(\Lambda^*,\gamma,\beta,\tau) = P_o(\gamma-\Lambda^*,\beta,\tau)$, and

$$Q_5(\Lambda^*,\gamma,\beta,\tau) = P_1(\gamma-\Lambda^*,\beta,\tau)\ . \tag{94}$$

$P_1(\gamma,\beta,\tau)$ is defined in Appendix A.

The expressions for $Q_2(\tau)$, $Q_3(\tau)$ can be expressed in a functionally simpler manner as

$$Q_2(\Lambda^*,\Lambda_1,\alpha,\beta,\tau) = \frac{Q_o(\Lambda^*,\Lambda_1,\tau) - Q_4(\Lambda^*,\Lambda_1-\alpha,\beta,\tau) + \alpha Q_1(\Lambda^*,\Lambda_1,\alpha,\beta,\tau)}{2\beta}$$

$$Q_3(\Lambda^*,\Lambda_1,\alpha,\beta,\tau) = \frac{Q_1(\Lambda^*,\Lambda_1,\alpha,\beta,\tau)-Q_5(\Lambda^*,\Lambda_1-\alpha,\beta,\tau)+\alpha Q_2(\Lambda^*,\Lambda_1,\alpha,\beta,\tau)}{2\beta} . \tag{95}$$

Again, the integrals for $Q_2(\tau)$, $Q_3(\tau)$, and $Q_5(\tau)$ in the $\beta = 0$ limit are finite and independent of β. The contribution from $B_k\ Q_k(\tau)$ for $k = 2,3$, and 5 therefore vanishes for $\beta = 0$ since those B_k have a factor β in them. The other limiting forms are handled correctly using the limiting forms for $P_o(\gamma,\beta,\tau)$, $P_1(\gamma,\beta,\tau)$ and $Q_o(\tau)$ given in Appendices A and B.

For the general case of $V_k(\tau)$ we obtain the results that

$$V_o(\Lambda^*,\Lambda_1,\tau) = \frac{1}{\Lambda_1-\Lambda^*}\left[\frac{1}{\Lambda^*}\left(1-e^{-\Lambda^*\tau}\right) - \frac{1}{\Lambda_1}\left(1-e^{-\Lambda_1\tau}\right)\right] ,$$

$$V_1(\Lambda^*,\Lambda_1,\alpha,\beta,\tau) = \frac{1}{\Lambda_1\Lambda^*} P_o(\Lambda_1-\alpha,\beta,\tau) - \frac{1}{\Lambda_1-\Lambda^*}\left[\frac{e^{-\Lambda^*\tau}}{\Lambda^*} P_o(\Lambda_1-\Lambda^*-\alpha,\beta,\tau) - \frac{e^{-\Lambda_1\tau}}{\Lambda_1} P_o(-\alpha,\beta,\tau)\right],$$

$$V_2(\Lambda^*,\Lambda_1,\alpha,\beta,\tau) = + \frac{(\Lambda_1-\Lambda^*-\alpha)}{2\beta(\Lambda_1-\Lambda^*)} \frac{1}{\Lambda^*} [P_o(\Lambda_1-\alpha,\beta,\tau) - e^{-\Lambda^*\tau} P_o(\Lambda_1-\Lambda^*-\alpha,\beta,\tau)]$$

$$+ \frac{\alpha}{2\beta(\Lambda_1-\Lambda^*)} \frac{1}{\Lambda_1-\Lambda^*} [P_o(\Lambda_1-\Lambda^*-\alpha,\beta,\tau)$$

$$- e^{(\Lambda_1-\Lambda^*)\tau} P_o(-\alpha,\beta,\tau)]$$

$$- \frac{1}{2\beta(\Lambda_1-\Lambda^*)} [\frac{1}{\Lambda^*} (1-e^{-\Lambda^*\tau}) - \frac{1}{\Lambda_1} (1-e^{-\Lambda_1\tau})] ,$$

$$V_3(\Lambda^*,\Lambda_1,\alpha,\beta,\tau) = \frac{1}{4\beta^2} [\frac{2\beta+(\Lambda_1-\Lambda^*-\alpha)^2}{\Lambda^*(\Lambda_1-\Lambda^*)} - \frac{(2\beta+\alpha^2)}{\Lambda_1(\Lambda_1-\Lambda^*)} + 1] P_o(\Lambda_1-\alpha,\beta,\tau)$$

$$+ \frac{1}{4\beta^2} \frac{2\beta+\alpha^2}{\Lambda_1(\Lambda_1-\Lambda^*)} e^{-\Lambda_1\tau} P_o(-\alpha,\beta,\tau)$$

$$- \frac{1}{4\beta^2} \frac{2\beta+(\Lambda_1-\Lambda^*-\alpha)^2}{\Lambda^*(\Lambda_1-\Lambda^*)} e^{-\Lambda^*\tau} P_o(\Lambda_1-\Lambda^*-\alpha,\beta,\tau)$$

$$- \frac{1}{4\beta^2} \frac{1}{\Lambda^*} (1-e^{-\Lambda^*\tau})$$

$$+ \frac{1}{4\beta^2} \frac{\alpha}{\Lambda_1-\Lambda^*} [\frac{1}{\Lambda^*} (1-e^{-\Lambda^*\tau}) - \frac{1}{\Lambda_1} (1-e^{-\Lambda_1\tau})] ,$$

$$V_4(\Lambda^*,\gamma,\beta,\tau) = \frac{1}{\Lambda^*}\,[P_o(\gamma,\beta,\tau) - e^{-\Lambda^*\tau}P_o(\gamma-\Lambda^*,\beta,\tau)], \text{ and}$$

$$V_5(\Lambda^*,\gamma,\beta,\tau) = -\frac{\gamma}{2\beta\Lambda^*}\,P_o(\gamma,\beta,\tau) + \frac{\gamma-\Lambda^*}{2\beta\Lambda^*}\,e^{-\Lambda^*\tau}\,P_o(\gamma-\Lambda^*,\beta,\tau)$$

$$+ \frac{1}{2\beta\Lambda^*}\,(1-e^{-\Lambda^*\tau})\,. \tag{96}$$

The expressions for $V_1(\tau)$, $V_2(\tau)$, $V_3(\tau)$, $V_4(\tau)$ and $V_5(\tau)$ can be expressed in a functionally simpler manner as

$$V_1(\Lambda^*,\Lambda_1,\tau) = \frac{V_4(\Lambda^*,\Lambda_1-\alpha,\beta,\tau) - e^{-\Lambda^*\tau}Q_1(\Lambda^*,\Lambda_1,\alpha,\beta,\tau)}{\Lambda_1}\,,$$

$$V_2(\Lambda^*,\Lambda_1,\alpha,\beta,\tau) = \frac{V_o(\Lambda^*,\Lambda_1,\tau) - V_4(\Lambda^*,\Lambda_1-\alpha,\beta,\tau) + \alpha V_1(\Lambda^*,\Lambda_1,\tau)}{2\beta}\,,$$

$$V_3(\Lambda^*,\Lambda_1,\alpha,\beta,\tau) = \frac{V_1(\Lambda^*,\Lambda_1,\tau) - V_5(\Lambda^*,\Lambda_1-\alpha,\beta,\tau) + \alpha V_2(\Lambda^*,\Lambda_1,\alpha,\beta,\tau)}{2\beta}\,,$$

$$V_4(\Lambda^*,\gamma,\beta,\tau) = \frac{P_o(\gamma,\beta,\tau) - e^{-\Lambda^*\tau}\,Q_4(\Lambda^*,\gamma,\beta,\tau)}{\Lambda^*}\,, \text{ and}$$

$$V_5(\Lambda^*,\gamma,\beta,\tau) = \frac{\hat{P}_o(\Lambda^*,\tau) - \gamma V_4(\Lambda^*,\gamma,\beta,\tau) - e^{-\Lambda^*\tau}\,Q_4(\Lambda^*,\gamma,\beta,\tau)}{2\beta}\,, \tag{97}$$

where we have used the identity $\gamma = \Lambda_1 - \alpha$ from Eq. (73).

Finally we remark that the integrals for $V_2(\tau)$, $V_3(\tau)$ and $V_5(\tau)$ given in Eq. (97) in the $\beta = 0$ limit are finite and independent of β. The contribution from $B_k V_k(\tau)$ for $k = 2,3,5$ therefore vanishes for $\beta = 0$ since those B_k have a factor β in them. The other limiting forms are handled correctly using the limiting forms for $P_o(\gamma,\beta,\tau)$ and $V_o(\Lambda^*,\Lambda_1,\tau)$ given in Appendices A and B.

As we shall see in Section IV, comparison of these four models indicates that the Constant Release-Renormalized model is adequate for the calculation of the release to the coolant and from the containment building.

III. CALCULATIONAL DATA BASE

The calculational data base for LARC-1 is composed of the following: (a) Temperature modeling, (b) Fission product release rates, (c) Particle coating fuel failure fractions, and (d) Aged particle coating fuel fracture fraction. Each of these is discussed in detail including the form and parameters used in the analytic fits as well as the graphic representations generated from the fits.

A. Temperature Modeling

The temperature modeling of LARC-1 is represented as a function of core volume fraction (x) and time (t). Four different models are available at present.

The first three models are based on data obtained from SORS,[2] CORCON,[3] and AYER.[4,5] These models involve three different calculations of the maximum and average temperature as a function of the time from the beginning of an LOFC. The temperature shape as a function of core volume fraction was obtained graphically from GASSAR.[6] A simple scaling law is used to construct T(x,t) from T(t) and T(x).

The fourth model is obtained from an inversion of the data made available from recent AYER calculations.[7] The core volume fraction at time t with temperature above T is transformed into T(x,t).

1. Temperature vs Core Volume Fraction

The fuel temperature, T(x), vs the core volume fraction x, or "fraction of the fuel volume above indicated temperature at rated power" is given graphically in the GASSAR report.[6] That graph was read and interpolated for a number of core volume fraction points, given in Table I.

TABLE I

GASSAR DATA T(x) vs x

x	T(x) K
0	1699.82
0.01	1588.71
0.03333	1479.26
0.06666	1402.59
0.1	1347.59
0.2	1255.37
0.3	1205.37
0.4	1173.41
0.5	1147.04
0.6	1127.59
0.7	1104.26
0.8	1079.08
0.9	1044.26
1.0	922.04

Originally a simple analytic polynominal fit to the data was used. That technique had an accuracy of about 1% in T(x), but did not have dT/dx continuous across fit boundaries, of which there were several.

However, with the implementation of a general one-dimensional spline method,[8-10] the accuracy of the fits is maintained, dT/dx is smooth, and d^2T/dx^2 is continuous.

The average temperature $\bar{T}$ is used in scaling and is determined from numerical integration of the spline representation as

$$\bar{T} = \int_0^1 T(x)\,dx = 1174.4 \text{ K} \cdot \tag{98}$$

A graphic display of the spline representation of $T(x)$ is given in Fig. 1.

2. SORS Data

The maximum and average temperature, $T_{MAX}(t)$ and $T_{AVG}(t)$, are displayed graphically in Fig. 6-2 of the SORS report[2] for a 3000 MW(t) reactor for lumped fuel/graphite temperature vs time. That graph was read and interpolated for $T_{MAX}(t)$ and $T_{AVG}(t)$ at a number of time points given in Table II.

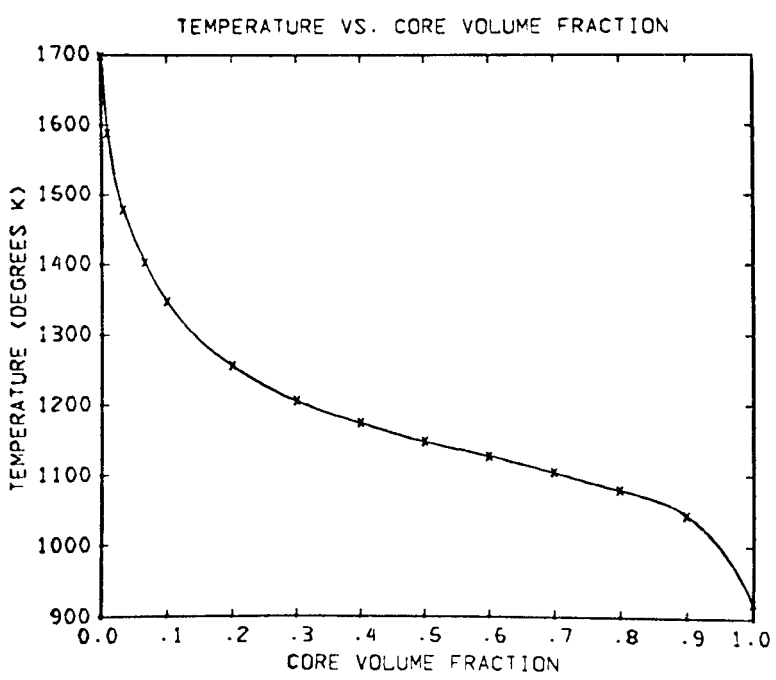


Fig. 1. Temperature vs core volume fraction.

TABLE II

SORS TEMPERATURE DATA

t(h)	T_{MAX}(K)	t(h)	T_{AVG}(K)
0	1227.59	0	1088.71
1.3	1644.26	1.1	1366.48
2.3	1922.04	2.5	1644.26
3.5	2199.82	4.2	1922.04
5	2477.59	6.3	2199.82
6.92	2755.37	10.0	2477.59
9.42	3033.15	14.8	2755.37
12.3	3310.93	22.5	3033.15
17.3	3588.71	34.6	3310.93
26.5	3922.04	40.0	3374.42
40.0	3922.04	50.0	3459.08

We note that the SORS data as given in Ref. (2) does not have a maximum temperature exceeding the graphite sublimation temperature (3925 K).

The results of the spline representation[9] of the data of Table II are displayed in Fig. 2.

3. CORCON Data

The maximum and average temperature, $T_{MAX}(t)$ and $T_{AVG}(t)$, are given in Table 6-4 of the CORCON report.[3] This data is reproduced in LARC-1 units in Table III.

The results of the spline representation of the data of Table III are displayed in Fig. 3.

We note that in Fig. 3 there is a depression of the $T_{MAX}(t)$ and $T_{AVG}(t)$ curves in the time range $1 < t < 5$ h of the

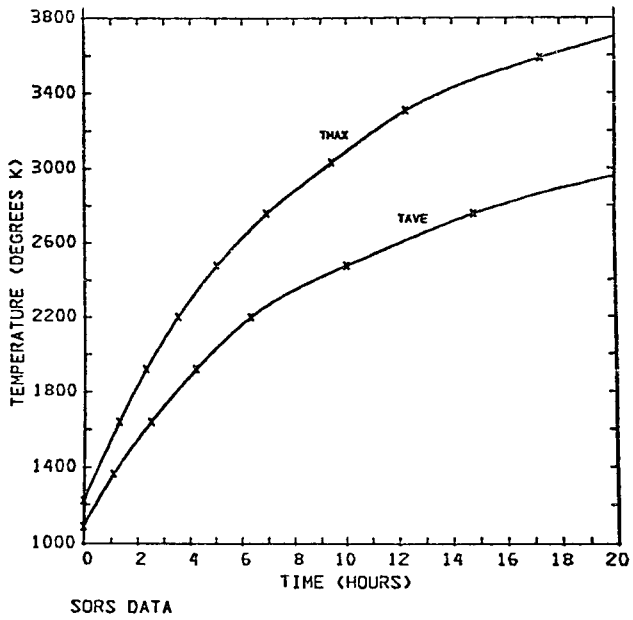


Fig. 2. Temperature vs time after LOFC, SORS graphic data.

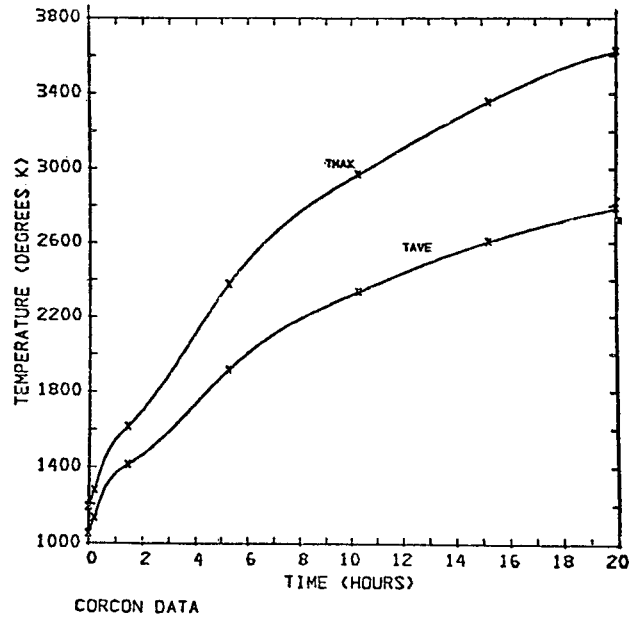


Fig. 3. Temperature vs time after LOFC, CORCON tabular data.

TABLE III

CORCON TEMPERATURE DATA

t(h)	T_{MAX}(K)	T_{AVG}(K)
0	1192.59	1052.59
0.0083	1192.59	1052.59
0.2167	1280.37	1134.82
1.45	1618.15	1413.71
5.25	2379.26	1920.37
10.25	2969.82	2338.71
15.25	3358.71	2608.71
20.25	3630.37	2793.71
25.25	3665.37	2938.15
30.25	3665.37	3026.48

CORCON data relative to the SORS data shape, Fig. 2. In general, after t = 1 h the CORCON data has lower temperatures, with differences upwards of 150 K, than SORS for both $T_{MAX}(t)$ and $T_{AVG}(t)$.

4. AYER Data

The maximum and average temperatures, $T_{MAX}(t)$ and $T_{AVG}(t)$ are reproduced in Table IV from AYER data.[4,5]

The results of the spline representation of the data of Table IV are displayed in Fig. 4.

We note that for this data $T_{MAX}(t)$ attains and exceeds the graphite sublimation temperature at 17 h.

Comparing the AYER to SORS temperature histories we note that $T_{MAX}(t)_{AYER} < T_{MAX}(t)_{SORS}$ for $0 < t < 15$ h and $T_{AVG}(t)_{AYER} < T_{AVG}(t)_{SORS}$ for $0 < t < 20$ h, with temperature differences of the order of 50-200 K. After 15 h, $T_{MAX}(t)_{AYER} > T_{MAX}(t)_{SORS}$ until $t \sim 20$ h when the 2 models are equal.

Comparing the AYER and CORCON temperature histories we note that $T_{MAX}(t)_{AYER} < T_{MAX}(t)_{CORCON}$ for $0 < t < 10.5$ h with a maximum difference of approximately 100 K. For $10.5 < t < 20$ h, $T_{MAX}(t)_{AYER} > T_{MAX}(t)_{CORCON}$ with a maximum difference of almost 200 K occurring at 17 h. $T_{AVG}(t)$, on the other hand, for AYER and CORCON data differ by less than 50 K over the range $0 < t < 20$ h. AYER is first lower than CORCON ($0 < t < 1.8$ h), then higher ($1.8 < t < 4.5$ h), then lower ($4.5 < 5 < 15$ h), and, finally higher ($15 < t < 20$ h).

5. Computation of T(x,t) for Models 1, 2, and 3

Using the temperature vs core volume fraction data, by spline interpolation we find T(x) for any x in the range $0 \leq x \leq 1$. The average temperature is given by $\overline{T} = 1174.4$ K from Eq. (98).

From the spline representations of $T_{MAX}(t)$ and $T_{AVG}(t)$ we find these quantities at any time t by spline interpolation.

In order to determine T(x,t) we use a simple scaling law given by

$$T(x,t) = \frac{T_{MAX}(t) - T_{AVG}(t)}{T(0) - \overline{T}} \left[T(x) - \overline{T}\right] + T_{AVG}(0) \quad . \tag{99}$$

TABLE IV

AYER TEMPERATURE DATA

t(h)	T_{MAX}(K)	T_{AVG}(K)
0.2	1199	1167
0.4	1278	1219
0.5	1315	1243
1.0	1461	1338
1.5	1589	1421
2.0	1704	1496
2.5	1810	1566
3.0	1908	1631
3.5	2002	1692
4.0	2091	1749
4.5	2176	1804
5.0	2257	1856
5.5	2335	1906
6.0	2411	1954
6.5	2483	1999
7.0	2554	2044
8.0	2687	2126
9.0	2815	2204
10.	2936	2278
11.	3053	2347
12.	3165	2414
13.	3273	2477
14.	3376	2538
15.	3475	2596
16.	3570	2653
17.	3663	2707
18.	3636	2756
19.	3664	2801
20.	3665	2840

This form scales the maximum to average difference of the T(x) curve to match the maximum to average difference of a model at time t.

The function T(x,t) and the isotherms are displayed for $0 < x < 1$, $0 \leq t \leq 20$ h in Fig. 5-10 for the SORS (Model 1), CORCON (Model 2) and AYER (Model 3) data.

6. AYER Fu-Cort Data

Data was available for $x = x(T,t)$ from recent results of the AYER code[4,7] in which the core volume was divided into 112 elements. Reinterpreting this data as the function T(x,t) and supplying additional interpolated points, we constructed the tabular values for T(x,t) given in Table V.

Performing a two-dimensional spline fit we calculate T(x,t) for any (x,t) in the range $0 \leq x \leq 1$, $0 < t < 20$ h by spline interpolation.

The T(x,t) and isotherms are displayed for Model 4 in Figs. 11 and 12.

Comparing Model 4 to Models 1-3 for the temperature field T(x,t), Figs. 5,7,9, and 11, we note that Model 4 maintains a larger fraction of the core ($x = 1$) at a lower temperature than the other models. Models 1-3, on the other hand exhibit a rise and then a decrease in the temperature as a function of time near $x = 1$. Maintaining any significant fraction of the core at a uniformly low temperature during a LOFC would seem to need further justification. As we shall see later, it results in a considerable reduction in the release to the coolant for $t > 9$ h.

B. Fission Product Release Rates

The graphic data for fission product release rates as a function of temperature (T) in the SORS[2] and GASSAR[12] reports has been fitted to Arrhenius relations of the form

$$r(T) = \alpha e^{-\beta/T} \tag{100}$$

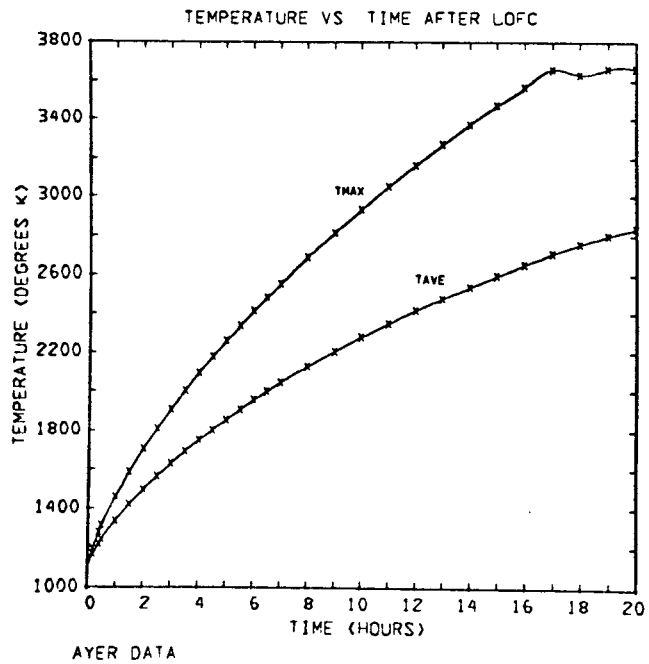


Fig. 4. Temperature vs time after LOFC, AYER tabular data.

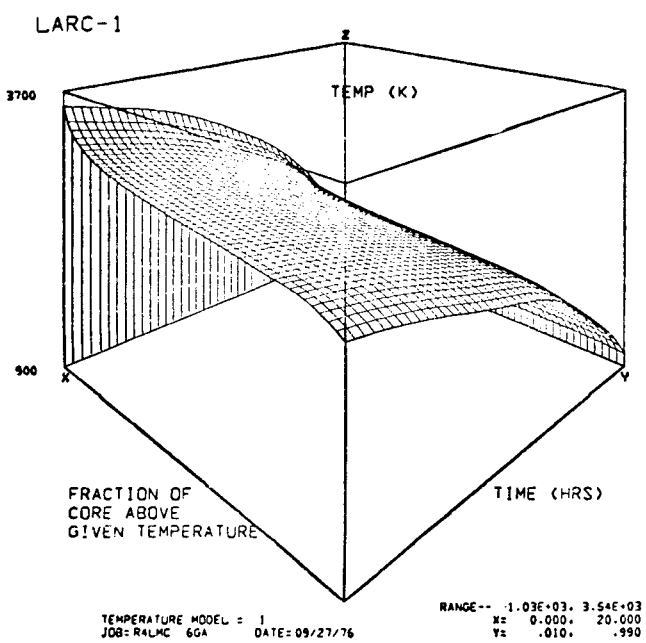


Fig. 5. Temperature model 1 vs time (x) and core volume fraction (y).

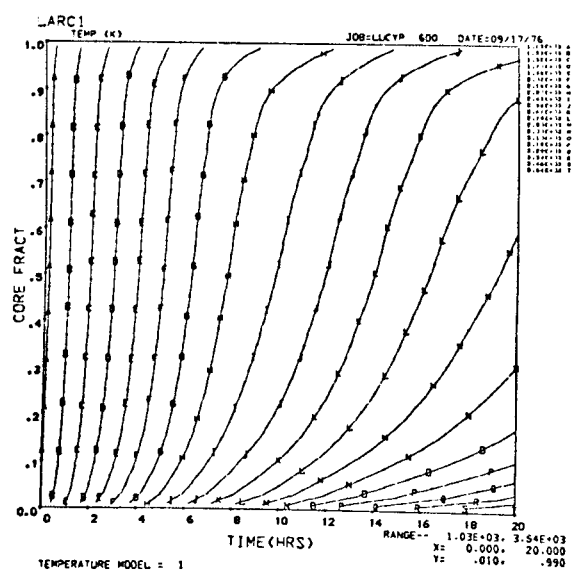


Fig. 6. Contours of temperature model 1 vs time (x) and core volume fraction (y).

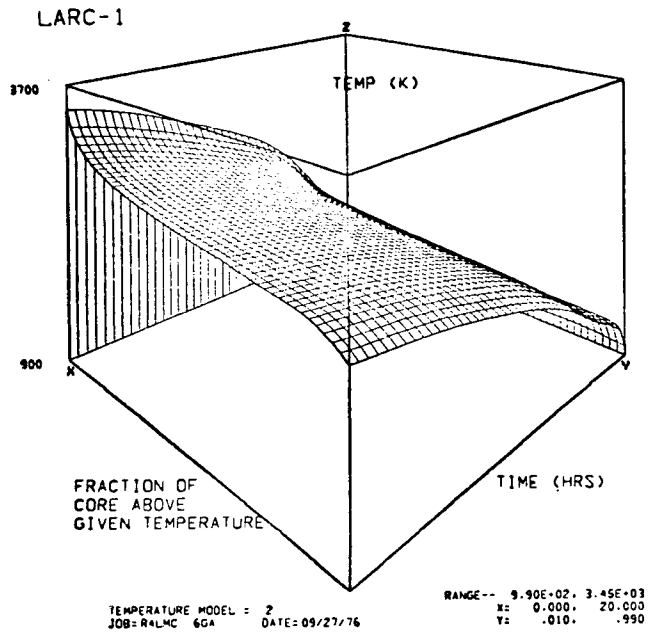


Fig. 7. Temperature model 2 vs time (x) and core volume fraction (y).

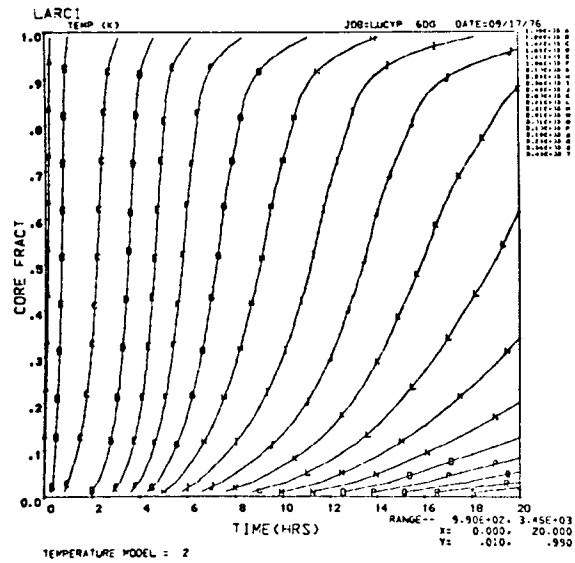


Fig. 8. Contours of temperature model 2 vs time (x) and core volume fraction (y).

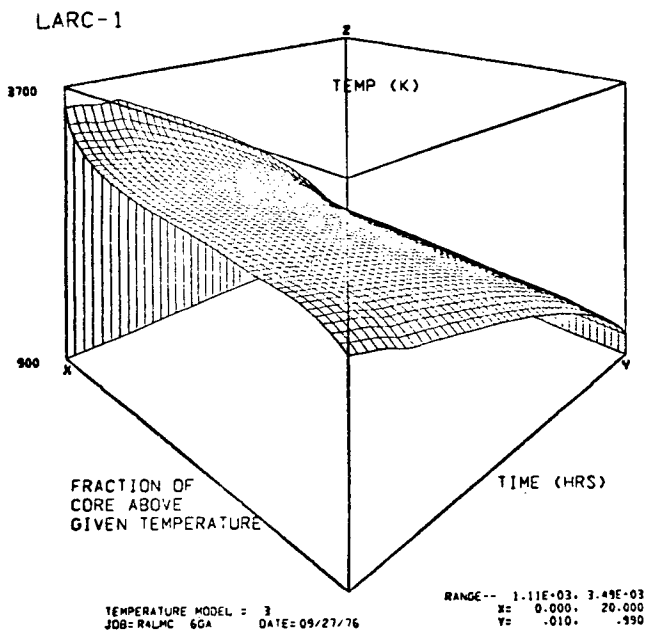


Fig. 9. Temperature model 3 vs time (x) and core volume fraction (y).

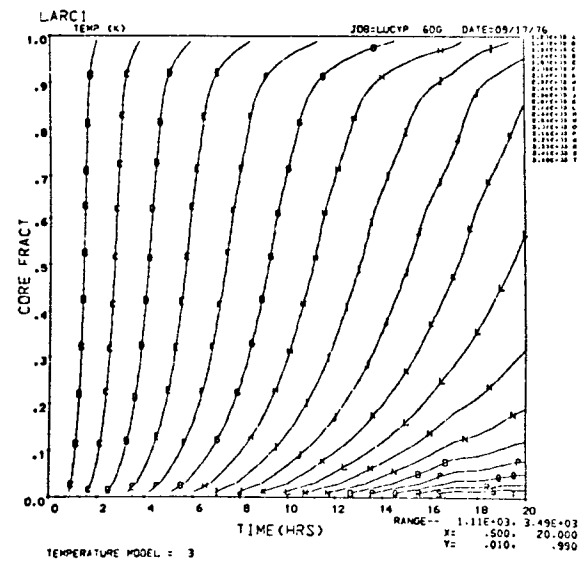


Fig. 10. Contours of temperature model 3 vs time (x) and core volume fraction (y).

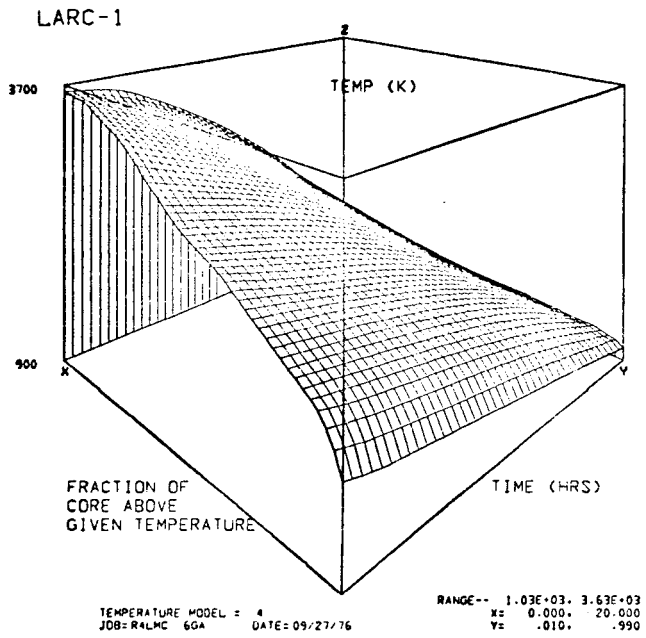


Fig. 11. Temperature model 4 vs time (x) and core volume fraction (y).

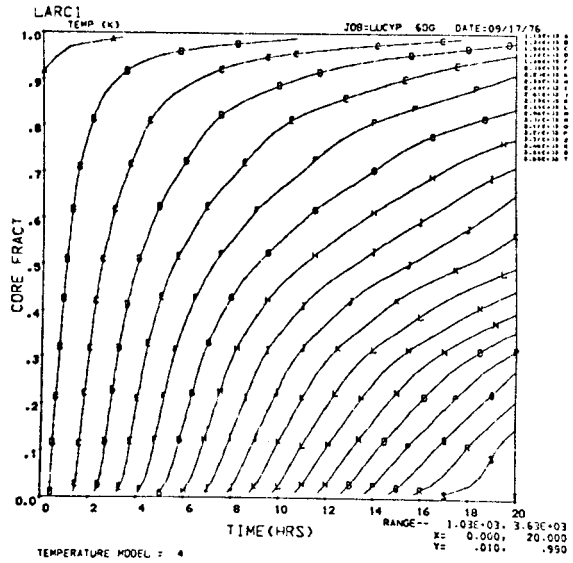


Fig. 12. Contours of temperature model 4 vs time (x) and core volume fraction (y).

for intact and failed particle coatings. The isotopes have been arranged in the 10 groupings as used by SORS, and listed in Table VI.

In the SORS data, the effects of BISO and TRISO particles have been "added for a conservative estimate."[2] In the GASSAR data, BISO and TRISO release rates are distinguished in some instances.

The fitted parameters for the SORS and GASSAR data are given in Tables VII and VIII, where the parameters are further subdivided as intact or failed. In the case of GASSAR parameters a subscript B (BISO) or T (TRISO) on the group index further distinguishes the release rate parameters.

The release rates using the parameters of Table VI-VIII are displayed graphically in Figs. 13-15. The SORS data is denoted as the Ft. St. Vrain fuel model.

TABLE V

TEMPERATURE VS TIME AND CORE FRACTION INDEX I, $I = \frac{\text{CORE FRACTION}}{112} + 1$
(Interpolated Fu-Cort Data)

I	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	12h	13h	14h	15h	16h	17h	18h	19h	20h
1	1455	1694	1895	2073	2236	2387	2526	2657	2782	2901	3016	3126	3232	3333	3431	3525	3616	3624	3630	3634
2	1454	1666	1861	2041	2206	2359	2501	2634	2760	2881	2996	3106	3211	3310	3402	3485	3553	3590	3613	3633
3	1452	1651	1841	2019	2184	2338	2481	2615	2743	2863	2979	3088	3192	3289	3378	3456	3519	3565	3600	3631
4	1450	1642	1828	2003	2168	2321	2465	2600	2727	2848	2963	3073	3176	3274	3358	3434	3497	3548	3590	3629
5	1448	1636	1819	1992	2155	2308	2452	2586	2714	2834	2949	3058	3161	3256	3342	3417	3481	3535	3582	3626
6	1446	1632	1811	1983	2145	2297	2440	2574	2701	2822	2936	3045	3147	3242	3327	3403	3468	3525	3575	3623
7	1444	1627	1805	1975	2136	2288	2430	2564	2690	2810	2924	3032	3134	3228	3314	3390	3457	3515	3569	3620
8	1442	1624	1800	1969	2128	2279	2420	2553	2680	2799	2913	3020	3121	3215	3301	3378	3446	3507	3563	3617
9	1440	1620	1795	1962	2121	2271	2411	2544	2669	2788	2901	3008	3109	3203	3289	3366	3436	3499	3558	3615
10	1438	1617	1790	1957	2114	2263	2403	2535	2660	2778	2890	2996	3096	3190	3276	3355	3426	3491	3552	3612
11	1436	1613	1786	1951	2108	2256	2395	2526	2650	2768	2879	2984	3084	3177	3264	3343	3415	3483	3546	3609
12	1434	1610	1782	1946	2102	2249	2387	2518	2641	2757	2868	2973	3071	3164	3251	3331	3405	3474	3540	3606
13	1432	1607	1778	1941	2096	2242	2380	2509	2632	2747	2857	2960	3059	3151	3238	3318	3393	3464	3534	3603
14	1430	1604	1774	1936	2090	2235	2372	2501	2622	2737	2845	2948	3046	3138	3224	3305	3381	3454	3525	3600
15	1428	1602	1770	1932	2085	2229	2364	2492	2612	2726	2834	2936	3032	3124	3210	3291	3368	3441	3513	3586
16	1427	1599	1767	1927	2079	2222	2357	2483	2603	2715	2822	2923	3019	3110	3196	3277	3354	3428	3500	3571
17	1425	1597	1763	1923	2074	2216	2349	2475	2593	2705	2811	2911	3006	3097	3182	3263	3340	3414	3486	3557
18	1423	1594	1760	1918	2068	2209	2342	2467	2584	2695	2800	2899	2994	3084	3169	3249	3326	3400	3472	3543
19	1421	1591	1756	1914	2063	2203	2335	2459	2575	2685	2789	2888	2982	3071	3156	3236	3312	3386	3457	3528
20	1419	1588	1753	1910	2058	2197	2328	2451	2567	2676	2779	2877	2970	3059	3143	3223	3299	3372	3444	3514
21	1417	1586	1749	1905	2053	2191	2321	2443	2558	2667	2769	2867	2959	3047	3131	3210	3286	3359	3430	3500
22	1415	1583	1746	1901	2048	2186	2315	2436	2550	2658	2760	2856	2948	3036	3119	3198	3274	3346	3417	3487

TABLE V(cont)

23	1413	1580	1742	1897	2043	2180	2308	2429	2542	2649	2750	2846	2938	3025	3108	3186	3261	3334	3405	3475
24	1410	1577	1738	1892	2038	2174	2302	2422	2534	2640	2741	2836	2927	3014	3096	3174	3249	3321	3392	3462
25	1408	1574	1735	1888	2033	2168	2295	2414	2526	2632	2732	2827	2917	3002	3084	3162	3237	3309	3380	3450
26	1405	1570	1731	1884	2028	2163	2289	2407	2518	2623	2723	2817	2906	2991	3072	3149	3224	3296	3367	3437
27	1402	1567	1727	1879	2023	2157	2283	2400	2511	2615	2713	2807	2895	2979	3060	3137	3211	3283	3354	3425
28	1400	1564	1723	1875	2018	2152	2277	2394	2503	2607	2704	2798	2884	2968	3047	3124	3198	3270	3341	3412
29	1398	1561	1720	1871	2013	2146	2271	2387	2496	2598	2695	2788	2873	2956	3035	3111	3185	3257	3329	3400
30	1396	1559	1716	1867	2008	2141	2264	2380	2488	2590	2685	2775	2861	2943	3022	3098	3171	3244	3316	3390
31	1394	1556	1713	1862	2003	2135	2258	2373	2480	2581	2675	2765	2849	2931	3008	3084	3157	3229	3302	3375
32	1392	1553	1709	1858	1998	2129	2251	2365	2472	2571	2665	2753	2837	2918	2995	3069	3142	3214	3286	3360
33	1390	1550	1706	1854	1993	2123	2244	2357	2463	2561	2654	2742	2825	2904	2980	3054	3126	3197	3268	3340
34	1388	1547	1702	1849	1987	2116	2237	2349	2453	2551	2643	2730	2812	2890	2965	3037	3108	3179	3249	3320
35	1386	1545	1698	1844	1981	2109	2229	2340	2444	2541	2632	2717	2798	2875	2949	3020	3090	3160	3230	3300
36	1384	1542	1694	1839	1975	2102	2221	2331	2434	2530	2620	2704	2784	2860	2932	3002	3072	3141	3210	3280
37	1382	1539	1690	1834	1969	2095	2213	2322	2424	2519	2608	2691	2769	2844	2915	2984	3053	3122	3191	3260
38	1380	1536	1686	1829	1963	2088	2205	2313	2414	2508	2596	2677	2754	2827	2897	2966	3034	3102	3171	3240
39	1378	1533	1682	1824	1957	2081	2197	2304	2404	2497	2583	2663	2739	2811	2880	2947	3015	3082	3151	3220
40	1376	1530	1678	1819	1951	2074	2189	2295	2393	2485	2570	2649	2723	2794	2862	2929	2995	3062	3130	3200
41	1374	1527	1674	1814	1945	2067	2181	2285	2383	2473	2557	2635	2708	2778	2845	2911	2976	3042	3109	3180
42	1372	1524	1670	1809	1939	2060	2172	2276	2372	2461	2543	2621	2693	2762	2828	2893	2957	3020	3082	3140
43	1371	1521	1666	1804	1933	2053	2164	2266	2361	2449	2531	2607	2679	2747	2812	2876	2938	3000	3061	3120
44	1369	1518	1662	1799	1927	2045	2155	2257	2350	2437	2518	2594	2665	2732	2797	2860	2921	2982	3041	3100

TABLE V (cont)

45	1367	1515	1658	1793	1920	2038	2147	2247	2340	2426	2506	2581	2651	2718	2782	2844	2904	2964	3022	3080
46	1365	1512	1654	1788	1913	2030	2138	2237	2329	2414	2494	2568	2638	2705	2768	2829	2888	2946	3003	3060
47	1363	1509	1649	1782	1907	2022	2129	2227	2319	2403	2482	2556	2625	2691	2754	2814	2872	2929	2985	3040
48	1361	1505	1645	1777	1900	2014	2120	2217	2308	2392	2470	2543	2612	2678	2739	2799	2856	2911	2966	3020
49	1359	1502	1640	1771	1893	2006	2111	2208	2297	2380	2458	2531	2599	2664	2725	2783	2839	2894	2947	3000
50	1358	1500	1636	1766	1887	1998	2102	2197	2286	2368	2445	2517	2585	2649	2709	2767	2822	2876	2928	2980
51	1356	1497	1632	1760	1880	1991	2093	2187	2275	2356	2432	2504	2571	2634	2693	2750	2804	2857	2909	2960
52	1354	1494	1628	1755	1874	1983	2084	2177	2264	2344	2419	2489	2555	2617	2676	2732	2786	2838	2889	2940
53	1352	1491	1624	1750	1867	1975	2075	2167	2252	2331	2405	2474	2539	2600	2658	2713	2766	2818	2869	2920
54	1350	1488	1620	1744	1860	1967	2066	2156	2240	2318	2391	2458	2522	2582	2639	2694	2747	2799	2849	2900
55	1348	1484	1615	1739	1853	1959	2056	2145	2228	2305	2376	2442	2505	2564	2621	2675	2728	2779	2830	2880
56	1346	1481	1611	1732	1846	1950	2046	2134	2216	2291	2361	2426	2488	2547	2603	2657	2709	2760	2810	2860
57	1344	1477	1606	1726	1838	1941	2036	2123	2203	2278	2347	2411	2472	2530	2585	2639	2691	2742	2791	2840
58	1342	1474	1600	1719	1830	1932	2025	2112	2191	2264	2332	2396	2457	2514	2569	2623	2674	2724	2773	2820
59	1340	1470	1595	1713	1822	1922	2015	2100	2178	2251	2319	2382	2442	2500	2554	2607	2658	2708	2755	2800
60	1338	1467	1590	1706	1814	1913	2004	2088	2166	2238	2305	2369	2429	2486	2540	2593	2644	2693	2741	2787
61	1336	1463	1585	1699	1806	1904	1994	2077	2154	2225	2292	2355	2415	2472	2527	2579	2630	2679	2727	2775
62	1334	1460	1580	1693	1798	1894	1983	2065	2141	2212	2279	2342	2401	2458	2513	2565	2616	2666	2714	2762
63	1332	1456	1575	1687	1790	1886	1973	2054	2129	2200	2265	2328	2387	2444	2499	2551	2602	2652	2701	2750
64	1330	1453	1570	1680	1783	1877	1964	2043	2118	2187	2252	2314	2373	2430	2484	2536	2588	2638	2688	2737
65	1328	1449	1565	1675	1776	1869	1954	2033	2106	2175	2239	2300	2359	2415	2469	2521	2573	2623	2674	2725
66	1326	1446	1561	1669	1769	1861	1945	2023	2095	2163	2226	2286	2344	2399	2453	2506	2557	2609	2661	2712
67	1324	1443	1556	1663	1762	1853	1936	2013	2085	2151	2214	2273	2330	2385	2438	2490	2542	2595	2647	2700

TABLE V (cont)

68	1322	1439	1551	1657	1755	1845	1928	2004	2075	2141	2202	2261	2317	2370	2423	2475	2527	2580	2634	2687
69	1320	1436	1547	1651	1748	1837	1919	1995	2065	2130	2191	2249	2303	2357	2408	2460	2513	2566	2620	2675
70	1318	1432	1542	1645	1741	1829	1911	1986	2055	2119	2180	2236	2291	2343	2394	2446	2498	2552	2607	2662
71	1316	1429	1537	1639	1733	1821	1901	1976	2044	2108	2168	2224	2277	2329	2380	2431	2484	2538	2594	2650
72	1314	1425	1532	1632	1726	1812	1892	1965	2033	2096	2155	2211	2264	2315	2365	2416	2469	2524	2580	2637
73	1312	1421	1526	1625	1717	1803	1882	1954	2021	2084	2142	2197	2250	2300	2351	2402	2454	2510	2567	2625
74	1310	1417	1521	1618	1709	1793	1871	1943	2009	2071	2129	2183	2235	2286	2336	2386	2440	2495	2553	2612
75	1308	1414	1515	1611	1701	1783	1860	1931	1996	2058	2115	2169	2221	2271	2320	2371	2424	2480	2538	2600
76	1306	1410	1510	1604	1692	1774	1849	1919	1984	2044	2101	2155	2206	2256	2305	2356	2409	2464	2521	2580
77	1304	1406	1504	1597	1684	1764	1839	1908	1972	2032	2088	2141	2192	2241	2291	2341	2393	2447	2503	2560
78	1302	1402	1499	1590	1676	1755	1829	1897	1960	2019	2075	2128	2178	2228	2277	2326	2378	2431	2485	2540
79	1300	1398	1493	1584	1668	1746	1819	1887	1949	2008	2063	2115	2166	2215	2263	2312	2363	2414	2467	2520
80	1296	1394	1488	1577	1661	1738	1810	1877	1939	1997	2052	2104	2154	2202	2250	2299	2348	2398	2449	2500
81	1292	1389	1482	1571	1653	1730	1802	1868	1929	1987	2042	2093	2143	2191	2238	2286	2334	2382	2431	2480
82	1288	1384	1477	1564	1646	1723	1793	1859	1920	1978	2032	2083	2132	2180	2227	2273	2320	2366	2413	2460
83	1284	1379	1471	1558	1640	1715	1785	1851	1911	1969	2022	2073	2122	2169	2215	2261	2306	2350	2395	2440
84	1280	1375	1466	1552	1633	1708	1778	1842	1903	1959	2013	2063	2112	2158	2204	2248	2291	2334	2377	2420
85	1276	1370	1460	1546	1626	1701	1770	1834	1894	1950	2003	2053	2101	2147	2192	2235	2277	2318	2359	2400
86	1272	1365	1455	1540	1619	1693	1762	1825	1885	1940	1993	2042	2090	2135	2179	2221	2262	2302	2341	2380
87	1268	1361	1450	1534	1613	1686	1753	1816	1875	1930	1982	2031	2078	2122	2165	2206	2246	2284	2322	2360
88	1264	1356	1444	1528	1606	1678	1745	1807	1865	1919	1970	2018	2064	2108	2150	2191	2229	2267	2303	2340
89	1260	1351	1439	1521	1598	1670	1736	1797	1854	1907	1958	2005	2050	2094	2135	2174	2212	2248	2284	2320
90	1256	1346	1433	1515	1591	1661	1726	1787	1843	1895	1945	1991	2036	2078	2118	2157	2194	2230	2265	2300

TABLE V (cont)

91	1252	1341	1427	1508	1583	1652	1717	1776	1831	1883	1931	1977	2020	2062	2101	2139	2176	2211	2246	2280
92	1248	1336	1421	1501	1575	1644	1707	1765	1819	1869	1917	1961	2004	2045	2084	2121	2157	2192	2226	2260
93	1244	1331	1415	1494	1567	1634	1696	1753	1806	1855	1902	1945	1987	2027	2066	2103	2138	2173	2207	2240
94	1240	1326	1409	1487	1559	1625	1685	1741	1792	1840	1885	1928	1969	2009	2047	2084	2119	2153	2187	2220
95	1236	1321	1402	1479	1549	1613	1673	1727	1777	1824	1868	1910	1951	1990	2028	2064	2100	2134	2168	2200
96	1232	1315	1395	1470	1538	1601	1659	1712	1761	1806	1850	1891	1931	1970	2008	2044	2080	2115	2149	2183
97	1228	1309	1387	1460	1527	1588	1644	1696	1743	1788	1831	1872	1911	1950	1987	2024	2060	2096	2131	2166
98	1224	1303	1378	1449	1514	1574	1629	1679	1726	1770	1812	1852	1891	1930	1967	2004	2041	2077	2114	2150
99	1220	1296	1369	1437	1501	1559	1613	1662	1708	1752	1793	1833	1872	1909	1947	1984	2021	2058	2096	2134
100	1216	1289	1359	1425	1487	1544	1596	1645	1690	1733	1774	1813	1852	1889	1926	1963	2001	2039	2077	2116
101	1212	1281	1348	1412	1472	1528	1580	1628	1672	1715	1755	1794	1832	1869	1906	1943	1981	2019	2059	2100
102	1208	1273	1337	1399	1457	1512	1562	1610	1654	1696	1735	1774	1811	1848	1884	1922	1959	1998	2039	2080
103	1200	1263	1325	1385	1441	1495	1544	1591	1634	1675	1715	1752	1789	1826	1862	1899	1937	1976	2017	2060
104	1189	1251	1311	1370	1425	1477	1525	1571	1613	1654	1692	1730	1766	1802	1838	1874	1912	1952	1994	2040
105	1178	1238	1297	1353	1407	1457	1504	1548	1590	1630	1667	1704	1740	1775	1810	1846	1884	1924	1968	2020
106	1167	1225	1281	1335	1387	1435	1480	1523	1564	1602	1639	1675	1710	1744	1779	1814	1851	1890	1933	1980
107	1156	1211	1264	1315	1363	1410	1453	1494	1533	1570	1606	1641	1674	1708	1742	1776	1812	1851	1893	1940
108	1145	1195	1243	1291	1336	1379	1420	1459	1497	1532	1567	1600	1633	1665	1698	1731	1767	1805	1848	1895
109	1134	1177	1220	1262	1304	1343	1382	1418	1453	1487	1520	1552	1583	1614	1646	1679	1714	1753	1798	1850
110	1123	1155	1191	1228	1265	1301	1336	1370	1403	1435	1466	1496	1526	1556	1586	1618	1652	1691	1739	1800
111	1110	1127	1159	1189	1221	1254	1286	1317	1347	1376	1405	1434	1462	1491	1520	1550	1582	1620	1667	1730
112	1050	1086	1119	1145	1174	1203	1231	1259	1287	1314	1341	1368	1394	1421	1448	1476	1506	1538	1578	1630
113	1000	1050	1075	1100	1125	1150	1175	1200	1225	1250	1275	1300	1325	1350	1375	1400	1425	1450	1475	1500

TABLE VI

ISOTOPE GROUPING OF RELEASE RATES	
Group	Isotopes
1	Sr
2	Cs, Rb
3	Ba, Sm, Eu
4	Ce
5	Xe
6	Kr
7	Zr, Nb, Mo, Te
8	Pm, Nd, Pr, Y, Pd, Sn, La
9	Ru, Rh
10	Se, Br, Te, Sb, I

TABLE VII

SORS RELEASE RATE PARAMETERS

	INTACT		FAILED	
Group	$\alpha(h^{-1})$	$\beta(K)$	$\alpha(h^{-1})$	$\beta(K)$
1	9.7733×10^{-4}	8.2621×10^{3}	1.82889×10^{4}	2.2861×10^{4}
2a	5.3231×10^{9}	5.8360×10^{4}	5.3231×10^{9}	5.8360×10^{4}
	$[\frac{1}{T} < 5.64 \times 10^{-4}(K)^{-1}]$		$[\frac{1}{T} < 5.64 \times 10^{-4}(K)^{-1}]$	
2b	4.6144×10^{-2}	1.3198×10^{4}	4.6144×10^{-2}	1.3198×10^{4}
	$[\frac{1}{T} > 5.64 \times 10^{-4}(K)^{-1}]$		$(5.64 \times 10^{-4} < \frac{1}{T} < 7.59 \times 10^{-4})$	
2c	9.7733×10^{-4}	8.2621×10^{3}	9.7733×10^{-4}	8.2621×10^{3}
			$[\frac{1}{T} > 7.59 \times 10^{-4}(K)^{-1}]$	
3	9.7733×10^{-4}	8.2621×10^{3}	8.9524×10^{3}	2.2657×10^{4}
4	9.7733×10^{-4}	8.2621×10^{3}	2.2317×10^{3}	2.1229×10^{4}
5	9.7733×10^{-4}	8.2621×10^{3}	8.9524×10^{3}	2.2657×10^{4}
6	7.2751×10^{-3}	8.6963×10^{3}	3.9423×10^{4}	2.2435×10^{4}

TABLE VII (cont)

SORS RELEASE RATE PARAMETERS

Group	INTACT $\alpha(h^{-1})$	INTACT $\beta(K)$	FAILED $\alpha(h^{-1})$	FAILED $\beta(K)$
7a	1.7385×10^{3}	3.5259×10^{4}	2.317×10^{3}	2.1229×10^{4}
	$[\frac{1}{T} < 5.33 \times 10^{-4} (K)^{-1}]$			
7b	9.7733×10^{-4}	8.2621×10^{3}		
	$[\frac{1}{T} > 5.33 \times 10^{-4} (K)^{-1}]$			
8	9.7733×10^{-4}	8.2621×10^{3}	2.2317×10^{3}	2.1229×10^{4}
9a	1.10548×10^{4}	3.4207×10^{4}	2.2317×10^{3}	2.1229×10^{4}
	$[\frac{1}{T} < 6.26 \times 10^{-4} (K)^{-1}]$			
9b	9.7733×10^{-4}	8.2621×10^{3}		
	$[\frac{1}{T} > 6.26 \times 10^{-4} (K)^{-1}]$			
10	9.7733×10^{-4}	8.2621×10^{3}	8.9524×10^{3}	2.2657×10^{4}

TABLE VIII

GASSAR RELEASE RATE PARAMETERS

Group	Intact $\alpha(h^{-1})$	Intact $\beta(K)$	Failed $\alpha(h^{-1})$	Failed $\beta(K)$
1_B*	39.3	1.2×10^4	1.5937×10^2	1.1861×10^4
1_T	5.40686	2.5798×10^4	1.5937×10^{-2}	1.1861×10^4
$2_{B,T}$	5.9769×10^2	2.3157×10^4	1.6154×10^6	2.6374×10^4
3_B	1.7191×10^2	1.7858×10^4	1.3192×10^3	1.7782×10^4
3_T	1.2282×10^{-2}	1.4834×10^4	1.3192×10^3	1.7782×10^4
4_B	1.58225×10^5	2.86525×10^4	1.2316×10^6	2.8319×10^4
4_T	5.40686	2.5798×10^4	1.2316×10^6	2.8319×10^4
$5_{B,T}$	1.0742×10^{-2}	1.0313×10^4	1.74925×10^3	1.95451×10^4
$6_{B,T}$	4.427×10^{-2}	1.0482×10^4	1.5004×10^3	1.7662×10^4
$7_{B,T}$	5.40686	2.5798×10^4	1.2316×10^6	2.8319×10^4
8_B	4.427×10^{-2}	1.0482×10^4	1.2316×10^6	2.8319×10^4
8_T	5.40686	2.5798×10^4	1.2316×10^6	2.8319×10^4
9_B	4.427×10^{-2}	1.0482×10^4	1.2316×10^6	2.8319×10^4
9_T	5.40686	2.5798×10^4	1.2316×10^6	2.8319×10^4
10_B	0.10280	1.0314×10^4	2.1494×10^3	1.8175×10^4
10_T	0.10280	1.0314×10^4	7.3605	1.3777×10^4

*B - BISO; T - TRISO; B,T - BISO and TRISO

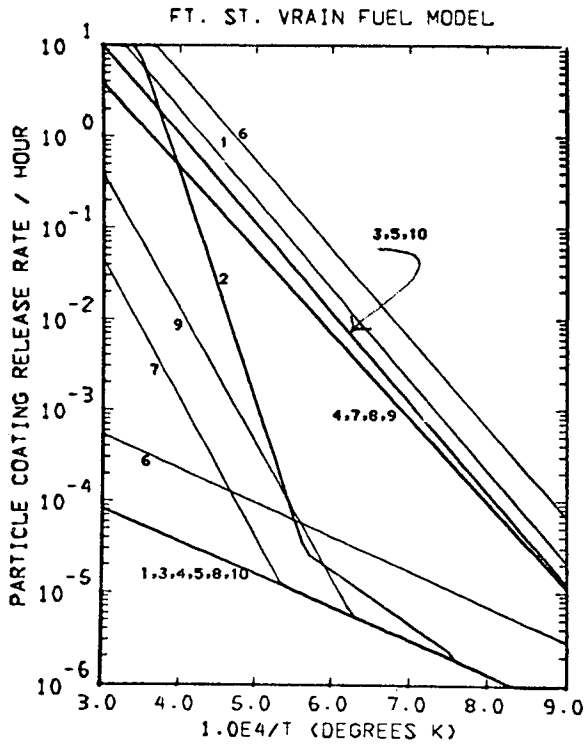


Fig. 13. Fission product release rate vs temperature, SORS data. The upper set of curves gives the release rate for failed particles; the lower set is for intact particles.

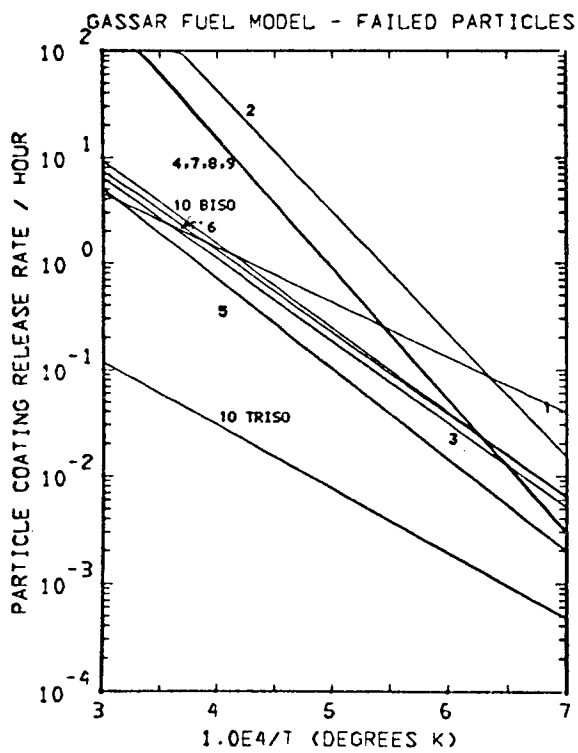


Fig. 14. Fission product release rate vs temperature for failed particles, GASSAR.

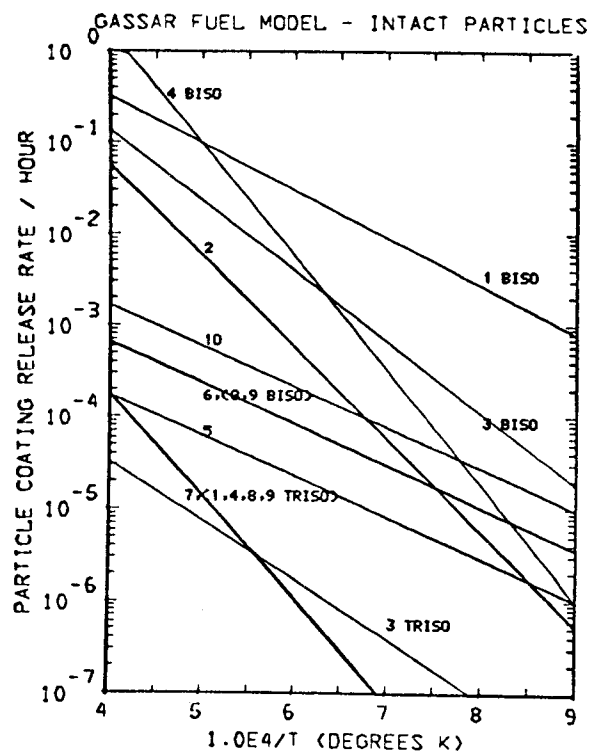


Fig. 15. Fission product release rate vs temperature for intact particles, GASSAR.

C. Fuel Failure Fraction (Particle Coatings)

The BISO and TRISO particle coatings begin to exhibit failure as a function of temperature (T) and age (t:time of a particular fuel rod in the reactor) of irradiation.

Analytic fits and a functional algorithm were developed from the graphic data displayed in the SORS[2] and GASSAR[6] reports for the failed fraction of particle coatings as a function of temperature and age, f(T,t).

SORS: f(T,t)

The SORS data is displayed graphically in Figs.5-1, 5-2 of the SORS report (see also Figs. 16 and 17). The failed fraction is approximated as a linear function of temperature in the partially failed region. The boundaries of no coating failures and 100% coating failures are a function of age and type (BISO, TRISO).

Using these assumptions we may write a simple analytic fit of the data to obtain the failed fraction, f(T,t), as a function of the temperature (T) and the age of the fuel (t) for BISO and TRISO fuels.

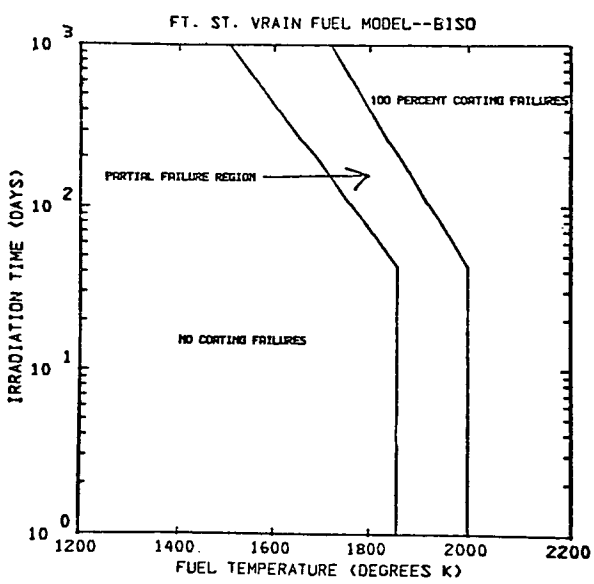


Fig. 16. Fuel failure diagram for BISO particles, SORS data.

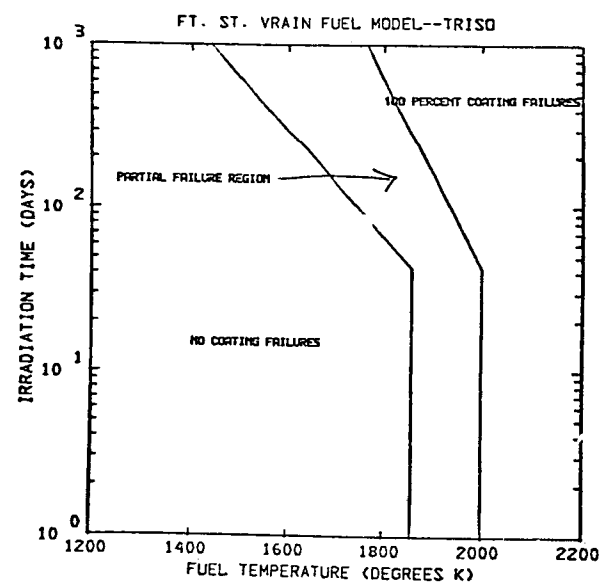


Fig. 17. Fuel failure diagram for TRISO particles, SORS data.

The temperatures for f = 0 (no coating failure) and f = 1 (100% coating failure) at 4 yr and 0.12 yr at the knee of the curves, are given in Table IX. The temperatures for $0 < t < 0.12$ yr are taken to be the same for BISO and TRISO fuels.

For $0 \leq t < 0.12$ yr, the failed fraction can be represented as a linear function of temperature by

$$f = A + BT \ , \tag{101}$$

where the coefficients A and B for BISO and TRISO are given in Table X.

For $0.12 < t < 4$ yr, we fit the f = 0 and f = 1 boundaries by $\alpha_i e^{\beta_i t}$ (i = 0,1) and perform a linear interpolation between the f = 0 and f = 1 boundaries. This approximation leads us to the form

$$f(T,t) = \frac{T(t) - T_0(t)}{T_1(t) - T_0(t)} \ , \tag{102}$$

where

$$T_i(t) = \alpha_i e^{\beta_i t} \quad (i = 0,1) \tag{103}$$

and the coefficients α_i and β_i for BISO and TRISO are given in Table X.

As is mentioned on page 6-3 of the SORS report,[2] linear fuel failure is assumed with 10% failed fuel at 4 yr. This is an amount that is added to the fraction that fails due to temperature; 2.5%, 5%, 7.5% , and 10% failure is added to the 1 yr-,2 yr-,3 yr- and 4-yr-old-fuel respectively.

Figures 16 through 21 were generated using the above equations and data.

TABLE IX

SORS TEMPERATURES (K) FOR AGED FRACTION FAILURES, f		
Type/f	f = 0	f = 1
BISO:		
0.12 yr	1858.15	1998.15
4 yr	1360.15	1599.15
TRISO:		
0.12 yr	1858.15	1998.15
4 yr	1273.15	1663.15

TABLE X

SORS AGE-TEMPERATURE FUEL FAILURE PARAMETERS

Type	$0 \leq t \leq 0.12$ yr			
	A	10^3B K		
BISO	-13.2725	7.14286		
TRISO	-13.2725	7.14286		
	$0.12 \text{ yr} \leq t \leq 4$ yr			
Type	$10^{-3}\alpha_o$(K)	$10^2\beta_o$(yr^{-1})	$10^{-3}\alpha_1$(K)	$10^2\beta_1$(yr^{-1})
BISO	1.87617	8.04098	2.01197	5.74098
TRISO	1.8801	9.74459	2.00953	4.72964

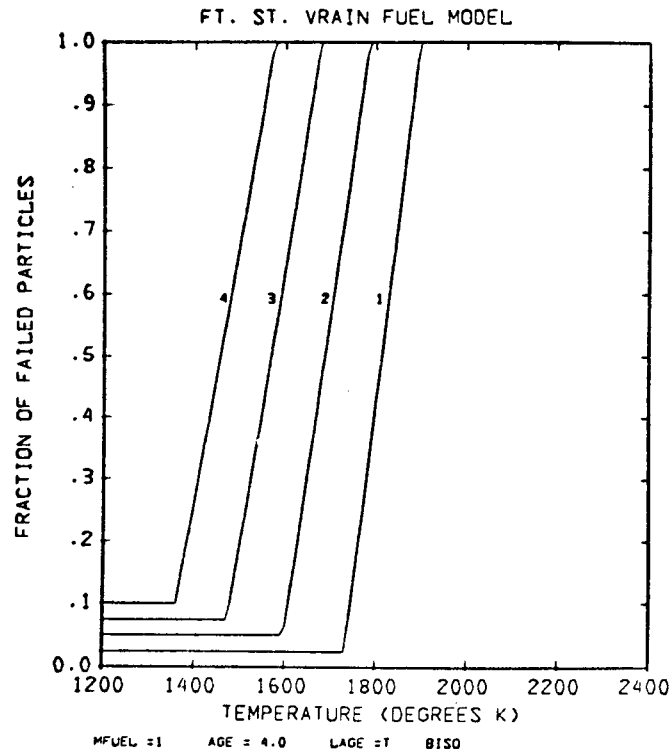


Fig. 18. Fraction of failed particles vs temperature, BISO particles, SORS data. This figure is derived from Fig. 16.

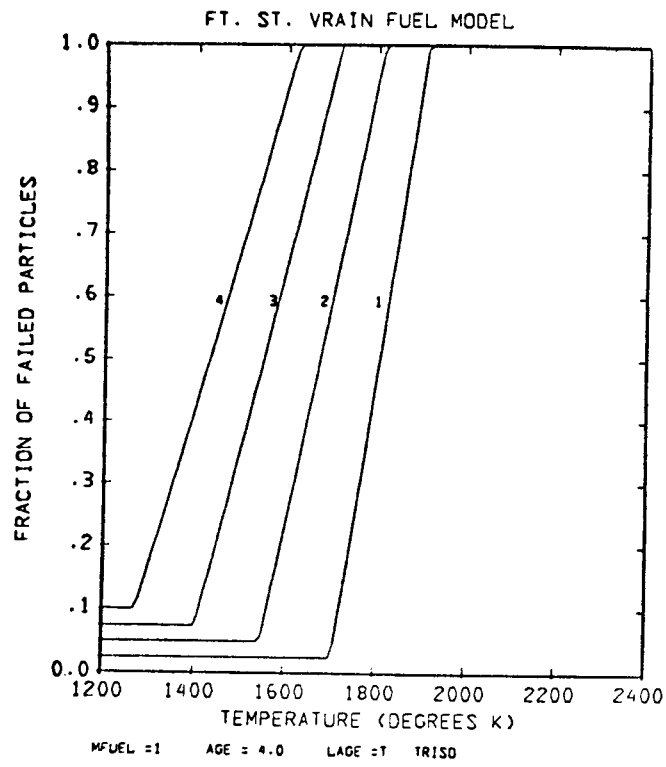


Fig. 19. Fraction of failed particles vs temperature, TRISO particles, SORS data. This figure is derived from Fig. 17.

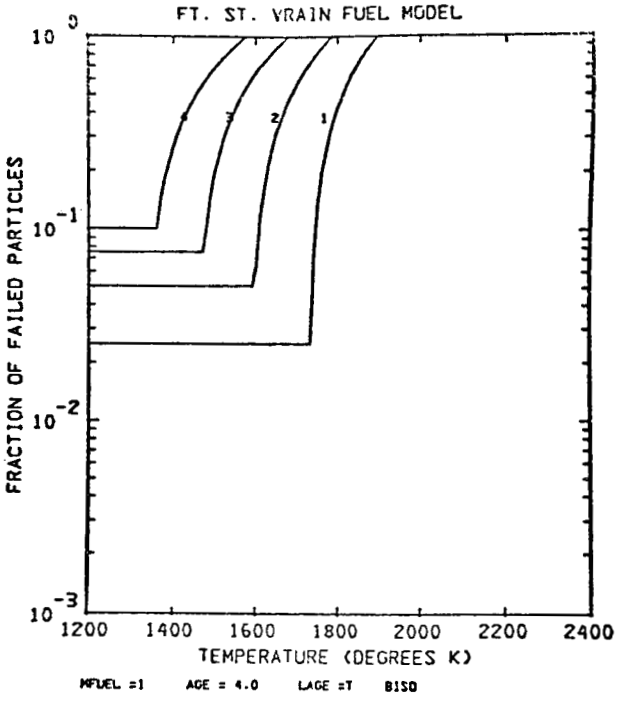


Fig. 20. Log of fraction of failed particles vs temperature, BISO particles, SORS data.

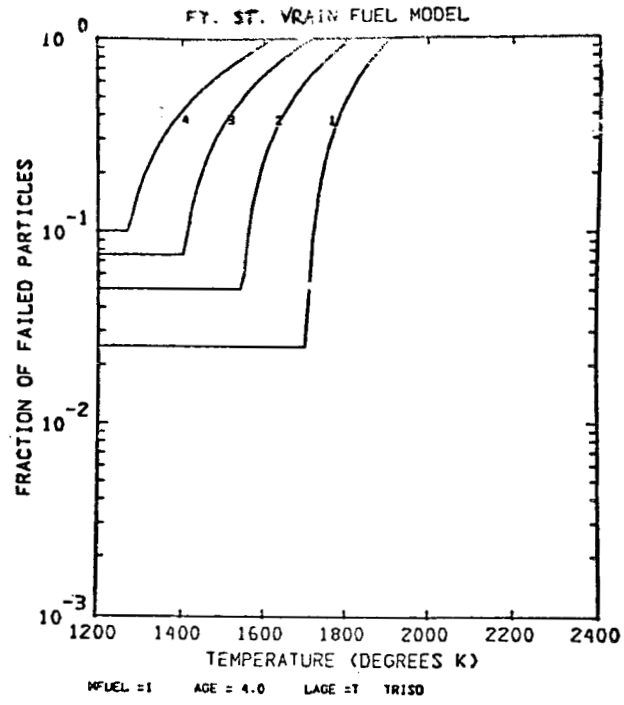


Fig. 21. Log of fraction of failed particles vs temperature, TRISO particles, SORS data.

GASSAR: f(T,t)

The graphic data obtained from Fig. 1 and 2 of the GASSAR report are summarized in Tables XI and XII for various aged fuels and particle coating failed fractions.

For the BISO particle coatings, a spline fit to the data was used below a certain failed fraction, f_o, and temperature T(marked with an asterisk in Table XI). Above f_o, a linear fit of the form

$$f(t) = A + BT \tag{104}$$

was used, where $f = 1$ if $T \geq T_1$. The BISO parameters A, B and the threshold for the linear fit, f_0, are given in Table XIII.

For the TRISO particle coatings an exponential fit of the form

$$f(t) = \alpha e^{\beta T} \tag{105}$$

TABLE XI

GASSAR BISO PARTICLE COATING FAILED FRACTIONS AND TEMPERATURES FOR VARIOUS AGES

Age = 1 yr		2 yr		3 yr		4 yr	
f	T(K)	f	T(K)	f	T(K)	f	T(K)
0.00179	T≤2073.15	0.00377	T<2073.16	0.00526	T≤1690.15	0.00718	T≤1673.15
0.282	2143.15	0.282	2143.15	0.0059	1743.15	0.0079	1697.15
1.0	2273.15	1.0	2273.15	0.0071	1793.15	0.010	1733.15
				0.0116	1873.15	0.021	1793.15
				0.0185	1917.15	0.0557	1853.15
				0.046	1973.15	0.10	1893.15
				0.057	2000.0	0.222	1973.15
				0.0815*	2073.15	0.4039*	2073.15
				0.10	2083.15	0.649	2153.15
				0.23	2113.15	1.0	2273.15
				1.0	2273.15		

*Linear fit above this fraction and temperature, spline fit below.

TABLE XII

GASSAR TRISO PARTICLE COATING FAILED FRACTIONS AND TEMPERATURES FOR VARIOUS AGES

Age = 1 yr		2 yr		3 yr		4 yr	
f	T(K)	f	T(K)	f	T(K)	f	T(K)
0.00157	1941.15	0.00385	1473.15	0.00601	1473.15	0.00677	1473.15
1.0	2273.15	0.00566	1902.15	0.00942	1888.85	0.0109	1873.15
		1.0	2273.15	1.0	2273.15	1.0	2273.15

TABLE XIII

GASSAR BISO FAILED FRACTION PARAMETERS

Age (yr)	f_o	A	$10^3 B(K)^{-1}$
1	0.00179	-10.3454	4.99105
2	0.00377	-10.3229	4.98115
3	0.0815	- 9.4394	4.5925
4	0.4039	- 5.7751	2.9805

was used for $f \leq f_o$, which corresponds for TRISO to the first row of Table XII. A linear fit of the form

$$f(T) = A + BT \tag{106}$$

was used above f_o, where $f = 1$ if $T \geq T_1$. The TRISO parameters and their temperature ranges are given in Table XIV.

The data described by these analytic fits are displayed for BISO and TRISO in Figs. 22-25.

D. Aged Fuel Failure Fraction (Particle Coatings)

Different segments of the HTGR core have been subjected to different irradiation times, or aging, due to the replacement of 1/4 of the fuel rods each year with new fuel rods.

SORS: For the SORS data, if this replacement process does not occur, we say the fuel is not aged, and the fraction of failed particle coatings is given by

$$\bar{f} = f(T,t) , \tag{107}$$

where t is the age in years and Eq. (107) is evaluated using Eqs.(102) and (103) of Section C with the parameters of Table X.

On the other hand, if the fuel replacement process occurs, we say the fuel is aged, and the fraction of failed particle coatings is given by

$$\bar{f} = \frac{1}{4} \sum_{i=1}^{4} f_i^{\,s} \, [\theta(t - i + 1) - \theta(t - i)] , \tag{108}$$

where t is the age in years, $i = [t] + 1$, and [ ] means "least integer", with

$$f_i^{\,s} = \begin{cases} 4f_1 & i = 1 \quad 0 \leq t \leq 1 \\ f_1 + 3f_2 & i = 2 \quad 1 \leq t \leq 2 \\ f_1 + f_2 + 2f_3 & i = 3 \quad 2 \leq t \leq 3 \\ f_1 + f_2 + f_3 + f_4 & i = 4 \quad 3 \leq t \leq 4 \end{cases} \tag{109}$$

TABLE XIV

GASSAR TRISO FAILED FRACTION PARAMETERS

Age (yr)	$\Delta T(K)$	$10^3\alpha$	$10^3\beta(K)^{-1}$	ΔT	A	$10^2\beta(K)^{-1}$
1	<1941.15	1.57		1941.15<T<2273.15	5.8361	0.300732
2	<1894.15	0.99966	0.915323	1894.15<T<2273.15	4.9638	0.262359
3	<1888.15	1.2240	1.08109	1888.15<T<2273.15	4.8593	0.257762
4	<1873.15	1.17176	1.19064	1873.15<T<2273.15	4.6209	0.24728

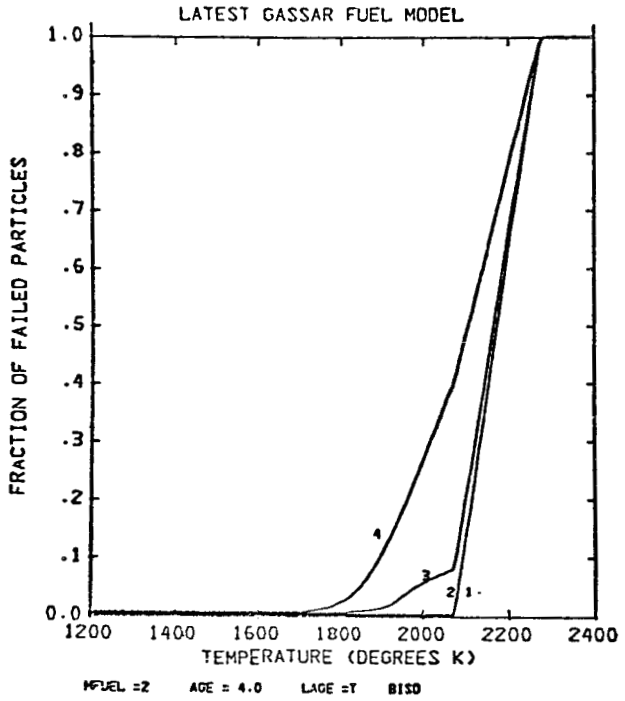


Fig. 22. Fraction of failed particles vs temperature, BISO particles, GASSAR data.

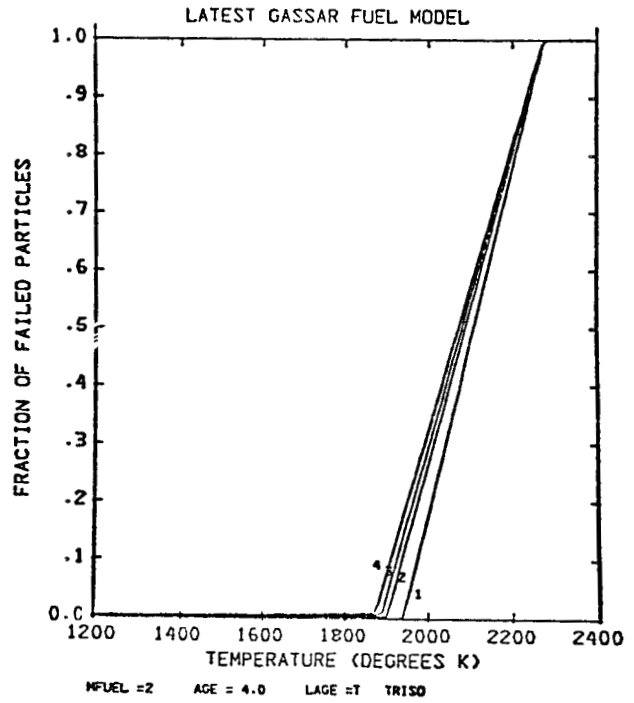


Fig. 23. Fraction of failed particles vs temperature, TRISO particles, GASSAR data.

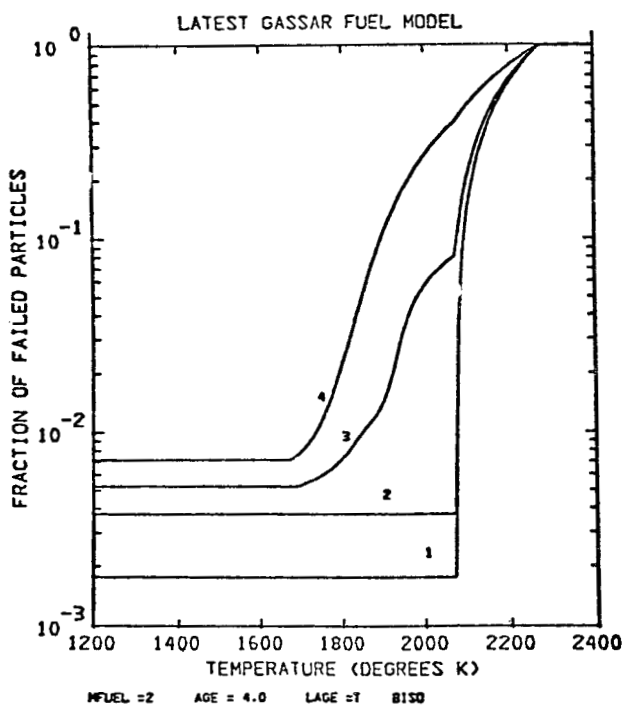


Fig. 24. Log of fraction of failed particles vs temperature, BISO particles, GASSAR data.

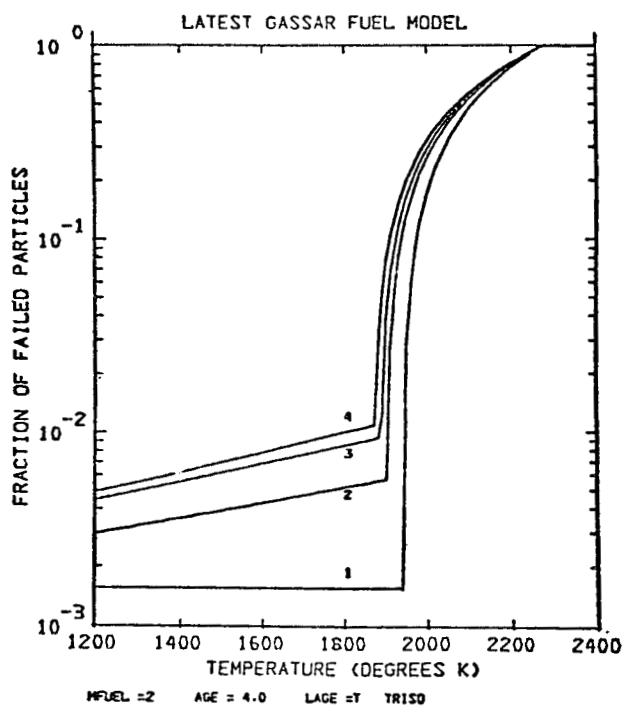


Fig. 25. Log of fraction of failed particles vs temperature, TRISO particles, GASSAR data.

and

$$f_i = f[T,\ t \bmod(4)] = f(T,\ i-1 + x)\ , \tag{110}$$

where $x \equiv t - [t]$, using the parameters of Table X.

GASSAR: For the GASSAR data, if the fuel is not aged, then a linear interpolation is performed between the two nearest ages, or

$$\bar{f} = \sum_{i=1}^{4} [(1-x) f_{i-1}^{G} + x f_i^{G}][\theta(t-i+1) - \theta(t-1)]\ , \tag{111}$$

where $f_o^G \equiv 0$, $i = [t] + 1$, $x = t - [t]$, and f_i^G is given by

$$f_i^G = f(T,t) = f(T,\ i-1 + x)\ , \tag{112}$$

using Eqs. (104-106) and Tables XIII and XIV of Sec. C.

On the other hand, if the fuel is aged, then the particle coating failed fuel fraction is given by

$$\bar{f} = \frac{1}{4} \sum_{i=1}^{4} \tilde{f}_i^G\ [\theta(t - i + 1) - \theta(t-1)]\ , \tag{113}$$

where

$$\tilde{f}_i^G = \begin{cases} 4xf_1^G & i = 1 \quad 0 \le t \le 1 \\ 3f_1^G - 2xf_1^G + 3xf_2^G & i = 2 \quad 1 \le t \le 2 \\ f_1^G + (2-x)f_2^G + 2xf_3^G & i = 3 \quad 2 \le t \le 3 \\ f_1^G + f_2^G + f_3^G + xf_4^G & i = 4 \quad 3 \le t \le 4 \end{cases} \tag{114}$$

with

$$f_i^G = f(T,t) = f(T,\ i-1 + x)\ , \qquad (115)$$

using Eqs. (104-106) and Tables XIII and XIV of Sec. C.

The failed fraction in BISO, TRISO, and TOTAL = 0.6 BISO + 0.4 TRISO for the SORS and GASSAR models are displayed in Figs. 26-37 for aged and not aged fuel. (LAGE = T and F respectively)

We note that the SORS (Ft. St. Vrain) model exhibits an exponential rise in the failed fraction between refuelings compared to the linear rise of the GASSAR model in the same circumstance. The temperatures of Fig. 1 were used and were held constant in time.

The maximum and minimum failed fraction for the SORS data are (0.08, 0.04). The maximum and minimum for the GASSAR data are (0.004, 0.0025). Thus, a factor of (20,16) decrease in the maximum and minimum, in going from SORS to GASSAR data is obtained.

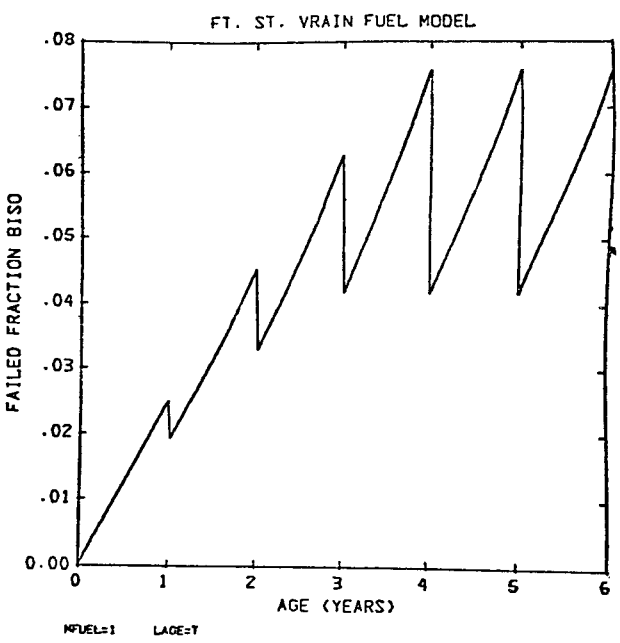


Fig. 26. Failed fraction vs age of the fuel in years, BISO particles, SORS data, aged fuel.

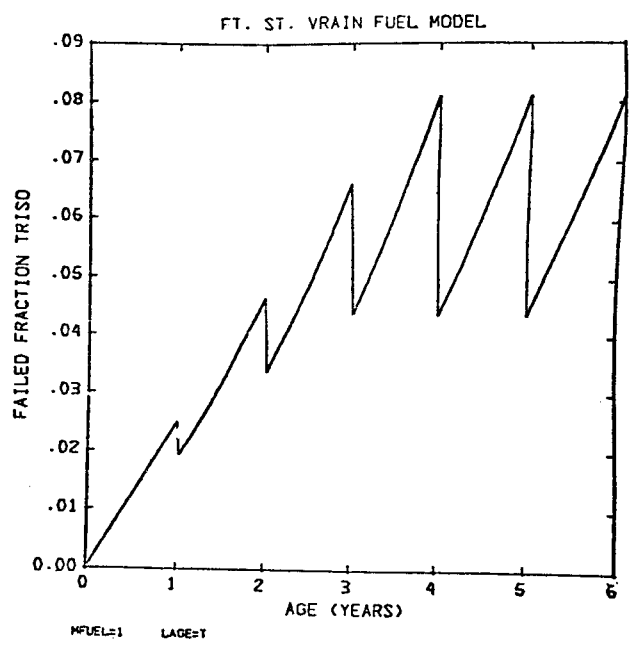


Fig. 27. Failed fraction vs age of the fuel in years, TRISO particles, SORS data, aged fuel.

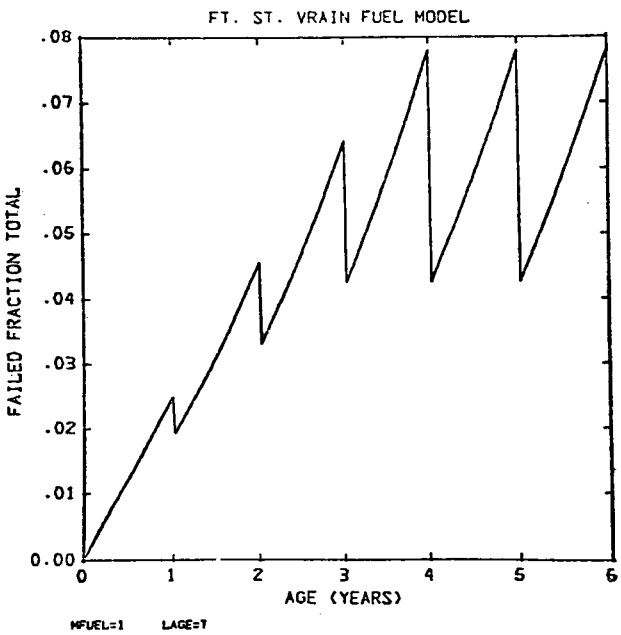


Fig. 28. Failed fraction vs age of the fuel in years, averaged total for aged fuel, SORS data.

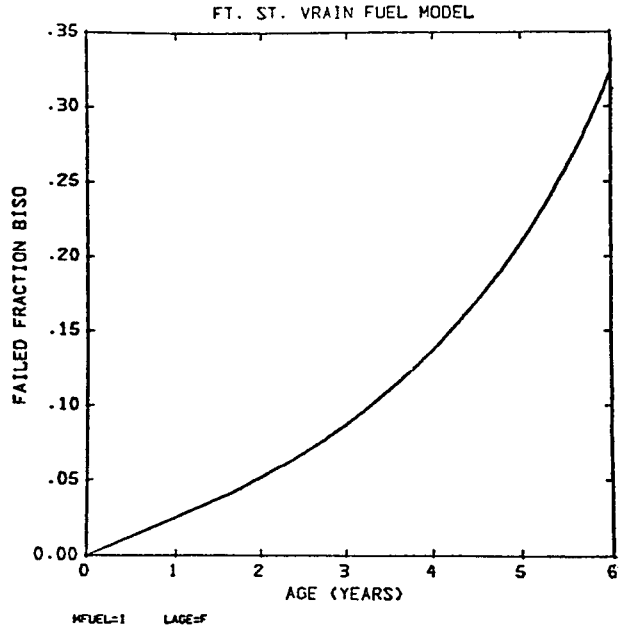


Fig. 29. Failed fraction vs age of the fuel in years, BISO particles, SORS data, fuel not aged.

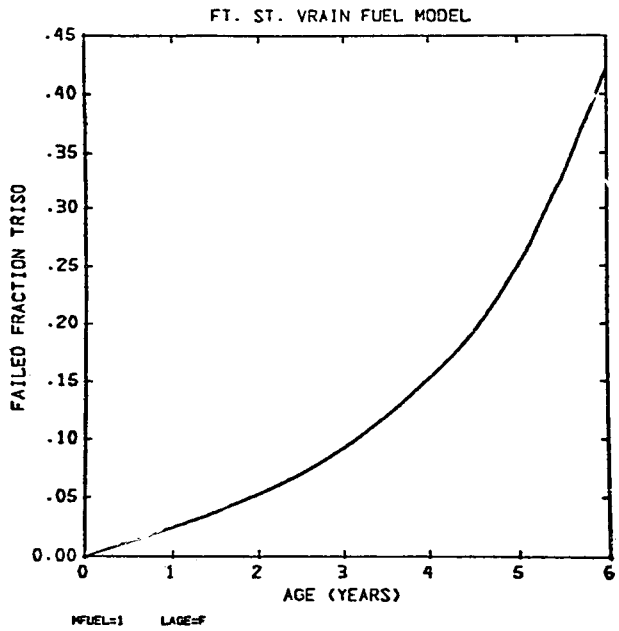


Fig. 30. Failed fraction vs age of the fuel in years, TRISO particles, SORS data, fuel not aged.

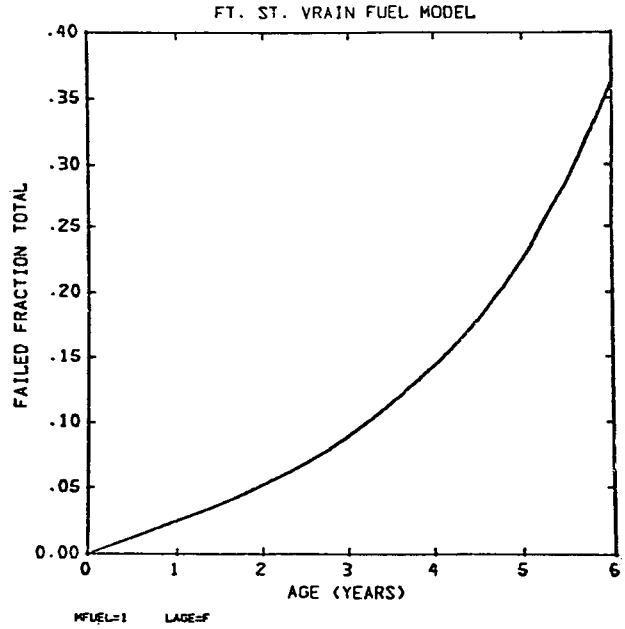


Fig. 31. Failed fraction vs age of the fuel in years, averaged total for fuel not aged, SORS data.

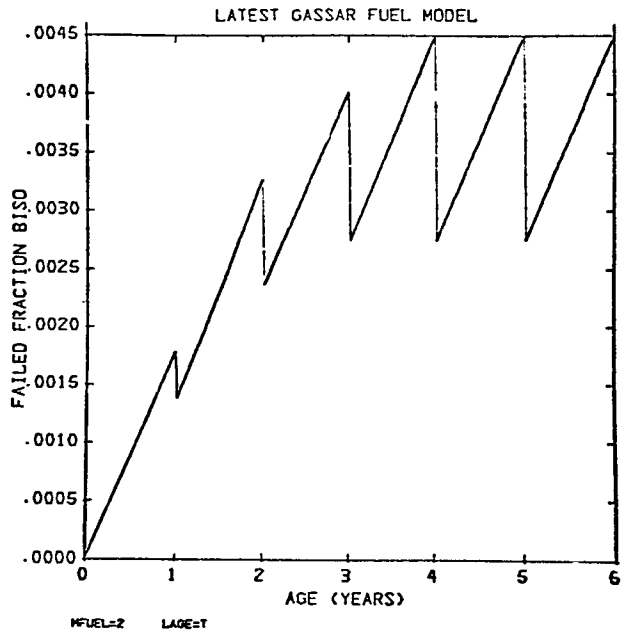


Fig. 32. Failed fraction vs age of the fuel in years, BISO particles, GASSAR data, aged fuel.

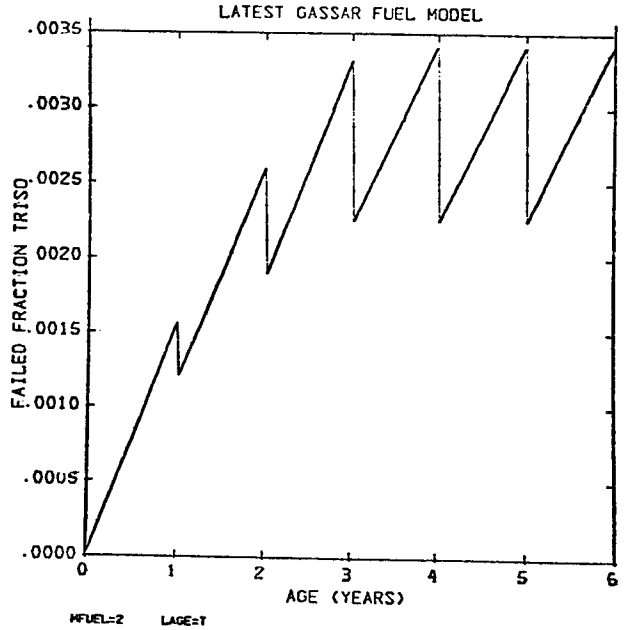


Fig. 33. Failed fraction vs age of the fuel in years, TRISO particles, GASSAR data, aged fuel.

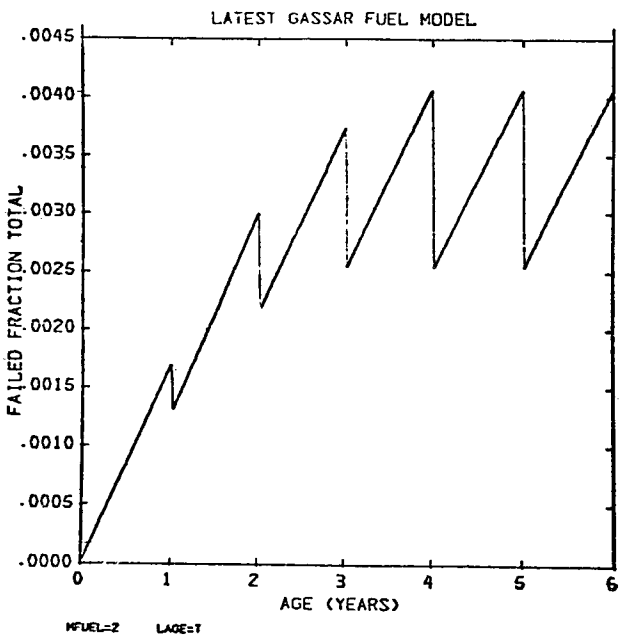


Fig. 34. Failed fraction vs age of the fuel in years, averaged total for aged fuel, GASSAR data.

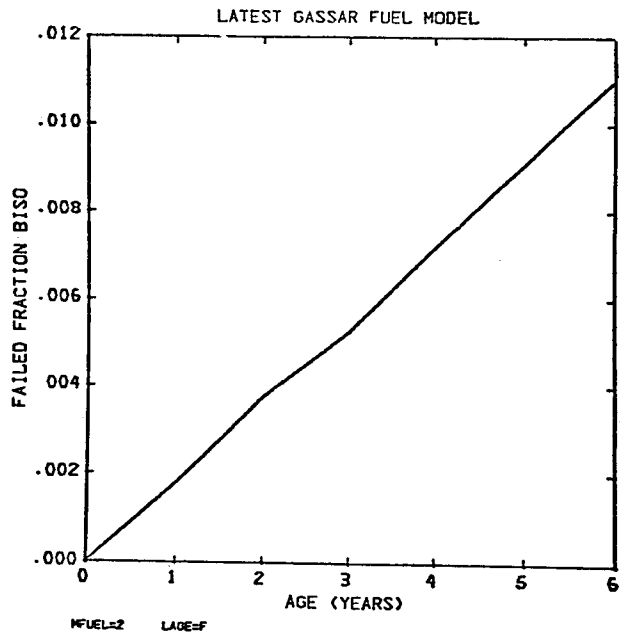


Fig. 35. Failed fraction vs age of the fuel in years, BISO particles, GASSAR data, fuel not aged.

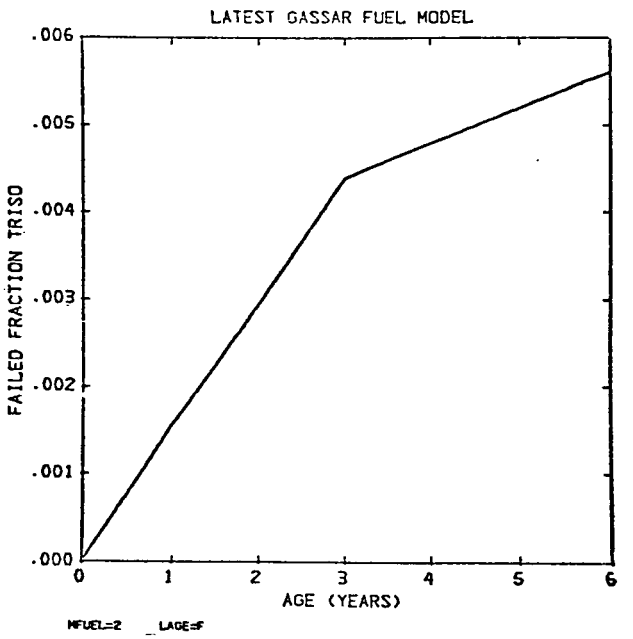


Fig. 36. Failed fraction vs age of the fuel in years, TRISO particles, GASSAR data, fuel not aged.

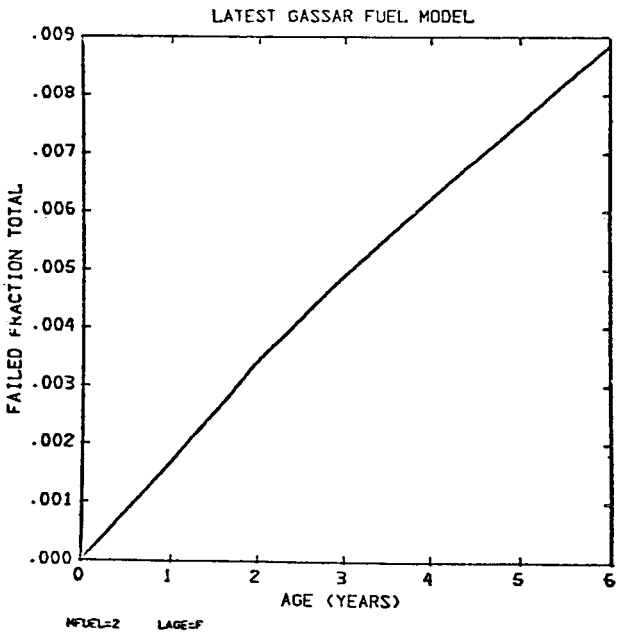
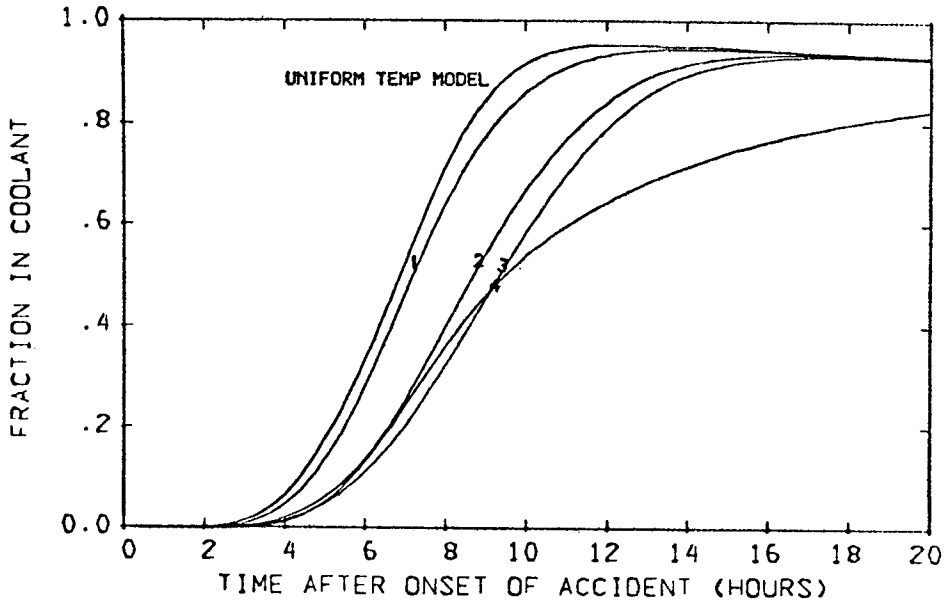


Fig. 37. Failed fraction vs age of the fuel in years, averaged total for fuel not aged, GASSAR data.

IV. COMPARISONS

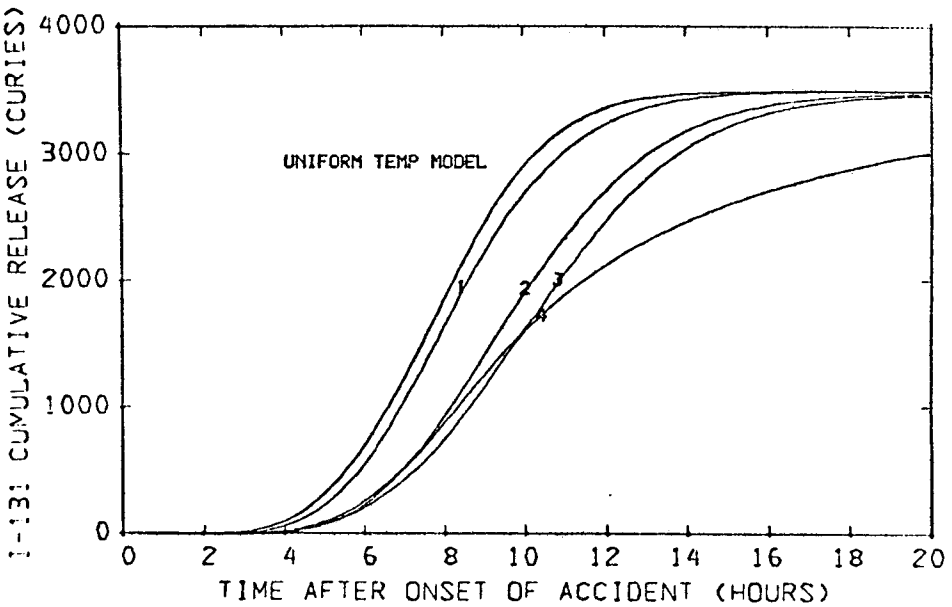
A comparison for ^{131}I was made for the Ft. St. Vrain fuel model (MFUEL = 1) with an average age of 2.5 yr (AGE = 2.5), fuel not aged (LAGE = F). A BISO-TRISO mixture (0.6, 0.4) was used (FRAC = 0.6). Six partitions of the core volume IC = 1, 5, 10, 25, 100, 200 and five partitions of the 20 h time period IT = 20, 40, 100, 300, 500 were used. A typical result is displayed in Figs. 38 and 39 and compared with the uniform temperature model of Ref. 1 for the fraction in the coolant and the cumulative release. Four temperature models SORS, CORCON, AYER, and AYER Fu-Cort (ITEMP = 1, 2, 3, 4) and the four equation models, Simplified Model-Renormalized, Constant Release-Renormalized, Linear Release-Renormalized, and Intact-Failed Self-Consistent fuel transition (NEQ = 1, 2, 3, 4) were used.

A typical terminal run output under the NOS system is displayed in Fig. 40.



I-131 ISO=10 MFUEL=1 AGE= 2.5 LAGE=F FRAC= .6 YIELD= .031
NTOT= 100 IVFMAX=100 JOB=R4LCP 5SS DATE=09/20/76
NEQ=2 CONSTANT RELEASE RATE, CONSTANT FAILURE

Fig. 38. LARC-1 and uniform temperature model results, fraction in coolant.



I-131 ISO=10 MFUEL=1 AGE= 2.5 LAGE=F FRAC= .6 YIELD= .031
NTOT= 100 IVFMAX=100 JOB=R4LCP 5SS DATE=09/20/76
NEQ=2 CONSTANT RELEASE RATE, CONSTANT FAILURE

Fig. 39. LARC-1 and uniform temperature model results, cumulative release.

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 JOBNAME =AJUI210       DATE = 76/08/30.      TIME =10.55.34
 ISOTOPE NAME =
? I-131
 DECAY CONSTANT (/HR)
? 3.58E-3
 RELEASE GROUP =
? 10
 YIELD (FRACTION) =
? .031
 AGE IN YEARS =
? 2.5
 FUEL TYPE (FT. ST. VRAIN =1, GASSAR =2) =
? 1
 FUEL AGED (T) OR NOT AGED (F)?
? F
 FRACTION OF BISO IN LOADING =
? 0.6
 NOBLE GAS?  (T OR F)
? F
 I-131          DECAY CONSTANT = 3.580E-03     GROUP =10      YIELD = 3.100E-02
 NZERO = 7.792E+07
 AGE =  2.50     LAGE =F      FRAC =   .60
 NEQ =4
 NTOT =  100
 TEMPERATURE MODEL USED = 1      MFUEL =1      ISOTOPE =I-131
 IVFMAX =  100
 INTERVAL TIME    AMOUNT      AMOUNT      FRACTION   AMOUNT IN      CUMULATED
 NUMBER   (HR)    REMAINING   IN COOLANT IN COOLANT CONTAINMENT    RELEASE
                  (CURIES)    (CURIES)               BLDG(CURIES)   (CURIES)


    5     1.00    7.76E+07    8.67E+02    1.11E-05    6.92E+02        .01
   10     2.00    7.73E+07    4.88E+04    6.26E-04    3.95E+04        .43
   15     3.00    7.63E+07    7.70E+05    9.88E-03    5.58E+05       9.82
   20     4.00    7.30E+07    3.77E+06    4.83E-02    2.35E+06      65.62
   25     5.00    6.59E+07    1.07E+07    1.37E-01    5.72E+06     229.13
   30     6.00    5.41E+07    2.22E+07    2.84E-01    1.01E+07     559.24
   35     7.00    3.95E+07    3.65E+07    4.68E-01    1.36E+07    1061.89
   40     8.00    2.57E+07    5.00E+07    6.42E-01    1.44E+07    1656.69
   45     9.00    1.51E+07    6.04E+07    7.75E-01    1.26E+07    2226.51
   50    10.00    8.13E+06    6.71E+07    8.61E-01    9.51E+06    2689.03
   55    11.00    4.03E+06    7.09E+07    9.10E-01    6.42E+06    3019.60
   60    12.00    1.84E+06    7.28E+07    9.35E-01    3.97E+06    3233.48
   65    13.00    7.72E+05    7.36E+07    9.45E-01    2.26E+06    3360.77
   70    14.00    2.99E+05    7.38E+07    9.48E-01    1.21E+06    3431.21
   75    15.00    1.06E+05    7.38E+07    9.47E-01    6.07E+05    3467.79
   80    16.00    3.40E+04    7.36E+07    9.44E-01    2.90E+05    3485.74
   85    17.00    9.81E+03    7.33E+07    9.41E-01    1.32E+05    3494.13
   90    18.00    2.51E+03    7.31E+07    9.38E-01    5.78E+04    3497.88
   95    19.00    5.71E+02    7.28E+07    9.35E-01    2.46E+04    3499.51
  100    20.00    1.15E+02    7.26E+07    9.31E-01    1.02E+04    3500.19
 DOES ANOTHER CASE FOLLOW?
? NO
EXIT
/
```

Fig. 40. Typical terminal run output for LARC-1 under NOS system.

The most sensitive test of these 320 calculations was the comparison of the fraction in the coolant and the cumulative release at 2 h time. These results are given in Appendix E. The main result is that at 2 h the maximum variation between (IT, IC) of (100, 100) and (500, 200) for the ^{131}I fraction release in the coolant is ∿ 20% for any temperature model whereas the various temperature models differ by as much as a factor of 3.7. Similarly for the cumulative release the maximum variation is ∿ 19% for any temperature model, whereas the various temperature models differ by as much as a factor of 3. At times greater than 2 h the variations decrease rapidly.

The ^{131}I fraction in the coolant and cumulative release as a function of time and model number (NEQ) are given in Tables XV - XXII for the four temperature models with IT = IC = 100. We note that better than two-digit agreement for the fraction in the coolant between the various equation models occurs after 4 h for all temperature models, Tables XV - XVIII.

Taking model 4, the Intact-Failed Self-Consistent Fuel model, as a standard, we compare the ^{131}I cumulative release in Tables XXIII-XXVI. Again we note that the maximum difference occurs at ∿ 2 h where as much as a 17% error can occur at the 0.4 Ci level. However, comparing Tables XIX - XXVI we can estimate an approximate upper bound on the error in the cumulative release, displayed in Fig. 41. A good rule of thumb is that the error made by the renormalized models compared to the Intact-Failed Self-Consistent model is " less than 5% at 50 Ci, and less than 1% at 300 Ci."

A similar set of comparisons was made for ^{127m}Te, and is summarized in Tables XXVII - XXIX for the fraction in the coolant, the cumulative release and the comparison to model 4. We note that the cumulative release at 20 h has only reached 25 Ci, as compared to 3500 for ^{131}I. The maximum error, 12%, occurs at 6 h as compared to 2 h for ^{131}I. The approximate upper bound for ^{131}I bounds the ^{127m}Te results.

TABLE XV

^{131}I FRACTION IN THE COOLANT
ITEMP = 1, IT = 100, IC = 100

T(H) \ NEQ	1,2	3	4
2	0.000522	0.000522	0.000626
4	0.0475	0.0475	0.0483
6	0.284	0.284	0.284
8	0.641	0.641	0.642
10	0.861	0.861	0.861
12	0.935	0.935	0.935
14	0.948	0.948	0.948
16	0.944	0.944	0.944
18	0.938	0.938	0.938
20	0.931	0.931	0.931

TABLE XVI

^{131}I FRACTION IN COOLANT AT 2 h
ITEMP = 2, IT = 100, IC = 100

T(H) \ NEQ	1,2	3	4
2	0.000157	0.000157	0.000175
4	0.0129	0.0129	0.0135
6	0.134	0.134	0.135
8	0.401	0.401	0.402
10	0.670	0.670	0.670
12	0.842	0.842	0.842
14	0.917	0.917	0.917
16	0.936	0.936	0.936
18	0.936	0.936	0.936
20	0.931	0.931	0.931

TABLE XVI

^{131}I FRACTION IN COOLANT
ITEMP = 3, IT = 100, IC = 100

T(H) \ NEQ	1,2	3	4
2	0.000144	0.000144	0.000169
4	0.0158	0.0158	0.0165
6	0.113	0.113	0.114
8	0.325	0.325	0.326
10	0.586	0.586	0.587
12	0.791	0.791	0.791
14	0.895	0.895	0.895
16	0.929	0.929	0.929
18	0.934	0.934	0.934
20	0.931	0.931	0.931

TABLE XVIII

^{131}I FRACTION IN COOLANT
ITEMP = 4, IT = 100, IC = 100

T(H) \ NEQ	1,2	3	4
2	0.000220	0.000220	0.000269
4	0.0205	0.0206	0.0211
6	0.139	0.139	0.139
8	0.362	0.362	0.362
10	0.540	0.540	0.540
12	0.646	0.646	0.646
14	0.717	0.717	0.717
16	0.767	0.767	0.767
18	0.803	0.803	0.802
20	0.827	0.827	0.827

TABLE XIX

^{131}I CUMULATIVE RELEASE (CURIES)
ITEMP = 1, IT = 100, IC = 100

T(H) \ NEQ	1	2	3	4
2	0.362	0.362	0.353	0.429
4	63.620	63.646	63.299	65.617
6	556.424	556.781	555.819	559.238
8	1654.131	1655.048	1654.214	1656.690
10	2687.453	2688.273	2687.888	2689.032
12	3232.777	3233.196	3233.047	3233.480
14	3430.953	3431.101	3431.045	3431.212
16	3485.639	3485.678	3485.651	3485.742
18	3497.822	3497.831	3497.810	3497.883
20	3500.136	3500.137	3500.118	3500.188

TABLE XX

^{131}CUMULATIVE RELEASE (CURIES)
ITEMP = 2, IT = 100, IC = 100

T(H) \ NEQ	1	2	3	4
2	0.164	0.164	0.162	0.177
4	15.101	15.105	14.994	16.071
6	235.211	235.330	234.763	237.816
8	942.483	942.944	942.250	945.159
10	1909.057	1909.699	1909.208	1911.122
12	2710.293	2710.852	2710.570	2711.583
14	3181.464	3181.803	3181.674	3182.123
16	3386.173	3386.317	3386.296	3386.450
18	3455.200	3455.246	3455.221	3455.327
20	3474.843	3474.855	3474.837	3474.919

TABLE XXI

^{131}I CUMULATIVE RELEASE (CURIES)
ITEMP = 3, IT = 100, IC = 100

T(H) \ NEQ	1	2	3	4
2	0.129	0.129	0.127	0.142
4	19.972	19.976	19.871	21.152
6	212.131	212.199	211.822	214.730
8	764.819	765.116	764.545	767.487
10	1620.123	1620.675	1620.123	1622.351
12	2468.057	2468.659	2468.291	2469.601
14	3043.649	3044.072	3043.891	3044.513
16	3323.847	3324.050	3323.975	3324.247
18	3429.105	3429.180	3429.143	3429.285
20	3463.127	3463.152	3463.130	3463.227

TABLE XXII

^{131}I CUMULATIVE RELEASE (CURIES)
ITEMP = 4, IT = 100, IC = 100

T(H) \ NEQ	1	2	3	4
2	0.186	0.186	0.183	0.214
4	27.313	27.320	27.172	28.390
6	262.656	262.801	262.290	264.627
8	888.430	889.010	888.353	890.765
10	1610.957	1611.575	1611.152	1612.910
12	2126.310	2126.664	2126.440	2127.661
14	2469.188	2469.388	2469.256	2470.152
16	2711.513	2711.641	2711.552	2712.238
18	2888.546	2888.635	2888.569	2889.110
20	3020.609	3020.671	3020.616	3021.063

TABLE XXIII

^{131}I: $|R_i/R_4 - 1| \times 10^2$

PERCENTAGE DIFFERENCE IN MODELS COMPARED TO MODEL 4
ITEMP = 1, IT = 100, IC = 100

T \ NEQ	1	2	3
2	15.62	15.62	17.72
4	3.04	3.00	3.53
6	0.50	0.44	0.61
8	0.15	0.10	0.15
10	0.06	0.03	0.04
12	0.02	0.009	0.013
14	0.008	0.003	0.005
16	0.003	0.002	0.003
18	0.002	0.0015	0.002
20	0.0015	0.0015	0.002

TABLE XXIV

^{131}I: $|R_i/R_4 - 1| \times 10^2$

PERCENTAGE DIFFERENCE IN MODELS COMPARED TO MODEL 4
ITEMP = 2, IT = 100, IC = 100

T \ NEQ	1	2	3
2	7.34	7.34	8.47
4	6.04	6.01	6.70
6	1.10	1.05	1.28
8	0.28	0.23	0.31
10	0.11	0.07	0.10
12	0.05	0.03	0.04
14	0.02	0.01	0.01
16	0.008	0.004	0.005
18	0.004	0.002	0.003
20	0.002	0.002	0.002

TABLE XXV

^{131}I: $|R_i/R_4 - 1| \times 10^2$

PERCENTAGE DIFFERENCE IN MODELS COMPARED TO MODEL 4
ITEMP = 3, IT = 100, IC = 100

T \ NEQ	1	2	3
2	9.15	9.15	10.56
4	5.58	5.56	6.06
6	1.21	1.18	1.35
8	0.35	0.31	0.38
10	0.14	0.10	0.14
12	0.06	0.04	0.05
14	0.03	0.01	0.02
16	0.01	0.006	0.008
18	0.005	0.003	0.004
20	0.003	0.002	0.003

TABLE XXVI

^{131}I: $|R_i/R_4 - 1| \times 10^2$

PERCENTAGE DIFFERENCE IN MODELS COMPARED TO MODEL 4
ITEMP = 4, IT = 100, IC = 100

T \ NEQ	1	2	3
2	13.08	13.08	14.49
4	3.79	3.77	4.29
6	0.74	0.69	0.88
8	0.26	0.20	0.27
10	0.12	0.08	0.11
12	0.06	0.05	0.06
14	0.04	0.03	0.04
16	0.03	0.02	0.03
18	0.020	0.016	0.019
20	0.015	0.013	0.015

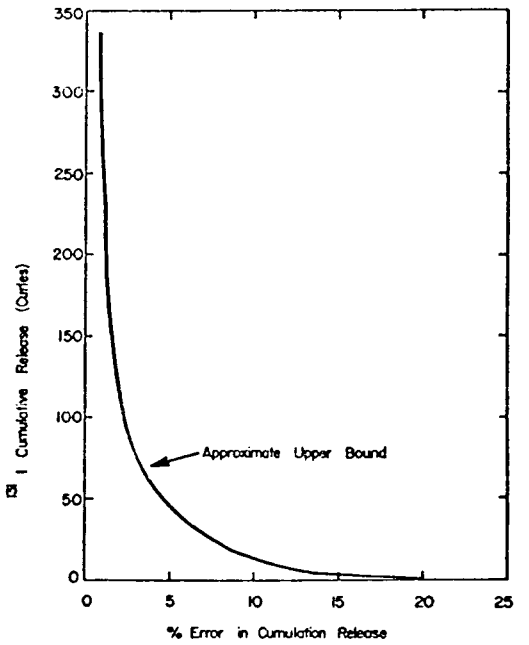

Fig. 41. Approximate upper bound to error in cumulative release in ^{131}I calculations using IT = IC = 100 for all temperature models.

TABLE XXVII

^{127m}Te FRACTION IN COOLANT
ITEMP = 4, IT = 100, IC = 100

T(H) \ NEQ	1,2	3	4
2	0.000128	0.000128	0.000128
4	0.00114	0.00114	0.00126
6	0.0435	0.0435	0.0484
8	0.205	0.205	0.210
10	0.324	0.324	0.327
12	0.405	0.405	0.408
14	0.475	0.475	0.477
16	0.539	0.539	0.541
18	0.594	0.594	0.595
20	0.642	0.642	0.644

TABLE XXVIII

^{127m}Te CUMULATIVE RELEASE (Ci)

ITEMP = 4, IT = 100, IC = 100

T(H) \ NEQ	1	2	3	4
2	0.002	0.002	0.002	0.002
4	0.019	0.019	0.019	0.020
6	0.627	0.629	0.627	0.713
8	5.063	5.071	5.067	5.269
10	10.573	10.571	10.577	10.733
12	14.597	14.601	14.600	14.717
14	17.746	17.749	17.748	17.847
16	20.517	20.519	20.519	20.605
18	22.970	22.971	22.971	23.039
20	25.102	25.103	25.102	25.160

TABLE XXIX

^{127m}Te: $|R_i/R_4 - 1| \times 10^2$

PERCENTAGE DIFFERENCE IN MODELS COMPARED TO MODEL 4

ITEMP = 4, IT = 100, IC = 100

T(H) \ NEQ	1	2	3
2	0.0	0.0	0.0
4	5.00	5.00	5.00
6	12.06	12.06	12.06
8	3.91	3.76	3.83
10	1.49	1.43	1.45
12	0.82	0.79	0.79
14	0.57	0.55	0.55
16	0.43	0.42	0.42
18	0.30	0.30	0.30
20	0.23	0.23	0.23

Results for three representative isotopes, ^{131}I, ^{135}Xe, and ^{138}Xe, are displayed in Figs. 42 through 45. On each figure four temperature models are displayed . The SORS (ITEMP = 1) model gives the largest release and the AYER-Fu Cort (ITEMP = 4) model the smallest.

The sensitivity of the accumulated release to fuel modeling where the fuel is the Ft. St. Vrain (FSV) or GASSAR model is illustrated in Figs. 42 and 43, respectively, where there is a 50% reduction at 9 h in using the GASSAR model.

The sensitivity of the temperature models and the effects of larger λ's is illustrated in Figs. 44 and 45 for ^{135}Xe and ^{138}Xe, respectively. For ^{135}Xe the different temperature models predict a 30% difference in fraction released in the coolant with a 4-h time spread in the maximum. The ^{135}Xe decay constant causes the decaying tail after the peak release.

The double peak exhibited by ^{137}Xe in Fig. 45 was investigated in detail and is explained as follows: the first peak is formed because of release from intact particles. Decay causes it to fall because most of the amount available for release is depleted by decay. During the fall, the rise in temperature of the SORS model is sufficient to cause a large increase in the failed fraction before decay again causes the second peak to fall off. In the CORCON and AYER temperature models. The temperature-time behavior is such that decay overrides the increased failure and a leveling off of the second peak is expected.

V. CONCLUSIONS

We have developed and compared four analytical models of fission product release from an HTGR core during the LOFC accident. We have also developed a numerical data base for release constants, temperature modeling, fission product release rates, coated fuel particle failure fraction and aged coated fuel particle failure fraction. Analytic fits and graphic displays for these data were given for the Ft. St. Vrain and GASSAR models.

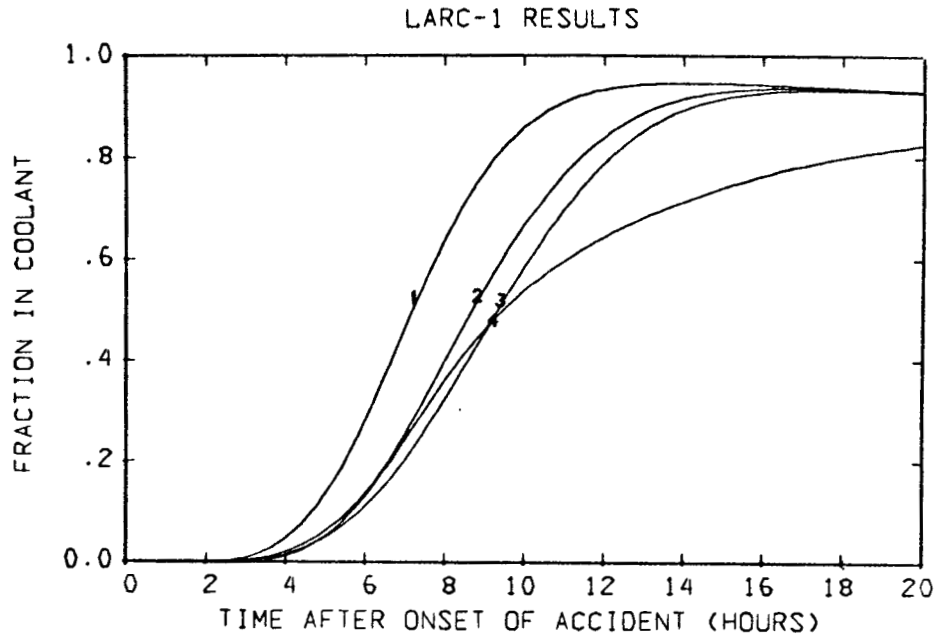

Fig. 42. Calculated time-dependent release of ^{131}I from the reactor core using the Ft. St. Vrain fuel failure model and using four different core temperature models.

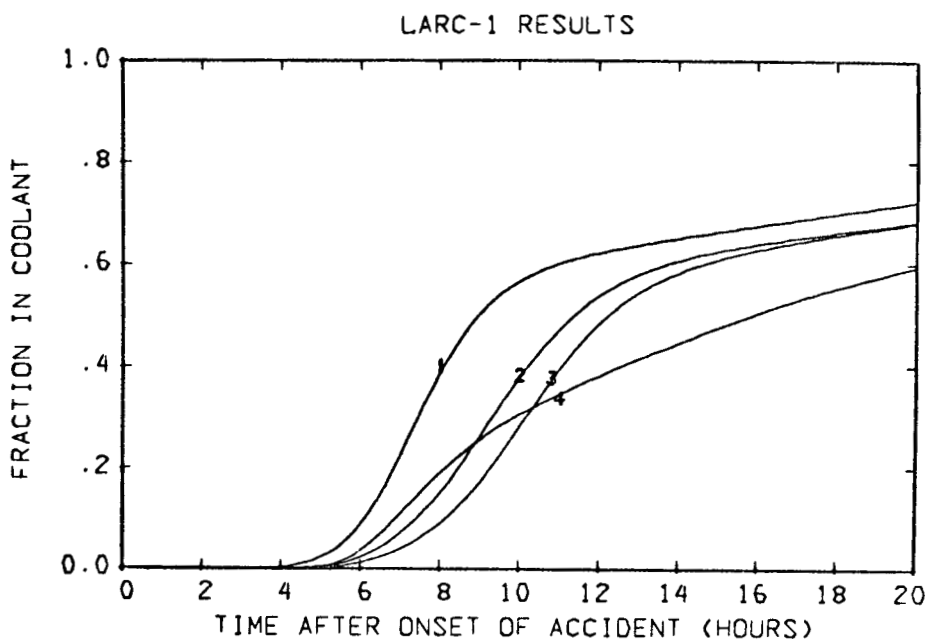

Fig. 43. Calculated time-dependent release of ^{131}I from the reactor core using the GASSAR fuel failure model and using four different core temperature models.

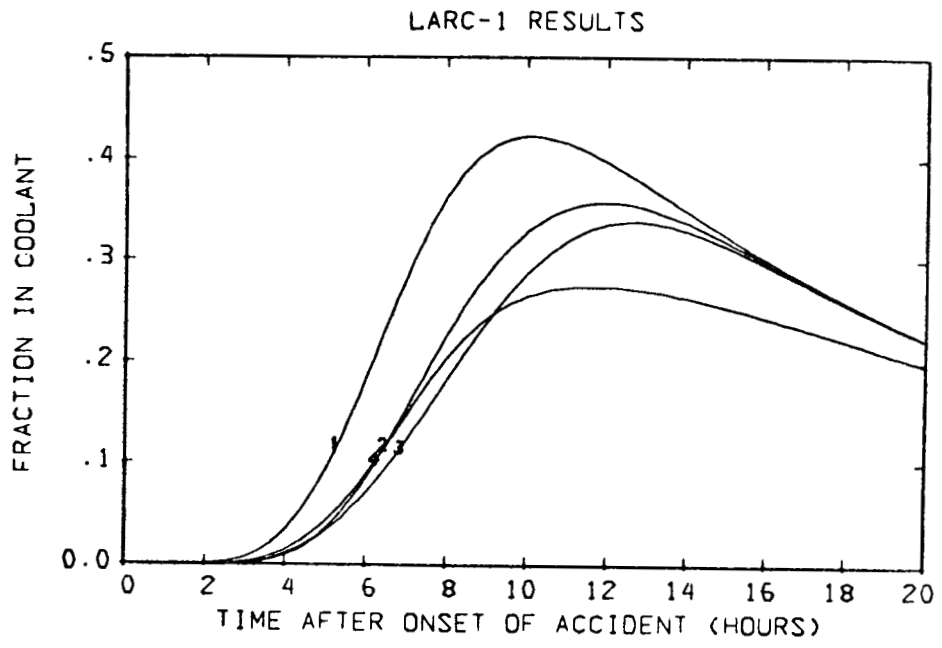

Fig. 44. Calculated time-dependent release of ^{135}Xe from a large HTGR using four different core temperature models.

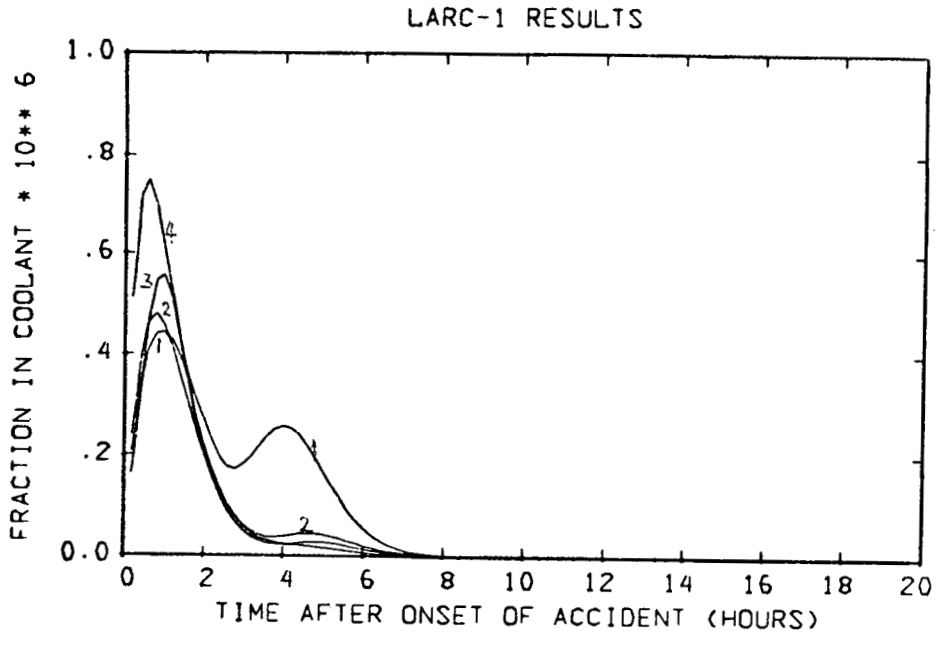

Fig. 45. Calculated time-dependent release of ^{138}Xe from a large HTGR using four different core temperature models.

The assumptions of the simplified model[1] have been systematically removed. However, the LARC-1 program neglects precursors, diffusion, and absorption and evaporation of the metallics. These topics will be treated in subsequent reports.

Comparison of the various analytic models indicates that the use of a renormalized constant release model is sufficiently accurate to warrant the extension of this method to more complex theoretical modelings.

Comparisons of the various temperature and release models indicate that these are the most sensitive LARC-1 parameters in that order. The need for detailed accurate temperature calculations and physically realistic release models, that are validated by experiment, must be emphasized.

REFERENCES

1. J. E. Foley, "^{131}I Release from an HTGR During the LOFC Accident," Los Alamos Scientific Laboratory report LA-5893-MS (March 1975).

2. M. H. Schwartz, D. B. Sedgley, and M. M. Mendonca, "SORS: Computer Programs for Analyzing Fission Product Release from HTGR Cores During Transient Temperature Excursions," General Atomic Company report GA-A12462 (April 1974).

3. K. E. Schwartztrauber and F. A. Silady, "CORCON: A Program for Analysis of HTGR Core Heatup Transients," General Atomic Company report GA-A12868 (July 1974).

4. R. G. Lawton, "The AYER Heat Conduction Computer Program," Los Alamos Scientific Laboratory report LA-5613-MS (May 1974).

5. J. H. Fu and G. E. Cort, "Fuel Failure Fraction and Iodine Release Calculation from GASSAR July 18, 1975 Models," Los Alamos Scientific Laboratory internal document (December 1975).

6. GASSAR-6, General Atomic Standard Safety Analysis report, GA-A13200, Vol. II, Chap. 4, Fig. 4.4-8 (July 1975).

7. J. H. Fu and G. E. Cort, "The Fraction Fuel Volume Above Certain Temperature Levels During an LOFC Accident," Los Alamos Scientific Laboratory internal document (March 1976).

8. J. L. Walsh, J. H. Ahlberg, and E. N. Nilson, "Best Approximation Properties of the Spline Fit," J. Math. and Mechanics, II No. 2, 225 (1962); J. H. Ahlberg, E. N. Nilson, and J. L. Walsh, The Theory of Splines and Their Applications, (Academic Press, Inc., New York 1967), p. 296.

9. T. L. Jordan and B. Fagen, Programs E102, E103, "Spline Interpolation and Function Evaluation," Los Alamos Scientific Laboratory Computing Division Program Library (April 1969).

10. T. L. Jordan, "Smoothing and Multivariant Interpolation with Splines," Los Alamos Scientific Laboratory report LA-3137 (June 1964).

11. T. L. Jordan, Program E104, "Two-Dimensional Bi-Cubic Spline Interpolation - Coefficient Calculation," Los Alamos Scientific Laboratory Computer Division Program Library (December 1967).

12. GASSAR-6, General Atomic Standard Safety Analysis report, GA-A13200, Vol. I, Chapt. 2, Appendix 2A, Amendment 3 (July 1975).

APPENDIX A

EVALUATION OF THE $M_k(\tau)$, and $\hat{P}_k(\tau)$ FUNCTIONS

The $M_k(\tau)$, $P_k(\tau)$, and $\hat{P}_k(\tau)$ functions are defined by

$$M_o(\Lambda_1,\tau) = e^{-\Lambda_1\tau} , \tag{A-1}$$

$$M_k(\Lambda_1,\alpha,\beta,\tau) = e^{-\Lambda_1\tau} P_{k-1}(-\alpha,\beta,\tau), \quad 1 \leq k \leq 3 \tag{A-2}$$

$$M_4(\gamma,\beta,\tau) = e^{-\gamma\tau-\beta\tau^2} , \tag{A-3}$$

$$M_5(\gamma,\beta,\tau) = \tau e^{-\gamma\tau-\beta\tau^2} , \tag{A-4}$$

$$P_k(\gamma,\beta,\tau) = \int_o^\tau ds\ s^k\ e^{-\gamma s-\beta s^2} , \text{ and} \tag{A-5}$$

$$\hat{P}_k(\tau) = \int_o^\tau ds\ M_k(s). \tag{A-6}$$

First, we investigate the function $P_k(\gamma,\beta,\tau)$ given by Eq. (A-5) as

$$P_k(\gamma,\beta,\tau) = \int_o^\tau ds\ s^k\ e^{-\gamma s-\beta s^2}$$

$$= \left(-\frac{\partial}{\partial\gamma}\right)^k P_o(\gamma,\beta,\tau) . \tag{A-7}$$

Thus, Eq. (A-5) need be integrated only for $k = 0$ as the other forms may be found by differentiation. For $\beta \neq 0$, we find

$$P_o(\gamma,\beta,\tau) = \int_o^\tau ds\ e^{-\gamma s-\beta s^2}$$

$$= \frac{1}{2}\sqrt{\frac{\pi}{\beta}}\ e^{\gamma^2/4\beta} \left[\mathrm{erf}\left(\sqrt{\beta}\tau + \frac{\gamma}{2\sqrt{\beta}}\right) - \mathrm{erf}\left(\frac{\gamma}{2\sqrt{\beta}}\right)\right] . \tag{A-8}$$

For $\beta = 0$, Eq. (A-8) becomes

$$P_o(\gamma,0,\tau) = \frac{1}{\gamma}\,(1 - e^{-\gamma\tau}) \tag{A-9}$$

and for $\beta = \gamma = 0$, we have

$$P_o(0,0,\tau) = \tau\,. \tag{A-10}$$

Using Eq. (A-7) we find for $P_1(\gamma,\beta,\tau)$ and its limiting forms

$$P_1(\gamma,\beta,\tau) = -\frac{\gamma}{2\beta}\,P_o(\gamma,\beta,\tau) + \frac{1}{2\beta}\,(1 - e^{-\gamma\tau-\beta\tau^2})\,, \tag{A-11}$$

$$P_1(\gamma,0,\tau) = \frac{1}{\gamma^2}\,[1 - (1 + \gamma\tau)e^{-\gamma\tau}]\,, \tag{A-12}$$

and

$$P_1(0,0,\tau) = \frac{\tau^2}{2}\,. \tag{A-13}$$

Similarly, for $P_2(\gamma,\beta,\tau)$ we have

$$P_2(\gamma,\beta,\tau) = \frac{1}{4\beta^2}\,[(\gamma^2+2\beta)P_o(\gamma,\beta,\tau) - \gamma(1-e^{-\gamma\tau-\beta\tau^2}) + (\gamma-2\beta\tau)\,e^{-\gamma\tau-\beta\tau^2}]\,, \tag{A-14}$$

$$P_2(\gamma,0,\tau) = \frac{1}{\gamma^3}\,[2 - (2+2\gamma\tau+\gamma^2\tau^2)\,e^{-\gamma\tau}]\,, \tag{A-15}$$

and

$$P_2(0,0,\tau) = \frac{\tau^3}{3}\,. \tag{A-16}$$

Using the results of Eqs.(A-7) - (A-16), we may determine the $M_k(\tau)$ functions as given by Eqs.(A-1) - (A-4). Specifically, for $\beta \neq 0$

$$M_1(\Lambda_1,\alpha,\beta,\tau) = e^{-\Lambda_1\tau} P_o(-\alpha,\beta,\tau), \tag{A-17}$$

$$M_2(\Lambda_1,\alpha,\beta,\tau) = \frac{e^{-\Lambda_1\tau}}{2\beta} [\alpha P_o(-\alpha,\beta,\tau) + 1 - e^{\alpha\tau-\beta\tau^2}], \tag{A-18}$$

and

$$M_3(\Lambda_1,\alpha,\beta,\tau) = \frac{e^{-\Lambda_1\tau}}{4\beta^2} [(\alpha^2+2\beta)P_o(-\alpha,\beta,\tau) + \alpha(1 - e^{\alpha\tau-\beta\tau^2}) - (\alpha-2\beta\tau)e^{\alpha\tau-\beta\tau^2}]. \tag{A-19}$$

For $\beta = 0$ and $\beta = \alpha = 0$, the $M_k(\tau)$ functions for $1 \leq k \leq 3$ are found from Eq. (A-2) and the limiting forms of $P_k(\gamma,\beta,\tau)$.

Next we address the evaluation of $\hat{P}_k(\tau)$. For k = 0, 4, and 5 integration of Eqs (A-1),(A-3), and (A-4) yields

$$\hat{P}_o(\Lambda_1,\tau) = \frac{1}{\Lambda_1} (1 - e^{-\Lambda_1\tau}) , \tag{A-20}$$

$$\hat{P}_4(\gamma,\beta,\tau) = P_o(\gamma,\beta,\tau) , \tag{A-21}$$

and

$$\hat{P}_5(\gamma,\beta,\tau) = P_1(\gamma,\beta,\tau) , \tag{A-22}$$

where we have used Eq. (A-7). For $1 \leq k \leq 3$, using Eqs.(A-6) and (A-2),

$$\hat{P}_k(\Lambda,\gamma,\beta,\tau) = (-\frac{\partial}{\partial\gamma})^k \hat{P}_1(\Lambda,\gamma,\beta,\tau), \tag{A-23}$$

where

$$\hat{P}_1(\Lambda,\gamma,\beta,\tau) = \int_0^\tau ds\ e^{-\Lambda s}\ P_o(\gamma,\beta,s)$$

$$= \frac{1}{\Lambda}\ [P_o(\Lambda+\gamma,\beta,\tau) - e^{-\Lambda\tau}P_o(\gamma,\beta,\tau)], \qquad \text{(A-24)}$$

which can be proved by direct integration using Eq. (A-8). Differentiating Eq. (A-24), according to Eq. (A-23), we find

$$\hat{P}_2(\Lambda,\gamma,\beta,\tau) = \int_0^\tau ds\ e^{-\Lambda s}\ P_1(\gamma,\beta,s)$$

$$= + \frac{(\Lambda+\gamma)}{2\beta\Lambda}\ P_o(\Lambda+\gamma,\beta,\tau) - \frac{\gamma}{2\beta\Lambda}\ e^{-\Lambda\tau}\ P_o(\gamma,\beta,\tau)$$

$$+ \frac{1}{2\beta\Lambda}\ (1 - e^{-\Lambda\tau}) \qquad \text{(A-25)}$$

and

$$\hat{P}_3(\Lambda,\gamma,\beta,\tau) = \int_0^\tau ds\ e^{-\Lambda s}\ P_2(\gamma,\beta,s)$$

$$= \frac{1}{4\beta^2}\{-\frac{[2\beta+(\gamma\ \Lambda)^2]}{\Lambda}\ P_o(\Lambda+\gamma,\beta,\tau)$$

$$+ \frac{(-2\beta+\gamma^2)}{\Lambda}\ e^{-\Lambda\tau}\ P_o(\gamma,\beta,\tau)+(1 - e^{-\beta\tau^2-(\Lambda+\gamma)\tau})$$

$$+ \frac{\gamma}{\Lambda}\ (1 - e^{-\Lambda\tau})\} \qquad \text{(A-26)}$$

Substituting $-\alpha\to\gamma$ and $\Lambda_1\to\Lambda$ in Eqs(A-24) - (A-26), we have the results

$$\hat{P}_1(\Lambda_1,\alpha,\beta,\tau) = \frac{1}{\Lambda_1}\,[P_o(\Lambda_1 - \alpha,\beta,\tau) - e^{-\Lambda_1\tau}\,P_o(-\alpha,\beta,\tau)], \tag{A-27}$$

$$\hat{P}_2(\Lambda_1,\alpha,\beta,\tau) = +\frac{1}{2\beta\Lambda_1}\,[(\Lambda_1-\alpha)P_o(\Lambda_1-\alpha,\beta,\tau)+\alpha e^{-\Lambda_1\tau}\,P_o(-\alpha,\beta,\tau)$$

$$- 1 + e^{-\Lambda_1\tau}], \tag{A-28}$$

and

$$\hat{P}_3(\Lambda_1,\alpha,\beta,\tau) = \frac{1}{4\beta^2}\{-\frac{[2\beta+(\Lambda_1-\alpha)^2]}{\Lambda_1}\,P_o(\Lambda_1-\alpha,\beta,\tau)$$

$$+\frac{(-2\beta+\alpha^2)}{\Lambda_1}\,e^{-\Lambda_1\tau}\,P_o(-\alpha,\beta,\tau)$$

$$+(1 - e^{-\beta\tau^2-(\Lambda_1-\alpha)\tau}) + \frac{\alpha}{\Lambda_1}\,(1 - e^{-\Lambda_1\tau})\} \tag{A-29}$$

For the case $\beta = 0$, $\hat{P}_k(\Lambda,\alpha,0,\tau)$ and $\hat{P}_k(\Lambda,0,0,\tau)$ are clearly integrable and convergent for $k = 2,3$ using the limiting forms for $P_k(\gamma,\beta,\tau)$. However, since for $k = 2,3$ these $\hat{P}_k(\Lambda,\alpha,0,\tau)$ and $\hat{P}_k(\Lambda, 0,0,\tau)$ are multiplied by $\beta\alpha b/2$ in the model solution, they are not needed. On the other hand $\hat{P}_o(\tau)$, $\hat{P}_1(\tau)$, $\hat{P}_4(\tau)$, and $\hat{P}_5(\tau)$ are needed since their coefficients in the model solution are (or can be) nonvanishing even if $\beta = 0$.

For $\beta = 0$, $\hat{P}_o(\Lambda_1,\tau)$ is still given by Eq. (A-20). For $\hat{P}_1(\Lambda,\alpha,0,\tau)$ we may use

$$\hat{P}_1(\Lambda_1,\alpha,0,\tau) = \frac{1}{\Lambda_1}\,[P_o(\Lambda_1-\alpha,0,\tau) - e^{-\Lambda_1\tau}\,P_o(-\alpha,0,\tau)] \tag{A-30}$$

where Eqs. (A-12) and (A-13) are applicable for $P_o(\gamma,0,\tau)$. Similarly,

$$\hat{P}_4(\gamma,0,\tau) = P_o(\gamma,0,\tau) = \frac{1}{\gamma}\,(1-e^{-\gamma\tau}) \tag{A-31}$$

$$\hat{P}_5(\gamma,0,\tau) = P_1(\gamma,0,\tau) = \frac{1}{\gamma^2}\,[1 - (1+\gamma\tau)e^{-\gamma\tau}]. \tag{A-32}$$

APPENDIX B

EVALUATION OF THE $Q_k(\tau)$ AND $V_k(\tau)$ FUNCTIONS

The functions $Q_k(\tau)$ and $V_k(\tau)$ are defined by

$$Q_k(\tau) = \int_o^\tau ds\; e^{\Lambda^* s}\; M_k(s) \tag{B-1}$$

and

$$V_k(\tau) = \int_o^\tau ds\; e^{-\Lambda^* s}\; Q_k(s)\;, \tag{B-2}$$

where the $M_k(\tau)$ functions are given explicitly in Appendix A. We shall need these functions for the parameters Λ^*, Λ_1, α, β, and γ non-zero and zero. However, knowing the limiting forms of the $P_k(\gamma,\beta,\tau)$ functions, using the fact that some functions [$Q_2(\tau)$, $Q_3(\tau)$, $Q_5(\tau)$, $V_2(\tau)$, $V_3(\tau)$, and $V_5(\tau)$] have finite $\beta = 0$ limits and are multiplied by β, and that these same functions are expressible in terms of $Q_o(\tau)$, $Q_1(\tau)$, $Q_4(\tau)$, $V_o(\tau)$, $V_1(\tau)$, and $V_4(\tau)$ leads to considerable simplification in that limiting forms are needed only for the latter functions.

Evaluation of $Q_k(\tau)$

$Q_o(\tau)$: For $\Lambda_1 \neq \Lambda^*$ using Eqs. (B-1) and (A-1), we have

$$Q_o(\Lambda^*,\Lambda_1,\tau) = \int_o^\tau ds\ e^{\Lambda^* s}\ e^{-\Lambda_1 s} = \frac{1}{\Lambda_1-\Lambda^*}\ [1-e^{-(\Lambda_1-\Lambda^*)\tau}] \qquad \text{(B-3)}$$

and for $\Lambda_1 = \Lambda^*$, Eq. (B-3) becomes

$$Q_o(\Lambda^*,\Lambda^*,\tau) = \tau\ . \qquad \text{(B-4)}$$

$Q_1(\tau)$: For $\Lambda_1 \neq \Lambda^*$, using Eqs.(B-1), (A-17) and (A-27) we have

$$Q_1(\Lambda^*,\Lambda_1,\alpha,\beta,\tau) = \int_o^\tau ds\ e^{\Lambda^* s}\ M_1(\Lambda_1,\alpha,\beta,s)$$

$$= \int_o^\tau ds\ e^{\Lambda^* s}\ e^{-\Lambda_1 s}\ P_o(-\alpha,\beta,s)$$

$$= \frac{1}{\Lambda_1-\Lambda^*}\ [P_o(\Lambda_1-\Lambda^*-\alpha,\beta,\tau)\ -e^{-(\Lambda_1-\Lambda^*)\tau}\ P_o(-\alpha,\beta,\tau)]. \qquad \text{(B-5)}$$

For $\Lambda_1 = \Lambda^*$, we have from Eq. (B-5)

$$Q_1(\Lambda^*,\Lambda^*,\alpha,\beta,\tau) = \int_o^\tau ds\ P_o(-\alpha,\beta,s)\ , \qquad \text{(B-6)}$$

where

$$P_o(\gamma,\beta,\tau) = \frac{1}{2}\sqrt{\frac{\pi}{\beta}}\ \ e^{\gamma^2/4\beta}\ [\mathrm{erf}(\sqrt{\beta}\tau + \frac{\gamma}{2\sqrt{\beta}}) - \mathrm{erf}\ (\frac{\gamma}{2\sqrt{\beta}})] \qquad \text{(B-7)}$$

and

$$\int_0^\tau ds\ P_o(\gamma,\beta,s) = \frac{1}{2\beta}\ [(\gamma + 2\beta\tau)P_o(\gamma,\beta,\tau) - 1 + e^{-\gamma\tau-\beta\tau^2}]. \qquad \text{(B-8)}$$

Thus,

$$Q_1(\Lambda^*,\Lambda^*,\alpha,\beta,\tau) = \frac{1}{2\beta}\ [(-\alpha + 2\beta\tau)P_o(-\alpha,\beta,\tau) - 1 + e^{\alpha\tau-\beta\tau^2}]. \qquad \text{(B-9)}$$

Now for $\Lambda_1 = \Lambda^*$, and $\beta = 0$, using Eq. (A-9) in Eq. (B-6) we find

$$Q_1(\Lambda^*,\Lambda^*,\alpha,0,\tau) = \int_0^\tau ds\ P_o(-\alpha,\ 0,s) = \frac{1}{\alpha^2}\ [e^{\alpha\tau} - (1+\alpha\tau)]. \qquad \text{(B-10)}$$

Finally, if $\Lambda_1 = \Lambda^*$, and $\alpha = \beta = 0$, we have

$$Q_1(\Lambda^*,\Lambda^*,0,0,\tau) = \frac{\tau^2}{2}\ , \qquad \text{(B-11)}$$

which follows from the limit of Eq. (B-10) as $\alpha \to 0$ or from using Eq. (A-10) for $P_o(0,0,\tau)$ in Eq. (B-10). The limiting forms for Eq. (B-5) for $\alpha = 0$ and $\beta \neq 0$ follow from Eq. (A-8), namely

$$P_o(0,\beta,\tau) = \frac{1}{2}\sqrt{\frac{\pi}{\beta}}\ \ \mathrm{erf}(\sqrt{\beta\tau})\,. \qquad \text{(B-12)}$$

<u>$Q_2(\tau)$:</u> For $\Lambda_1 \neq \Lambda^*$ and $\beta \neq 0$, using Eqs.(B-1), (A-8), (A-18) and (A-24), we find

$$Q_2(\Lambda^*,\Lambda_1,\alpha,\beta,\tau) = \int_0^\tau ds\ e^{\Lambda^* s}\ M_2(\Lambda_1,\alpha,\beta,s)$$

$$= \frac{1}{2\beta(\Lambda_1-\Lambda^*)}\Big[(\Lambda_1-\Lambda^*-\alpha)P_o(\Lambda_1-\Lambda^*-\alpha,\beta,\tau) + \alpha e^{-(\Lambda_1-\Lambda^*)\tau} \times P_o(-\alpha,\beta,\tau) - [1-e^{-(\Lambda_1-\Lambda^*)\tau}]\Big]. \tag{B-13}$$

Further limiting forms are not needed explicitly. For the cases

(a) $\Lambda_1 = \Lambda^*$, $\beta \neq 0$,

(b) $\Lambda_1 = \Lambda^*$, $\beta = 0$, $\alpha \neq \Lambda_1-\Lambda^*$,

(c) $\Lambda_1 = \Lambda^*$, $\beta = 0$, $\alpha = \Lambda_1-\Lambda^*$,

(d) $\Lambda_1 = \Lambda^*$, $\beta = 0$, $\alpha \neq 0$,

(e) $\Lambda_1 = \Lambda^*$, $\beta = 0$, $\alpha = 0$,

the integral for $Q_2(\Lambda^*,\Lambda_1,\alpha,\beta,\tau)$ is finite. In addition for $\beta = 0$, $Q_2(\tau)$ is independent of β. Since B_2 has a coefficient involving a factor β, the $\beta = 0$ contribution from $Q_2(\tau)$ vanishes. Re-expressing $Q_2(\tau)$ as

$$Q_2(\Lambda^*,\Lambda_1,\alpha,\beta,\tau) = \frac{Q_o(\Lambda^*,\Lambda_1,\tau)-Q_4(\Lambda^*,\Lambda_1-\alpha,\beta,\tau)+\alpha Q_1(\Lambda^*,\Lambda_1,\alpha,\beta,\tau)}{2\beta} \tag{B-14}$$

eliminates the necessity for the $\Lambda_1 = \Lambda^*$ limit since it is automatically accounted for by the limiting forms of $Q_o(\tau)$, $Q_1(\tau)$, and $Q_4(\tau)$. In Eq. (B-14) we have used the identity $\gamma = \Lambda_1-\alpha$ from the definitions given in the text.

<u>$Q_3(\tau)$:</u> For $\Lambda_1 \neq \Lambda^*$ and $\beta \neq 0$, using Eqs.(B-1), (A-7), (A-8), (A-19), and (A-24), we find

$$Q_3(\Lambda^*,\Lambda_1,\alpha,\beta,\tau) = \int_0^\tau ds\ e^{\Lambda^* s}\ M_3(\Lambda_1,\alpha,\beta,s)$$

$$= \frac{1}{4\beta^2}\left\{\frac{[2\beta+(\Lambda_1-\Lambda^*-\alpha)^2]}{\Lambda_1-\Lambda^*}\ P_o(\Lambda_1-\Lambda^*-\alpha,\beta,\tau)\right.$$

$$- \frac{2\beta+\alpha^2}{\Lambda_1-\Lambda^*}\ e^{-(\Lambda_1-\Lambda^*)\tau}\ P_o(-\alpha,\beta,\tau)$$

$$- [1-e^{-\beta\tau^2-(\Lambda_1-\Lambda^*-\alpha)\tau}]$$

$$\left.+ \frac{\alpha}{\Lambda_1-\Lambda^*}\ [1-e^{-(\Lambda_1-\Lambda^*)\tau}]\right\}. \qquad \text{(B-15)}$$

Further limiting cases are not needed explicitly, just as for the $Q_2(\tau)$ function. The coefficient B_3 has a coefficient β, and all the limiting forms involving $\beta = 0$ for $Q_3(\tau)$ are finite and do not involve β. Thus, the $\beta = 0$ contribution from $Q_3(\tau)$ vanishes.

Re-expressing $Q_3(\tau)$ in Eq. (B-15) as

$$Q_3(\Lambda^*,\Lambda_1,\alpha,\beta,\tau) = \frac{Q_1(\Lambda^*,\Lambda_1,\alpha,\beta,\tau)-Q_5(\Lambda^*,\Lambda_1-\alpha,\beta,\tau)+\alpha Q_2(\Lambda^*,\Lambda_1,\alpha,\beta,\tau)}{2\beta} \qquad \text{(B-16)}$$

eliminates the necessity for the $\Lambda_1 = \Lambda^*$ limit since it is automatically accounted for by the limiting forms of $Q_1(\tau)$, $Q_2(\tau)$, and $Q_5(\tau)$.

<u>$Q_4(\tau)$:</u> Using Eqs. (B-1), (A-3), and (A-7) we have

$$Q_4(\Lambda^*,\gamma,\beta,\tau) = \int_0^\tau ds\ e^{\Lambda^* s}\ M_4(\gamma,\beta,s) = P_o(\gamma-\Lambda^*,\beta,\tau). \qquad \text{(B-17)}$$

The limiting forms are given in Appendix A.

$\underline{Q_5(\tau)}$: Using Eqs. (B-1), (A-4) and (A-7) we have

$$Q_5(\Lambda^*,\gamma,\beta,\tau) = \int_0^\tau ds\ e^{\Lambda^* s}\ M_5(\gamma,\beta,s) = P_1(\gamma-\Lambda^*,\beta,\tau). \qquad \text{(B-18)}$$

For $\beta \neq 0$, from Appendix A we have

$$Q_5(\Lambda^*,\gamma,\beta,\tau) = \frac{1}{2\beta}\ [-(\gamma-\Lambda^*)P_o(\gamma-\Lambda^*,\beta,\tau)+1-e^{-(\gamma-\Lambda^*)\tau-\beta\tau^2}]. \qquad \text{(B-19)}$$

Using Eq. (A-12) for $\beta = 0$, $\gamma \neq \Lambda^*$ find

$$Q_5(\Lambda^*,\gamma,0,\tau) = \frac{1}{(\gamma-\Lambda^*)^2}\ \{1-[1+(\gamma-\Lambda^*)\tau]\ e^{-(\gamma-\Lambda^*)\tau}\}. \qquad \text{(B-20)}$$

For $\beta = 0$ and $\gamma = \Lambda^*$, Eq. (B-20) limits to

$$Q_5(\Lambda^*,\Lambda^*,0,\tau) = \frac{\tau^2}{2} \quad . \qquad \text{(B-21)}$$

Since B_5 has β as a factor, the $\beta = 0$ limits will not contribute.

<u>Evaluation of $V_k(\tau)$:</u>

$\underline{V_o(\tau)}$: For $\Lambda_1 \neq \Lambda^*$, using Eqs. (B-2) and (B-3) we have

$$V_o(\Lambda^*,\Lambda_1,\tau) = \int_0^\tau ds\ e^{-\Lambda^* s}\ Q_o(\Lambda^*,\Lambda_1,s)$$

$$= \frac{1}{\Lambda_1-\Lambda^*}\ [\frac{1}{\Lambda^*}\ (1-e^{-\Lambda^*\tau}) - \frac{1}{\Lambda_1}\ (1-e^{-\Lambda_1\tau})]. \qquad \text{(B-22)}$$

For $\Lambda_1 = \Lambda^*$, using Eq. (B-4) in Eq. (B-22) we find

$$V_o(\Lambda^*,\Lambda^*,\tau) = \frac{1}{\Lambda^{*2}} [1-(1+\Lambda^*\tau)\ e^{-\Lambda^*\tau}] \ . \tag{B-23}$$

<u>$V_1(\tau)$:</u> For $\Lambda_1 \neq \Lambda^*$, using Eqs. (B-2), (B-5), and (A-24) we find

$$V_1(\Lambda^*,\Lambda_1,\alpha,\beta,\tau) = \int_o^\tau ds\ e^{-\Lambda^* s}\ Q_1(\Lambda^*,\Lambda_1,\alpha,\beta,s)$$

$$= \frac{1}{\Lambda_1 \Lambda^*}\ P_o(\Lambda_1-\alpha,\beta,\tau)$$

$$- \frac{1}{\Lambda_1-\Lambda^*}\ [\frac{e^{-\Lambda^*\tau}}{\Lambda^*}\ P_o(\Lambda_1-\Lambda^*-\alpha,\beta,\tau)$$

$$- \frac{e^{-\Lambda_1\tau}}{\Lambda_1}\ P_o(-\alpha,\beta,\tau)] \ . \tag{B-24}$$

One could use the identity

$$\int_o^\tau ds\ s\ e^{-\Lambda s}\ P_o(\gamma,\beta,s) = -\frac{\partial}{\partial\Lambda}\ [\hat{P}_1(\Lambda,\gamma,\beta,\tau)]$$

$$= \frac{2\beta-\Lambda(\Lambda+\gamma)}{2\beta\Lambda^2}\ P_o(\Lambda+\gamma,\beta,\tau) - \frac{1+\Lambda\tau}{\Lambda^2}\ e^{-\Lambda\tau}P_o(\gamma,\beta,\tau)$$

$$+ \frac{1}{2\beta\Lambda}\ [1-e^{-\beta\tau^2-(\gamma+\Lambda)\tau}] \ , \tag{B-25}$$

to solve explicitly for $V_1(\Lambda^*,\Lambda^*,\alpha,\beta,\tau)$. On the other hand, one can rewrite Eq. (B-24) as

$$V_1(\Lambda^*,\Lambda_1,\alpha,\beta,\tau) = \frac{V_4(\Lambda^*,\Lambda_1-\alpha,\beta,\tau) - e^{-\Lambda^*\tau}Q_1(\Lambda^*,\Lambda_1,\alpha,\beta,\tau)}{\Lambda_1} \qquad \text{(B-26)}$$

and incorporate the limiting forms from $Q_1(\tau)$ and $V_4(\tau)$.

$\underline{V_2(\tau)}$: For $\Lambda_1 \neq \Lambda^*$ and $\beta \neq 0$, using Eqs. (B-2), (B-13), and (A-24), we find

$$\begin{aligned} V_2(\Lambda^*,\Lambda_1,\alpha,\beta,\tau) &= \int_0^\tau ds\, e^{-\Lambda^* s}\, Q_2(\Lambda^*,\Lambda_1,\alpha,\beta,s) \\ &= \frac{\Lambda_1-\Lambda^*-\alpha}{2\beta(\Lambda_1-\Lambda^*)}\,\frac{1}{\Lambda^*}\,[P_o(\Lambda_1-\alpha,\beta,\tau)-e^{-\Lambda^*\tau}P_o(\Lambda_1-\Lambda^*-\alpha,\beta,\tau)] \\ &\quad + \frac{\alpha}{2\beta(\Lambda_1-\Lambda^*)}\,\frac{1}{\Lambda_1-\Lambda^*}\,[P_o(\Lambda_1-\Lambda^*-\alpha,\beta,\tau)-e^{(\Lambda_1-\Lambda)\tau}\times \\ &\qquad P_o(-\alpha,\beta,\tau)] \\ &\quad - \frac{1}{2\beta(\Lambda_1-\Lambda^*)}\,[\frac{1}{\Lambda^*}(1-e^{-\Lambda^*\tau}) - \frac{1}{\Lambda_1}(1-e^{-\Lambda_1\tau})]. \end{aligned} \qquad \text{(B-27)}$$

Further limiting forms are not needed explicitly. For the cases given in connection with $Q_2(\tau)$, all the $V_2(\tau)$ integrals are also finite. In addition in the $\beta = 0$ limit they are finite and independent of β. Since B_2 has a factor β, the contribution $B_2V_2(\tau)$ is zero.

We may re-express $V_2(\tau)$ as

$$V_2(\Lambda^*,\Lambda_1,\alpha,\beta,\tau) = \frac{V_o(\Lambda^*,\Lambda_1,\tau) - V_4(\Lambda^*,\Lambda_1-\alpha,\beta,\tau) + \alpha V_1(\Lambda^*,\Lambda_1,\alpha,\beta,\tau)}{2\beta}, \tag{B-28}$$

which eliminates the necessity for using an explicit $\Lambda_1 = \Lambda^*$ limit except through the limiting forms for $V_o(\tau)$, $V_1(\tau)$, and $V_4(\tau)$.

<u>$V_3(\tau)$:</u> For $\Lambda_1 \neq \Lambda^*$ and $\beta \neq 0$, using Eqs. (B-2), (B-15) and (A-24), we find

$$\begin{aligned}
V_3(\Lambda^*,\Lambda_1,\alpha,\beta,\tau) &= \int_o^\tau ds\, e^{-\Lambda^* s}\, Q_3(\Lambda^*,\Lambda_1,\alpha,\beta,s) \\
&= \frac{1}{4\beta^2}\left\{\frac{[2\beta+(\Lambda_1-\Lambda^*-\alpha)^2]}{\Lambda^*(\Lambda_1-\Lambda^*)} - \frac{2\beta+\alpha^2}{\Lambda_1(\Lambda_1-\Lambda^*)} + 1\right\}P_o(\Lambda_1-\alpha,\beta,\tau) \\
&\quad + \frac{1}{4\beta^2}\,\frac{2\beta+\alpha^2}{\Lambda_1(\Lambda_1-\Lambda^*)}\, e^{-\Lambda_1\tau}\, P_o(-\alpha,\beta,\tau) \\
&\quad - \frac{1}{4\beta^2}\,\frac{2\beta+(\Lambda_1-\Lambda^*-\alpha^2)}{\Lambda^*(\Lambda_1-\Lambda^*)}\, e^{-\Lambda^*\tau}\, P_o(\Lambda_1-\Lambda^*-\alpha,\beta,\tau) \\
&\quad - \frac{1}{4\beta^2}\,\frac{1}{\Lambda^*}\,(1-e^{-\Lambda^*\tau}) \\
&\quad + \frac{1}{4\beta^2}\,\frac{\alpha}{\Lambda_1-\Lambda^*}\left[\frac{1}{\Lambda^*}(1-e^{-\Lambda^*\tau}) - \frac{1}{\Lambda_1}(1-e^{-\Lambda_1\tau})\right]
\end{aligned} \tag{B-29}$$

Further limiting forms are not needed explicitly, just as for the $V_2(\tau)$ function. The coefficient B_3 has a factor β, and all the limiting forms involving $\beta = 0$ for $V_3(\tau)$ are finite and do not involve β. Thus, the $B_3V_3(\tau)$ contribution vanishes for $\beta = 0$.

Re-expressing $V_3(\tau)$ we have

$$V_3(\Lambda^*,\Lambda_1,\alpha,\beta,\tau) = \frac{V_1(\Lambda^*,\Lambda_1,\alpha,\beta,\tau)-V_5(\Lambda^*,\Lambda_1-\alpha,\beta,\tau)+\alpha V_2(\Lambda^*,\Lambda_1,\alpha,\beta,\tau)}{2\beta}, \tag{B-30}$$

which eliminates the necessity for using explicit limiting forms for $\Lambda_1 = \Lambda^*$ except in $V_1(\tau)$, $V_2(\tau)$ and $V_5(\tau)$. Of course, $V_2(\tau)$, as given by Eq. (B-28) is expressible in terms of $V_o(\tau)$, $V_1(\tau)$, and $V_4(\tau)$.

<u>$V_4(\tau)$:</u> Using Eqs. (B-2),(B-17), and (A-24), we find

$$V_4(\Lambda^*,\gamma,\beta,\tau) = \int_o^\tau ds\ e^{-\Lambda^* s}\ Q_4(\Lambda^*,\gamma,\beta,s)$$

$$= \frac{1}{\Lambda^*}\ [P_o(\gamma,\beta,\tau) - e^{-\Lambda^*\tau}\ P_o(\gamma-\Lambda^*,\beta,\tau)] \tag{B-31}$$

The limiting forms for $V_4(\tau)$ are accounted for by the forms given for the $P_o(\gamma,\beta,\tau)$ function in Appendix A.

<u>$V_5(\tau)$:</u> For $\beta \neq 0$, using Eqs. (B-2),(B-18), and (A-24), we find

$$V_5(\Lambda^*,\gamma,\beta,\tau) = \int_0^\tau ds\ e^{-\Lambda^* s}\ Q_5(\Lambda^*,\gamma,\beta,s)$$

$$= -\frac{\gamma}{2\beta\Lambda^*} P_o(\gamma,\beta,\tau) + \frac{\gamma-\Lambda^*}{2\beta\Lambda^*} e^{-\Lambda^*\tau} P_o(\gamma-\Lambda^*,\beta,\tau)$$

$$+ \frac{1}{2\beta\Lambda^*} (1-e^{-\Lambda^*\tau}) \qquad \text{(B-32)}$$

The limiting cases for $\beta = 0$ yield finite integrals for $V_5(\tau)$. Since B_5 has a factor β, the $\beta = 0$ limit contribution from $V_5(\tau)$ vanishes. The necessity for writing the other limiting cases for $V_5(\tau)$ is removed by re-expressing Eq. (B-32) for $\beta \neq 0$ as

$$V_5(\Lambda^*,\gamma,\beta,\tau) = \frac{\frac{1}{\Lambda^*}(1-e^{-\Lambda^*\tau}) - \gamma V_4(\Lambda^*,\gamma,\beta,\tau) - e^{-\Lambda^*\tau} Q_4(\Lambda^*,\gamma,\beta,\tau)}{2\beta} \qquad \text{(B-33)}$$

and using the limiting forms for $V_4(\tau)$ and $Q_4(\tau)$.

APPENDIX C
CODE LISTING FOR LARC-1

LASL Identification: LP-0721

```
COPYSF      3 FILES FROM COMPILE

      PROGRAM LARC1 (INP,OUT,FILM,FSET12=FILM)                          LARC1      2
      PARAMETER (N500=500),(N501=N500+1)                                LARC1      3
      REAL NPRIME,L,N1,N2,N3,N4,NZER,NZERO,LAMBDA                       LARC1      4
      DIMENSION NPRIME(N500), L(N500), T(N501), RPRIME(N500), RSUM(N500) LARC1      5
     1, V(N500), FF(N501), ZN(N500), ZR(N500), ZA(N500), ZF(N500), ZN1(N LARC1      6
     2500), ZN2(N500), ZN3(N500), ZN4(N500), ZR1(N500), ZR2(N500), ZR3(N LARC1      7
     3500), ZR4(N500), ZA1(N500), ZA2(N500), ZA3(N500), ZA4(N500), ZF1(N LARC1      8
     4500), ZF2(N500), ZF3(N500), ZF4(N500), TABLE(N500,4), TABLX(N500,4 LARC1      9
     5)                                                                 LARC1     10
      DIMENSION TITLE1(7), TITLE2(6), TITLE3(4), XLIM(2), YLIM(2)        LARC1     11
      DIMENSION ISET(6), NSET(5)                                        LARC1     12
      COMMON /LINEW/ IXSAVE,IYSAVE,IX2,IY2                              LARC1     13
      LOGICAL LAGE,BISO,NOBGAS                                          LARC1     14
      REAL N1OLD,N2OLD,N3OLD,N4OLD                                      LARC1     15
      COMMON /LA/ LAGE,AGE,MFUEL,ISO,BISO                               LARC1     16
      COMMON /TMODEL/ MODEL                                             LARC1     17
C     MODEL = 1     SORS DATA FROM TMAX, TAVE GRAPHS                    LARC1     18
C     MODEL = 2     CORCON TABULAR DATA                                 LARC1     19
C     MODEL = 3     FU - CORT TABULAR DATA                              LARC1     20
      DATA ISET/1,5,10,25,100,200/                                      LARC1     21
      DATA NSET/20,40,100,300,500/                                      LARC1     22
      INUM=6                                                            LARC1     23
      NNUM=5                                                            LARC1     24
      NEQ=4                                                             LARC1     25
C     NEQ INDICATES WHICH EQUATION SET TO USE                           LARC1     26
C     NEQ = 1       SIMPLE EQ FIRST HALF, OLD EQ SECOND HALF            LARC1     27
C     NEQ = 2       SIMPLE EQ BOTH HALVES                               LARC1     28
C     NEQ = 3       LINEAR RELEASE BOTH HALVES                          LARC1     29
C     NEQ = 4       LINEAR FAILURE BOTH HALVES                          LARC1     30
      NZER=3.1*3.E9/3.7                                                 LARC1     31
      CALL GETQ (4LKJBN,JOBNAME)                                        LARC1     32
      CALL DATE1 (DATE)                                                 LARC1     33
      Z=FRACR0(0.0)                                                     LARC1     34
      ITEMP=4                                                           LARC1     35
      ITEMP=1                                                           LARC1     36
      IF (ITEMP.EQ.4) Z=SPLINE(0.0,0.0)                                 LARC1     37
   10 CONTINUE                                                          LARC1     38
      READ 360, NAME,LAMBDA,ISO,YIELD,AGE,MFUEL,LAGE,FRAC,NOBGAS        LARC1     39
      IF (ISO.LT.1) GO TO 200                                           LARC1     40
      NZERO=NZER*YIELD                                                  LARC1     41
C     UNITS OF NZERO ARE CI (CURIES).                                   LARC1     42
      PRINT 220, NAME,LAMBDA,ISO,YIELD,NZERO                            LARC1     43
      PRINT 230, AGE,LAGE,FRAC                                          LARC1     44
      IF (NOBGAS) PRINT 240                                             LARC1     45
      VSET=0.9                                                          LARC1     46
      IF (NOBGAS) VSET=0.0                                              LARC1     47
C     I ASSUMED RELEASED AS  91 PERCENT ELEMENTAL, 5 PERCENT PARTICULATE LARC1     48
C      AND 4 PERCENT ORGANIC.                                           LARC1     49
C     FOR THESE MATERIALS THE CLEANUP SYSTEM FILTER EFFICIENCIES ARE    LARC1     50
C      .90, .99, AND .70 RESPECTIVELY.                                  LARC1     51
C     THEREFORE EACH RELEASE IS REDUCED BY                              LARC1     52
C          (.90).91 + (.05).99 + (.04).70 = .8965                       LARC1     53
C     RELEASED FRACTION IS THEREFORE .1035                              LARC1     54
C     LAMBDA IS THE RADIOACTIVE DECAY CONSTANT IN UNITS OF PER HOUR     LARC1     55
      IVEMAX=100                                                        LARC1     56
      NTOT=100                                                          LARC1     57
      PRINT 210, NEQ                                                    LARC1     58
      IPRTF=NTOT/20                                                     LARC1     59
      PRINT 250, NTOT                                                   LARC1     60
C     NTOT IS THE TOTAL NUMBER OF INTERVALS                             LARC1     61
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      DT=20./NTOT                                                       LARC1     62
      NTOT1=NTOT+1                                                      LARC1     63
      DO 20 I=1,NTOT1                                                   LARC1     64
   20 T(I)=(I-1)*DT                                                     LARC1     65
      DO 190 NR=1,ITEMP                                                 LARC1     66
      MODEL=NR                                                          LARC1     67
      PRINT 260, MODEL,MFUEL,NAME                                       LARC1     68
      IF (NR.EQ.4) GO TO 40                                             LARC1     69
C     CALCULATE SECOND DERIVATIVES FOR SPLINE....                       LARC1     70
      Z=TMAX0(0.0)                                                      LARC1     71
      Z=TAVE0(0.0)                                                      LARC1     72
      Z=TEMP0(0.0)                                                      LARC1     73
C     T(I) ARE THE TIMES OF THE INTERVAL BOUNDARIES (IN HOURS)          LARC1     74
      TDELT=TEMP(0.0)-1174.4                                            LARC1     75
      DO 30 I=1,NTOT1                                                   LARC1     76
      TIME=T(I)                                                         LARC1     77
   30 FF(I)=(TMAX(TIME)-TAVE(TIME))/TDELT                               LARC1     78
   40 CONTINUE                                                          LARC1     79
      XLIM(1)=T(1)                                                      LARC1     80
      XLIM(2)=T(NTOT1)                                                  LARC1     81
      DO 50 I=1,NTOT                                                    LARC1     82
      ZN1(I)=0.0                                                        LARC1     83
      ZN2(I)=0.0                                                        LARC1     84
      ZN3(I)=0.0                                                        LARC1     85
      ZN4(I)=0.0                                                        LARC1     86
      ZR1(I)=0.0                                                        LARC1     87
      ZR2(I)=0.0                                                        LARC1     88
      ZR3(I)=0.0                                                        LARC1     89
      ZR4(I)=0.0                                                        LARC1     90
      ZA1(I)=0.0                                                        LARC1     91
      ZA2(I)=0.0                                                        LARC1     92
      ZA3(I)=0.0                                                        LARC1     93
      ZA4(I)=0.0                                                        LARC1     94
      ZF1(I)=0.0                                                        LARC1     95
      ZF2(I)=0.0                                                        LARC1     96
      ZF3(I)=0.0                                                        LARC1     97
      ZF4(I)=0.0                                                        LARC1     98
C     1 REFERS TO FAILED BISO                                           LARC1     99
C     2 REFERS TO FAILED TRISO                                          LARC1    100
C     3 REFERS TO INTACT BISO                                           LARC1    101
C     4 REFERS TO INTACT TRISO                                          LARC1    102
C     NPRIME(I) IS THE AMOUNT OF THE ISOTOPE PRESENT IN THE CONTAINMENT LARC1    103
C     BUILDING AT THE END OF THE ITH TIME INTERVAL (I.E. AT TIME T(I)). LARC1    104
      NPRIME(I)=0.0                                                     LARC1    105
      RPRIME(I)=0.0                                                     LARC1    106
      RSUM(I)=0.0                                                       LARC1    107
      L(I)=.001/24                                                      LARC1    108
      V(I)=VSET                                                         LARC1    109
C     L IS THE CONTAINMENT BUILDING LEAK RATE..ASSUMED TO BE .001/DAY   LARC1    110
C     FOR THE FIRST 24 HOURS AND .0005/DAY THEREAFTER.                  LARC1    111
C     VSET=.0965                                                        LARC1    112
C     VSET ASSUMED TO BE .9 BY FOLEY.                                   LARC1    113
   50 CONTINUE                                                          LARC1    114
      PRINT 270, IVFMAX                                                 LARC1    115
      PER=1./IVFMAX                                                     LARC1    116
      DO 120 IVF=1,IVFMAX                                               LARC1    117
      BIN=PER*(IVF-0.5)                                                 LARC1    118
      IF (NR.NE.4) TEM=TEMP(BIN)                                        LARC1    119
C     TEM IS THE INITIAL AVERAGE TEMPERATURE OF ONE PERCENT OF THE TOTAL LARC1    120
C     CORE INVENTORY                                                    LARC1    121
      IF (NR.NE.4) TE=FF(1)*(TEM-1174.4)+TAVE(T(1))                     LARC1    122
      IF (NR.EQ.4) TE=SPL(0.,BIN)                                       LARC1    123
      FB=FRACB(TE)                                                      LARC1    124
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      FT=FRACT(TE)                                                      LARC1   125
C     FRACB = FRACTION OF BISO PARTICLES WITH FAILED COATINGS           LARC1   126
C     FRACT = FRACTION OF TRISO PARTICLES WITH FAILED COATINGS          LARC1   127
C     FRAC = 0.6 = FRACTION OF BISO FUEL IN THE LOADING                 LARC1   128
      BISO=.T.                                                          LARC1   129
      R1=RF(TE)                                                         LARC1   130
      R3=RI(TE)                                                         LARC1   131
      BISO=.FALSE.                                                      LARC1   132
      R2=RF(TE)                                                         LARC1   133
      R4=RI(TE)                                                         LARC1   134
      N1=NZERO*PER*FRAC*FB                                              LARC1   135
      N2=NZERO*PER*(1.0-FRAC)*FT                                        LARC1   136
      N3=NZERO*PER*FRAC*(1.0-FB)                                        LARC1   137
      N4=NZERO*PER*(1.0-FRAC)*(1.0-FT)                                  LARC1   138
      A1=0.0                                                            LARC1   139
      A2=0.0                                                            LARC1   140
      A3=0.0                                                            LARC1   141
      A4=0.0                                                            LARC1   142
C     NI IS THE AMOUNT OF THE ITH COMPONENT REMAINING IN THE CORE       LARC1   143
C     RRI IS THE AMOUNT OF THE ITH COMPONENT RELEASED TO THE COOLANT    LARC1   144
C     AI IS THE AMOUNT OF THE ITH COMPONENT IN THE COOLANT              LARC1   145
C     ALL THESE REFER TO THE GIVEN TIME STEP AND CORE FRACTION.         LARC1   146
      SUM=0.0                                                           LARC1   147
      PN1=0.0                                                           LARC1   148
      PN2=0.0                                                           LARC1   149
      PN3=0.0                                                           LARC1   150
      PN4=0.0                                                           LARC1   151
      DO 110 I=1,NTOT                                                   LARC1   152
      DT=T(I+1)-T(I)                                                    LARC1   153
      FBOLD=FB                                                          LARC1   154
      FTOLD=FT                                                          LARC1   155
      TIME=T(I+1)                                                       LARC1   156
C     TEMPB=TEMPERATURE AT BOUNDARY TIMES                               LARC1   157
      IF (NR.NE.4) TEMPB=FF(I+1)*(TEM-1174.4)+TAVE(TIME)                LARC1   158
      IF (NR.EQ.4) TEMPB=SPL(TIME,BIN)                                  LARC1   159
      FB=FRACB(TEMPB)                                                   LARC1   160
      FT=FRACT(TEMPB)                                                   LARC1   161
      R1OLD=R1                                                          LARC1   162
      R2OLD=R2                                                          LARC1   163
      R3OLD=R3                                                          LARC1   164
      R4OLD=R4                                                          LARC1   165
      BISO=.TRUE.                                                       LARC1   166
      R1=RF(TEMPB)                                                      LARC1   167
      R3=RI(TEMPB)                                                      LARC1   168
      BISO=.FALSE.                                                      LARC1   169
      R2=RF(TEMPB)                                                      LARC1   170
      R4=RI(TEMPB)                                                      LARC1   171
C     R(I) IS THE AVERAGE RELEASE CONSTANT OF THE ISOTOPE DURING THE ITH LARC1   172
C     INTERVAL.                                                         LARC1   173
      N1OLD=N1                                                          LARC1   174
      N2OLD=N2                                                          LARC1   175
      N3OLD=N3                                                          LARC1   176
      N4OLD=N4                                                          LARC1   177
      DECAY=LAMBDA+V(I)+L(I)                                            LARC1   178
      GO TO (60,70,80,90), NEQ                                          LARC1   179
   60 CONTINUE                                                          LARC1   180
      CALL CALC1 (N1,N3,R1,R3,LAMBDA,DT,FB,N1,N3,RR1,RR3,R1OLD,R3OLD)   LARC1   181
      CALL CALC1 (N2,N4,R2,R4,LAMBDA,DT,FT,N2,N4,RR2,RR4,R2OLD,R4OLD)   LARC1   182
      CALL FTN (PN1,RP1,RR1,LAMBDA,DECAY,DT,L(I))                       LARC1   183
      CALL FTN (PN2,RP2,RR2,LAMBDA,DECAY,DT,L(I))                       LARC1   184
      CALL FTN (PN3,RP3,RR3,LAMBDA,DECAY,DT,L(I))                       LARC1   185
      CALL FTN (PN4,RP4,RR4,LAMBDA,DECAY,DT,L(I))                       LARC1   186
      GO TO 100                                                         LARC1   187
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   70 CONTINUE                                                          LARC1    188
      CALL CALC1 (N1,N3,R1,R3,LAMBDA,DT,FB,N1,N3,RR1,RR3,R1OLD,R3OLD)   LARC1    189
      CALL CALC1 (N2,N4,R2,R4,LAMBDA,DT,FT,N2,N4,RR2,RR4,R2OLD,R4OLD)   LARC1    190
      CALL FTN1 (PN1,RP1,LAMBDA,DECAY,DT,L(I),N1OLD,R1,R1OLD)           LARC1    191
      CALL FTN1 (PN2,RP2,LAMBDA,DECAY,DT,L(I),N2OLD,R2,R2OLD)           LARC1    192
      CALL FTN1 (PN3,RP3,LAMBDA,DECAY,DT,L(I),N3OLD,R3,R3OLD)           LARC1    193
      CALL FTN1 (PN4,RP4,LAMBDA,DECAY,DT,L(I),N4OLD,R4,R4OLD)           LARC1    194
      GO TO 100                                                         LARC1    195
   80 CONTINUE                                                          LARC1    196
      CALL CALC2 (N1,N3,R1,R3,LAMBDA,DT,FB,N1,N3,RR1,RR3,R1OLD,R3OLD)   LARC1    197
      CALL CALC2 (N2,N4,R2,R4,LAMBDA,DT,FT,N2,N4,RR2,RR4,R2OLD,R4OLD)   LARC1    198
      CALL FTN2 (PN1,RP1,LAMBDA,DECAY,DT,L(I),N1OLD,R1,R1OLD)           LARC1    199
      CALL FTN2 (PN2,RP2,LAMBDA,DECAY,DT,L(I),N2OLD,R2,R2OLD)           LARC1    200
      CALL FTN2 (PN3,RP3,LAMBDA,DECAY,DT,L(I),N3OLD,R3,R3OLD)           LARC1    201
      CALL FTN2 (PN4,RP4,LAMBDA,DECAY,DT,L(I),N4OLD,R4,R4OLD)           LARC1    202
      GO TO 100                                                         LARC1    203
   90 CONTINUE                                                          LARC1    204
      CALL CALC3 (N1,N3,R1,R3,LAMBDA,DT,FB,FBOLD,N1,N3,RR1,RR3,R1OLD,R3O LARC1    205
     1LD)                                                               LARC1    206
      CALL CALC3 (N2,N4,R2,R4,LAMBDA,DT,FT,FTOLD,N2,N4,RR2,RR4,R2OLD,R4O LARC1    207
     1LD)                                                               LARC1    208
      CALL FTN3 (PN1,PN3,RP1,RP3,LAMBDA,DECAY,DT,L(I),N1OLD,N3OLD,R1,R1O LARC1    209
     1LD,R3,R3OLD,FB,FBOLD)                                             LARC1    210
      CALL FTN3 (PN2,PN4,RP2,RP4,LAMBDA,DECAY,DT,L(I),N2OLD,N4OLD,R2,R2O LARC1    211
     1LD,R4,R4OLD,FT,FTOLD)                                             LARC1    212
  100 CONTINUE                                                          LARC1    213
      ELD=EXP(-LAMBDA*DT)                                               LARC1    214
      A1=A1*ELD+RR1                                                     LARC1    215
      A2=A2*ELD+RR2                                                     LARC1    216
      A3=A3*ELD+RR3                                                     LARC1    217
      A4=A4*ELD+RR4                                                     LARC1    218
C     ZNI(J) IS THE TOTAL AMOUNT OF THE ITH COMPONENT REMAINING IN THE  LARC1    219
C     CORE AT THE END OF THE JTH INTERVAL                               LARC1    220
C     ZRI(J) IS THE TOTAL AMOUNT OF THE ITH COMPONENT RELEASED TO THE   LARC1    221
C     COOLANT DURING THE JTH INTERVAL                                   LARC1    222
C     ZAI(J) IS THE AMOUNT OF THE ITH COMPONENT IN THE COOLANT AT THE   LARC1    223
C     END OF THE JTH INTERVAL                                           LARC1    224
C     ZFI(J) IS THE FRACTION OF THE ITH COMPONENT IN THE COOLANT AT THE LARC1    225
C     END OF THE JTH INTERVAL                                           LARC1    226
      PN=PN1+PN2+PN3+PN4                                                LARC1    227
      RP=RP1+RP2+RP3+RP4                                                LARC1    228
      NPRIME(I)=NPRIME(I)+PN                                            LARC1    229
      RPRIME(I)=RPRIME(I)+RP                                            LARC1    230
      SUM=SUM+RP                                                        LARC1    231
      RSUM(I)=RSUM(I)+SUM                                               LARC1    232
      ZN1(I)=ZN1(I)+N1                                                  LARC1    233
      ZN2(I)=ZN2(I)+N2                                                  LARC1    234
      ZN3(I)=ZN3(I)+N3                                                  LARC1    235
      ZN4(I)=ZN4(I)+N4                                                  LARC1    236
      ZR1(I)=ZR1(I)+RR1                                                 LARC1    237
      ZR2(I)=ZR2(I)+RR2                                                 LARC1    238
      ZR3(I)=ZR3(I)+RR3                                                 LARC1    239
      ZR4(I)=ZR4(I)+RR4                                                 LARC1    240
      ZA1(I)=ZA1(I)+A1                                                  LARC1    241
      ZA2(I)=ZA2(I)+A2                                                  LARC1    242
      ZA3(I)=ZA3(I)+A3                                                  LARC1    243
      ZA4(I)=ZA4(I)+A4                                                  LARC1    244
      ZF1(I)=ZF1(I)+A1/NZERO                                            LARC1    245
      ZF2(I)=ZF2(I)+A2/NZERO                                            LARC1    246
      ZF3(I)=ZF3(I)+A3/NZERO                                            LARC1    247
      ZF4(I)=ZF4(I)+A4/NZERO                                            LARC1    248
  110 CONTINUE                                                          LARC1    249
  120 CONTINUE                                                          LARC1    250
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      DO 130 I=1,NTOT                                                   LARC1     251
      ZN(I)=ZN1(I)+ZN2(I)+ZN3(I)+ZN4(I)                                 LARC1     252
      ZR(I)=ZR1(I)+ZR2(I)+ZR3(I)+ZR4(I)                                 LARC1     253
      ZA(I)=ZA1(I)+ZA2(I)+ZA3(I)+ZA4(I)                                 LARC1     254
      ZF(I)=ZF1(I)+ZF2(I)+ZF3(I)+ZF4(I)                                 LARC1     255
      TABLE(I,NR)=ZF(I)                                                 LARC1     256
      TABLX(I,NR)=RSUM(I)                                               LARC1     257
  130 CONTINUE                                                          LARC1     258
      PRINT 310                                                         LARC1     259
      PRINT 320, (I,T(I+1),ZR(I),ZN(I),ZA(I),ZF(I),I=IPRTF,NTOT,IPRTF)  LARC1     260
      IF (NR.NE.ITEMP) GO TO 160                                        LARC1     261
      IOP=1                                                             LARC1     262
C     LINEAR-LINEAR PLOT  X,Y AXES                                      LARC1     263
      NCHAR=57                                                          LARC1     264
C     CHARACTER WILL BE  .                                              LARC1     265
      ICON=1                                                            LARC1     266
C     POINTS WILL BE CONNECTED                                          LARC1     267
      YLIM(1)=100.                                                      LARC1     268
      YLIM(2)=0.                                                        LARC1     269
      DO 140 II=1,NTOT                                                  LARC1     270
      DO 140 JJ=1,NR                                                    LARC1     271
      YLIM(1)=AMIN1(YLIM(1),TABLE(II,JJ))                               LARC1     272
      YLIM(2)=AMAX1(YLIM(2),TABLE(II,JJ))                               LARC1     273
  140 CONTINUE                                                          LARC1     274
      CALL SPLOT (IOP,2,XLIM,YLIM,48,0)                                 LARC1     275
      ENCODE (67,280,TITLE1)NAME,ISO,MFUEL,AGE,LAGE,FRAC,YIELD          LARC1     276
      ENCODE (60,290,TITLE2)NTOT,IVFMAX,JOBNAME,DATE                    LARC1     277
      ENCODE (35,240,TITLE3)                                            LARC1     278
      DO 150 IR=1,NR                                                    LARC1     279
      CALL PLOT (NTOT,T(2),1,TABLE(1,IR),1,NCHAR,ICON)                  LARC1     280
      ENCODE (5,350,TSAVE)IR                                            LARC1     281
      CALL WLCH (IXSAVE-15,IYSAVE,5,TSAVE,1)                            LARC1     282
  150 CONTINUE                                                          LARC1     283
      CALL WLCV (50,800,20,20HFRACTION IN COOLANT ,1)                   LARC1     284
      CALL WLCH (300,940,36,36HTIME AFTER ONSET OF ACCIDENT (HOURS),1)  LARC1     285
      CALL WLCH (100,965,67,TITLE1,1)                                   LARC1     286
      CALL WLCH (100,990,60,TITLE2,1)                                   LARC1     287
      IF (NEQ.EQ.1) CALL WLCH (100,5,64,64HNEQ=1  CONSTANT RELEASE RATE, LARC1     288
     1 CONSTANT FAILURE, AVERAGED RELEASE,1)                            LARC1     289
      IF (NEQ.EQ.2) CALL WLCH (100,5,46,46HNEQ=2  CONSTANT RELEASE RATE, LARC1     290
     1 CONSTANT FAILURE,1)                                              LARC1     291
      IF (NEQ.EQ.3) CALL WLCH (100,5,44,44HNEQ=3  LINEAR RELEASE RATE, C LARC1     292
     1ONSTANT FAILURE,1)                                                LARC1     293
      IF (NEQ.EQ.4) CALL WLCH (100,5,44,44HNEQ=4  CONSTANT RELEASE RATE, LARC1     294
     1 LINEAR FAILURE,1)                                                LARC1     295
      CALL ADV (1)                                                      LARC1     296
  160 CONTINUE                                                          LARC1     297
      PRINT 340                                                         LARC1     298
      PRINT 330, (I,T(I+1),NPRIME(I),RPRIME(I),RSUM(I),I=IPRTF,NTOT,IPRT LARC1     299
     1F)                                                                LARC1     300
      IF (NR.NE.ITEMP) GO TO 190                                        LARC1     301
      YLIM(1)=100.                                                      LARC1     302
      YLIM(2)=0.                                                        LARC1     303
      DO 170 II=1,NTOT                                                  LARC1     304
      DO 170 JJ=1,ITEMP                                                 LARC1     305
      YLIM(1)=AMIN1(YLIM(1),TABLX(II,JJ))                               LARC1     306
      YLIM(2)=AMAX1(YLIM(2),TABLX(II,JJ))                               LARC1     307
  170 CONTINUE                                                          LARC1     308
      CALL SPLOT (IOP,2,XLIM,YLIM,48,0)                                 LARC1     309
      DO 180 IS=1,ITEMP                                                 LARC1     310
      CALL PLOT (NTOT,T(2),1,TABLX(1,IS),1,NCHAR,ICON)                  LARC1     311
      ENCODE (5,350,TSAVE)IS                                            LARC1     312
      CALL WLCH (IXSAVE-15,IYSAVE,5,TSAVE,1)                            LARC1     313
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  180 CONTINUE                                                          LARC1     314
      CALL WLCV (50,800,26,26HCUMULATED RELEASE (CURIES),1)             LARC1     315
      IF (NEQ.EQ.1) CALL WLCH (100,5,64,64HNEQ=1  CONSTANT RELEASE RATE, LARC1     316
     1 CONSTANT FAILURE, AVERAGED RELEASE,1)                            LARC1     317
      IF (NEQ.EQ.2) CALL WLCH (100,5,46,46HNEQ=2  CONSTANT RELEASE RATE, LARC1     318
     1 CONSTANT FAILURE,1)                                              LARC1     319
      IF (NEQ.EQ.3) CALL WLCH (100,5,44,44HNEQ=3  LINEAR RELEASE RATE, C LARC1     320
     1ONSTANT FAILURE,1)                                                LARC1     321
      IF (NEQ.EQ.4) CALL WLCH (100,5,44,44HNEQ=4  CONSTANT RELEASE RATE, LARC1     322
     1 LINEAR FAILURE,1)                                                LARC1     323
      CALL WLCH (300,940,36,36HTIME AFTER ONSET OF ACCIDENT (HOURS),1)  LARC1     324
      CALL WLCH (100,965,67,TITLE1,1)                                   LARC1     325
      CALL WLCH (100,990,60,TITLE2,1)                                   LARC1     326
      IF (NOBGAS) CALL WLCH (100,1023,35,TITLE3,1)                      LARC1     327
      CALL ADV (1)                                                      LARC1     328
  190 CONTINUE                                                          LARC1     329
      GO TO 10                                                          LARC1     330
  200 CALL EXIT                                                         LARC1     331
C                                                                       LARC1     332
  210 FORMAT (* NEQ =*,I1)                                              LARC1     333
  220 FORMAT (1X,A10,5X,16HDECAY CONSTANT =,E10.3,5X,7HGROUP =,I2,5X,7HY LARC1     334
     1IELD =,E10.3,5X,7HNZERO =,E10.3)                                  LARC1     335
  230 FORMAT (6H AGE =,F6.2,5X,6HLAGE =,L1,5X,6HFRAC =,F6.2)            LARC1     336
  240 FORMAT (* NOBLE GAS....CLEANUP RATE ZERO     *)                   LARC1     337
  250 FORMAT (* NTOT =*,I5)                                             LARC1     338
  260 FORMAT (* TEMPERATURE MODEL USED =*,I2,5X,*MFUEL =*,I1,5X,*ISOTOPE LARC1     339
     1 =*,A10)                                                          LARC1     340
  270 FORMAT (* IVFMAX =*,I5)                                           LARC1     341
  280 FORMAT (A10,*ISO=*,I2,2X,*MFUEL=*,I1,2X,*AGE=*,F4.1,2X,*LAGE=*,L1, LARC1     342
     12X,*FRAC=*,F4.1,2X,*YIELD=*,F5.2)                                 LARC1     343
  290 FORMAT (*NTOT=*,I4,2X,*IVFMAX=*,I3,10X,*JOB=*,A10,2X,*DATE=*,A8)  LARC1     344
  300 FORMAT (A10,E10.3,I10,E10.3,F8.2,I1,L1,F10.3,9X,I1)               LARC1     345
  310 FORMAT (* INTERVAL NO.      TIME       AMOUNT RELEASED       AMOUNT R LARC1     346
     1EMAINING    AMOUNT IN COOLANT     FRACTION IN COOLANT*//)        LARC1     347
  320 FORMAT (I10,0PF12.2,1P4E21.2)                                     LARC1     348
  330 FORMAT (I10,F12.2,1PE25.5,0P2F25.5)                               LARC1     349
  340 FORMAT (/13H INTERVAL NO.,5X,4HTIME,5X,23HAMT IN CONTAINMENT BLDG, LARC1     350
     113X,12HAMT RELEASED,8X,17HCUMULATED RELEASE,//)                   LARC1     351
  350 FORMAT (I1,4X)                                                    LARC1     352
      END                                                               LARC1     353
      FUNCTION RI (T)                                                   LARC1     354
      LOGICAL LAGE,BISO                                                 LARC1     355
      COMMON /LA/ LAGE,AGE,MFUEL,ISO,BISO                               LARC1     356
      IF (MFUEL.EQ.1) GO TO 160                                         LARC1     357
      GO TO (10,30,40,60,80,90,100,110,130,150), ISO                    LARC1     358
   10 IF (BISO) GO TO 20                                                LARC1     359
      RI=5.46686*EXP(-25798./T)                                         LARC1     360
      RETURN                                                            LARC1     361
   20 RI=39.3*EXP(-12000./T)                                            LARC1     362
      RETURN                                                            LARC1     363
   30 RI=597.69*EXP(-23157./T)                                          LARC1     364
      RETURN                                                            LARC1     365
   40 IF (BISO) GO TO 50                                                LARC1     366
      RI=.012282*EXP(-14834./T)                                         LARC1     367
      RETURN                                                            LARC1     368
   50 RI=171.91*EXP(-17858./T)                                          LARC1     369
      RETURN                                                            LARC1     370
   60 IF (BISO) GO TO 70                                                LARC1     371
      RI=5.46686*EXP(-25798./T)                                         LARC1     372
      RETURN                                                            LARC1     373
   70 RI=1.58225E5*EXP(-28652.5/T)                                      LARC1     374
      RETURN                                                            LARC1     375
   80 RI=.016742*EXP(-10313./T)                                         LARC1     376
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      RETURN                                                            LARC1     377
   90 RI=.04427*EXP(-10482./T)                                          LARC1     378
      RETURN                                                            LARC1     379
  100 RI=5.40686*EXP(-25798./T)                                         LARC1     380
      RETURN                                                            LARC1     381
  110 IF (BISO) GO TO 120                                               LARC1     382
      RI=5.40686*EXP(-25798./T)                                         LARC1     383
      RETURN                                                            LARC1     384
  120 RI=.04427*EXP(-10482./T)                                          LARC1     385
      RETURN                                                            LARC1     386
  130 IF (BISO) GO TO 140                                               LARC1     387
      RI=5.40686*EXP(-25798./T)                                         LARC1     388
      RETURN                                                            LARC1     389
  140 RI=.04427*EXP(-10482./T)                                          LARC1     390
      RETURN                                                            LARC1     391
  150 RI=.10280*EXP(-10314./T)                                          LARC1     392
      RETURN                                                            LARC1     393
  160 GO TO (170,180,210,220,230,240,250,270,280,300), ISO               LARC1     394
  170 RI=9.7733E-4*EXP(-8262.1/T)                                       LARC1     395
      RETURN                                                            LARC1     396
  180 IF (1./T.GT.5.64E-4) GO TO 190                                    LARC1     397
      RI=5.3231E9*EXP(-58360./T)                                        LARC1     398
      RETURN                                                            LARC1     399
  190 IF (1./T.GT.7.59E-4) GO TO 200                                    LARC1     400
      RI=.046144*EXP(-13198./T)                                         LARC1     401
      RETURN                                                            LARC1     402
  200 RI=9.7733E-4*EXP(-8262.1/T)                                       LARC1     403
      RETURN                                                            LARC1     404
  210 RI=9.7733E-4*EXP(-8262.1/T)                                       LARC1     405
      RETURN                                                            LARC1     406
  220 RI=9.7733E-4*EXP(-8262.1/T)                                       LARC1     407
      RETURN                                                            LARC1     408
  230 RI=9.7733E-4*EXP(-8262.1/T)                                       LARC1     409
      RETURN                                                            LARC1     410
  240 RI=7.2751E-3*EXP(-8696.3/T)                                       LARC1     411
      RETURN                                                            LARC1     412
  250 IF (1./T.GT.5.33E-4) GO TO 260                                    LARC1     413
      RI=1738.5*EXP(-35259./T)                                          LARC1     414
      RETURN                                                            LARC1     415
  260 RI=9.7733E-4*EXP(-8262.1/T)                                       LARC1     416
      RETURN                                                            LARC1     417
  270 RI=9.7733E-4*EXP(-8262.1/T)                                       LARC1     418
      RETURN                                                            LARC1     419
  280 IF (1./T.GT.6.26E-4) GO TO 290                                    LARC1     420
      RI=1.10548E4*EXP(-34207./T)                                       LARC1     421
      RETURN                                                            LARC1     422
  290 RI=9.7733E-4*EXP(-8262.1/T)                                       LARC1     423
      RETURN                                                            LARC1     424
  300 RI=9.7733E-4*EXP(-8262.1/T)                                       LARC1     425
      RETURN                                                            LARC1     426
      END                                                               LARC1     427
      FUNCTION RF (T)                                                   LARC1     428
      LOGICAL LAGE,BISO                                                 LARC1     429
      COMMON /LA/ LAGE,AGE,MFUEL,ISO,BISO                               LARC1     430
      IF (MFUEL.EQ.1) GO TO 120                                         LARC1     431
      GO TO (10,20,30,40,50,60,70,80,90,100), ISO                       LARC1     432
   10 RF=159.37*EXP(-11861./T)                                          LARC1     433
      RETURN                                                            LARC1     434
   20 RF=1.6154E6*EXP(-26374./T)                                        LARC1     435
      RETURN                                                            LARC1     436
   30 RF=1319.2*EXP(-17782./T)                                          LARC1     437
      RETURN                                                            LARC1     438
   40 RF=1.2316E6*EXP(-28319./T)                                        LARC1     439
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      RETURN                                                            LARC1     440
   50 RF=1749.25*EXP(-19545.1/T)                                        LARC1     441
      RETURN                                                            LARC1     442
   60 RF=1500.4*EXP(-17662./T)                                          LARC1     443
      RETURN                                                            LARC1     444
   70 RF=1.2316E6*EXP(-28319./T)                                        LARC1     445
      RETURN                                                            LARC1     446
   80 RF=1.2316E6*EXP(-28319./T)                                        LARC1     447
      RETURN                                                            LARC1     448
   90 RF=1.2316E6*EXP(-28319./T)                                        LARC1     449
      RETURN                                                            LARC1     450
  100 IF (BISO) GO TO 110                                               LARC1     451
      RF=7.3605*EXP(-13777./T)                                          LARC1     452
      RETURN                                                            LARC1     453
  110 RF=2149.4*EXP(-18175./T)                                          LARC1     454
      RETURN                                                            LARC1     455
  120 GO TO (130,140,170,180,190,200,210,220,230,240), ISO               LARC1     456
  130 RF=1.8289E4*EXP(-22861./T)                                        LARC1     457
      RETURN                                                            LARC1     458
  140 IF (1./T.GT.5.64E-4) GO TO 150                                    LARC1     459
      RF=5.3231E9*EXP(-58360./T)                                        LARC1     460
      RETURN                                                            LARC1     461
  150 IF (1./T.GT.7.59E-4) GO TO 160                                    LARC1     462
      RF=.046144*EXP(-13198./T)                                         LARC1     463
      RETURN                                                            LARC1     464
  160 RF=9.7733E-4*EXP(-8262.1/T)                                       LARC1     465
      RETURN                                                            LARC1     466
  170 RF=8952.4*EXP(-22657./T)                                          LARC1     467
      RETURN                                                            LARC1     468
  180 RF=2231.7*EXP(-21229./T)                                          LARC1     469
      RETURN                                                            LARC1     470
  190 RF=8952.4*EXP(-22657./T)                                          LARC1     471
      RETURN                                                            LARC1     472
  200 RF=3942.3.*EXP(-22435./T)                                         LARC1     473
      RETURN                                                            LARC1     474
  210 RF=2231.7*EXP(-21229./T)                                          LARC1     475
      RETURN                                                            LARC1     476
  220 RF=2231.7*EXP(-21229./T)                                          LARC1     477
      RETURN                                                            LARC1     478
  230 RF=2231.7*EXP(-21229./T)                                          LARC1     479
      RETURN                                                            LARC1     480
  240 RF=8952.4*EXP(-22657./T)                                          LARC1     481
      RETURN                                                            LARC1     482
      END                                                               LARC1     483
      FUNCTION FRACB0 (T)                                               LARC1     484
      DIMENSION IOP(2), TAB(3)                                          LARC1     485
      LOGICAL LAGE,BISO                                                 LARC1     486
      COMMON /LA/ LAGE,AGE,MFUEL,ISO,BISO                               LARC1     487
      COMMON /F/ F1,F2,F3,F4                                            LARC1     488
      DIMENSION W3(8), A(8), B(8), C(8), W4(8), FRAC3(8), T3(8), FRAC4(8 LARC1     489
     1), T4(8)                                                          LARC1     490
      DATA FRAC3/.00526,.0059,.0071,.0116,.0185,.046,.057,.0815/        LARC1     491
      DATA T3/1690.15,1743.15,1793.15,1873.15,1917.15,1973.15,2000.0,267 LARC1     492
     13.15/                                                             LARC1     493
      DATA FRAC4/.00718,.0079,.01,.021,.0557,.10,.222,.4039/            LARC1     494
      DATA T4/1673.15,1697.15,1733.15,1793.15,1853.15,1893.15,1973.15,20 LARC1     495
     173.15/                                                            LARC1     496
C     SPLINE BOUNDARY CONDITIONS ETC.                                   LARC1     497
      IJ=1                                                              LARC1     498
      IOP(1)=5                                                          LARC1     499
      IOP(2)=5                                                          LARC1     500
      N3=8                                                              LARC1     501
      N4=8                                                              LARC1     502
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      CALL SPL1D1 (N3,T3,FRAC3,W3,IOP,IJ,A,B,C)                         LARC1    503
      CALL SPL1D1 (N4,T4,FRAC4,W4,IOP,IJ,A,B,C)                         LARC1    504
      RETURN                                                            LARC1    505
      ENTRY FRACB                                                       LARC1    506
      IAGE=AGE                                                          LARC1    507
      IAGE1=IAGE+1                                                      LARC1    508
      F1=0.0                                                            LARC1    509
      F2=0.0                                                            LARC1    510
      F3=0.0                                                            LARC1    511
      F4=0.0                                                            LARC1    512
      F23=0.0                                                           LARC1    513
      X=AGE-IAGE                                                        LARC1    514
      IF (X.NE.0.0) GO TO 10                                            LARC1    515
      IF (AGE.EQ.0.0) GO TO 10                                          LARC1    516
      X=1.0                                                             LARC1    517
      IAGE1=IAGE                                                        LARC1    518
      IAGE=IAGE-1                                                       LARC1    519
   10 CONTINUE                                                          LARC1    520
      IF (MFUEL.EQ.1) GO TO 160                                         LARC1    521
      F1=1.0                                                            LARC1    522
      F2=1.0                                                            LARC1    523
      F3=1.0                                                            LARC1    524
      F4=1.0                                                            LARC1    525
      IF (T.GE.2273.15) GO TO 50                                        LARC1    526
      IF (T.GE.2073.15) GO TO 40                                        LARC1    527
      F1=.00179                                                         LARC1    528
      F2=.00377                                                         LARC1    529
      IF (T.LT.1673.15) GO TO 20                                        LARC1    530
      CALL SPL1D2 (N4,T4,FRAC4,W4,IJ,T,TAB)                             LARC1    531
      F4=TAB(1)                                                         LARC1    532
      IF (T.LT.1690.15) GO TO 30                                        LARC1    533
      CALL SPL1D2 (N3,T3,FRAC3,W3,IJ,T,TAB)                             LARC1    534
      F3=TAB(1)                                                         LARC1    535
      GO TO 50                                                          LARC1    536
   20 F4=.00718                                                         LARC1    537
   30 F3=.00526                                                         LARC1    538
      GO TO 50                                                          LARC1    539
   40 CONTINUE                                                          LARC1    540
      F1=-10.3454+4.99105E-3*T                                          LARC1    541
      F2=-10.3229+4.98115E-3*T                                          LARC1    542
      F3=-9.439441+4.592500E-3*T                                        LARC1    543
      F4=-5.775124+2.98050E-3*T                                         LARC1    544
   50 CONTINUE                                                          LARC1    545
      F23=0.5*(F2+F3)                                                   LARC1    546
      IF (.NOT.LAGE) GO TO 100                                          LARC1    547
      IF (IAGE.GT.3) GO TO 90                                           LARC1    548
      GO TO (60,70,80,90), IAGE1                                        LARC1    549
   60 FRACB=AGE*F1                                                      LARC1    550
      GO TO 150                                                         LARC1    551
   70 FRACB=0.25*(3.*F1-2.*X*F1+3.*X*F2)                                LARC1    552
      GO TO 150                                                         LARC1    553
   80 FRACB=0.25*(F1+(2.-X)*F2+2.*X*F3)                                 LARC1    554
      GO TO 150                                                         LARC1    555
   90 FRACB=0.25*(F1+F2+F3+X*F4)                                        LARC1    556
      GO TO 150                                                         LARC1    557
  100 IF (IAGE.GT.3) GO TO 140                                          LARC1    558
      GO TO (110,120,130,140), IAGE1                                    LARC1    559
  110 FRACB=AGE*F1                                                      LARC1    560
      GO TO 150                                                         LARC1    561
  120 FRACB=F1+X*(F2-F1)                                                LARC1    562
      GO TO 150                                                         LARC1    563
  130 FRACB=F2+X*(F3-F2)                                                LARC1    564
      GO TO 150                                                         LARC1    565
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  140 FRACB=F3+(AGE-3.)*(F4-F3)                                          LARC1    566
  150 RETURN                                                             LARC1    567
C     SORS FUEL AGE MODEL--BISO                                          LARC1    568
  160 IF (LAGE) GO TO 200                                                LARC1    569
      FRACB=1.0                                                          LARC1    570
      IF (AGE.GT.0.12) GO TO 180                                         LARC1    571
      IF (T.GT.1998.15) GO TO 190                                        LARC1    572
      IF (T.LT.1858.15) GO TO 170                                        LARC1    573
      FRACB=-13.2725+7.14286E-3*T                                        LARC1    574
      GO TO 190                                                          LARC1    575
  170 FRACB=0.0                                                          LARC1    576
      GO TO 190                                                          LARC1    577
C     BISO CONSTANTS                                                     LARC1    578
  180 TONE=2011.97*EXP(-.0574098*AGE)                                    LARC1    579
      IF (T.GE.TONE) GO TO 190                                           LARC1    580
      TZERO=1876.17*EXP(-.0804098*AGE)                                   LARC1    581
      IF (T.LE.TZERO) GO TO 170                                          LARC1    582
      FRACB=(T-TZERO)/(TONE-TZERO)                                       LARC1    583
  190 FRACB=FRACB+.025*AGE                                               LARC1    584
      FRACB=AMIN1(FRACB,1.0)                                             LARC1    585
      RETURN                                                             LARC1    586
  200 F1=1.0                                                             LARC1    587
      F2=1.0                                                             LARC1    588
      F3=1.0                                                             LARC1    589
      F4=1.0                                                             LARC1    590
      AGE1=X                                                             LARC1    591
      AGE2=1.+X                                                          LARC1    592
      AGE3=2.+X                                                          LARC1    593
      AGE4=3.+X                                                          LARC1    594
      IF (X.GT.0.12) GO TO 220                                           LARC1    595
      IF (T.GT.1998.15) GO TO 230                                        LARC1    596
      IF (T.LT.1858.15) GO TO 210                                        LARC1    597
      F1=-13.2725+7.14286E-3*T                                           LARC1    598
      GO TO 230                                                          LARC1    599
  210 F1=0.0                                                             LARC1    600
      GO TO 230                                                          LARC1    601
  220 TONE1=2011.97*EXP(-.0574098*AGE1)                                  LARC1    602
      IF (T.GT.TONE1) GO TO 290                                          LARC1    603
      TZERO1=1876.17*EXP(-.0804098*AGE1)                                 LARC1    604
      IF (T.LE.TZERO1) GO TO 210                                         LARC1    605
      F1=(T-TZERO1)/(TONE1-TZERO1)                                       LARC1    606
  230 TONE2=2011.97*EXP(-.0574098*AGE2)                                  LARC1    607
      IF (T.GT.TONE2) GO TO 290                                          LARC1    608
      TZERO2=1876.17*EXP(-.0804098*AGE2)                                 LARC1    609
      IF (T.LE.TZERO2) GO TO 240                                         LARC1    610
      F2=(T-TZERO2)/(TONE2-TZERO2)                                       LARC1    611
      GO TO 250                                                          LARC1    612
  240 F2=0.0                                                             LARC1    613
  250 TONE3=2011.97*EXP(-.0574098*AGE3)                                  LARC1    614
      IF (T.GT.TONE3) GO TO 290                                          LARC1    615
      TZERO3=1876.17*EXP(-.0804098*AGE3)                                 LARC1    616
      IF (T.LE.TZERO3) GO TO 260                                         LARC1    617
      F3=(T-TZERO3)/(TONE3-TZERO3)                                       LARC1    618
      GO TO 270                                                          LARC1    619
  260 F3=0.0                                                             LARC1    620
  270 TONE4=2011.97*EXP(-.0574098*AGE4)                                  LARC1    621
      IF (T.GT.TONE4) GO TO 290                                          LARC1    622
      TZERO4=1876.17*EXP(-.0804098*AGE4)                                 LARC1    623
      IF (T.LE.TZERO4) GO TO 280                                         LARC1    624
      F4=(T-TZERO4)/(TONE4-TZERO4)                                       LARC1    625
      GO TO 290                                                          LARC1    626
  280 F4=0.0                                                             LARC1    627
  290 IF (LAGE.GT.3) GO TO 330                                           LARC1    628
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  140 GO TO (300,310,320,330), IAGE1                                LARC1   629
  300 F1=F1+.025*AGE1                                               LARC1   630
      FRACB=F1                                                      LARC1   631
      GO TO 340                                                     LARC1   632
  310 F1=F1+.025*AGE1                                               LARC1   633
      F2=F2+.025*AGE2                                               LARC1   634
      FRACB=0.25*(F1+3.*F2)                                         LARC1   635
      GO TO 340                                                     LARC1   636
  320 F1=F1+.025*AGE1                                               LARC1   637
      F2=F2+.025*AGE2                                               LARC1   638
      F3=F3+.025*AGE3                                               LARC1   639
      FRACB=0.25*(F1+F2+2.*F3)                                      LARC1   640
      GO TO 340                                                     LARC1   641
  330 F1=F1+.025*AGE1                                               LARC1   642
      F2=F2+.025*AGE2                                               LARC1   643
      F3=F3+.025*AGE3                                               LARC1   644
      F4=F4+.025*AGE4                                               LARC1   645
      FRACB=0.25*(F1+F2+F3+F4)                                      LARC1   646
  340 FRACB=AMIN1(FRACB,1.0)                                        LARC1   647
      RETURN                                                        LARC1   648
      END                                                           LARC1   649
      FUNCTION FRACT (T)                                            LARC1   650
      LOGICAL LAGE,BISO                                             LARC1   651
      COMMON /LA/ LAGE,AGE,MFUEL,ISO,BISO                           LARC1   652
      COMMON /F/ F1,F2,F3,F4                                        LARC1   653
      IAGE=AGE                                                      LARC1   654
      IAGE1=IAGE+1                                                  LARC1   655
      F1=0.0                                                        LARC1   656
      F2=0.0                                                        LARC1   657
      F3=0.0                                                        LARC1   658
      F4=0.0                                                        LARC1   659
      F23=0.0                                                       LARC1   660
      X=AGE-IAGE                                                    LARC1   661
      IF (X.NE.0.0) GO TO 10                                        LARC1   662
      IF (AGE.EQ.0.0) GO TO 10                                      LARC1   663
      X=1.0                                                         LARC1   664
      IAGE1=IAGE                                                    LARC1   665
      IAGE=IAGE-1                                                   LARC1   666
   10 CONTINUE                                                      LARC1   667
      IF (MFUEL.EQ.1) GO TO 170                                     LARC1   668
      F1=1.0                                                        LARC1   669
      F2=1.0                                                        LARC1   670
      F3=1.0                                                        LARC1   671
      F4=1.0                                                        LARC1   672
      IF (T.GE.2273.15) GO TO 60                                    LARC1   673
      IF (T.GE.1941.15) GO TO 20                                    LARC1   674
      F1=.00157                                                     LARC1   675
      IF (T.GE.1902.15) GO TO 30                                    LARC1   676
C     THIS IS A CHANGE IN CALCULATION OF F2 IN FRACT                LARC1   677
      F2=9.99665E-4*EXP(9.15323E-4*T)                               LARC1   678
      IF (T.GE.1888.85) GO TO 40                                    LARC1   679
      F3=1.22240E-3*EXP(1.08109E-3*T)                               LARC1   680
      IF (T.GE.1873.15) GO TO 50                                    LARC1   681
      F4=1.17176E-3*EXP(1.19064E-3*T)                               LARC1   682
      GO TO 60                                                      LARC1   683
   20 F1=-5.8361+.300732E-2*T                                       LARC1   684
   30 F2=-5.6922+.258005E-2*T                                       LARC1   685
   40 F3=-4.8593+.257762E-2*T                                       LARC1   686
   50 F4=-4.6209+.24728E-2*T                                        LARC1   687
   60 CONTINUE                                                      LARC1   688
      F23=0.5*(F2+F3)                                               LARC1   689
      IF (.NOT.LAGE) GO TO 110                                      LARC1   690
      IF (IAGE.GT.3) GO TO 100                                      LARC1   691
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      GO TO (70,80,90,100), IAGE1                                       LARC1    692
   70 FRACT=AGE*F1                                                      LARC1    693
      GO TO 160                                                         LARC1    694
   80 FRACT=0.25*(3.*F1-2.*X*F1+3.*X*F2)                                LARC1    695
      GO TO 160                                                         LARC1    696
   90 FRACT=0.25*(F1+(2.-X)*F2+2.*X*F3)                                 LARC1    697
      GO TO 160                                                         LARC1    698
  100 FRACT=0.25*(F1+F2+F3+X*F4)                                        LARC1    699
      GO TO 160                                                         LARC1    700
  110 IF (IAGE.GT.3) GO TO 150                                          LARC1    701
      GO TO (120,130,140,150), IAGE1                                    LARC1    702
  120 FRACT=AGE*F1                                                      LARC1    703
      GO TO 160                                                         LARC1    704
  130 FRACT=F1+X*(F2-F1)                                                LARC1    705
      GO TO 160                                                         LARC1    706
  140 FRACT=F2+X*(F3-F2)                                                LARC1    707
      GO TO 160                                                         LARC1    708
  150 FRACT=F3+(AGE-3.)*(F4-F3)                                         LARC1    709
  160 RETURN                                                            LARC1    710
C     SORS FUEL AGE MODEL--TRISO                                        LARC1    711
  170 IF (LAGE) GO TO 210                                               LARC1    712
      FRACT=1.0                                                         LARC1    713
      IF (AGE.GT.0.12) GO TO 190                                        LARC1    714
      IF (T.GT.1998.15) GO TO 200                                       LARC1    715
      IF (T.LT.1858.15) GO TO 180                                       LARC1    716
      FRACT=-13.2725+7.14286E-3*T                                       LARC1    717
      GO TO 200                                                         LARC1    718
  180 FRACT=0.0                                                         LARC1    719
      GO TO 200                                                         LARC1    720
  190 TONE=2009.53*EXP(-.0472964*AGE)                                   LARC1    721
      IF (T.GE.TONE) GO TO 200                                          LARC1    722
      TZERO=1880.1*EXP(-.0974459*AGE)                                   LARC1    723
      IF (T.LE.TZERO) GO TO 180                                         LARC1    724
      FRACT=(T-TZERO)/(TONE-TZERO)                                      LARC1    725
  200 FRACT=FRACT+.025*AGE                                              LARC1    726
      FRACT=AMIN1(FRACT,1.0)                                            LARC1    727
      RETURN                                                            LARC1    728
  210 F1=1.0                                                            LARC1    729
      F2=1.0                                                            LARC1    730
      F3=1.0                                                            LARC1    731
      F4=1.0                                                            LARC1    732
      AGE1=X                                                            LARC1    733
      AGE2=1.+X                                                         LARC1    734
      AGE3=2.+X                                                         LARC1    735
      AGE4=3.+X                                                         LARC1    736
      IF (X.GT.0.12) GO TO 230                                          LARC1    737
      IF (T.GT.1998.15) GO TO 240                                       LARC1    738
      IF (T.LT.1858.15) GO TO 220                                       LARC1    739
      F1=-13.2725+7.14286E-3*T                                          LARC1    740
      GO TO 240                                                         LARC1    741
  220 F1=0.0                                                            LARC1    742
      GO TO 240                                                         LARC1    743
  230 TONE1=2009.53*EXP(-.0472964*AGE1)                                 LARC1    744
      IF (T.GT.TONE1) GO TO 300                                         LARC1    745
      TZERO1=1880.1*EXP(-.0974459*AGE1)                                 LARC1    746
      IF (T.LE.TZERO1) GO TO 220                                        LARC1    747
      F1=(T-TZERO1)/(TONE1-TZERO1)                                      LARC1    748
  240 TONE2=2009.53*EXP(-.0472964*AGE2)                                 LARC1    749
      IF (T.GT.TONE2) GO TO 300                                         LARC1    750
      TZERO2=1880.1*EXP(-.0974459*AGE2)                                 LARC1    751
      IF (T.LE.TZERO2) GO TO 250                                        LARC1    752
      F2=(T-TZERO2)/(TONE2-TZERO2)                                      LARC1    753
      GO TO 260                                                         LARC1    754
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  250 F2=0.0                                                            LARC1     755
  260 TONE3=2009.53*EXP(-.0472964*AGE3)                                 LARC1     756
      IF (T.GT.TONE3) GO TO 300                                         LARC1     757
      TZERO3=1880.1*EXP(-.0974459*AGE3)                                 LARC1     758
      IF (T.LE.TZERO3) GO TO 270                                        LARC1     759
      F3=(T-TZERO3)/(TONE3-TZERO3)                                      LARC1     760
      GO TO 280                                                         LARC1     761
  270 F3=0.0                                                            LARC1     762
  280 TONE4=2009.53*EXP(-.0472964*AGE4)                                 LARC1     763
      IF (T.GT.TONE4) GO TO 300                                         LARC1     764
      TZERO4=1880.1*EXP(-.0974459*AGE4)                                 LARC1     765
      IF (T.LE.TZERO4) GO TO 290                                        LARC1     766
      F4=(T-TZERO4)/(TONE4-TZERO4)                                      LARC1     767
      GO TO 300                                                         LARC1     768
  290 F4=0.0                                                            LARC1     769
  300 IF (IAGE.GT.3) GO TO 340                                          LARC1     770
      GO TO (310,320,330,340), IAGE1                                    LARC1     771
  310 F1=F1+.025*AGE1                                                   LARC1     772
      FRACT=F1                                                          LARC1     773
      GO TO 350                                                         LARC1     774
  320 F1=F1+.025*AGE1                                                   LARC1     775
      F2=F2+.025*AGE2                                                   LARC1     776
      FRACT=0.25*(F1+3.*F2)                                             LARC1     777
      GO TO 350                                                         LARC1     778
  330 F1=F1+.025*AGE1                                                   LARC1     779
      F2=F2+.025*AGE2                                                   LARC1     780
      F3=F3+.025*AGE3                                                   LARC1     781
      FRACT=0.25*(F1+F2+2.*F3)                                          LARC1     782
      GO TO 350                                                         LARC1     783
  340 F1=F1+.025*AGE1                                                   LARC1     784
      F2=F2+.025*AGE2                                                   LARC1     785
      F3=F3+.025*AGE3                                                   LARC1     786
      F4=F4+.025*AGE4                                                   LARC1     787
      FRACT=0.25*(F1+F2+F3+F4)                                          LARC1     788
  350 FRACT=AMIN1(FRACT,1.0)                                            LARC1     789
      RETURN                                                            LARC1     790
      END                                                               LARC1     791
      SUBROUTINE PLOT(N,X,MX,Y,MY,ICHAR,ICON)                           LARC1     792
      DIMENSION X(1), Y(1)                                              LARC1     793
      COMMON /CJE07/ IXL,IXR,IYT,IYB,XL,XR,YT,YB                        LARC1     794
      COMMON /LJNEW/ IXSAVE,IYSAVE,IX2,IY2                              LARC1     795
C     THIS SUBROUTINE IS MODIFIED BY THE INCLUSION OF LJNEW             LARC1     796
C     LJNEW IS INCLUDED SO THAT IXSAVE, IYSAVE MAY BE USED FOR TITLES   LARC1     797
      INTEGER BLANK,PLTDOT                                              LARC1     798
      DATA BLANK,PLTDOT/60B,52B/                                        LARC1     799
      IXSAVE=X(1)                                                       LARC1     800
      IYSAVE=Y(1)                                                       LARC1     801
      YN6=0.6*Y(N)                                                      LARC1     802
      IF (N.EQ.2) YN6=-2.0                                              LARC1     803
      FX=XR-XL                                                          LARC1     804
      IF (FX.NE.0) FX=(IXR-IXL)/FX                                      LARC1     805
      FY=YB-YT                                                          LARC1     806
      IF (FY.NE.0) FY=(IYB-IYT)/FY                                      LARC1     807
      K=1                                                               LARC1     808
      M=N-1                                                             LARC1     809
      I=0                                                               LARC1     810
      J=0                                                               LARC1     811
      L=0                                                               LARC1     812
      JCON=ICON                                                         LARC1     813
      IF ((ICHAR.EQ.BLANK).OR.((ICHAR.EQ.PLTDOT).AND.(M*JCON.NE.0))) K=0 LARC1    814
   10 IX2=MIN0(MAX0(IXL+IFIX((X(I+1)-XL)*FX),IXL),IXR)                  LARC1     815
      IY2=MIN0(MAX0(IYT+IFIX((Y(J+1)-YT)*FY),IYT),IYB)                  LARC1     816
      IF (K.NE.0) CALL PLT (IX2,IY2,ICHAR)                              LARC1     817
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      IF (L.NE.0) CALL DRV (IX1,IY1,IX2,IY2)                            LARC1    818
      IF (M.LE.0) GO TO 30                                              LARC1    819
      IF (Y(J+1).GT.YN6) GO TO 20                                       LARC1    820
      IXSAVE=IX2                                                        LARC1    821
      IYSAVE=IY2                                                        LARC1    822
   20 CONTINUE                                                          LARC1    823
      M=M-1                                                             LARC1    824
      I=I+MX                                                            LARC1    825
      J=J+MY                                                            LARC1    826
      L=JCON                                                            LARC1    827
      IX1=IX2                                                           LARC1    828
      IY1=IY2                                                           LARC1    829
      GO TO 10                                                          LARC1    830
   30 RETURN                                                            LARC1    831
      END                                                               LARC1    832
      FUNCTION TEMP0 (VF)                                               LARC1    833
      DIMENSION IOP(2), TAB(3)                                          LARC1    834
      DIMENSION X(14), TEMPF(14), W(14), A(14), B(14), C(14)            LARC1    835
      COMMON /SPEC/ TEMPF,X                                             LARC1    836
      DATA X/0.,.01,.03333,.06666,.1,.2,.3,.4,.5,.6,.7,.8,.9,1./        LARC1    837
      DATA TEMPF/1699.82,1588.71,1479.26,1402.59,1347.59,1255.37,1205.37 LARC1    838
     1,1173.41,1147.04,1127.59,1104.26,1079.08,1044.26,922.04/          LARC1    839
C     SPLINE BOUNDARY CONDITIONS ETC.                                   LARC1    840
      IJ=1                                                              LARC1    841
      IOP(1)=5                                                          LARC1    842
      IOP(2)=5                                                          LARC1    843
      N1=14                                                             LARC1    844
      CALL SPL1D1 (N1,X,TEMPF,W,IOP,IJ,A,B,C)                           LARC1    845
      RETURN                                                            LARC1    846
      ENTRY TEMP                                                        LARC1    847
      CALL SPL1D2 (N1,X,TEMPF,W,IJ,VF,TAB)                              LARC1    848
      TEMP=TAB(1)                                                       LARC1    849
      RETURN                                                            LARC1    850
      END                                                               LARC1    851
      FUNCTION TMAX0 (T)                                                LARC1    852
      DIMENSION IOP(2), TAB(3)                                          LARC1    853
      DIMENSION TT(29), TMAXF(29), W(29), A(29), B(29), C(29)           LARC1    854
      COMMON /TMODEL/ MODEL                                             LARC1    855
      COMMON /SPECM/ NT,TT,TMAXF                                        LARC1    856
C     THIS COMMON CONTAINS DIMENSIONS IN MAIN PROGRAM                   LARC1    857
C     SORS DATA                                                         LARC1    858
      DIMENSION T1(11), TMAX1(11)                                       LARC1    859
      DATA T1/0.,1.3,2.3,3.5,5.,6.92,9.42,12.3,17.3,26.5,40./           LARC1    860
      DATA TMAX1/1227.59,1644.26,1922.04,2199.82,2477.59,2755.37,3033.15 LARC1    861
     1,3310.93,3588.71,3922.04,3922.04/                                 LARC1    862
C     CORCON TABULAR DATA                                               LARC1    863
      DIMENSION T2(10), TMAX2(10)                                       LARC1    864
      DATA T2/0.,.0083,.2167,1.45,5.25,10.25,15.25,20.25,25.25,30.25/   LARC1    865
      DATA TMAX2/1192.59,1192.59,1280.37,1618.15,2379.26,2969.82,3358.71 LARC1    866
     1,3630.37,3665.37,3665.37/                                         LARC1    867
C     FU - CORT DATA                                                    LARC1    868
      DIMENSION T3(29), TMAX3(29)                                       LARC1    869
      DATA T3/.2,.4,.5,1.0,1.5,2.0,2.5,3.0,3.5,4.0,4.5,5.0,5.5,6.0,6.5,7 LARC1    870
     1.,8.,9.,10.,11.,12.,13.,14.,15.,16.,17.,18.,19.,20./              LARC1    871
      DATA TMAX3/1199.,1278.,1315.,1461.,1589.,1704.,1810.,1908.,2002.,2 LARC1    872
     1091.,2176.,2257.,2335.,2411.,2483.,2554.,2687.,2815.,2936.,3053.,3 LARC1    873
     2165.,3273.,3376.,3475.,3570.,3663.,3636.,3664.,3665./             LARC1    874
C     SPLINE BOUNDARY CONDITIONS ETC.                                   LARC1    875
      IJ=1                                                              LARC1    876
      IOP(1)=5                                                          LARC1    877
      IOP(2)=5                                                          LARC1    878
      GO TO (10,30,50), MODEL                                           LARC1    879
   10 N2=11                                                             LARC1    880
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      NT=9                                                              LARC1     881
      DO 20 I=1,N2                                                      LARC1     882
      TT(I)=T1(I)                                                       LARC1     883
      TMAXF(I)=TMAX1(I)                                                 LARC1     884
   20 CONTINUE                                                          LARC1     885
      GO TO 70                                                          LARC1     886
   30 N2=10                                                             LARC1     887
      NT=8                                                              LARC1     888
      DO 40 I=1,N2                                                      LARC1     889
      TT(I)=T2(I)                                                       LARC1     890
      TMAXF(I)=TMAX2(I)                                                 LARC1     891
   40 CONTINUE                                                          LARC1     892
      GO TO 70                                                          LARC1     893
   50 N2=29                                                             LARC1     894
      NT=29                                                             LARC1     895
      DO 60 I=1,N2                                                      LARC1     896
      TT(I)=T3(I)                                                       LARC1     897
      TMAXF(I)=TMAX3(I)                                                 LARC1     898
   60 CONTINUE                                                          LARC1     899
   70 CALL SPL1D1 (N2,TT,TMAXF,W,IOP,IJ,A,B,C)                          LARC1     900
      RETURN                                                            LARC1     901
      ENTRY TMAX                                                        LARC1     902
      CALL SPL1D2 (N2,TT,TMAXF,W,IJ,T,TAB)                              LARC1     903
      TMAX=TAB(1)                                                       LARC1     904
      RETURN                                                            LARC1     905
      END                                                               LARC1     906
      FUNCTION TAVE0 (T)                                                LARC1     907
      DIMENSION IOP(2), TAB(3)                                          LARC1     908
      DIMENSION TT(29), TAVEF(29), W(29), A(29), B(29), C(29)           LARC1     909
      COMMON /TMODEL/ MODEL                                             LARC1     910
      COMMON /SPECA/ NT,TT,TAVEF                                        LARC1     911
C     THIS COMMON CONTAINS DIMENSIONS IN MAIN PROGRAM                   LARC1     912
C     IN THE MAIN PROGRAM, TT IS CALLED T3 IN THIS COMMON STATEMENT     LARC1     913
C     SORS DATA                                                         LARC1     914
      DIMENSION T1(11), TAVE1(11)                                       LARC1     915
      DATA T1/0.,1.1,2.5,4.2,6.3,10.,14.8,22.5,34.6,40.,50./            LARC1     916
      DATA TAVE1/1088.71,1366.48,1644.26,1922.04,2199.82,2477.59,2755.37 LARC1     917
     1,3033.15,3310.93,3374.42,3459.08/                                 LARC1     918
C     CORCON TABULAR DATA                                               LARC1     919
      DIMENSION T2(10), TAVE2(10)                                       LARC1     920
      DATA T2/0.,.0083,.2167,1.45,5.25,10.25,15.25,20.25,25.25,30.25/   LARC1     921
      DATA TAVE2/1052.59,1052.59,1134.82,1413.71,1920.37,2338.71,2608.71 LARC1     922
     1,2793.71,2938.15,3026.48/                                         LARC1     923
C     FU - CORT DATA                                                    LARC1     924
      DIMENSION T3(29), TAVE3(29)                                       LARC1     925
      DATA T3/.2,.4,.5,1.0,1.5,2.0,2.5,3.0,3.5,4.0,4.5,5.0,5.5,6.0,6.5,7 LARC1     926
     1.,8.,9.,10.,11.,12.,13.,14.,15.,16.,17.,18.,19.,20./              LARC1     927
      DATA TAVE3/1167.,1219.,1243.,1338.,1421.,1496.,1566.,1631.,1692.,1 LARC1     928
     1749.,1804.,1856.,1906.,1954.,1999.,2044.,2126.,2204.,2278.,2347.,2 LARC1     929
     2414.,2477.,2538.,2596.,2653.,2707.,2756.,2801.,2840./             LARC1     930
C     SPLINE BOUNDARY CONDITIONS ETC.                                   LARC1     931
      IJ=1                                                              LARC1     932
      IOP(1)=5                                                          LARC1     933
      IOP(2)=5                                                          LARC1     934
      GO TO (10,30,50), MODEL                                           LARC1     935
   10 N3=11                                                             LARC1     936
      NT=7                                                              LARC1     937
      DO 20 I=1,N3                                                      LARC1     938
      TT(I)=T1(I)                                                       LARC1     939
      TAVEF(I)=TAVE1(I)                                                 LARC1     940
   20 CONTINUE                                                          LARC1     941
      GO TO 70                                                          LARC1     942
   30 N3=10                                                             LARC1     943
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      NT=8                                                              LARC1     944
      DO 40 I=1,N3                                                      LARC1     945
      TT(I)=T2(I)                                                       LARC1     946
      TAVEF(I)=TAVE2(I)                                                 LARC1     947
   40 CONTINUE                                                          LARC1     948
      GO TO 70                                                          LARC1     949
   50 N3=29                                                             LARC1     950
      NT=29                                                             LARC1     951
      DO 60 I=1,N3                                                      LARC1     952
      TT(I)=T3(I)                                                       LARC1     953
      TAVEF(I)=TAVE3(I)                                                 LARC1     954
   60 CONTINUE                                                          LARC1     955
   70 CALL SPL1D1 (N3,TT,TAVEF,W,IOP,IJ,A,B,C)                          LARC1     956
      RETURN                                                            LARC1     957
      ENTRY TAVE                                                        LARC1     958
      CALL SPL1D2 (N3,TT,TAVEF,W,IJ,T,TAB)                              LARC1     959
      TAVE=TAB(I)                                                       LARC1     960
      RETURN                                                            LARC1     961
      END                                                               LARC1     962
      SUBROUTINE FIN(PN,RP,RR,LAMBDA,DECAY,DT,RLEAK)                    LARC1     963
C     ORIGINAL ANSWERS                                                  LARC1     964
      REAL LAMBDA                                                       LARC1     965
      E=EXP(-DECAY*DT)                                                  LARC1     966
      RD=RR/(DECAY*DT)                                                  LARC1     967
      RP=RLEAK*((PN-RD)*(1.-E)/DECAY+RD*DT)                             LARC1     968
      PN=PN*E+RD*(1.-E)                                                 LARC1     969
      RETURN                                                            LARC1     970
      END                                                               LARC1     971
      SUBROUTINE FIN1(PN,RP,LAMBDA,DECAY,DT,RLEAK,OLD,R,ROLD)           LARC1     972
C     SIMPLE EQUATIONS SECOND HALF                                      LARC1     973
      REAL LAMBDA                                                       LARC1     974
      E=EXP(-DECAY*DT)                                                  LARC1     975
      E1=1.-E                                                           LARC1     976
      S=0.5*(R+ROLD)                                                    LARC1     977
      ALA=LAMBDA+S                                                      LARC1     978
      EL=EXP(-ALA*DT)                                                   LARC1     979
      EM=1.-EL                                                          LARC1     980
      IF (DECAY.EQ.ALA) GO TO 10                                        LARC1     981
      RP=RLEAK*(PN*E1/DECAY+S*OLD*(EM/ALA-E1/DECAY)/(DECAY-ALA))        LARC1     982
      PN=E*PN+S*OLD*(EL-E)/(DECAY-ALA)                                  LARC1     983
      GO TO 20                                                          LARC1     984
   10 RP=RLEAK*(PN*E1/DECAY+S*OLD*(E1-DECAY*DT*E)/(DECAY*DECAY))        LARC1     985
      PN=E*(PN+S*OLD*DT)                                                LARC1     986
   20 RETURN                                                            LARC1     987
      END                                                               LARC1     988
      SUBROUTINE FIN2(PN,RP,LAMBDA,DECAY,DT,RLEAK,OLD,R,ROLD)           LARC1     989
C     LINEAR RELEASE SECOND HALF                                        LARC1     990
      REAL LAMBDA                                                       LARC1     991
      E=EXP(-DECAY*DT)                                                  LARC1     992
      E1=1.-E                                                           LARC1     993
      S=0.5*(R+ROLD)                                                    LARC1     994
      ALA=LAMBDA+ROLD                                                   LARC1     995
      BH=0.5*(R-ROLD)/DT                                                LARC1     996
      PTERM=(DECAY-LAMBDA)*PZERO(ALA-DECAY,BH,DT)                       LARC1     997
      RP=RLEAK*(PN*E1/DECAY+OLD*(E1-LAMBDA*PZERO(ALA,BH,DT)-E*PTERM)/DEC LARC1    998
     1AY)                                                               LARC1     999
      PN=E*(PN+OLD*(PTERM+1.-EXP((DECAY-LAMBDA-S)*DT)))                 LARC1    1000
      RETURN                                                            LARC1    1001
      END                                                               LARC1    1002
      SUBROUTINE FIN3(PNF,PNI,RPF,RPI,LAMBDA,DECAY,DT,RLEAK,NFOLD,NIOLD, LARC1   1003
     1RA,RFOLD,RB,RIOLD,F,FOLD)                                         LARC1    1004
C     LINEAR FAILURE SECOND HALF                                        LARC1    1005
      REAL LAMBDA,NFOLD,NIOLD,M0,M4                                     LARC1    1006
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      E=EXP(-DECAY*DT)                                                  LARC1    1007
      E1=1.-E                                                           LARC1    1008
      RF=0.5*(RA+RFOLD)                                                 LARC1    1009
      RI=0.5*(RB+RIOLD)                                                 LARC1    1010
      RFP=LAMBDA+RF                                                     LARC1    1011
      RIP=LAMBDA+RI                                                     LARC1    1012
      A4=NIOLD                                                          LARC1    1013
      A0=NFOLD                                                          LARC1    1014
      DF=F-FOLD                                                         LARC1    1015
      DFDT=DF/DT                                                        LARC1    1016
      DR=RF-RI                                                          LARC1    1017
      FIOLD=1.-FOLD                                                     LARC1    1018
      ALPHA=FIOLD*DR                                                    LARC1    1019
      GAM=RFP-ALPHA                                                     LARC1    1020
C     GAM=RFP*FOLD+RIP*FIOLD                                            LARC1    1021
      BET=DR*DFDT                                                       LARC1    1022
      BETA=BET/2.                                                       LARC1    1023
      IF (FIOLD.EQ.0.0) A5=0.0                                          LARC1    1024
      IF (FIOLD.NE.0.0) A5=-DFDT*A4/FIOLD                               LARC1    1025
      A1=-A5+DR*FOLD*A4                                                 LARC1    1026
      A2=-DR*(FIOLD-FOLD)*A5                                            LARC1    1027
      A3=DR*DFDT*A5                                                     LARC1    1028
      DT2=DT*DT                                                         LARC1    1029
      M4=EXP(-GAM*DT-BETA*DT2)                                          LARC1    1030
      M0=EXP(-RFP*DT)                                                   LARC1    1031
      QE=M0/E                                                           LARC1    1032
      DL=DECAY-RFP                                                      LARC1    1033
      ADL=ALPHA+DL                                                      LARC1    1034
      Q4=PZERO(GAM-DECAY,BETA,DT)                                       LARC1    1035
      IF (BET.NE.0.0) Q5=(1.-M4/E+ADL*Q4)/BET                           LARC1    1036
C     THIS IS Q5 FOR BETA .NE. 0.0                                      LARC1    1037
      IF (DL.EQ.0.0) GO TO 10                                           LARC1    1038
      Q0=(QE-1.0)/DL                                                    LARC1    1039
      Q1=(QE*PZERO(-ALPHA,BETA,DT)-Q4)/DL                               LARC1    1040
      GO TO 40                                                          LARC1    1041
   10 Q0=DT                                                             LARC1    1042
C     THIS IS Q0 FOR DL = 0.0                                           LARC1    1043
      IF (BET.EQ.0.0) GO TO 20                                          LARC1    1044
      Q1=DT*Q4-Q5                                                       LARC1    1045
C     THIS IS Q1 FOR BETA .NE. 0.0, DL = 0.0                            LARC1    1046
      GO TO 40                                                          LARC1    1047
   20 IF (ALPHA.EQ.0.0) GO TO 30                                        LARC1    1048
      Q1=(Q4-Q0)/ALPHA                                                  LARC1    1049
C     THIS IS Q1 FOR BETA = 0.0, DL = 0.0, ALPHA .NE. 0.0               LARC1    1050
      GO TO 40                                                          LARC1    1051
   30 Q1=0.5*DT2                                                        LARC1    1052
C     THIS IS Q1 FOR BETA = 0.0, DL = 0.0, ALPHA = 0.0                  LARC1    1053
   40 V0=(E1/DECAY-E*Q0)/RFP                                            LARC1    1054
      V4=(PZERO(GAM,BETA,DT)-E*Q4)/DECAY                                LARC1    1055
      V1=(V4-E*Q1)/RFP                                                  LARC1    1056
      IF (BET.EQ.0.0) GO TO 50                                          LARC1    1057
      Q2=(Q0-Q4+ALPHA*Q1)/BET                                           LARC1    1058
      Q3=(Q1-Q5+ALPHA*Q2)/BET                                           LARC1    1059
      V2=(V0-V4+ALPHA*V1)/BET                                           LARC1    1060
      V5=(E1/DECAY-GAM*V4-E*Q4)/BET                                     LARC1    1061
      V3=(V1-V5+ALPHA*V2)/BET                                           LARC1    1062
      RPF=RLEAK*(PNF*E1/DECAY+RF*(A0*V0+A1*V1+A2*V2+A3*V3))             LARC1    1063
      RPI=RLEAK*(PNI*E1/DECAY+RI*(A4*V4+A5*V5))                         LARC1    1064
      PNF=E*(PNF+RF*(A0*Q0+A1*Q1+A2*Q2+A3*Q3))                          LARC1    1065
      PNI=E*(PNI+RI*(A4*Q4+A5*Q5))                                      LARC1    1066
      GO TO 60                                                          LARC1    1067
   50 CONTINUE                                                          LARC1    1068
      RPF=RLEAK*(PNF*E1/DECAY+RF*(A0*V0+A1*V1))                         LARC1    1069
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      RPI=RLEAK*(PNI*E1/DECAY+RI*A4*V4)                                 LARC1    1070
      PNF=E*(PNF+RF*(A0*Q0+A1*Q1))                                      LARC1    1071
      PNI=E*(PNI+RI*A4*Q4)                                              LARC1    1072
   60 RETURN                                                            LARC1    1073
      END                                                               LARC1    1074
      SUBROUTINE CALC1(NFOLD,NIOLD,RA,RB,LAMBDA,DT,F,NF,NI,RRF,RRI,RFOLD LARC1    1075
     1,RIOLD)                                                           LARC1    1076
C     SIMPLE EQUATIONS FIRST HALF                                       LARC1    1077
      REAL NFP,NIP                                                      LARC1    1078
      REAL NFOLD,NIOLD,LAMBDA,NF,NI,M0,M1,M2,M3,M4,M5                   LARC1    1079
      IF ((NFOLD+NIOLD).EQ.0.0) GO TO 10                                LARC1    1080
      A0=NFOLD                                                          LARC1    1081
      A4=NIOLD                                                          LARC1    1082
      RF=0.5*(RA+RFOLD)                                                 LARC1    1083
      RI=0.5*(RB+RIOLD)                                                 LARC1    1084
      RFP=RF*LAMBDA                                                     LARC1    1085
      RIP=RI*LAMBDA                                                     LARC1    1086
      RFL=RFP*DT                                                        LARC1    1087
      RIL=RIP*DT                                                        LARC1    1088
      M0=EXP(-RFL)                                                      LARC1    1089
      EI=EXP(-RIL)                                                      LARC1    1090
      NFP=NFOLD*M0                                                      LARC1    1091
      NIP=NIOLD*EI                                                      LARC1    1092
      SUM=NFP+NIP                                                       LARC1    1093
      NF=F*SUM                                                          LARC1    1094
      NI=(1.-F)*SUM                                                     LARC1    1095
      RRF=RF*(A0-NFP)/RFP                                               LARC1    1096
      RRI=RI*(A4-NIP)/RIP                                               LARC1    1097
      GO TO 20                                                          LARC1    1098
   10 NF=0.0                                                            LARC1    1099
      NI=0.0                                                            LARC1    1100
      RRF=0.0                                                           LARC1    1101
      RRI=0.0                                                           LARC1    1102
   20 RETURN                                                            LARC1    1103
      END                                                               LARC1    1104
      SUBROUTINE CALC2(NFOLD,NIOLD,RA,RB,LAMBDA,DT,F,NF,NI,RRF,RRI,RFOLD LARC1    1105
     1,RIOLD)                                                           LARC1    1106
C     LINEAR RELEASE FIRST HALF                                         LARC1    1107
      REAL NFP,NIP                                                      LARC1    1108
      REAL NFOLD,NIOLD,LAMBDA,NF,NI                                     LARC1    1109
      IF ((NFOLD+NIOLD).EQ.0.0) GO TO 10                                LARC1    1110
      RF=RA                                                             LARC1    1111
      RI=RB                                                             LARC1    1112
      A0=NFOLD                                                          LARC1    1113
      A4=NIOLD                                                          LARC1    1114
      EF=EXP(-LAMBDA*DT-0.5*(RFOLD+RF)*DT)                              LARC1    1115
      EI=EXP(-LAMBDA*DT-0.5*(RIOLD+RI)*DT)                              LARC1    1116
      NFP=NFOLD*EF                                                      LARC1    1117
      NIP=NIOLD*EI                                                      LARC1    1118
      SUM=NFP+NIP                                                       LARC1    1119
      NF=F*SUM                                                          LARC1    1120
      NI=(1.-F)*SUM                                                     LARC1    1121
      GAMF=RFOLD+LAMBDA                                                 LARC1    1122
      GAMI=RIOLD+LAMBDA                                                 LARC1    1123
      BETF=(RF-RFOLD)/DT                                                LARC1    1124
      BETAF=BETF/2.                                                     LARC1    1125
      RRF=-A0*LAMBDA*PZERO(GAMF,BETAF,DT)+A0*(1.-EF)                    LARC1    1126
      BETI=(RI-RIOLD)/DT                                                LARC1    1127
      BETAI=BETI/2.                                                     LARC1    1128
      RRI=-A4*LAMBDA*PZERO(GAMI,BETAI,DT)+A4*(1.-EI)                    LARC1    1129
      GO TO 20                                                          LARC1    1130
   10 NF=0.0                                                            LARC1    1131
      NI=0.0                                                            LARC1    1132
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      RRF=0.0                                                           LARC1   1133
      RRI=0.0                                                           LARC1   1134
   20 RETURN                                                            LARC1   1135
      END                                                               LARC1   1136
      SUBROUTINE PZERO(A,B,C)                                           LARC1   1137
      DATA SQPI/1.772453850905514/                                      LARC1   1138
      CFNEW(Z,D)=RERFC(D)-EXP(Z*Z-2.*D*Z)*RERFC(D-Z)                    LARC1   1139
      IF (B.EQ.0.0) GO TO 10                                            LARC1   1140
      IF (B.LT.0.0) GO TO 30                                            LARC1   1141
      SQB=SQRT(B)                                                       LARC1   1142
      SQB2=SQB+SQB                                                      LARC1   1143
      ARG1=SQB*C                                                        LARC1   1144
      ARG2=-A/SQB2                                                      LARC1   1145
      PZERO=SQPI*FNEW(ARG1,ARG2)/SQB2                                   LARC1   1146
      RETURN                                                            LARC1   1147
   10 IF (A.EQ.0.0) GO TO 20                                            LARC1   1148
      PZERO=(1.-EXP(-A*C))/A                                            LARC1   1149
      RETURN                                                            LARC1   1150
   20 PZERO=C                                                           LARC1   1151
      RETURN                                                            LARC1   1152
   30 CONTINUE                                                          LARC1   1153
      SQB=SQRT(-B)                                                      LARC1   1154
      SQB2=SQB+SQB                                                      LARC1   1155
      ARG1=SQB*C                                                        LARC1   1156
C     ARG1=Z  (ALWAYS POSITIVE)                                         LARC1   1157
      ARG2=A/SQB2                                                       LARC1   1158
      PZERO=SQPI*CFNEW(ARG1,ARG2)/SQB2                                  LARC1   1159
      RETURN                                                            LARC1   1160
      END                                                               LARC1   1161
      FUNCTION RERFC (Z)                                                LARC1   1162
      IF (ABS(Z).GT.4.0) GO TO 10                                       LARC1   1163
      RERFC=QERFC(Z)                                                    LARC1   1164
      RETURN                                                            LARC1   1165
   10 RERFC=AERFC(Z)                                                    LARC1   1166
      RETURN                                                            LARC1   1167
      END                                                               LARC1   1168
      FUNCTION QERFC (ZTEMP)                                            LARC1   1169
      COMPLEX S,T,Z                                                     LARC1   1170
      DATA EPS/1.0E-15/                                                 LARC1   1171
      DATA SQPI/1.772453850905516/                                      LARC1   1172
      IF (ZTEMP.EQ.0.0) GO TO 30                                        LARC1   1173
      Z=CMPLX(0.0,ZTEMP)                                                LARC1   1174
      D=SQPI/2                                                          LARC1   1175
      T=Z/D                                                             LARC1   1176
      S=T+1.0                                                           LARC1   1177
      L=1                                                               LARC1   1178
      K=1                                                               LARC1   1179
   10 CONTINUE                                                          LARC1   1180
      K=K+1                                                             LARC1   1181
      T=T*Z*D                                                           LARC1   1182
      D=2./((K+1)*D)                                                    LARC1   1183
      S=S+T                                                             LARC1   1184
      IF (CABS(S).EQ.0.0) GO TO 20                                      LARC1   1185
      IF (CABS(T)/CABS(S).GT.EPS) GO TO 10                              LARC1   1186
      L=L+1                                                             LARC1   1187
      IF (L.LT.4) GO TO 10                                              LARC1   1188
      QERFC=AIMAG(S)                                                    LARC1   1189
      RETURN                                                            LARC1   1190
   20 PRINT 40, Z,K,L                                                   LARC1   1191
      GO TO 10                                                          LARC1   1192
   30 QERFC=0.0                                                         LARC1   1193
      RETURN                                                            LARC1   1194
C                                                                       LARC1   1195
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   40 FORMAT (* S=0.0 FOR Z=*,E10.3,* K=*,I10,* L=*,I10)                LARCI   1196
      END                                                               LARC1   1197
      FUNCTION AERFC (Z)                                                LARC1   1198
      DATA EPS/1.0E-15/                                                 LARC1   1199
      DATA SQPI/1.772453850905516/                                      LARC1   1200
      IF (Z.EQ.0.0) GO TO 40                                            LARC1   1201
      CON=1.0/(Z*SQPI)                                                  LARC1   1202
      U=Z*Z                                                             LARC1   1203
      D=0.5                                                             LARC1   1204
      T=D/U                                                             LARC1   1205
      S=1.0+T                                                           LARC1   1206
      L=1                                                               LARC1   1207
      K=1                                                               LARC1   1208
   10 CONTINUE                                                          LARC1   1209
      K=K+1                                                             LARC1   1210
      D=K-0.5                                                           LARC1   1211
      TSAVE=T                                                           LARC1   1212
      T=T*D/U                                                           LARC1   1213
      S=S+T                                                             LARC1   1214
      IF (T.GT.TSAVE) GO TO 20                                          LARC1   1215
      IF (S.EQ.0.0) GO TO 30                                            LARC1   1216
      IF (ABS(T/S).GT.EPS) GO TO 10                                     LARC1   1217
      L=L+1                                                             LARC1   1218
      IF (L.LT.4) GO TO 10                                              LARC1   1219
   20 CONTINUE                                                          LARC1   1220
      AERFC=CON*S                                                       LARC1   1221
      RETURN                                                            LARC1   1222
   30 PRINT 50, Z,K,L                                                   LARC1   1223
      GO TO 10                                                          LARC1   1224
   40 AERFC=0.0                                                         LARC1   1225
      RETURN                                                            LARC1   1226
C                                                                       LARC1   1227
   50 FORMAT (* S=0.0 FOR Z=*,E10.3,* K=*,I10,* L=*,I10)                LARC1   1228
      END                                                               LARC1   1229
      SUBROUTINE CALC3(NFOLD,NIOLD,RA,RB,LAMBDA,DT,F,FOLD,NF,NI,RRF,RRI, LARC1   1230
     1RFOLD,RIOLD)                                                      LARC1   1231
C     LINEAR FAILURE FIRST HALF                                         LARC1   1232
      REAL NFOLD,NIOLD,LAMBDA,NF,NI,M0,M1,M2,M3,M4,M5                   LARC1   1233
      DATA SQPI/1.772453850905514/                                      LARC1   1234
      IF ((NFOLD+NIOLD).EQ.0.0) GO TO 70                                LARC1   1235
      A0=NFOLD                                                          LARC1   1236
      A4=NIOLD                                                          LARC1   1237
      RF=0.5*(RA+RFOLD)                                                 LARC1   1238
      RI=0.5*(RB+RIOLD)                                                 LARC1   1239
      RFP=RF+LAMBDA                                                     LARC1   1240
      RIP=RI+LAMBDA                                                     LARC1   1241
      RFL=RFP*DT                                                        LARC1   1242
      RIL=RIP*DT                                                        LARC1   1243
      M0=EXP(-RFL)                                                      LARC1   1244
      EI=EXP(-RIL)                                                      LARC1   1245
      P0=(1.-M0)/RFP                                                    LARC1   1246
      DF=F-FOLD                                                         LARC1   1247
      DFDT=DF/DT                                                        LARC1   1248
      FI=1.-F                                                           LARC1   1249
      FIOLD=1.-FOLD                                                     LARC1   1250
      IF (RF.NE.RI) GO TO 30                                            LARC1   1251
      IF (F.GT.0.0) GO TO 10                                            LARC1   1252
      NF=0.0                                                            LARC1   1253
      RRF=0.0                                                           LARC1   1254
      NI=A4*EI                                                          LARC1   1255
      RRI=(1.-EI)*RI*A4/RIP                                             LARC1   1256
      GO TO 80                                                          LARC1   1257
   10 IF (FOLD.LT.1.0) GO TO 20                                         LARC1   1258
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      NI=0.0                                                            LARC1   1259
      RRI=0.0                                                           LARC1   1260
      NF=A0*M0                                                          LARC1   1261
      RRF=RF*A0*P0                                                      LARC1   1262
      GO TO 80                                                          LARC1   1263
   20 NI=A4*FI*FI/FIOLD                                                 LARC1   1264
      NF=M0*(A0+DF*A4/FIOLD)                                            LARC1   1265
      PART=DFDT*RI*A4*(1.-(1.+RFL)*M0)/(FIOLD*RFP*RFP)                  LARC1   1266
      RRF=PART+RF*A0*P0                                                 LARC1   1267
      RRI=-PART+RF*A4*P0                                                LARC1   1268
      GO TO 80                                                          LARC1   1269
   30 IF (F.GT.0.0) GO TO 40                                            LARC1   1270
      NF=0.0                                                            LARC1   1271
      RRF=0.0                                                           LARC1   1272
      NI=FI*A4                                                          LARC1   1273
      RRI=RI*(A4-NI)/RIP                                                LARC1   1274
      GO TO 80                                                          LARC1   1275
   40 IF (FOLD.LT.1.0) GO TO 50                                         LARC1   1276
      NI=0.0                                                            LARC1   1277
      RRI=0.0                                                           LARC1   1278
      NF=A0*M0                                                          LARC1   1279
      RRF=RF*A0*P0                                                      LARC1   1280
      GO TO 80                                                          LARC1   1281
   50 DT2=DT*DT                                                         LARC1   1282
      DR=RF-RI                                                          LARC1   1283
      A1=(DFDT+DR*FOLD*FIOLD)*A4/FIOLD                                  LARC1   1284
      A5=-DFDT*A4/FIOLD                                                 LARC1   1285
      A2=-DR*(FIOLD-FOLD)*A5                                            LARC1   1286
      A3=DR*DFDT*A5                                                     LARC1   1287
      ALPHA=FIOLD*DR                                                    LARC1   1288
      GAM=RFP*FOLD+RIP*FIOLD                                            LARC1   1289
      IF (DF.EQ.0.0) GO TO 60                                           LARC1   1290
      BET=DR*DFDT                                                       LARC1   1291
      BETA=BET/2.                                                       LARC1   1292
      IF (BETA.LT.0.0) PRINT 90, BETA,DF,DR                             LARC1   1293
      IF (BETA.LT.0.0) BETA=0.0                                         LARC1   1294
      SQB=SQRT(BETA)                                                    LARC1   1295
      SQB2=SQB+SQB                                                      LARC1   1296
      SQBT=SQB*DT                                                       LARC1   1297
      SQC=ALPHA/SQB2                                                    LARC1   1298
      SQE=-GAM/SQB2                                                     LARC1   1299
      W6=FNEW(SQBT,SQE)                                                 LARC1   1300
      W7=M0*FNEW(SQBT,SQC)                                              LARC1   1301
      M4=EXP(-GAM*DT-BETA*DT2)                                          LARC1   1302
      M5=DT*M4                                                          LARC1   1303
      M1=SQRT*W7/SQB2                                                   LARC1   1304
      M2=(M0-M4+ALPHA*M1)/BET                                           LARC1   1305
      M3=(ALPHA*M2+M1-M5)/BET                                           LARC1   1306
      P4=SQRT*W6/SQB2                                                   LARC1   1307
      P5=(1.-GAM*P4-M4)/BET                                             LARC1   1308
      P1=(P4-M1)/RFP                                                    LARC1   1309
      P2=(P0-P4+ALPHA*P1)/BET                                           LARC1   1310
      P3=(ALPHA*P2+P1-P5)/BET                                           LARC1   1311
      NF=A0*M0+A1*M1+A2*M2+A3*M3                                        LARC1   1312
      NI=A4*M4+A5*M5                                                    LARC1   1313
      RRF=RF*(A0*P0+A1*P1+A2*P2+A3*P3)                                  LARC1   1314
      RRI=RI*(A4*P4+A5*P5)                                              LARC1   1315
      GO TO 80                                                          LARC1   1316
   60 M4=EXP(-GAM*DT)                                                   LARC1   1317
      M1=(M4-M0)/ALPHA                                                  LARC1   1318
      P4=(1.-M4)/GAM                                                    LARC1   1319
      P1=(P4-P0)/ALPHA                                                  LARC1   1320
      NF=A0*M0+A1*M1                                                    LARC1   1321
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      NI=A4*M4                                                          LARC1    1322
      RRF=RF*(A0*P0+A1*P1)                                              LARC1    1323
      RRI=RI*A4*P4                                                      LARC1    1324
      GO TO 80                                                          LARC1    1325
   70 NF=0.0                                                            LARC1    1326
      NI=0.0                                                            LARC1    1327
      RRF=0.0                                                           LARC1    1328
      RRI=0.0                                                           LARC1    1329
   80 RETURN                                                            LARC1    1330
C                                                                       LARC1    1331
   90 FORMAT (* BETA NEGATIVE IN CALC.  BETA =*,E10.3,*  DF =*,F10.3,*  LARC1    1332
     1DR =*,F10.3,*  BETA SET TO ZERO*)                                 LARC1    1333
      END                                                               LARC1    1334
      FUNCTION FNEW (Z,D)                                               LARC1    1335
      IF (D.LT.0.0) GO TO 20                                            LARC1    1336
      IF (Z.GT.D) GO TO 10                                              LARC1    1337
C     CASE 1  D.GT.0.  D.GT.Z                                           LARC1    1338
      FNEW=EXP(-Z*Z+2.*Z*D)*PQERFC(D-Z)-PQERFC(D)                       LARC1    1339
      RETURN                                                            LARC1    1340
C     CASE 2  D.GT.0.  Z.GT.D                                           LARC1    1341
   10 FNEW=2.*EXP(D*D)-PQERFC(D)-EXP(-Z*Z+2.*Z*D)*PQERFC(Z-D)           LARC1    1342
      RETURN                                                            LARC1    1343
C     CASE 3  D.LT.0.  Z.GT.D                                           LARC1    1344
   20 IF (D.GT.Z) GO TO 30                                              LARC1    1345
      FNEW=PQERFC(-D)-EXP(-Z*Z+2.*Z*D)*PQERFC(Z-D)                      LARC1    1346
      RETURN                                                            LARC1    1347
C     CASE 4  D.LT.0.  D.GT.Z                                           LARC1    1348
   30 FNEW=-2.*EXP(D*D)+PQERFC(-D)+EXP(-Z*Z+2.*Z*D)*PQERFC(D-Z)         LARC1    1349
      RETURN.                                                           LARC1    1350
      END                                                               LARC1    1351
      FUNCTION SPLINE (TIME,PIN)                                        LARC1    1352
      DIMENSION IBD(6), Z1(113), Z2(113), Z3(113), FX(20,113), FY(20,113 LARC1    1353
     1), FXY(20,113)                                                    LARC1    1354
      DIMENSION TE(20,113), T(20), F(113)                               LARC1    1355
      DIMENSION T1(200), T2(200), T3(200), T4(200), T5(200), T6(200), T7 LARC1    1356
     1(200)                                                             LARC1    1357
      DIMENSION T8(200), T9(200), T10(200), T11(200), T12(60)           LARC1    1358
      DATA T1/1455.,1694.,1895.,2073.,2236.,2387.,2526.,2657.,2782.,2901 LARC1    1359
     1.,3016.,3126.,3232.,3333.,3431.,3525.,3616.,3624.,3630.,3634.,1454 LARC1    1360
     2.,1691.,1891.,2070.,2232.,2380.,2521.,2650.,2775.,2896.,3012.,3120 LARC1    1361
     3.,3225.,3323.,3420.,3517.,3610.,3620.,3627.,3633.,1452.,1688.,1886 LARC1    1362
     4.,2065.,2227.,2372.,2514.,2640.,2764.,2887.,3000.,3110.,3212.,3312 LARC1    1363
     5.,3410.,3506.,3600.,3612.,3622.,3631.,1450.,1685.,1881.,2060.,2222 LARC1    1364
     6.,2364.,2507.,2630.,2752.,2872.,2987.,3100.,3200.,3300.,3398.,3492 LARC1    1365
     7.,3584.,3602.,3618.,3629.,1448.,1682.,1877.,2052.,2214.,2357.,2495 LARC1    1366
     8.,2620.,2741.,2857.,2967.,3075.,3180.,3285.,3385.,3481.,3567.,3593 LARC1    1367
     9.,3616.,3626.,1446.,1679.,1872.,2044.,2207.,2350.,2490.,2610.,2730 LARC1    1368
     $.,2850.,2956.,3062.,3167.,3271.,3371.,3464.,3550.,3584.,3614.,3623 LARC1    1369
     $.,1444.,1676.,1868.,2036.,2200.,2340.,2480.,2600.,2719.,2837.,2945 LARC1    1370
     $.,3050.,3155.,3257.,3357.,3448.,3534.,3576.,3612.,3620.,1442.,1673 LARC1    1371
     $.,1863.,2027.,2185.,2330.,2470.,2590.,2710.,2825.,2935.,3040.,3145 LARC1    1372
     $.,3245.,3343.,3431.,3517.,3567.,3610.,3617.,1440.,1670.,1859.,2018 LARC1    1373
     $.,2170.,2315.,2460.,2580.,2699.,2812.,2925.,3035.,3135.,3235.,3329 LARC1    1374
     $.,3415.,3500.,3550.,3600.,3615.,1438.,1667.,1854.,2009.,2159.,2305 LARC1    1375
     $.,2450.,2572.,2686.,2800.,2910.,3020.,3120.,3220.,3315.,3400.,3493 LARC1    1376
     $.,3537.,3590.,3612./                                              LARC1    1377
      DATA T2/1436.,1664.,1850.,2000.,2151.,2297.,2445.,2564.,2678.,2790 LARC1    1378
     1.,2900.,3010.,3110.,3205.,3295.,3383.,3467.,3530.,3580.,3609.,1434 LARC1    1379
     2.,1661.,1846.,1996.,2146.,2292.,2440.,2556.,2670.,2784.,2894.,3000 LARC1    1380
     3.,3100.,3192.,3281.,3366.,3450.,3522.,3570.,3606.,1432.,1658.,1841 LARC1    1381
     4.,1992.,2141.,2287.,2433.,2548.,2663.,2778.,2888.,2990.,3085.,3175 LARC1    1382
     5.,3265.,3350.,3433.,3515.,3560.,3603.,1430.,1655.,1836.,1988.,2136 LARC1    1383
     6.,2282.,2425.,2540.,2655.,2770.,2880.,2980.,3071.,3162.,3252.,3336 LARC1    1384
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7.,3416.,3498.,3557.,3600.,1428.,1652.,1832.,1984.,2130.,2277.,2416 LARC1   1385
8.,2531.,2646.,2760.,2870.,2970.,3060.,3150.,3240.,3320.,3400.,3481 LARC1   1386
9.,3546.,3586.,1427.,1649.,1827.,1980.,2126.,2272.,2408.,2520.,2630 LARC1   1387
$.,2740.,2850.,2960.,3040.,3120.,3220.,3308.,3380.,3464.,3520.,3571 LARC1   1388
$.,1425.,1646.,1823.,1975.,2122.,2267.,2400.,2510.,2610.,2730.,2840 LARC1   1389
$.,2950.,3020.,3100.,3200.,3288.,3360.,3433.,3510.,3557.,1423.,1643 LARC1   1390
$.,1818.,1971.,2118.,2262.,2393.,2500.,2600.,2720.,2830.,2931.,3010 LARC1   1391
$.,3088.,3187.,3277.,3340.,3400.,3500.,3543.,1421.,1640.,1814.,1947 LARC1   1392
$.,2115.,2257.,2386.,2493.,2593.,2710.,2820.,2912.,3000.,3077.,3175 LARC1   1393
$.,3266.,3320.,3387.,3483.,3528.,1419.,1636.,1809.,1962.,2112.,2252 LARC1   1394
$.,2380.,2486.,2586.,2700.,2810.,2905.,2990.,3066.,3162.,3255.,3360 LARC1   1395
$.,3375.,3467.,3514./                                               LARC1   1396
 DATA T3/1417.,1632.,1805.,1958.,2108.,2247.,2373.,2480.,2579.,2690 LARC1   1397
1.,2800.,2900.,2980.,3055.,3150.,3244.,3292.,3362.,3450.,3500.,1415 LARC1   1398
2.,1628.,1800.,1953.,2104.,2241.,2366.,2473.,2572.,2680.,2790.,2899 LARC1   1399
3.,2970.,3044.,3137.,3233.,3285.,3350.,3433.,3487.,1413.,1624.,1797 LARC1   1400
4.,1949.,2100.,2236.,2360.,2467.,2564.,2671.,2779.,2878.,2960.,3033 LARC1   1401
5.,3125.,3222.,3277.,3348.,3417.,3475.,1410.,1620.,1794.,1945.,2095 LARC1   1402
6.,2231.,2353.,2460.,2557.,2662.,2769.,2867.,2950.,3022.,3112.,3211 LARC1   1403
7.,3269.,3336.,3400.,3462.,1408.,1616.,1791.,1941.,2090.,2225.,2346 LARC1   1404
8.,2454.,2550.,2652.,2758.,2856.,2940.,3011.,3100.,3200.,3262.,3324 LARC1   1405
9.,3387.,3450.,1405.,1612.,1788.,1937.,2084.,2216.,2340.,2448.,2544 LARC1   1406
$.,2643.,2747.,2845.,2930.,3000.,3088.,3191.,3246.,3312.,3373.,3437 LARC1   1407
$.,1402.,1608.,1785.,1933.,2079.,2211.,2333.,2442.,2537.,2633.,2737 LARC1   1408
$.,2834.,2920.,2993.,3075.,3172.,3231.,3300.,3360.,3425.,1400.,1604 LARC1   1409
$.,1781.,1928.,2074.,2206.,2326.,2436.,2531.,2624.,2726.,2823.,2910 LARC1   1410
$.,2986.,3063.,3143.,3215.,3283.,3349.,3412.,1398.,1600.,1777.,1924 LARC1   1411
$.,2069.,2200.,2320.,2430.,2525.,2615.,2715.,2812.,2900.,2975.,3050 LARC1   1412
$.,3125.,3200.,3267.,3333.,3400.,1396.,1598.,1773.,1920.,2063.,2193 LARC1   1413
$.,2315.,2425.,2515.,2610.,2710.,2810.,2885.,2960.,3034.,3110.,3183 LARC1   1414
$.,3250.,3317.,3390./                                               LARC1   1415
 DATA T4/1394.,1596.,1769.,1916.,2058.,2186.,2310.,2420.,2505.,2605 LARC1   1416
1.,2705.,2805.,2870.,2947.,3023.,3100.,3167.,3233.,3300.,3375.,1392 LARC1   1417
2.,1594.,1765.,1912.,2053.,2180.,2305.,2415.,2500.,2600.,2700.,2800 LARC1   1418
3.,2855.,2930.,3010.,3085.,3153.,3222.,3280.,3360.,1390.,1592.,1741 LARC1   1419
4.,1908.,2048.,2174.,2300.,2410.,2497.,2593.,2680.,2775.,2840.,2920 LARC1   1420
5.,3000.,3070.,3140.,3211.,3260.,3340.,1388.,1590.,1757.,1904.,2043 LARC1   1421
6.,2167.,2290.,2400.,2493.,2586.,2678.,2752.,2826.,2900.,2983.,3056 LARC1   1422
7.,3128.,3200.,3240.,3320.,1386.,1588.,1754.,1900.,2038.,2160.,2280 LARC1   1423
8.,2386.,2479.,2573.,2667.,2740.,2813.,2887.,2945.,3040.,3110.,3175 LARC1   1424
9.,3220.,3300.,1384.,1586.,1750.,1895.,2032.,2153.,2270.,2372.,2466 LARC1   1425
$.,2550.,2655.,2733.,2800.,2873.,2948.,3024.,3100.,3150.,3200.,3280 LARC1   1426
$.,1382.,1584.,1746.,1890.,2027.,2147.,2260.,2359.,2453.,2547.,2644 LARC1   1427
$.,2722.,2789.,2860.,2930.,3000.,3070.,3115.,3160.,3260.,1380.,1582 LARC1   1428
$.,1742.,1885.,2022.,2140.,2250.,2345.,2440.,2535.,2633.,2710.,2779 LARC1   1429
$.,2844.,2909.,2975.,3040.,3080.,3133.,3240.,1378.,1580.,1738.,1880 LARC1   1430
$.,2016.,2134.,2240.,2335.,2430.,2525.,2622.,2705.,2769.,2835.,2900 LARC1   1431
$.,2950.,3025.,3060.,3117.,3220.,1376.,1578.,1735.,1875.,2011.,2127 LARC1   1432
$.,2230.,2325.,2420.,2515.,2612.,2695.,2758.,2816.,2875.,2925.,3000 LARC1   1433
$.,3040.,3100.,3200./                                               LARC1   1434
 DATA T5/1374.,1575.,1731.,1870.,2005.,2120.,2225.,2318.,2412.,2506 LARC1   1435
1.,2600.,2673.,2736.,2800.,2850.,2900.,2973.,3025.,3079.,3180.,1372 LARC1   1436
2.,1573.,1727.,1866.,2000.,2110.,2220.,2310.,2400.,2500.,2575.,2644 LARC1   1437
3.,2712.,2781.,2837.,2890.,2946.,3000.,3059.,3140.,1371.,1571.,1723 LARC1   1438
4.,1862.,1992.,2105.,2215.,2305.,2390.,2487.,2559.,2629.,2700.,2762 LARC1   1439
5.,2825.,2878.,2932.,2985.,3043.,3120.,1369.,1569.,1720.,1858.,1984 LARC1   1440
6.,2100.,2210.,2300.,2380.,2475.,2548.,2600.,2670.,2741.,2812.,2864 LARC1   1441
7.,2916.,2970.,3026.,3100.,1367.,1566.,1716.,1854.,1975.,2090.,2205 LARC1   1442
8.,2290.,2370.,2463.,2536.,2590.,2660.,2730.,2800.,2850.,2900.,2956 LARC1   1443
9.,3011.,3080.,1365.,1563.,1712.,1850.,1967.,2080.,2200.,2280.,2360 LARC1   1444
$.,2450.,2524.,2580.,2650.,2720.,2785.,2837.,2889.,2945.,3000.,3060 LARC1   1445
$.,1363.,1560.,1708.,1846.,1958.,2070.,2182.,2270.,2350.,2437.,2512 LARC1   1446
$.,2573.,2640.,2710.,2770.,2823.,2877.,2933.,2985.,3040.,1361.,1557 LARC1   1447
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$,,1704.,1841.,1948.,2056.,2164.,2260.,2340.,2425.,2500.,2567.,2633 LARC1    1448
$,,2700.,2755.,2808.,2866.,2921.,2970.,3020.,1359.,1554.,1700.,1837 LARC1    1449
$,,1939.,2042.,2146.,2250.,2330.,2412.,2488.,2555.,2622.,2691.,2761 LARC1    1450
$,,2800.,2855.,2910.,2955.,3000.,1358.,1551.,1695.,1832.,1934.,2036 LARC1    1451
$,,2138.,2240.,2320.,2400.,2475.,2542.,2611.,2669.,2726.,2784.,2842 LARC1    1452
$,,2900.,2945.,2980./                                               LARC1    1453
 DATA T4/1356.,1548.,1690.,1828.,1929.,2030.,2130.,2230.,2310.,2383 LARC1    1454
1,,2460.,2525.,2600.,2656.,2713.,2767.,2821.,2875.,2922.,2960.,1354 LARC1    1455
2,,1545.,1685.,1824.,1924.,2024.,2120.,2220.,2300.,2367.,2434.,2510 LARC1    1456
3,,2586.,2643.,2700.,2750.,2800.,2850.,2900.,2940.,1352.,1542.,1680 LARC1    1457
4,,1820.,1920.,2020.,2115.,2210.,2283.,2350.,2417.,2505.,2573.,2631 LARC1    1458
5,,2680.,2735.,2780.,2835.,2880.,2920.,1350.,1539.,1675.,1816.,1917 LARC1    1459
6,,2015.,2110.,2200.,2267.,2333.,2400.,2490.,2560.,2620.,2660.,2720 LARC1    1460
7,,2760.,2820.,2860.,2900.,1348.,1536.,1670.,1812.,1915.,2010.,2165 LARC1    1461
8,,2190.,2260.,2325.,2390.,2465.,2530.,2590.,2640.,2690.,2740.,2800 LARC1    1462
9,,2840.,2880.,1346.,1533.,1665.,1808.,1905.,2000.,2095.,2180.,2250 LARC1    1463
$,,2315.,2380.,2450.,2500.,2550.,2600.,2650.,2700.,2750.,2800.,2860 LARC1    1464
$,,1344.,1530.,1660.,1804.,1895.,1985.,2080.,2170.,2240.,2310.,2370 LARC1    1465
$,,2430.,2480.,2530.,2590.,2637.,2683.,2733.,2786.,2840.,1342.,1527 LARC1    1466
$,,1655.,1800.,1885.,1970.,2055.,2150.,2230.,2305.,2360.,2410.,2460 LARC1    1467
$,,2510.,2560.,2623.,2667.,2717.,2768.,2820.,1340.,1524.,1650.,1791 LARC1    1468
$,,1875.,1960.,2045.,2130.,2215.,2290.,2350.,2400.,2450.,2500.,2560 LARC1    1469
$,,2610.,2650.,2700.,2750.,2800.,1338.,1521.,1645.,1784.,1867.,1950 LARC1    1470
$,,2033.,2116.,2200.,2262.,2341.,2387.,2440.,2490.,2540.,2600.,2645 LARC1    1471
$,,2690.,2740.,2787./                                               LARC1    1472
 DATA T7/1336.,1518.,1640.,1774.,1858.,1942.,2026.,2110.,2183.,2250 LARC1    1473
1,,2312.,2375.,2430.,2480.,2530.,2588.,2640.,2680.,2730.,2775.,1334 LARC1    1474
2,,1515.,1635.,1765.,1849.,1933.,2016.,2100.,2167.,2233.,2300.,2363 LARC1    1475
3,,2420.,2470.,2520.,2575.,2630.,2670.,2720.,2762.,1332.,1512.,1630 LARC1    1476
4,,1755.,1840.,1924.,2008.,2084.,2150.,2216.,2284.,2350.,2410.,2460 LARC1    1477
5,,2510.,2565.,2620.,2660.,2710.,2750.,1330.,1509.,1625.,1745.,1830 LARC1    1478
6,,1915.,2000.,2067.,2133.,2200.,2267.,2337.,2400.,2450.,2505.,2558 LARC1    1479
7,,2610.,2650.,2700.,2737.,1328.,1506.,1620.,1735.,1827.,1910.,1990 LARC1    1480
8,,2057.,2123.,2190.,2255.,2300.,2375.,2438.,2490.,2550.,2600.,2640 LARC1    1481
9,,2683.,2725.,1326.,1503.,1615.,1725.,1825.,1905.,1980.,2047.,2116 LARC1    1482
$,,2180.,2235.,2285.,2355.,2400.,2467.,2533.,2575.,2620.,2667.,2715 LARC1    1483
$,,1324.,1500.,1610.,1720.,1820.,1900.,1970.,2037.,2108.,2170.,2224 LARC1    1484
$,,2270.,2332.,2375.,2437.,2500.,2550.,2600.,2650.,2700.,1322.,1495 LARC1    1485
$,,1605.,1715.,1810.,1890.,1960.,2030.,2100.,2160.,2210.,2260.,2310 LARC1    1486
$,,2360.,2410.,2460.,2510.,2560.,2610.,2687.,1320.,1490.,1600.,1710 LARC1    1487
$,,1800.,1880.,1955.,2025.,2092.,2154.,2205.,2255.,2306.,2356.,2405 LARC1    1488
$,,2450.,2500.,2550.,2600.,2675.,1318.,1484.,1595.,1705.,1790.,1870 LARC1    1489
$,,1945.,2020.,2083.,2147.,2200.,2250.,2303.,2352.,2400.,2440.,2486 LARC1    1490
$,,2532.,2579.,2662./                                               LARC1    1491
 DATA T8/1316.,1479.,1590.,1700.,1780.,1860.,1935.,2010.,2075.,2140 LARC1    1492
1,,2195.,2245.,2300.,2343.,2387.,2430.,2472.,2514.,2557.,2650.,1314 LARC1    1493
2,,1473.,1584.,1690.,1770.,1850.,1925.,2000.,2067.,2133.,2185.,2234 LARC1    1494
3,,2283.,2328.,2375.,2420.,2461.,2502.,2543.,2637.,1312.,1468.,1578 LARC1    1495
4,,1680.,1760.,1840.,1913.,1988.,2053.,2116.,2168.,2220.,2267.,2314 LARC1    1496
5,,2362.,2410.,2450.,2489.,2528.,2625.,1310.,1462.,1572.,1670.,1750 LARC1    1497
6,,1830.,1901.,1975.,2040.,2100.,2150.,2200.,2250.,2300.,2350.,2390 LARC1    1498
7,,2425.,2465.,2510.,2612.,1308.,1457.,1565.,1659.,1740.,1820.,1887 LARC1    1499
8,,1957.,2026.,2082.,2134.,2184.,2234.,2282.,2330.,2365.,2400.,2445 LARC1    1500
9,,2489.,2600.,1306.,1452.,1559.,1649.,1732.,1810.,1875.,1940.,2013 LARC1    1501
$,,2063.,2117.,2167.,2217.,2267.,2310.,2351.,2387.,2430.,2477.,2580 LARC1    1502
$,,1304.,1446.,1553.,1638.,1724.,1800.,1860.,1925.,2000.,2045.,2100 LARC1    1503
$,,2150.,2200.,2250.,2300.,2337.,2374.,2416.,2458.,2560.,1302.,1441 LARC1    1504
$,,1547.,1631.,1716.,1789.,1845.,1916.,1980.,2030.,2082.,2133.,2183 LARC1    1505
$,,2233.,2275.,2317.,2360.,2403.,2445.,2540.,1300.,1435.,1541.,1624 LARC1    1506
$,,1708.,1779.,1840.,1908.,1960.,2015.,2065.,2115.,2166.,2217.,2259 LARC1    1507
$,,2300.,2350.,2393.,2437.,2520.,1296.,1430.,1535.,1617.,1700.,1760 LARC1    1508
$,,1833.,1900.,1952.,2010.,2060.,2107.,2153.,2200.,2244.,2289.,2335 LARC1    1509
$,,2382.,2422.,2500./                                               LARC1    1510
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 DATA T9/1292.,1424.,1528.,1609.,1694.,1759.,1825.,1891.,1948.,2065 LARC1     1511
1.,2055.,2100.,2146.,2192.,2235.,2278.,2321.,2364.,2407.,2480.,1288 LARC1     1512
2.,1418.,1520.,1600.,1687.,1751.,1816.,1881.,1942.,2000.,2050.,2093 LARC1     1513
3.,2139.,2184.,2227.,2270.,2313.,2356.,2400.,2460.,1284.,1412.,1512 LARC1     1514
4.,1594.,1680.,1744.,1808.,1872.,1936.,1990.,2043.,2086.,2129.,2175 LARC1     1515
5.,2217.,2260.,2305.,2348.,2387.,2440.,1280.,1406.,1505.,1588.,1674 LARC1     1516
6.,1737.,1800.,1863.,1923.,1980.,2026.,2072.,2120.,2170.,2212.,2256 LARC1     1517
7.,2295.,2337.,2374.,2420.,1276.,1400.,1500.,1582.,1667.,1730.,1793 LARC1     1518
8.,1854.,1910.,1960.,2015.,2065.,2115.,2165.,2200.,2240.,2280.,2320 LARC1     1519
9.,2360.,2400.,1272.,1395.,1494.,1576.,1660.,1723.,1787.,1845.,1905 LARC1     1520
$.,1955.,2010.,2060.,2110.,2160.,2190.,2230.,2270.,2310.,2345.,2380 LARC1     1521
$.,1268.,1389.,1488.,1571.,1654.,1716.,1780.,1842.,1897.,1946.,2000 LARC1     1522
$.,2050.,2100.,2140.,2180.,2220.,2260.,2300.,2330.,2360.,1264.,1384 LARC1     1523
$.,1482.,1565.,1647.,1710.,1773.,1837.,1890.,1940.,1987.,2037.,2081 LARC1     1524
$.,2120.,2165.,2210.,2247.,2281.,2315.,2340.,1260.,1379.,1475.,1559 LARC1     1525
$.,1640.,1705.,1766.,1825.,1879.,1927.,1975.,2020.,2062.,2100.,2150 LARC1     1526
$.,2200.,2233.,2267.,2300.,2320.,1256.,1374.,1469.,1553.,1633.,1700 LARC1     1527
$.,1752.,1805.,1857.,1910.,1962.,2012.,2047.,2083.,2131.,2178.,2216 LARC1     1528
$.,2247.,2274.,2300./                                               LARC1     1529
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10.,1950.,2000.,2033.,2067.,2112.,2156.,2200.,2227.,2254.,2280.,194 LARC1     1531
28.,1362.,1457.,1541.,1620.,1675.,1730.,1785.,1835.,1887.,1937.,198 LARC1     1532
30.,2000.,2050.,2100.,2130.,2160.,2190.,2220.,2260.,1244.,1357.,145 LARC1     1533
41.,1535.,1613.,1665.,1717.,1769.,1821.,1873.,1925.,1960.,1995.,203 LARC1     1534
50.,2065.,2100.,2135.,2170.,2205.,2240.,1240.,1351.,1445.,1529.,160 LARC1     1535
67.,1658.,1709.,1760.,1811.,1862.,1912.,1946.,1980.,2015.,2055.,209 LARC1     1536
74.,2128.,2163.,2191.,2220.,1236.,1346.,1439.,1523.,1600.,1650.,170 LARC1     1537
80.,1753.,1800.,1850.,1900.,1933.,1967.,2000.,2044.,2088.,2121.,215 LARC1     1538
95.,2177.,2200.,1232.,1340.,1432.,1517.,1587.,1643.,1696.,1747.,170 LARC1     1539
$2.,1838.,1876.,1909.,1942.,1975.,2022.,2060.,2100.,2128.,2157.,218 LARC1     1540
$3.,1228.,1334.,1425.,1511.,1575.,1637.,1690.,1733.,1776.,1815.,185 LARC1     1541
$3.,1885.,1917.,1950.,2000.,2033.,2066.,2100.,2133.,2166.,1224.,132 LARC1     1542
$8.,1418.,1505.,1562.,1615.,1667.,1700.,1740.,1780.,1825.,1860.,190 LARC1     1543
$0.,1925.,1970.,2000.,2044.,2075.,2122.,2150.,1220.,1322.,1411.,150 LARC1     1544
$0.,1550.,1600.,1633.,1667.,1700.,1740.,1780.,1820.,1860.,1900.,194 LARC1     1545
$0.,1980.,2022.,2050.,2111.,2134.,1216.,1317.,1404.,1475.,1527.,158 LARC1     1546
$0.,1620.,1663.,1695.,1730.,1770.,1810.,1849.,1888.,1926.,1960.,200 LARC1     1547
$0.,2025.,2100.,2116./                                              LARC1     1548
 DATA T11/1212.,1311.,1400.,1450.,1500.,1550.,1605.,1660.,1690.,172 LARC1     1549
10.,1760.,1800.,1838.,1876.,1913.,1940.,1978.,2000.,2050.,2100.,120 LARC1     1550
28.,1306.,1373.,1400.,1481.,1540.,1587.,1635.,1672.,1710.,1745.,178 LARC1     1551
31.,1815.,1850.,1900.,1920.,1955.,1990.,2025.,2080.,1200.,1300.,134 LARC1     1552
47.,1395.,1463.,1520.,1565.,1610.,1655.,1700.,1731.,1762.,1794.,182 LARC1     1553
55.,1863.,1900.,1933.,1967.,2000.,2060.,1189.,1283.,1335.,1300.,144 LARC1     1554
65.,1500.,1550.,1600.,1637.,1675.,1710.,1745.,1780.,1810.,1842.,188 LARC1     1555
70.,1916.,1950.,1983.,2040.,1178.,1268.,1321.,1374.,1427.,1480.,153 LARC1     1556
80.,1580.,1600.,1650.,1700.,1733.,1767.,1794.,1821.,1860.,1900.,193 LARC1     1557
93.,1967.,2020.,1167.,1251.,1300.,1350.,1410.,1460.,1510.,1560.,157 LARC1     1558
$5.,1625.,1666.,1700.,1733.,1767.,1800.,1833.,1867.,1900.,1950.,198 LARC1     1559
$0.,1156.,1234.,1280.,1335.,1393.,1440.,1490.,1540.,1550.,1600.,163 LARC1     1560
$2.,1667.,1700.,1733.,1767.,1800.,1833.,1867.,1900.,1940.,1145.,121 LARC1     1561
$7.,1260.,1318.,1375.,1420.,1450.,1520.,1535.,1565.,1598.,1633.,146 LARC1     1562
$6.,1700.,1733.,1765.,1775.,1833.,1865.,1895.,1134.,1190.,1240.,130 LARC1     1563
$0.,1350.,1400.,1430.,1465.,1500.,1530.,1565.,1600.,1632.,1665.,170 LARC1     1564
$0.,1730.,1765.,1800.,1830.,1850.,1123.,1170.,1220.,1270.,1320.,135 LARC1     1565
$5.,1390.,1424.,1458.,1492.,1520.,1550.,1580.,1607.,1635.,1665.,149 LARC1     1566
$2.,1720.,1750.,1800./                                              LARC1     1567
 DATA T12/1110.,1140.,1200.,1240.,1280.,1320.,1350.,1380.,1410.,144 LARC1     1568
10.,1470.,1500.,1525.,1550.,1575.,1600.,1625.,1650.,1675.,1730.,105 LARC1     1569
20.,1110.,1150.,1190.,1220.,1245.,1270.,1300.,1325.,1350.,1380.,141 LARC1     1570
30.,1435.,1455.,1490.,1520.,1545.,1570.,1600.,1630.,1000.,1050.,107 LARC1     1571
45.,1100.,1125.,1150.,1175.,1200.,1225.,1250.,1275.,1300.,1325.,135 LARC1     1572
50.,1375.,1400.,1425.,1450.,1475.,1500./                            LARC1     1573
```

```
      EQUIVALENCE (T1(1),TE(1,1)), (T2(1),TE(1,11)), (T3(1),TE(1,21)), (
     1T4(1),TE(1,31)), (T5(1),TE(1,41)), (T6(1),TE(1,51)), (T7(1),TE(1,6
     21)), (T8(1),TE(1,71)), (T9(1),TE(1,81)), (T10(1),TE(1,91)), (T11(1
     3),TE(1,101)), (T12(1),TE(1,111))
      DO 10 I=1,10
      DO 10 I=2,19
      DO 10 J=2,112
      TE(I,J)=0.25*(TE(I-1,J)+TE(I+1,J)+TE(I,J+1)+TE(I,J-1))
   10 CONTINUE
      CALL ADV (1)
      WRITE (12,60)(J,(TE(I,J),I=1,20),J=1,113)
      CALL ADV (1)
      DO 20 I=1,20
   20 T(I)=I
      DB=1./112
      DO 30 I=1,113
   30 F(I)=(I-1)*DB
      IBD(1)=3
      IBD(2)=3
      IBD(3)=3
      IBD(4)=3
      IBD(5)=1
      IBD(6)=1
      FXY(1,1)=0.0
      FXY(1,113)=0.0
      FXY(20,1)=0.0
      FXY(20,113)=0.0
      DO 40 I=1,20
      FX(I,1)=(TE(I,2)-TE(I,1))/DB
      FX(I,113)=(TE(I,113)-TE(I,112))/DB
   40 CONTINUE
      DO 50 I=1,113
      FY(1,I)=TE(2,I)-TE(1,I)
      FY(20,I)=TE(20,I)-TE(19,I)
   50 CONTINUE
      CALL SPL2D1 (113,F,20,T,TE,FX,FY,FXY,20,IBD,71,72,73)
      RETURN
      ENTRY SPL
      SPL=SPL2D2(BIN,TIME,113,F,20,T,TE,FX,FY,FXY,20,0,0)
      RETURN
C
   60 FORMAT (/1X,I3,20F6.0)
      END
```

COPYSF .END OF FILE

```
      FUNCTION ERFC(Z)                                                  C335A
      DIMENSION A(8),B(9),C(5),D(6),E(4)                                C335A
      DATA(A(I),I=1,8)/883.47394260349 5,1549.67931240372,              C335A
     C1347.19413409759,723.04000277529,255.50049469958,                 C335A
     C59.2400101129141,8.37653108141970,.564189559442610/               C335A
      DATA(B(I),I=1,9)/883.47394260399,2546.57854530975,                C335A
     C3337.22136993926,2606.71201526511,1333.56997567996,               C335A
     C460.285123691601,105.500254397688,14.8470122375234,1.0/           C335A
      DATA(C(I),I=1,5)/1.63271613512628,2.35360143283567,               C335A
     C3.03185804944392,.895157182255506,.564189583547936/               C335A
      DATA(D(I),I=1,6)/1.29314873038422,5.08080210486989,               C335A
     C4.96496300826808,5.87382846427043,1.58662479494697,1.0/           C335A
      DATA(E(I),I=1,4)/-.5,.75,-1.875,1.772453850905516/                C335A
      ERFC = 0.0                                                        C335A
      IF (Z .GE. 26.) RETURN                                            C335A
      IF ( Z.GE. 0.5) GO TO 1                                           C335A
      ERFC = 1.0 - ERF(Z)                                               C335A
      RETURN                                                            C335A
    1 ERFC = EXP(-Z*Z)                                                  C335A
      GO TO 6                                                           C335A
      ENTRY PQERFC                                                      C335A
      IF (Z .GE. 0.5) GO TO 7                                           C335A
      ERFC = EXP(Z*Z) * (1.0 - ERF(Z))                                  C335A
      RETURN                                                            C335A
    7 ERFC = 1.0                                                        C335A
    6 IF (Z .GE. 100.)  GO TO 3                                         C335A
      IF (Z .GE.  8.0)  GO TO 2                                         C335A
      P=(A(1)+Z*(A(2)+Z*(A(3)+Z*(A(4)+Z*(A(5)+Z*(A(6)+Z*(A(7)+Z*A(8))))) C335A
     C)))/(B(1)+Z*(B(2)+Z*(B(3)+Z*(B(4)+Z*(B(5)+Z*(B(6)+Z*(B(7)+Z*(B(8)+ C335A
     CZ*B(9))))))))                                                     C335A
      GO TO 4                                                           C335A
    2 P=(C(1)+Z*(C(2)+Z*(C(3)+Z*(C(4)+Z*C(5)))))/                      C335A
     C(D(1)+Z*(D(2)+Z*(D(3)+Z*(D(4)+Z*(D(5)+Z*D(6))))))                C335A
      GO TO 4                                                           C335A
    3 W = 1./(Z*Z)                                                      C335A
      P=(1.+W*(E(1)+W*(E(2)+W*E(3))))/(E(4)*Z)                          C335A
    4 ERFC = ERFC*P                                                     C335A
      RETURN                                                            C335A
      END                                                               C335A
```

APPENDIX D

PLOTS

```
      PROGRAM PLOTS (INP,OUT,FILM,PSET12=FILM)                          PLOTS     2
      DIMENSION X(14), TEMPF(14)                                        PLOTS     3
      DIMENSION BIN(101), TIME(101), TPLOT(101), TM(101), TA(101)        PLOTS     4
      COMMON /SPEC/ TEMPF,X                                             PLOTS     5
      COMMON /SPECM/ N2,TT(29),TMAXF(29)                                PLOTS     6
      COMMON /SPECA/ N3,T3(29),TAVEF(29)                                PLOTS     7
C     IN TAVEO, T3 IS CALLED TT IN THIS COMMON STATEMENT                PLOTS     8
      COMMON /CJE07/ IXL,IXR,IYT,IYB,XMN,XMX,YMX,YMN                    PLOTS     9
      COMMON /CJE08/ XMIN,XMAX,INTVALX,KX,YMIN,YMAX,INTVALY,KY          PLOTS    10
      COMMON /TMODEL/ MODEL                                             PLOTS    11
      COMMON /LJNEW/ IXSAVE,IYSAVE,IX2,IY2                              PLOTS    12
      NCHAR=27                                                          PLOTS    13
      Z=TEMPO(0.0)                                                      PLOTS    14
      NTOT=101                                                          PLOTS    15
      DB=1./(NTOT-1)                                                    PLOTS    16
      DT=20./(NTOT-1)                                                   PLOTS    17
      DO 10 I=1,NTOT                                                    PLOTS    18
      BIN(I)=(I-1)*DB                                                   PLOTS    19
      TIME(I)=(I-1)*DT                                                  PLOTS    20
      TPLOT(I)=TEMP(BIN(I))                                             PLOTS    21
   10 CONTINUE                                                          PLOTS    22
      PRINT 40                                                          PLOTS    23
      PRINT 50, (I,BIN(I),TPLOT(I),I=1,NTOT)                            PLOTS    24
      CALL PLOPB (BIN,TPLOT,NTOT,1,0,NCHAR,0.,8.,7.,36HTEMPERATURE VS. C PLOTS    25
     1ORE VOLUME FRACTION,36,20HCORE VOLUME FRACTION,20,23HTEMPERATURE ( PLOTS    26
     2DEGREES K),23,0,0,2,2)                                            PLOTS    27
      CALL PLOPB (X,TEMPF,14,1,-1,-1RX,0.,8.,7.,0,0,0,0,0,0,0,0,2,2)    PLOTS    28
      CALL ADV (1)                                                      PLOTS    29
      DO 30 MODEL=1,3                                                   PLOTS    30
      Z=TMAXO(0.0)                                                      PLOTS    31
      T=TAVEO(0.0)                                                      PLOTS    32
      DO 20 I=1,NTOT                                                    PLOTS    33
      TM(I)=TMAX(TIME(I))                                               PLOTS    34
      TA(I)=TAVE(TIME(I))                                               PLOTS    35
   20 CONTINUE                                                          PLOTS    36
      PRINT 60, MODEL                                                   PLOTS    37
      PRINT 70, (I,TIME(I),TM(I),TA(I),I=1,NTOT)                        PLOTS    38
      XMIN=0.                                                           PLOTS    39
      XMAX=20.                                                          PLOTS    40
      INTVALX=10                                                        PLOTS    41
      KX=0                                                              PLOTS    42
      YMIN=1000.                                                        PLOTS    43
      YMAX=3800.                                                        PLOTS    44
      INTVALY=7                                                         PLOTS    45
      KY=0                                                              PLOTS    46
      CALL PLOPB (TIME,TM,NTOT,1,0,1RM,-2.,8.,8.,31HTEMPERATURE VS. TIME PLOTS    47
     1 AFTER LOFC,31,12HTIME (HOURS),-12,23HTEMPERATURE (DEGREES K),23,0 PLOTS    48
     2,0,2,2)                                                           PLOTS    49
      CALL PLOPB (TT,TMAXF,N2,1,-1,-1RX,0.,8.,8.,0,0,0,0,0,0,0,0,2,2)   PLOTS    50
      CALL PLOPB (TIME,TA,NTOT,1,0,-1RA,-2.,8.,8.,0,0,0,-12,0,0,0,0,2,2) PLOTS    51
      CALL PLOPB (T3,TAVEF,N3,1,-1,-1RX,0.,8.,8.,0,0,0,0,0,0,0,0,2,2)   PLOTS    52
      CALL CONVRT (9.0,IX,XMN,XMX,IXL,IXR)                              PLOTS    53
      IF (MODEL.EQ.1) CALL CONVRT (3200.,IY,YMN,YMX,IYB,IYT)            PLOTS    54
      IF (MODEL.NE.1) CALL CONVRT (3050.,IY,YMN,YMX,IYB,IYT)            PLOTS    55
      CALL DLCH (IX,IY,4,4HTMAX,1)                                      PLOTS    56
      CALL CONVRT (12.,IX,XMN,XMX,IXL,IXR)                              PLOTS    57
      IF (MODEL.EQ.1) CALL CONVRT (2750.,IY,YMN,YMX,IYB,IYT)            PLOTS    58
      IF (MODEL.NE.1) CALL CONVRT (2600.,IY,YMN,YMX,IYB,IYT)            PLOTS    59
      CALL DLCH (IX,IY,4,4HTAVE,1)                                      PLOTS    60
      IF (MODEL.EQ.1) CALL DLCH (100,1000,9,9HSORS DATA,2)              PLOTS    61
      IF (MODEL.EQ.2) CALL DLCH (100,1000,11,11HCORCON DATA,2)          PLOTS    62
      IF (MODEL.EQ.3) CALL DLCH (100,1000,9,9HAYER DATA,2)              PLOTS    63
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      CALL ADV (1)                                                      PLOTS     64
   30 CONTINUE                                                          PLOTS     65
      CALL PLOT4                                                        PLOTS     66
      CALL PLOT1                                                        PLOTS     67
      CALL PLOT2                                                        PLOTS     68
      CALL PLOT3                                                        PLOTS     69
      CALL EXIT                                                         PLOTS     70
C                                                                       PLOTS     71
   40 FORMAT (5X,1HI,7X,3HBIN,3X,16HTEMP HIGHER THAN/)                  PLOTS     72
   50 FORMAT (1X,I5,5X,F5.2,5X,F10.2)                                   PLOTS     73
   60 FORMAT (///5X,1HI,9X,4HTIME,11X,4HTMAX,11X,4HTAVE,10X,6HMODEL=,I1/ PLOTS     74
     1)                                                                 PLOTS     75
   70 FORMAT (1X,I5,5X,F8.2,2F15.2)                                     PLOTS     76
      END                                                               PLOTS     77
      SUBROUTINE PLOT1                                                  PLOTS     78
      DIMENSION FB(131), F1B(131), F2B(131), F3B(131), F4B(131), TT(131) PLOTS     79
     1, FT(131), F1T(131), F2T(131), F3T(131), F4T(131)                 PLOTS     80
      DIMENSION TITLE(5)                                                PLOTS     81
      LOGICAL LAGE,BISO                                                 PLOTS     82
      COMMON /F/ F1,F2,F3,F4                                            PLOTS     83
      COMMON /LA/ LAGE,AGE,MFUEL,ISO,BISO                               PLOTS     84
      COMMON /LJNEW/ IXSAVE,IYSAVE,IX2,IY2                              PLOTS     85
      COMMON /CJE07/ IXL,IXR,IYT,IYB,XMN,XMX,YMX,YMN                    PLOTS     86
      COMMON /CJE08/ XMIN,XMAX,INTVALX,KX,YMIN,YMAX,INTVALY,KY          PLOTS     87
C     INITIALIZE PLOTS                                                  PLOTS     88
      NCHAR=27                                                          PLOTS     89
C     INITIALIZE SPLINE                                                 PLOTS     90
      Z=FRACB0(0.0)                                                     PLOTS     91
      NN=131                                                            PLOTS     92
      LAGE=.T.                                                          PLOTS     93
      AGE=4.0                                                           PLOTS     94
      DO 110 MFUEL=1,2                                                  PLOTS     95
      PRINT 140                                                         PLOTS     96
      PRINT 150, MFUEL,AGE,LAGE                                         PLOTS     97
      IOPT=1                                                            PLOTS     98
      DO 10 I=1,NN                                                      PLOTS     99
      T=1100.+(I-1)*10.                                                 PLOTS    100
      FB(I)=FRACB(T)                                                    PLOTS    101
      F1B(I)=F1                                                         PLOTS    102
      F2B(I)=F2                                                         PLOTS    103
      F3B(I)=F3                                                         PLOTS    104
      F4B(I)=F4                                                         PLOTS    105
      TT(I)=T                                                           PLOTS    106
      FT(I)=FRACT(T)                                                    PLOTS    107
      F1T(I)=F1                                                         PLOTS    108
      F2T(I)=F2                                                         PLOTS    109
      F3T(I)=F3                                                         PLOTS    110
      F4T(I)=F4                                                         PLOTS    111
   10 CONTINUE                                                          PLOTS    112
      PRINT 160                                                         PLOTS    113
      PRINT 170, (I,TT(I),F1B(I),F2B(I),F3B(I),F4B(I),FB(I),I=1,NN)     PLOTS    114
      XMIN=1200.                                                        PLOTS    115
      XMAX=2400.                                                        PLOTS    116
      INTVALX=6                                                         PLOTS    117
      KX=0                                                              PLOTS    118
      YMIN=0.0                                                          PLOTS    119
      YMAX=1.0                                                          PLOTS    120
      INTVALY=10                                                        PLOTS    121
      KY=1                                                              PLOTS    122
      CALL PLOPB (TT,F1B,NN,1,0,NCHAR,0.,7.,8.,0,0,23HTEMPERATURE (DEGRE PLOTS    123
     1ES K),-23,28HFRACTION OF FAILED PARTICLES,28,0,0,2,2)             PLOTS    124
      CALL PLOPB (TT,F2B,NN,1,0,-NCHAR,0.,7.,8.,0,0,0,-23,0,0,0,0,2,2)  PLOTS    125
      CALL PLOPB (TT,F3B,NN,1,0,-NCHAR,0.,7.,8.,0,0,0,-23,0,0,0,0,2,2)  PLOTS    126
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      CALL PLOPB (TT,F4B,NN,1,0,-NCHAR,0.,7.,8.,0,0,0,-23,0,0,0,0,2,2)   PLOTS    127
      IF (MFUEL.EQ.1) CALL DLCH (250,5,24,24HFT. ST. VBAIN FUEL MODEL,2) PLOTS    128
      IF (MFUEL.EQ.2) CALL DLCH (250,5,24,24HLATEST GASSAR FUEL MODEL,2) PLOTS    129
      IF (MFUEL.NE.1) GO TO 20                                           PLOTS    130
      CALL CONVRT (1480.,IX,XMN,XMX,IXL,IXR)                             PLOTS    131
      CALL CONVRT (0.6,IY,YMN,YMX,IYB,IYT)                               PLOTS    132
      CALL DLCH (IX,IY,1,1H4,1)                                          PLOTS    133
      CALL CONVRT (1580.,IX,XMN,XMX,IXL,IXR)                             PLOTS    134
      CALL DLCH (IX,IY,1,1H3,1)                                          PLOTS    135
      CALL CONVRT (1690.,IX,XMN,XMX,IXL,IXR)                             PLOTS    136
      CALL DLCH (IX,IY,1,1H2,1)                                          PLOTS    137
      CALL CONVRT (1810.,IX,XMN,XMX,IXL,IXR)                             PLOTS    138
      CALL DLCH (IX,IY,1,1H1,1)                                          PLOTS    139
      GO TO 30                                                           PLOTS    140
   20 CALL CONVRT (2100.,IX,XMN,XMX,IXL,IXR)                             PLOTS    141
      CALL CONVRT (.05,IY,YMN,YMX,IYB,IYT)                               PLOTS    142
      CALL DLCH (IX,IY,1,1H1,1)                                          PLOTS    143
      CALL CONVRT (2060.,IX,XMN,XMX,IXL,IXR)                             PLOTS    144
      CALL DLCH (IX,IY,1,1H2,1)                                          PLOTS    145
      CALL CONVRT (2000.,IX,XMN,XMX,IXL,IXR)                             PLOTS    146
      CALL CONVRT (.08,IY,YMN,YMX,IYB,IYT)                               PLOTS    147
      CALL DLCH (IX,IY,1,1H3,1)                                          PLOTS    148
      CALL CONVRT (1880.,IX,XMN,XMX,IXL,IXR)                             PLOTS    149
      CALL CONVRT (.15,IY,YMN,YMX,IYB,IYT)                               PLOTS    150
      CALL DLCH (IX,IY,1,1H4,1)                                          PLOTS    151
   30 CONTINUE                                                           PLOTS    152
      ENCODE (43,150,TITLE)MFUEL,AGE,LAGE                                PLOTS    153
      CALL DLCH (100,1005,43,TITLE,1)                                    PLOTS    154
      CALL ADV (1)                                                       PLOTS    155
      PRINT 140                                                          PLOTS    156
      PRINT 180, MFUEL,AGE,LAGE                                          PLOTS    157
      PRINT 160                                                          PLOTS    158
      PRINT 170, (I,TT(I),F1T(I),F2T(I),F3T(I),F4T(I),FT(I),I=1,NN)      PLOTS    159
      CALL PLOPB (TT,F1T,NN,1,0,NCHAR,0.,7.,8.,0,0,23HTEMPERATURE (DEGRE PLOTS    160
     1ES K),-23,28HFRACTION OF FAILED PARTICLES,28,0,0,2,2)              PLOTS    161
      CALL PLOPB (TT,F2T,NN,1,0,-NCHAR,0.,7.,8.,0,0,0,-23,0,0,0,0,2,2)   PLOTS    162
      CALL PLOPB (TT,F3T,NN,1,0,-NCHAR,0.,7.,8.,0,0,0,-23,0,0,0,0,2,2)   PLOTS    163
      CALL PLOPB (TT,F4T,NN,1,0,-NCHAR,0.,7.,8.,0,0,0,-23,0,0,0,0,2,2)   PLOTS    164
      IF (MFUEL.EQ.1) CALL DLCH (250,5,24,24HFT. ST. VBAIN FUEL MODEL,2) PLOTS    165
      IF (MFUEL.EQ.2) CALL DLCH (250,5,24,24HLATEST GASSAR FUEL MODEL,2) PLOTS    166
      IF (MFUEL.NE.1) GO TO 40                                           PLOTS    167
      CALL CONVRT (1480.,IX,XMN,XMX,IXL,IXR)                             PLOTS    168
      CALL CONVRT (0.6,IY,YMN,YMX,IYB,IYT)                               PLOTS    169
      CALL DLCH (IX,IY,1,1H4,1)                                          PLOTS    170
      CALL CONVRT (1580.,IX,XMN,XMX,IXL,IXR)                             PLOTS    171
      CALL DLCH (IX,IY,1,1H3,1)                                          PLOTS    172
      CALL CONVRT (1690.,IX,XMN,XMX,IXL,IXR)                             PLOTS    173
      CALL DLCH (IX,IY,1,1H2,1)                                          PLOTS    174
      CALL CONVRT (1810.,IX,XMN,XMX,IXL,IXR)                             PLOTS    175
      CALL DLCH (IX,IY,1,1H1,1)                                          PLOTS    176
      GO TO 50                                                           PLOTS    177
   40 CALL CONVRT (1970.,IX,XMN,XMX,IXL,IXR)                             PLOTS    178
      CALL CONVRT (.05,IY,YMN,YMX,IYB,IYT)                               PLOTS    179
      CALL DLCH (IX,IY,1,1H1,1)                                          PLOTS    180
      CALL CONVRT (1930.,IX,XMN,XMX,IXL,IXR)                             PLOTS    181
      CALL CONVRT (.08,IY,YMN,YMX,IYB,IYT)                               PLOTS    182
      CALL DLCH (IX,IY,1,1H2,1)                                          PLOTS    183
      CALL CONVRT (1900.,IX,XMN,XMX,IXL,IXR)                             PLOTS    184
      CALL CONVRT (.09,IY,YMN,YMX,IYB,IYT)                               PLOTS    185
      CALL DLCH (IX,IY,1,1H3,1)                                          PLOTS    186
      CALL CONVRT (1870.,IX,XMN,XMX,IXL,IXR)                             PLOTS    187
      CALL CONVRT (0.1,IY,YMN,YMX,IYB,IYT)                               PLOTS    188
      CALL DLCH (IX,IY,1,1H4,1)                                          PLOTS    189
```

```
50 CONTINUE                                                          PLOTS    190
   ENCODE (43,180,TITLE)MFUEL,AGE,LAGE                               PLOTS    191
   CALL DLCH (100,1005,43,TITLE,1)                                   PLOTS    192
   CALL ADV (1)                                                      PLOTS    193
   FLIMIT=1.0E-3                                                     PLOTS    194
   DO 60 I=1,NN                                                      PLOTS    195
   IF (F1B(I).EQ.0.0) F1B(I)=FLIMIT                                  PLOTS    196
   IF (F2B(I).EQ.0.0) F2B(I)=FLIMIT                                  PLOTS    197
   IF (F3B(I).EQ.0.0) F3B(I)=FLIMIT                                  PLOTS    198
   IF (F4B(I).EQ.0.0) F4B(I)=FLIMIT                                  PLOTS    199
   IF (FB(I).EQ.0.0) FB(I)=FLIMIT                                    PLOTS    200
   IF (F1T(I).EQ.0.0) F1T(I)=FLIMIT                                  PLOTS    201
   IF (F2T(I).EQ.0.0) F2T(I)=FLIMIT                                  PLOTS    202
   IF (F3T(I).EQ.0.0) F3T(I)=FLIMIT                                  PLOTS    203
   IF (F4T(I).EQ.0.0) F4T(I)=FLIMIT                                  PLOTS    204
   IF (FT(I).EQ.0.0) FT(I)=FLIMIT                                    PLOTS    205
60 CONTINUE                                                          PLOTS    206
   YMIN=-3.                                                          PLOTS    207
   YMAX=0.0                                                          PLOTS    208
   INTVALY=3                                                         PLOTS    209
   KY=0                                                              PLOTS    210
   CALL PLOPB (TT,F1B,NN,-1,0,NCHAR,0.,7.,8.,0,0,23HTEMPERATURE (DEGR PLOTS    211
  1EES K),-23,28HFRACTION OF FAILED PARTICLES,28,0,0,2,2)            PLOTS    212
   CALL PLOPB (TT,F2B,NN,-1,0,-NCHAR,0.,7.,8.,0,0,0,-23,0,0,0,0,2,2) PLOTS    213
   CALL PLOPB (TT,F3B,NN,-1,0,-NCHAR,0.,7.,8.,0,0,0,-23,0,0,0,0,2,2) PLOTS    214
   CALL PLOPB (TT,F4B,NN,-1,0,-NCHAR,0.,7.,8.,0,0,0,-23,0,0,0,0,2,2) PLOTS    215
   IF (MFUEL.EQ.1) CALL DLCH (250,5,24,24HFT. ST. VRAIN FUEL MODEL,2) PLOTS    216
   IF (MFUEL.EQ.2) CALL DLCH (250,5,24,24HLATEST GASSAR FUEL MODEL,2) PLOTS    217
   IF (MFUEL.NE.1) GO TO 70                                          PLOTS    218
   CALL CONVRT (1420.,IX,XMN,XMX,IXL,IXR)                            PLOTS    219
   CALL CONVRT (-.4,IY,YMN,YMX,IYB,IYT)                              PLOTS    220
   CALL DLCH (IX,IY,1,1H4,1)                                         PLOTS    221
   CALL CONVRT (1530.,IX,XMN,XMX,IXL,IXR)                            PLOTS    222
   CALL DLCH (IX,IY,1,1H3,1)                                         PLOTS    223
   CALL CONVRT (1640.,IX,XMN,XMX,IXL,IXR)                            PLOTS    224
   CALL DLCH (IX,IY,1,1H2,1)                                         PLOTS    225
   CALL CONVRT (1760.,IX,XMN,XMX,IXL,IXR)                            PLOTS    226
   CALL DLCH (IX,IY,1,1H1,1)                                         PLOTS    227
   GO TO 80                                                          PLOTS    228
70 CALL CONVRT (1740.,IX,XMN,XMX,IXL,IXR)                            PLOTS    229
   CALL CONVRT (-1.8,IY,YMN,YMX,IYB,IYT)                             PLOTS    230
   CALL DLCH (IX,IY,1,1H4,1)                                         PLOTS    231
   CALL CONVRT (1800.,IX,XMN,XMX,IXL,IXR)                            PLOTS    232
   CALL CONVRT (-2.0,IY,YMN,YMX,IYB,IYT)                             PLOTS    233
   CALL DLCH (IX,IY,1,1H3,1)                                         PLOTS    234
   CALL CONVRT (1900.,IX,XMN,XMX,IXL,IXR)                            PLOTS    235
   CALL CONVRT (-2.3,IY,YMN,YMX,IYB,IYT)                             PLOTS    236
   CALL DLCH (IX,IY,1,1H2,1)                                         PLOTS    237
   CALL CONVRT (2000.,IX,XMN,XMX,IXL,IXR)                            PLOTS    238
   CALL CONVRT (-2.6,IY,YMN,YMX,IYB,IYT)                             PLOTS    239
   CALL DLCH (IX,IY,1,1H1,1)                                         PLOTS    240
80 CONTINUE                                                          PLOTS    241
   ENCODE (43,150,TITLE)MFUEL,AGE,LAGE                               PLOTS    242
   CALL DLCH (100,1005,43,TITLE,1)                                   PLOTS    243
   CALL ADV (1)                                                      PLOTS    244
   CALL PLOPB (TT,F1T,NN,-1,0,NCHAR,0.,7.,8.,0,0,23HTEMPERATURE (DEGR PLOTS    245
  1EES K),-23,28HFRACTION OF FAILED PARTICLES,28,0,0,2,2)            PLOTS    246
   CALL PLOPB (TT,F2T,NN,-1,0,-NCHAR,0.,7.,8.,0,0,0,-23,0,0,0,0,2,2) PLOTS    247
   CALL PLOPB (TT,F3T,NN,-1,0,-NCHAR,0.,7.,8.,0,0,0,-23,0,0,0,0,2,2) PLOTS    248
   CALL PLOPB (TT,F4T,NN,-1,0,-NCHAR,0.,7.,8.,0,0,0,-23,0,0,0,0,2,2) PLOTS    249
   IF (MFUEL.EQ.1) CALL DLCH (250,5,24,24HFT. ST. VRAIN FUEL MODEL,2) PLOTS    250
   IF (MFUEL.EQ.2) CALL DLCH (250,5,24,24HLATEST GASSAR FUEL MODEL,2) PLOTS    251
   IF (MFUEL.NE.1) GO TO 90                                          PLOTS    252
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      CALL CONVRT (1400.,IX,XMN,XMX,IXL,IXR)                            PLOTS    253
      CALL CONVRT (-.4,IY,YMN,YMX,IYB,IYT)                              PLOTS    254
      CALL DLCH (IX,IY,1,1H4,1)                                         PLOTS    255
      CALL CONVRT (1510.,IX,XMN,XMX,IXL,IXR)                            PLOTS    256
      CALL DLCH (IX,IY,1,1H3,1)                                         PLOTS    257
      CALL CONVRT (1630.,IX,XMN,XMX,IXL,IXR)                            PLOTS    258
      CALL DLCH (IX,IY,1,1H2,1)                                         PLOTS    259
      CALL CONVRT (1760.,IX,XMN,XMX,IXL,IXR)                            PLOTS    260
      CALL DLCH (IX,IY,1,1H1,1)                                         PLOTS    261
      GO TO 100                                                         PLOTS    262
   90 CALL CONVRT (1800.,IX,XMN,XMX,IXL,IXR)                            PLOTS    263
      CALL CONVRT (-1.9,IY,YMN,YMX,IYB,IYT)                             PLOTS    264
      CALL DLCH (IX,IY,1,1H4,1)                                         PLOTS    265
      CALL CONVRT (-2.15,IY,YMN,YMX,IYB,IYT)                            PLOTS    266
      CALL DLCH (IX,IY,1,1H3,1)                                         PLOTS    267
      CALL CONVRT (-2.3,IY,YMN,YMX,IYB,IYT)                             PLOTS    268
      CALL DLCH (IX,IY,1,1H2,1)                                         PLOTS    269
      CALL CONVRT (-2.7,IY,YMN,YMX,IYB,IYT)                             PLOTS    270
      CALL DLCH (IX,IY,1,1H1,1)                                         PLOTS    271
  100 CONTINUE                                                          PLOTS    272
      ENCODE (43,180,TITLE)MFUEL,AGE,LAGE                               PLOTS    273
      CALL DLCH (100,1005,43,TITLE,1)                                   PLOTS    274
      CALL ADV (1)                                                      PLOTS    275
  110 CONTINUE                                                          PLOTS    276
      XMIN=1200.                                                        PLOTS    277
      XMAX=2200.                                                        PLOTS    278
      INTVALX=5                                                         PLOTS    279
      KX=0                                                              PLOTS    280
      YMIN=0.0                                                          PLOTS    281
      YMAX=3.0                                                          PLOTS    282
      INTVALY=3                                                         PLOTS    283
      KY=0                                                              PLOTS    284
C     FIRST FOR BISO.......                                             PLOTS    285
C     USE FB ARRAY FOR LOWER TEMP, FT FOR HIGHER TEMP, TT FOR TIME      PLOTS    286
      TT(1)=1.0                                                         PLOTS    287
      FB(1)=1858.15                                                     PLOTS    288
      FT(1)=1998.15                                                     PLOTS    289
      TT(2)=43.                                                         PLOTS    290
      FB(2)=1858.15                                                     PLOTS    291
      FT(2)=1998.15                                                     PLOTS    292
      TT(3)=1000.0                                                      PLOTS    293
C     1000. DAYS = 1000./365.25 YEARS                                   PLOTS    294
      FB(3)=1876.17*EXP(-80.4098/365.25)                                PLOTS    295
      FT(3)=2011.97*EXP(-57.4098/365.25)                                PLOTS    296
      CALL PLOPB (FB,TT,3,-1.0,NCHAR,0.,8.,8.,30HFT. ST. VRAIN FUEL MODE PLOTS    297
     1L--BISO,30,28HFUEL TEMPERATURE (DEGREES K),-28,23HIRRADIATION TIME PLOTS    298
     2 (DAYS),23,0,0,2,2)                                               PLOTS    299
      CALL PLOPB (FT,TT,3,-1.0,-NCHAR,0.,8.,8.,0,0,0,-28,0,0,0,0,2,2)   PLOTS    300
      CALL CONVRT (1400.,IX,XMN,XMX,IXL,IXR)                            PLOTS    301
      CALL CONVRT (1.2,IY,YMN,YMX,IYB,IYT)                              PLOTS    302
      CALL WLCH (IX,IY,19,19HNO COATING FAILURES,1)                     PLOTS    303
      CALL CONVRT (1250.,IX,XMN,XMX,IXL,IXR)                            PLOTS    304
      CALL CONVRT (2.2,IY,YMN,YMX,IYB,IYT)                              PLOTS    305
      CALL WLCH (IX,IY,22,22HPARTIAL FAILURE REGION,1)                  PLOTS    306
      CALL CONVRT (1800.,IX,XMN,XMX,IXL,IXR)                            PLOTS    307
      CALL CONVRT (2.7,IY,YMN,YMX,IYB,IYT)                              PLOTS    308
      CALL WLCH (IX,IY,28,28H100 PERCENT COATING FAILURES,1)            PLOTS    309
      CALL ADV (1)                                                      PLOTS    310
C     FOR TRISO DO THE SAME.                                            PLOTS    311
      FB(3)=1880.1*EXP(-97.4459/365.25)                                 PLOTS    312
      FT(3)=2009.53*EXP(-47.2964/365.25)                                PLOTS    313
C     THESE NUMBERS ARE THE SAME AS THOSE IN THE FRACB AND FRACT SUBROUT PLOTS    314
C     INES.....5/9/76   L.C.                                            PLOTS    315
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      CALL PLOPB (FB,TT,3,-1.0,NCHAR,0.,8.,8.,31HFT. ST. VRAIN FUEL MODE PLOTS      316
     1L--TRIS0,31,28HFUEL TEMPERATURE (DEGREES K),-28,23HIRRADIATION TIM PLOTS      317
     2E (DAYS),23,0,0,2,2)                                                PLOTS      318
      CALL PLOPB (FT,TT,3,-1.0,-NCHAR,0.,8.,8.,0,0,0,-28,0,0,0,0,2,2)     PLOTS      319
      CALL CONVRT (1400.,IX,XMN,XMX,IXL,IXR)                              PLOTS      320
      CALL CONVRT (1.2,IY,YMN,YMX,IYB,IYT)                                PLOTS      321
      CALL WLCH (IX,IY,19,19HNO COATING FAILURES,1)                       PLOTS      322
      CALL CONVRT (1250.,IX,XMN,XMX,IXL,IXR)                              PLOTS      323
      CALL CONVRT (2.2,IY,YMN,YMX,IYB,IYT)                                PLOTS      324
      CALL WLCH (IX,IY,22,22HPARTIAL FAILURE REGION,1)                    PLOTS      325
      CALL CONVRT (1800.,IX,XMN,XMX,IXL,IXR)                              PLOTS      326
      CALL CONVRT (2.7,IY,YMN,YMX,IYB,IYT)                                PLOTS      327
      CALL WLCH (IX,IY,28,28H100 PERCENT COATING FAILURES,1)              PLOTS      328
      CALL ADV (1)                                                        PLOTS      329
C     NOW WE USE F1B, F2B, F3B TO REPRESENT J. FOLEY, AYER AND SORS       PLOTS      330
C     MODELS FIRST HALF, F1T AND F2T TO REPRESENT J. FOLEY AND AYER       PLOTS      331
C     MODELS SECOND HALF.                                                 PLOTS      332
C     INITIALIZE SPLINE FUNCTIONS                                         PLOTS      333
      Z=UTMPO(0.0)                                                        PLOTS      334
      Z=AYERO(0.0)                                                        PLOTS      335
      Z=SORSO(0.0)                                                        PLOTS      336
      Z=UTMPCO(0.0)                                                       PLOTS      337
      Z=AYERCO(0.0)                                                       PLOTS      338
      NN=101                                                              PLOTS      339
      DT=20./(NN-1)                                                       PLOTS      340
      DO 130 I=1,NN                                                       PLOTS      341
      TT(I)=(I-1)*DT                                                      PLOTS      342
      T=TT(I)                                                             PLOTS      343
      IF (T.LT.2.0) GO TO 120                                             PLOTS      344
      F1B(I)=UTMP(T)                                                      PLOTS      345
      F2B(I)=AYER(T)                                                      PLOTS      346
      F3B(I)=SORS(T)                                                      PLOTS      347
      F1T(I)=UTMPC(T)                                                     PLOTS      348
      F2T(I)=AYERC(T)                                                     PLOTS      349
      GO TO 130                                                           PLOTS      350
  120 F1B(I)=0.0                                                          PLOTS      351
      F2B(I)=0.0                                                          PLOTS      352
      F3B(I)=0.0                                                          PLOTS      353
      F1T(I)=0.0                                                          PLOTS      354
      F2T(I)=0.0                                                          PLOTS      355
  130 CONTINUE                                                            PLOTS      356
      XMIN=0.0                                                            PLOTS      357
      XMAX=20.0                                                           PLOTS      358
      INTVALX=10                                                          PLOTS      359
      KX=0                                                                PLOTS      360
      YMIN=0.0                                                            PLOTS      361
      YMAX=1.0                                                            PLOTS      362
      INTVALY=5                                                           PLOTS      363
      KY=1                                                                PLOTS      364
      CALL PLOPB (TT,F1B,NN,1,0,NCHAR,0.,8.,5.,42HUNIFORM TEMPERATURE, A PLOTS      365
     1YER AND SORS RESULTS,42,36HTIME AFTER ONSET OF ACCIDENT (HOURS),-3 PLOTS      366
     25,19HFRACTION IN COOLANT,19,0,0,2,2)                                PLOTS      367
      CALL PLOPB (TT,F2B,66,1,0,-NCHAR,0.,8.,5.,0,0,0,-36,0,0,0,0,2,2)    PLOTS      368
      CALL PLOPB (TT,F3B,81,1,0,-NCHAR,0.,8.,5.,0,0,0,-36,0,0,0,0,2,2)    PLOTS      369
      CALL CONVRT (2.0,IX,XMN,XMX,IXL,IXR)                                PLOTS      370
      CALL CONVRT (0.8,IY,YMN,YMX,IYB,IYT)                                PLOTS      371
      CALL WLCH (IX,IY,18,18HUNIFORM TEMP MODEL,1)                        PLOTS      372
      CALL CONVRT (4.0,IX,XMN,XMX,IXL,IXR)                                PLOTS      373
      CALL CONVRT (0.4,IY,YMN,YMX,IYB,IYT)                                PLOTS      374
      CALL WLCH (IX,IY,4,4HAYER,1)                                        PLOTS      375
      CALL CONVRT (8.0,IX,XMN,XMX,IXL,IXR)                                PLOTS      376
      CALL CONVRT (0.5,IY,YMN,YMX,IYB,IYT)                                PLOTS      377
      CALL WLCH (IX,IY,4,4HSORS,1)                                        PLOTS      378
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      CALL ADV (1)                                                      PLOTS    379
      YMAX=4000.                                                        PLOTS    380
      INTVALY=4                                                         PLOTS    381
      KY=0                                                              PLOTS    382
      CALL PLOPB (TT,F1T,NN,1,0,NCHAR,0.,8.,5.,36HUNIFORM TEMPERATURE AN PLOTS    383
     1D AYER RESULTS,36,36HTIME AFTER ONSET OF ACCIDENT (HOURS),-36,33HT PLOTS    384
     2-131 CUMULATIVE RELEASE (CURIES),33,0,0,2,2)                      PLOTS    385
      CALL PLOPB (TT,F2T,NN,1,0,-NCHAR,0.,8.,5.,0,0,0,-36,0,0,0,0,2,2)  PLOTS    386
      CALL CONVRT (4.0,IX,XMN,XMX,IXL,IXR)                              PLOTS    387
      CALL CONVRT (3000.,IY,YMN,YMX,IYB,IYT)                            PLOTS    388
      CALL WLCH (IX,IY,18,18HUNIFORM TEMP MODEL,1)                      PLOTS    389
      CALL CONVRT (10.,IX,XMN,XMX,IXL,IXR)                              PLOTS    390
      CALL CONVRT (2400.,IY,YMN,YMX,IYB,IYT)                            PLOTS    391
      CALL WLCH (IX,IY,4,4HAYER,1)                                      PLOTS    392
      CALL ADV (1)                                                      PLOTS    393
      RETURN                                                            PLOTS    394
C                                                                       PLOTS    395
  140 FORMAT (1H0)                                                      PLOTS    396
  150 FORMAT (* MFUEL =*,I1,5X,*AGE =*,F4.1,5X,*LAGE =*,L1,*    BISO*)  PLOTS    397
  160 FORMAT (/4X,1HI,14X,1HT,13X,2HF1,13X,2HF2,13X,2HF3,13X,2HF4,14X,1H PLOTS    398
     1F/)                                                               PLOTS    399
  170 FORMAT (I5,6F15.5)                                                PLOTS    400
  180 FORMAT (* MFUEL =*,I1,5X,*AGE =*,F4.1,5X,*LAGE =*,L1,*   TRISO*)  PLOTS    401
      END                                                               PLOTS    402
      SUBROUTINE PLOT2                                                  PLOTS    403
      LOGICAL LAGE,BISO                                                 PLOTS    404
      DIMENSION FRAC(241), BFRAC(241), TFRAC(241), A(241)               PLOTS    405
      DIMENSION FUEL(2)                                                 PLOTS    406
      COMMON /LA/ LAGE,AGE,MFUEL,ISO,BISO                               PLOTS    407
C     LAGE IS A LOGICAL VARIABLE SET TRUE IF ALL FOUR AGES OF FUEL ARE  PLOTS    408
C     TO BE USED.  IF LAGE IS TRUE, AGE IS SET EQUAL TO THE TIME SINCE  PLOTS    409
C     THE REACTOR WAS TURNED ON.                                        PLOTS    410
C     IF LAGE IS FALSE, AGE IS SET EQUAL TO THE AGE OF ALL OF THE FUEL. PLOTS    411
C     MFUEL = 1  FT. ST. VRAIN FUEL MODEL                               PLOTS    412
C     MFUEL = 2  GASSAR FUEL MODEL                                      PLOTS    413
      NCHAR=27                                                          PLOTS    414
C     INITIALIZE PLOTS                                                  PLOTS    415
C     INITIALIZE SPLINE                                                 PLOTS    416
      DO 30 IL=1,2                                                      PLOTS    417
      IF (IL.EQ.1) LAGE=.T.                                             PLOTS    418
      IF (IL.EQ.2) LAGE=.F.                                             PLOTS    419
      DO 30 MFUEL=1,2                                                   PLOTS    420
      ENCODE (18,40,FUEL)MFUEL,LAGE                                     PLOTS    421
      PRINT 50, MFUEL,LAGE                                              PLOTS    422
      NTL=241                                                           PLOTS    423
      DO 20 IAGE=1,NTL                                                  PLOTS    424
      AGE=(IAGE-1)*0.025                                                PLOTS    425
      A(IAGE)=AGE                                                       PLOTS    426
      BFRAC(IAGE)=0.0                                                   PLOTS    427
      TFRAC(IAGE)=0.0                                                   PLOTS    428
      NN=100                                                            PLOTS    429
      DO 10 I=1,NN                                                      PLOTS    430
      PER=1./NN                                                         PLOTS    431
      BIN=PER*I-PER/2                                                   PLOTS    432
      T=TEMP(BIN)                                                       PLOTS    433
      FB=FRACB(T)                                                       PLOTS    434
      BFRAC(IAGE)=BFRAC(IAGE)+FB                                        PLOTS    435
      FT=FRACT(T)                                                       PLOTS    436
      TFRAC(IAGE)=TFRAC(IAGE)+FT                                        PLOTS    437
   10 CONTINUE                                                          PLOTS    438
      BFRAC(IAGE)=BFRAC(IAGE)*PER                                       PLOTS    439
      TFRAC(IAGE)=TFRAC(IAGE)*PER                                       PLOTS    440
      FRAC(IAGE)=0.6*BFRAC(IAGE)+0.4*TFRAC(IAGE)                        PLOTS    441
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   20 CONTINUE                                                          PLOTS     442
      PRINT 40                                                          PLOTS     443
      PRINT 70, (I,A(I),BFRAC(I),TFRAC(I),FRAC(I),I=1,NTL)              PLOTS     444
      CALL PLOPB (A,BFRAC,NTL,1,0,NCHAR,0.,8.,8.,0,0,11HAGE (YEARS),11,2 PLOTS     445
     10HFAILED FRACTION BISO,20,0,0,2,2)                                PLOTS     446
      CALL DLCH (100,1005,18,FUEL,1)                                    PLOTS     447
      IF (MFUEL.EQ.1) CALL DLCH (325,5,24,24HFT. ST. VRAIN FUEL MODEL,2) PLOTS     448
      IF (MFUEL.EQ.2) CALL DLCH (325,5,24,24HLATEST GASSAR FUEL MODEL,2) PLOTS     449
      CALL ADV (1)                                                      PLOTS     450
      CALL PLOPB (A,TFRAC,NTL,1,0,NCHAR,0.,8.,8.,0,0,11HAGE (YEARS),11,2 PLOTS     451
     11HFAILED FRACTION TRISO,21,0,0,2,2)                               PLOTS     452
      CALL DLCH (100,1005,18,FUEL,1)                                    PLOTS     453
      IF (MFUEL.EQ.1) CALL DLCH (325,5,24,24HFT. ST. VRAIN FUEL MODEL,2) PLOTS     454
      IF (MFUEL.EQ.2) CALL DLCH (325,5,24,24HLATEST GASSAR FUEL MODEL,2) PLOTS     455
      CALL ADV (1)                                                      PLOTS     456
      CALL PLOPB (A,FRAC,NTL,1,0,NCHAR,0.,8.,8.,0,0,11HAGE (YEARS),11,2) PLOTS     457
     1HFAILED FRACTION TOTAL,21,0,0,2,2)                                PLOTS     458
      CALL DLCH (100,1005,18,FUEL,1)                                    PLOTS     459
      IF (MFUEL.EQ.1) CALL DLCH (325,5,24,24HFT. ST. VRAIN FUEL MODEL,2) PLOTS     460
      IF (MFUEL.EQ.2) CALL DLCH (325,5,24,24HLATEST GASSAR FUEL MODEL,2) PLOTS     461
      CALL ADV (1)                                                      PLOTS     462
   30 CONTINUE                                                          PLOTS     463
      RETURN                                                            PLOTS     464
C                                                                       PLOTS     465
   40 FORMAT (*MFUEL=*,I1,5X,*LAGE=*,L1)                                PLOTS     466
   50 FORMAT (*0MFUEL =*,I1,5X,*LAGE =*,L1)                             PLOTS     467
   60 FORMAT (///4X,1HI,17X,3HAGE,15X,5HFRACB,15X,5HFRACT,16X,4HFRAC/)  PLOTS     468
   70 FORMAT (I5,4F20.5)                                                PLOTS     469
      END                                                               PLOTS     470
      SUBROUTINE PLOT3                                                  PLOTS     471
      LOGICAL LAGE,BISO                                                 PLOTS     472
      DIMENSION RINTAC(151), RFAILD(151), TT(151), TT4(151), RTLOG(151), PLOTS     473
     1 RFLOG(151)                                                       PLOTS     474
      COMMON /CJE07/ IXL,IXR,IYT,IYB,XMN,XMX,YMX,YMN                    PLOTS     475
      COMMON /CJE08/ XMIN,XMAX,INTVALX,KX,YMIN,YMAX,INTVALY,KY          PLOTS     476
      COMMON /LA/ LAGE,AGE,MFUEL,ISO,BISO                               PLOTS     477
      COMMON /LJNEW/ IXSAVE,IYSAVE,IX2,IY2                              PLOTS     478
      NCHAR=27                                                          PLOTS     479
      NN=41                                                             PLOTS     480
      DO 10 I=1,NN                                                      PLOTS     481
      TT4(I)=9.0-(I-1)*0.1                                              PLOTS     482
   10 TT(I)=1.0E4/TT4(I)                                                PLOTS     483
      MFUEL=1                                                           PLOTS     484
      XMIN=3.0                                                          PLOTS     485
      XMAX=9.0                                                          PLOTS     486
      INTVALX=6                                                         PLOTS     487
      BISO=.F.                                                          PLOTS     488
      KX=1                                                              PLOTS     489
      YMIN=-6.                                                          PLOTS     490
      YMAX=1.                                                           PLOTS     491
      INTVALY=7                                                         PLOTS     492
      KY=0                                                              PLOTS     493
      CALL PLOPB (TT4,RFAILD,NN,-1,0,NCHAR,0.,5.,7.,24HFT. ST. VRAIN FUE PLOTS     494
     1L MODEL,-24,19H1.0E4/T (DEGREES K),-19,36HPARTICLE COATING RELEASE PLOTS     495
     2 RATE / HOUR,36,0,0,2,2)                                          PLOTS     496
      CALL CONVRT (3.5,IX,XMN,XMX,IXL,IXR)                              PLOTS     497
      CALL CONVRT (-4.75,IY,YMN,YMX,IYB,IYT)                            PLOTS     498
      CALL WLCH (IX,IY,12,12H1,3,4,5,8,10,1)                            PLOTS     499
      CALL CONVRT (-3.5,IY,YMN,YMX,IYB,IYT)                             PLOTS     500
      CALL WLCH (IX,IY,1,1H6,1)                                         PLOTS     501
      CALL CONVRT (3.6,IX,XMN,XMX,IXL,IXR)                              PLOTS     502
      CALL CONVRT (-2.5,IY,YMN,YMX,IYB,IYT)                             PLOTS     503
      CALL WLCH (IX,IY,1,1H7,1)                                         PLOTS     504
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      CALL CONVRT (3.9,IX,XMN,XMX,IXL,IXR)                              PLOTS     505
      CALL CONVRT (-2.0,IY,YMN,YMX,IYB,IYT)                             PLOTS     506
      CALL WLCH (IX,IY,1,1H9,1)                                         PLOTS     507
      CALL CONVRT (4.5,IX,XMN,XMX,IXL,IXR)                              PLOTS     508
      CALL CONVRT (-1.5,IY,YMN,YMX,IYB,IYT)                             PLOTS     509
      CALL WLCH (IX,IY,1,1H2,1)                                         PLOTS     510
      CALL CONVRT (6.0,IX,XMN,XMX,IXL,IXR)                              PLOTS     511
      CALL CONVRT (-3.0,IY,YMN,YMX,IYB,IYT)                             PLOTS     512
      CALL WLCH (IX,IY,7,7H4,7,8,9,1)                                   PLOTS     513
      CALL CONVRT (6.5,IX,XMN,XMX,IXL,IXR)                              PLOTS     514
      CALL CONVRT (-1.0,IY,YMN,YMX,IYB,IYT)                             PLOTS     515
      CALL WLCH (IX,IY,6,6H3.5,10,1)                                    PLOTS     516
      CALL CONVRT (4.5,IX,XMN,XMX,IXL,IXR)                              PLOTS     517
      CALL CONVRT (0.0,IY,YMN,YMX,IYB,IYT)                              PLOTS     518
      CALL WLCH (IX,IY,1,1H1,1)                                         PLOTS     519
      CALL CONVRT (4.75,IX,XMN,XMX,IXL,IXR)                             PLOTS     520
      CALL CONVRT (0.1,IY,YMN,YMX,IYB,IYT)                              PLOTS     521
      CALL WLCH (IX,IY,1,1H6,1)                                         PLOTS     522
      DO 30 ISO=1,10                                                    PLOTS     523
      DO 20 I=1,NN                                                      PLOTS     524
      T=TT(I)                                                           PLOTS     525
      RINTAC(I)=RI(T)                                                   PLOTS     526
      RFAILD(I)=RF(T)                                                   PLOTS     527
      RILOG(I)=ALOG10(RINTAC(I))                                        PLOTS     528
      RFLOG(I)=ALOG10(RFAILD(I))                                        PLOTS     529
   20 CONTINUE                                                          PLOTS     530
      PRINT 80, ISO,MFUEL                                               PLOTS     531
      PRINT 90, (I,TT(I),TT4(I),RINTAC(I),RILOG(I),RFAILD(I),RFLOG(I),I= PLOTS     532
     11,NN)                                                             PLOTS     533
      CALL PLOPB (TT4,RFAILD,NN,-1,0,-NCHAR,0.,5.,7.,0.0,0,-19,0.0,0,0.2 PLOTS     534
     1,2)                                                               PLOTS     535
      CALL PLOPB (TT4,RINTAC,NN,-1,0,-NCHAR,0.,5.,7.,0.0,0,-19,0.0,0,0.2 PLOTS     536
     1,2)                                                               PLOTS     537
   30 CONTINUE                                                          PLOTS     538
      MFUEL=2                                                           PLOTS     539
      CALL ADV (1)                                                      PLOTS     540
      XMIN=3.0                                                          PLOTS     541
      XMAX=7.0                                                          PLOTS     542
      INTVALX=4                                                         PLOTS     543
      KX=0                                                              PLOTS     544
      YMIN=-4.                                                          PLOTS     545
      YMAX=2.0                                                          PLOTS     546
      INTVALY=6                                                         PLOTS     547
      KY=0                                                              PLOTS     548
      CALL PLOPB (TT4,RFAILD,NN,-1,0,NCHAR,2.,5.,7.,36HGASSAR FUEL MODEL PLOTS     549
     1 - FAILED PARTICLES,-36,19H1.0E4/T (DEGREES K),-19,36HPARTICLE COA PLOTS     550
     2TING RELEASE RATE / HOUR,36,0,0,2,2)                              PLOTS     551
      CALL CONVRT (4.0,IX,XMN,XMX,IXL,IXR)                              PLOTS     552
      CALL CONVRT (-1.4,IY,YMN,YMX,IYB,IYT)                             PLOTS     553
      CALL WLCH (IX,IY,8,8H10 TRISO,1)                                  PLOTS     554
      CALL CONVRT (-0.4,IY,YMN,YMX,IYB,IYT)                             PLOTS     555
      CALL WLCH (IX,IY,1,1H5,1)                                         PLOTS     556
      CALL CONVRT (6.0,IX,XMN,XMX,IXL,IXR)                              PLOTS     557
      CALL CONVRT (-1.6,IY,YMN,YMX,IYB,IYT)                             PLOTS     558
      CALL WLCH (IX,IY,1,1H3,1)                                         PLOTS     559
      CALL CONVRT (3.9,IX,XMN,XMX,IXL,IXR)                              PLOTS     560
      CALL CONVRT (0.4,IY,YMN,YMX,IYB,IYT)                              PLOTS     561
      CALL WLCH (IX,IY,1,1H6,1)                                         PLOTS     562
      CALL CONVRT (3.6,IX,XMN,XMX,IXL,IXR)                              PLOTS     563
      CALL CONVRT (0.6,IY,YMN,YMX,IYB,IYT)                              PLOTS     564
      CALL WLCH (IX,IY,7,7H10 BTSO,1)                                   PLOTS     565
      CALL CONVRT (6.8,IX,XMN,XMX,IXL,IXR)                              PLOTS     566
      CALL CONVRT (-1.3,IY,YMN,YMX,IYB,IYT)                             PLOTS     567
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      CALL WLCH (IX,IY,1,1H1,1)                                         PLOTS    568
      CALL CONVRT (3.6,IX,XMN,XMX,IXL,IXR)                              PLOTS    569
      CALL CONVRT (1.0,IY,YMN,YMX,IYB,IYT)                              PLOTS    570
      CALL WLCH (IX,IY,7,7H4,7,8.9,1)                                   PLOTS    571
      CALL CONVRT (4.25,IX,XMN,XMX,IXL,IXR)                             PLOTS    572
      CALL CONVRT (1.5,IY,YMN,YMX,IYB,IYT)                              PLOTS    573
      CALL WLCH (IX,IY,1,1H2,1)                                         PLOTS    574
      DO 50 ISO1=1,11                                                   PLOTS    575
      ISO=ISO1                                                          PLOTS    576
      IF (ISO.EQ.11) BISO=.T.                                           PLOTS    577
      IF (ISO.EQ.11) ISO=10                                             PLOTS    578
      DO 40 I=1,NN                                                      PLOTS    579
      T=TT(I)                                                           PLOTS    580
      RFAILD(I)=RF(T)                                                   PLOTS    581
      RFLOG(I)=ALOG10(RFAILD(I))                                        PLOTS    582
   40 CONTINUE                                                          PLOTS    583
      PRINT 80, ISO,MFUEL                                               PLOTS    584
      PRINT 100, (I,TT(I),TT4(I),RFAILD(I),RFLOG(I),I=1,NN)             PLOTS    585
      CALL PLOPB (TT4,RFAILD,NN,-1,0,-NCHAR,0.,5.,7.,0.0,0,-1,0,0,0,0,2, PLOTS    586
     12)                                                                PLOTS    587
   50 CONTINUE                                                          PLOTS    588
      CALL ADV (1)                                                      PLOTS    589
      XMIN=4.0                                                          PLOTS    590
      XMAX=9.0                                                          PLOTS    591
      YMIN=-7.                                                          PLOTS    592
      YMAX=0.                                                           PLOTS    593
      INTVALX=5                                                         PLOTS    594
      KX=0                                                              PLOTS    595
      INTVALY=7                                                         PLOTS    596
      KY=0                                                              PLOTS    597
      CALL PLOPB (TT4,RINTAC,NN,-1,0,NCHAR,2.,5.,7.,36HGASSAR FUEL MODEL PLOTS    598
     1 - INTACT PARTICLES,-36,19H1.0E4/T (DEGREES K),-19,36HPARTICLE COA PLOTS    599
     2TING RELEASE RATE / HOUR,36,0.0,2,2)                              PLOTS    600
      CALL CONVRT (7.0,IX,XMN,XMX,IXL,IXR)                              PLOTS    601
      CALL CONVRT (-6.2,IY,YMN,YMX,IYB,IYT)                             PLOTS    602
      CALL WLCH (IX,IY,7,7H3 TRISO,1)                                   PLOTS    603
      CALL CONVRT (4.8,IX,XMN,XMX,IXL,IXR)                              PLOTS    604
      CALL CONVRT (-4.8,IY,YMN,YMX,IYB,IYT)                             PLOTS    605
      CALL WLCH (IX,IY,17,17H7,(1,4,8,9 TRISO),1)                       PLOTS    606
      CALL CONVRT (5.0,IX,XMN,XMX,IXL,IXR)                              PLOTS    607
      CALL CONVRT (-4.1,IY,YMN,YMX,IYB,IYT)                             PLOTS    608
      CALL WLCH (IX,IY,1,1H5,1)                                         PLOTS    609
      CALL CONVRT (-3.7,IY,YMN,YMX,IYB,IYT)                             PLOTS    610
      CALL WLCH (IX,IY,12,12H6,(8,9 BISO),1)                            PLOTS    611
      CALL CONVRT (-3.1,IY,YMN,YMX,IYB,IYT)                             PLOTS    612
      CALL WLCH (IX,IY,2,2H10,1)                                        PLOTS    613
      CALL CONVRT (-2.1,IY,YMN,YMX,IYB,IYT)                             PLOTS    614
      CALL WLCH (IX,IY,1,1H2,1)                                         PLOTS    615
      CALL CONVRT (8.0,IX,XMN,XMX,IXL,IXR)                              PLOTS    616
      CALL CONVRT (-4.0,IY,YMN,YMX,IYB,IYT)                             PLOTS    617
      CALL WLCH (IX,IY,6,6H3 BISO,1)                                    PLOTS    618
      CALL CONVRT (-2.4,IY,YMN,YMX,IYB,IYT)                             PLOTS    619
      CALL WLCH (IX,IY,6,6H1 BISO,1)                                    PLOTS    620
      CALL CONVRT (4.6,IX,XMN,XMX,IXL,IXR)                              PLOTS    621
      CALL CONVRT (-0.4,IY,YMN,YMX,IYB,IYT)                             PLOTS    622
      CALL WLCH (IX,IY,6,6H4 BISO,1)                                    PLOTS    623
      DO 70 ISO=1,10                                                    PLOTS    624
      DO 70 IBISO=1,2                                                   PLOTS    625
      IF (IBISO.EQ.1) BISO=.F.                                          PLOTS    626
      IF (IBISO.EQ.2) BISO=.T.                                          PLOTS    627
      DO 60 I=1,NN                                                      PLOTS    628
      T=TT(I)                                                           PLOTS    629
      RINTAC(I)=RI(T)                                                   PLOTS    630
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      RILOG(I)=ALOG10(RINTAC(I))                                        PLOTS     631
   60 CONTINUE                                                          PLOTS     632
      PRINT 80, ISO,MFUEL                                               PLOTS     633
      CALL PLOPB (TT4,RINTAC,NN,-1,0,-NCHAR,0.,5.,7.,0,0,0,-1,0,0,0,0,5, PLOTS     634
     12)                                                                PLOTS     635
   70 CONTINUE                                                          PLOTS     636
      CALL ADV (1)                                                      PLOTS     637
      RETURN                                                            PLOTS     638
C                                                                       PLOTS     639
   80 FORMAT (6H0ISO =,I2,3X,7HMFUEL =,I1,10X,7H1.0E4/T,18X,2HRT,15X,5HR PLOTS     640
     1ILOG,18X,2HRF,15X,5HRFLOG/)                                       PLOTS     641
   90 FORMAT (1A,I5,F12.1,5F20.5)                                       PLOTS     642
  100 FORMAT (1X,I5,F12.1,E20.5,40X,2E20.5)                             PLOTS     643
      END                                                               PLOTS     644
      SUBROUTINE PLOT4                                                  PLOTS     645
      INTEGER DATE                                                      PLOTS     646
      DIMENSION T(41), FF(41), TX(41,50), B(50), VECP(250), ITITLE(36)  PLOTS     647
      DIMENSION TEMP1(41,50), TEMP2(41,50)                              PLOTS     648
      COMMON /TMODEL/ MODEL                                             PLOTS     649
      DO 10 I=1,36                                                      PLOTS     650
   10 ITITLE(I)=10H                                                     PLOTS     651
      CALL GETQ (4LKJBN,JOBNAME)                                        PLOTS     652
      CALL DATE1 (DATE)                                                 PLOTS     653
      ITITLE(1)=JOBNAME                                                 PLOTS     654
      ITITLE(2)=DATE                                                    PLOTS     655
      ITITLE(12)=10HTEMPERATUR                                          PLOTS     656
      ITITLE(13)=10HE MODEL =                                           PLOTS     657
      Z=SPLIME(0.0,0.0)                                                 PLOTS     658
      Z=TEMP0(0.0)                                                      PLOTS     659
      CALL ADV (1)                                                      PLOTS     660
      NTOT=40                                                           PLOTS     661
      IVFMAX=50                                                         PLOTS     662
      DT=20./NTOT                                                       PLOTS     663
      NTOT1=NTOT+1                                                      PLOTS     664
      DO 20 I=1,NTOT1                                                   PLOTS     665
   20 T(I)=(I-1)*DT                                                     PLOTS     666
      ITEMP=4                                                           PLOTS     667
      DO 60 MODEL=1,ITEMP                                               PLOTS     668
      ENCODE (10,70,ITITLE(14))MODEL                                    PLOTS     669
      IF (MODEL.EQ.4) GO TO 40                                          PLOTS     670
      Z=TAVE0(0.0)                                                      PLOTS     671
      Z=TMAX0(0.0)                                                      PLOTS     672
      TDELT=TEMP(0.0)-1174.4                                            PLOTS     673
      DO 30 I=1,NTOT1                                                   PLOTS     674
      TIME=T(I)                                                         PLOTS     675
   30 FF(I)=(TMAX(TIME)-TAVE(TIME))/TDELT                               PLOTS     676
   40 CONTINUE                                                          PLOTS     677
      PER=1./IVFMAX                                                     PLOTS     678
      DO 50 IVF=1,IVFMAX                                                PLOTS     679
      BIN=PER*(IVF-0.5)                                                 PLOTS     680
      B(IVF)=BIN                                                        PLOTS     681
      DO 50 I=1,NTOT1                                                   PLOTS     682
      TIME=T(I)                                                         PLOTS     683
      IF (MODEL.NE.4) TE=FF(I)*(TEMP(BIN)-1174.4)+TAVE(TIME)            PLOTS     684
      IF (MODEL.EQ.4) TE=SPL(TIME,BIN)                                  PLOTS     685
      TX(I,IVF)=TE                                                      PLOTS     686
   50 CONTINUE                                                          PLOTS     687
      ITITLE(9)=10HTIME(HRS)                                            PLOTS     688
      ITITLE(10)=10HCORE FRACT                                          PLOTS     689
      ITITLE(11)=10HTEMP (K)                                            PLOTS     690
      PRINT 90, MODEL                                                   PLOTS     691
      PRINT 90, (J,(TX(I,J),I=1,NTOT1,2),J=1,IVFMAX)                    PLOTS     692
      CALL PLNOW (TX,NTOT1,IVFMAX,T,B,VECP,250,ITITLE)                  PLOTS     693
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      CALL PICTURE (TX,TEMP1,TEMP2,NTOT1,IVFMAX,NTOT1,1.0,1.0,2.0,2.0,2.
     10,900.,3700.,0,-2,3,0,-1.)
C     WRITE JOB IDENTIFICATION
      CALL DLCH (154,992,4,4HJOB=,1)
      CALL DLCH (206,992,10,ITITLE,1)
C     WRITE DATE
      CALL DLCH (400,992,5,5HDATE=,1)
      CALL DLCH (464,992,10,ITITLE(2),1)
C     WRITE TO
      CALL DLCH (154,972,60,ITITLE(12),1)
C     WRITE FUNCTION RANGE
      CALL DLCH (696,952,7,7HRANGE--,1)
      CALL DLCH (780,952,20,ITITLE(3),1)
C     WRITE X RANGE
      CALL DLCH (780,972,20,ITITLE(5),1)
C     WRITE Y RANGE
      CALL DLCH (780,992,20,ITITLE(7),1)
      CALL ADV (1)
      CALL ADV (1)
   60 CONTINUE
      CALL EXH
C
      RETURN
C
   70 FORMAT (I2,8X)
   80 FORMAT (//* TEMPERATURE MODEL =*,I1/)
   90 FORMAT (1X,I3,21F6.0/)
      END
      FUNCTION UTMP0 (T)
C     THESE NUMBERS FROM TABULAR DATA IN REPORT BY J. FOLEY
      DIMENSION IOP(2), TAB(3)
      DIMENSION X(16), F(16), W(16), A(16), B(16), C(16)
      DATA X/2.,3.,4.,5.,6.,7.,8.,9.,10.,11.,12.,13.,14.,16.,18.,20./
      DATA F/0.,.0157,.0658,.1774,.3355,.5280,.7147,.8470,.9177,.9473,.9
     1550,.9537,.953,.946,.939,.933/
C     SPLINE BOUNDARY CONDITIONS ETC.
      IJ=1
      IOP(1)=5
      IOP(2)=5
      N1=16
      CALL SPL1D1 (N1,X,F,W,IOP,IJ,A,B,C)
      RETURN
      ENTRY UTMP
      CALL SPL1D2 (N1,X,F,W,IJ,T,TAB)
      UTMP=TAB(1)
      RETURN
      END
      FUNCTION AYER0 (T)
C     THESE NUMBERS FROM GRAPHICAL DATA IN REPORT BY J. FOLEY
      DIMENSION IOP(2), TAB(3)
      DIMENSION X(7), F(7), W(7), A(7), B(7), C(7)
      DATA X/2.,4.,6.,8.,10.,12.,13./
      DATA F/0.,.115,.435,.645,.75,.82,.845/
C     SPLINE BOUNDARY CONDITIONS ETC.
      IJ=1
      IOP(1)=5
      IOP(2)=5
      N1=7
      CALL SPL1D1 (N1,X,F,W,IOP,IJ,A,B,C)
      RETURN
      ENTRY AYER
      CALL SPL1D2 (N1,X,F,W,IJ,T,TAB)
      AYER=TAB(1)
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      RETURN                                                            PLOTS
      END                                                               PLOTS
      FUNCTION SORS0 (T)                                                PLOTS
C     THESE NUMBERS FROM GRAPHICAL DATA IN REPORT BY J. FOLEY           PLOTS
      DIMENSION IOP(2), TAB(3)                                          PLOTS
      DIMENSION X(8), F(8), W(8), A(8), B(8), C(8)                      PLOTS
      DATA X/2.,4.,6.,8.,10.,12.,14.,16./                               PLOTS
      DATA F/0.,.085,.340,.560,.70,.79,.845,.88/                        PLOTS
C     SPLINE BOUNDARY CONDITIONS ETC.                                   PLOTS
      IJ=1                                                              PLOTS
      IOP(1)=5                                                          PLOTS
      IOP(2)=5                                                          PLOTS
      N1=8                                                              PLOTS
      CALL SPL1D1 (N1,X,F,W,IOP,IJ,A,B,C)                               PLOTS
      RETURN                                                            PLOTS
      ENTRY SORS                                                        PLOTS
      CALL SPL1D2 (N1,X,F,W,IJ,T,TAB)                                   PLOTS
      SORS=TAB(1)                                                       PLOTS
      RETURN                                                            PLOTS
      END                                                               PLOTS
      FUNCTION UTMPC0 (T)                                               PLOTS
C     THESE NUMBERS FROM TABULAR DATA IN REPORT BY J. FOLEY             PLOTS
      DIMENSION IOP(2), TAB(3)                                          PLOTS
      DIMENSION X(16), F(16), W(16), A(16), B(16), C(16)                PLOTS
      DATA X/2.,3.,4.,5.,6.,7.,8.,9.,10.,11.,12.,13.,14.,16.,18.,20./   PLOTS
      DATA F/0.,19.2,102.8,319.4,702.7,1240.,1866.,2456.,2909.,3200.,3336 PLOTS
     11.,3439.,3473.,3493.,3496.,3496./                                 PLOTS
C     SPLINE BOUNDARY CONDITIONS ETC.                                   PLOTS
      IJ=1                                                              PLOTS
      IOP(1)=5                                                          PLOTS
      IOP(2)=5                                                          PLOTS
      N1=16                                                             PLOTS
      CALL SPL1D1 (N1,X,F,W,IOP,IJ,A,B,C)                               PLOTS
      RETURN                                                            PLOTS
      ENTRY UTMPC                                                       PLOTS
      CALL SPL1D2 (N1,X,F,W,IJ,T,TAB)                                   PLOTS
      UTMPC=TAB(1)                                                      PLOTS
      RETURN                                                            PLOTS
      END                                                               PLOTS
      FUNCTION AYERC0 (T)                                               PLOTS
C     THESE NUMBERS FROM GRAPHICAL DATA IN REPORT BY J. FOLEY           PLOTS
      DIMENSION IOP(2), TAB(3)                                          PLOTS
      DIMENSION X(8), F(8), W(8), A(8), B(8), C(8)                      PLOTS
      DATA X/2.,4.,6.,8.,10.,12.,14.,19./                               PLOTS
      DATA F/0.,250.,1020.,1930.,2480.,2800.,3000.,3110./               PLOTS
C     SPLINE BOUNDARY CONDITIONS ETC.                                   PLOTS
      IJ=1                                                              PLOTS
      IOP(1)=5                                                          PLOTS
      IOP(2)=5                                                          PLOTS
      N1=8                                                              PLOTS
      CALL SPL1D1 (N1,X,F,W,IOP,IJ,A,B,C)                               PLOTS
      RETURN                                                            PLOTS
      ENTRY AYERC                                                       PLOTS
      CALL SPL1D2 (N1,X,F,W,IJ,T,TAB)                                   PLOTS
      AYERC=TAB(1)                                                      PLOTS
      RETURN                                                            PLOTS
      END                                                               PLOTS
      SUBROUTINE PLOPB(X,Y,NPTS,INC,LNN,NSYM,C,XAA,YAA,LABELZ,NZL,LABELX PLOTS
     1,NXL,LABELY,NYL,LABELR,NRL,LSIZE,ISIZE)                           PLOTS
C     PLOPB PRODUCES A STANDARD 2-DIMENSIONAL PLOT SIMILAR TO PLOUR     PLOTS
C     WHICH IS SUITABLE FOR PUBLICATION.                                PLOTS
C     LABELS MAY BE WRITTEN ON 4 SIDES OF PLOT                          PLOTS
C     LSIZE IS THE SIZE OF THE LABELS. 1SIABS(LSIZE)<6                  PLOTS
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C     IF LSIZE > 0, DEPENDENT VARIABLES ARE PLOTTED ON LEFT-HAND SCALE   PLOTS   820
C     IF LSIZE < 0, DEPENDENT VARIABLES ARE PLOTTED ON RIGHT-HAND SCALE  PLOTS   821
C     ISIZE IS THE SIZE OF THE SCALES. 1SIABS(ISIZE)<4                   PLOTS   822
C     LINEAR PLOTS FOR DEPENDENT VARIABLES MAY HAVE 2 SCALES ON          PLOTS   823
C     MULTIPLE PLOTS.                                                    PLOTS   824
C     IF ISIZE < 0, ONLY LEFT SIDE OF PLOT HAS SCALE                     PLOTS   825
C     IF LSIZE > 0 AND ISIZE < 0, ALLOWANCE IS MADE TO DRAW SCALE ON     PLOTS   826
C     RIGHT SIDE WITH A LATER CALL TO PLOPB                              PLOTS   827
C     IF LSIZE < 0 AND ISIZE < 0, SCALE IS DRAWN ON RIGHT SIDE.          PLOTS   828
C     SCALES PRINT 4 FIGURES. DATA MUST BE ADJUSTED BEFORE CALL PLOPB.   PLOTS   829
C     IF LABEL OTHER THAN TOP DOES NOT FIT ON ONE LINE,                  PLOTS   830
C     LSIZE WILL BE REDUCED BY 1                                         PLOTS   831
C     ALSO THE LOG AXES WILL BE FULL CYCLES.                             PLOTS   832
C     IF XXA AND/OR YYA ARE NON-ZERO THE LENGTHS                         PLOTS   833
C     WILL BE CONSIDERED AS RATIOS WHERE THE LONGEST                     PLOTS   834
C     SIDE IS FITTED ON A 860 POINT LINE.                                PLOTS   835
C     AXES LENGTHS WILL BE REDUCED IN ORDER TO ALLOW ROOM FOR            PLOTS   836
C     LABELS AND SCALES IF NECESSARY.                                    PLOTS   837
      COMMON /CJE07/ IXL,IXR,IYT,IYB,XMN,XMX,YMX,YMN                     PLOTS   838
      COMMON /CJE08/ XMIN,XMAX,MAJORX,KX,YMIN,YMAX,MAJORY,KY             PLOTS   839
      DIMENSION X(1), Y(1)                                               PLOTS   840
      DIMENSION ISZ(6), IVSZ(6)                                          PLOTS   841
      DATA ISZ/12,18,24,30,36,42/                                        PLOTS   842
      DATA IVSZ/16,24,32,40,48,56/                                       PLOTS   843
      INTEGER GRIDF                                                      PLOTS   844
      B=AMAX1(AMAX1(C,0.)*(LNN+1),0.)                                    PLOTS   845
      LIN=LNN                                                            PLOTS   846
      KSYM=IABS(NSYM)                                                    PLOTS   847
      KINC=MAX0(IABS(INC),1)                                             PLOTS   848
      MPTS=IABS(NPTS)                                                    PLOTS   849
      MZL=MZM=IABS(NZL)                                                  PLOTS   850
      XXA=ABS(XAA)                                                       PLOTS   851
      YYA=ABS(YAA)                                                       PLOTS   852
      NXN=NXM=IABS(NXL)                                                  PLOTS   853
      NYN=NYM=IABS(NYL)                                                  PLOTS   854
      NRN=NRM=IABS(NRL)                                                  PLOTS   855
      LSZ=IABS(LSIZE)                                                    PLOTS   856
      ISIZ=IABS(ISIZE)                                                   PLOTS   857
      GRIDF=AMAX1(1.,ABS(C))                                             PLOTS   858
      IF (NSYM.GT.0) CALL ADV (1)                                        PLOTS   859
      IF (NXL.LT.0) GO TO 50                                             PLOTS   860
      IF ((NSYM.LT.0).A.(ISIZE.GT.0)) GO TO 100                          PLOTS   861
      CALL MAXV (X,KINC,MPTS,ISUB,XMX)                                   PLOTS   862
      CALL MAXV (Y,KINC,MPTS,ISUB,YMX)                                   PLOTS   863
      CALL MINV (X,KINC,MPTS,ISUB,XMN)                                   PLOTS   864
      CALL MINV (Y,KINC,MPTS,ISUB,YMN)                                   PLOTS   865
      IF (XXA.EQ.0) XXA=6.                                               PLOTS   866
      IF (YYA.EQ.0) YYA=10.                                              PLOTS   867
      IF (NPTS.LT.0) GO TO 20                                            PLOTS   868
      IF (XMN.NE.XMX) GO TO 10                                           PLOTS   869
      DXM=.001*ABS(XMX)                                                  PLOTS   870
      IF (DXM.EQ.0) DXM=.0001                                            PLOTS   871
      XMN=XMN-DXM                                                        PLOTS   872
      XMX=XMX+DXM                                                        PLOTS   873
   10 CALL ASCL (5,XMN,XMX,MAJX,MINX,KKX)                                PLOTS   874
      GO TO 30                                                           PLOTS   875
   20 XMN=ALOG10(XMN)                                                    PLOTS   876
      XMX=ALOG10(XMX)                                                    PLOTS   877
   30 IF (INC.LT.0) GO TO 60                                             PLOTS   878
      IF (YMN.NE.YMX) GO TO 40                                           PLOTS   879
      DYM=.001*ABS(YMX)                                                  PLOTS   880
      IF (DYM.EQ.0) DYM=.0001                                            PLOTS   881
      YMN=YMN-DYM                                                        PLOTS   882
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      YMX=YMX+DYM                                                       PLOTS     883
   40 CALL ASCL (5,YMN,YMX,MAJY,MINY,KKY)                               PLOTS     884
      GO TO 70                                                          PLOTS     885
   50 XMN=XMIN                                                          PLOTS     886
      XMX=XMAX                                                          PLOTS     887
      MAJX=MAKX=MAJORX                                                  PLOTS     888
      KKX=KX                                                            PLOTS     889
      YMN=YMIN                                                          PLOTS     890
      YMX=YMAX                                                          PLOTS     891
      MAJY=MAKY=MAJORY                                                  PLOTS     892
      KKY=KY                                                            PLOTS     893
      GO TO 70                                                          PLOTS     894
   60 YMN=ALOG10(YMN)                                                   PLOTS     895
      YMX=ALOG10(YMX)                                                   PLOTS     896
   70 MAKX=GRIDF*MAJX                                                   PLOTS     897
      MAKY=GRIDF*MAJY                                                   PLOTS     898
      IF (NSYM.LT.0) GO TO 90                                           PLOTS     899
      IXL=4.5*ISZ(ISIZ)+1.5*IVSZ(LSZ)                                   PLOTS     900
      IH=IVSZ(ISIZ)                                                     PLOTS     901
      IF (INC.GE.0) IH=IH/2                                             PLOTS     902
      IYT=2*MAX0(IVSZ(LSZ),IH)                                          PLOTS     903
      IF ((MZL+1)*ISZ(LSZ).GT.1023-IXL/2) IYT=IYT+IVSZ(LSZ)             PLOTS     904
      FACT=860./AMAX1(XXA,YYA)                                          PLOTS     905
      IXR=MIN0(IXL+IFIX(FACT*XXA),1023-MAX0(3*IVSZ(LSZ)/2+ISZ(ISIZ),5*IS PLOTS     906
     1Z(ISIZ)/2))                                                       PLOTS     907
      IF (ISIZE.LT.0) IXR=IXR-4*ISZ(ISIZ)                               PLOTS     908
      IYB=MIN0(IYT+IFIX(FACT*YYA),1023-5*IVSZ(ISIZ)/3-3*IVSZ(LSZ)/2)    PLOTS     909
      CALL FRAME (IXL,IXR,IYT,IYB)                                      PLOTS     910
      IF (SIGN(1.,XAA).GT.0) GO TO 80                                   PLOTS     911
      SWAP=XMN                                                          PLOTS     912
      XMN=XMX                                                           PLOTS     913
      XMX=SWAP                                                          PLOTS     914
   80 IF (SIGN(1.,YAA).GT.0) GO TO 90                                   PLOTS     915
      SWAP=YMN                                                          PLOTS     916
      YMN=YMX                                                           PLOTS     917
      YMX=SWAP                                                          PLOTS     918
   90 CALL DGA (IXL,IXR,IYT,IYB,XMN,XMX,YMX,YMN)                        PLOTS     919
  100 IF (LSIZE.LT.0) MAKY=-MAKY                                        PLOTS     920
      IF ((NSYM.LT.0).A.(LSIZE.GT.0)) GO TO 230                         PLOTS     921
      IF ((NSYM.LT.0).A.(LSIZE.LT.0).A.(ISIZE.GT.0)) GO TO 230          PLOTS     922
      IF (NPTS.LT.0.AND.INC.LT.0) CALL DLGLGT                           PLOTS     923
      IF (NPTS.LT.0.AND.INC.GE.0) CALL DLGLNT (MAKY,ISIZE)              PLOTS     924
      IF (NPTS.GE.0.AND.INC.LT.0) CALL DLNLGT (MAKX,ISIZE)              PLOTS     925
      IF (NPTS.GE.0.AND.INC.GE.0) CALL DLNLNT (MAKX,MAKY,ISIZE)         PLOTS     926
      IF (NPTS.LT.0) GO TO 110                                          PLOTS     927
      IF (NSYM.GT.0) CALL SRLN (MAJX,KKX,ISIZ)                          PLOTS     928
      GO TO 120                                                         PLOTS     929
  110 IF (NSYM.GT.0) CALL SRLG (ISIZ)                                   PLOTS     930
  120 IF (INC.LT.0) GO TO 130                                           PLOTS     931
      IF ((LSIZE.GT.0).A.(NSYM.GT.0)) CALL SLLN (MAJY,KKY,ISIZ)         PLOTS     932
      IF ((LSIZE.LT.0).A.(ISIZE.LT.0)) CALL SRLN (MAJY,KKY,ISIZ)        PLOTS     933
      GO TO 140                                                         PLOTS     934
  130 CALL SLLG (ISIZ)                                                  PLOTS     935
      IF (ISIZE.LT.0) CALL SRLG (ISIZ)                                  PLOTS     936
  140 CALL EXL                                                          PLOTS     937
      IF (NSYM.LT.0) GO TO 230                                          PLOTS     938
      KSZ=LSZ                                                           PLOTS     939
      IF (NYL.GE.0) GO TO 220                                           PLOTS     940
      KSZ=-KSZ                                                          PLOTS     941
      IF (MZM.EQ.0) GO TO 160                                           PLOTS     942
      DO 150 K=1,MZM                                                    PLOTS     943
      CALL FETCH (K,LABELZ,KK)                                          PLOTS     944
      IF (KK.GE.608) MZM=MZM+1                                          PLOTS     945
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  150 CONTINUE                                                          PLOTS    946
  160 IF (NXM.EQ.0) GO TO 180                                           PLOTS    947
      DO 170 K=1,NXM                                                    PLOTS    948
      CALL FETCH (K,LABELX,KK)                                          PLOTS    949
      IF (KK.GE.60B) NXM=NXM+1                                          PLOTS    950
  170 CONTINUE                                                          PLOTS    951
  180 IF (NYM.EQ.0) GO TO 200                                           PLOTS    952
      DO 190 K=1,NYM                                                    PLOTS    953
      CALL FETCH (K,LABELY,KK)                                          PLOTS    954
      IF (KK.GE.60B) NYM=NYM+1                                          PLOTS    955
  190 CONTINUE                                                          PLOTS    956
  200 IF (NRM.EQ.0) GO TO 220                                           PLOTS    957
      DO 210 K=1,NRM                                                    PLOTS    958
      CALL FETCH (K,LABELR,KK)                                          PLOTS    959
      IF (KK.GE.60B) NRM=NRM+1                                          PLOTS    960
  210 CONTINUE                                                          PLOTS    961
  220 CONTINUE                                                          PLOTS    962
      IF (NXN.NE.0) CALL DLCH (MAX0(IXL/2,IXL+(IXR-IXL-ISZ(LSZ)*NXN)/2), PLOTS    963
     1IYB+5*IVSZ(ISIZ)/3+IVSZ(LSZ)/2,NXM,LABELX,KSZ)                    PLOTS    964
      IF (NYN.NE.0) CALL DLCV (0,MIN0((IYB+1023)/2,IYB-(IYB-IYT-ISZ(LSZ) PLOTS    965
     1*NYN)/2),NYM,LABELY,KSZ)                                          PLOTS    966
      IF (NZL.NE.0) CALL DLCH (MAX0(IXL/2,IXL+(IXR-IXL-ISZ(LSZ)*MZL)/2), PLOTS    967
     10,MZM,LABELZ,KSZ)                                                 PLOTS    968
      IXX=IXR                                                           PLOTS    969
      IF (ISIZE.LT.0) IXX=IXX+4*ISZ(ISIZ)                               PLOTS    970
      IF (NRN.NE.0) CALL DLCV (IXX+IVSZ(LSZ)/2+ISZ(ISIZ)/2,MIN0((IYB+102 PLOTS    971
     13)/2,IYB-(IYB-IYT-ISZ(LSZ)*NRN)/2),NRM,LABELR,KSZ)                PLOTS    972
      CALL EXH                                                          PLOTS    973
  230 IF (NZL.LT.0) GO TO 320                                           PLOTS    974
C     PLOT POINTS AND/OR LINE                                           PLOTS    975
      MPTS=MPTS*KINC                                                    PLOTS    976
      DO 310 NXP=1,MPTS,KINC                                            PLOTS    977
      XTWO=X(NXP)                                                       PLOTS    978
      YTWO=Y(NXP)                                                       PLOTS    979
      IF (NPTS.LT.0) XTWO=ALOG10(XTWO)                                  PLOTS    980
      IF (INC.LT.0) YTWO=ALOG10(YTWO)                                   PLOTS    981
      CALL CONVRT (XTWO,NXTWO,XMN,XMX,IXL,IXR)                          PLOTS    982
      CALL CONVRT (YTWO,NYTWO,YMN,YMX,IYB,IYT)                          PLOTS    983
      IF (NXP.EQ.1) GO TO 290                                           PLOTS    984
      IF (LIN.GE.0) GO TO 280                                           PLOTS    985
  240 IF (MOD(((NXP-1)/KINC),IABS(LIN)).NE.0) GO TO 250                 PLOTS    986
      CALL EXL                                                          PLOTS    987
      CALL DLCH (NXTWO,NYTWO,0,KSYM,1)                                  PLOTS    988
      CALL EXH                                                          PLOTS    989
      GO TO 300                                                         PLOTS    990
  250 IF (B.EQ.0.) GO TO 300                                            PLOTS    991
  260 DO 270 IB=1,4                                                     PLOTS    992
  270 CALL PLT (NXTWO,NYTWO,42)                                         PLOTS    993
      GO TO 300                                                         PLOTS    994
  280 IF (B.EQ.0.) CALL DRV (NXONE,NYONE,NXTWO,NYTWO)                   PLOTS    995
  290 IF (LIN.NE.0) GO TO 240                                           PLOTS    996
      IF (B.NE.0.) GO TO 260                                            PLOTS    997
  300 NYONE=NYTWO                                                       PLOTS    998
      NXONE=NXTWO                                                       PLOTS    999
  310 CONTINUE                                                          PLOTS   1000
  320 RETURN                                                            PLOTS   1001
      END                                                               PLOTS   1002
      SUBROUTINE SLLN(NNY,NK,ISIZE)                                     PLOTS   1003
      COMMON /CJE07/ IXL,IXR,IYT,IYB,XL,XR,YT,YB                        PLOTS   1004
      DIMENSION ISZ(4), IVSZ(4)                                         PLOTS   1005
      DATA ISZ/12,18,24,30/                                             PLOTS   1006
      DATA IVSZ/16,24,32,40/                                            PLOTS   1007
      DATA MASK1/7/00000000000000000B/                                  PLOTS   1008
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      DATA MASK2/00777777777777777777B/                                 PLOTS    1009
      NNK=NK                                                            PLOTS    1010
      NC=MAX0(INT(ALOG10(AMAX1(ABS(YT),ABS(YB)))+.00001)+1,1)           PLOTS    1011
      IF (MIN0(YT,YB).LT.0) NC=NC+1                                     PLOTS    1012
      IF (NNK.GT.0) NC=NC+1                                             PLOTS    1013
   10 IF (ISZ(ISIZE)*(NC+NNK+.5).LT.IXL) GO TO 20                       PLOTS    1014
      IF (NNK.GT.0) NNK=NNK-1                                           PLOTS    1015
      IF (NNK.GT.0) GO TO 10                                            PLOTS    1016
   20 NC=MIN0(NC+NNK,4)                                                 PLOTS    1017
      IF (YT.GE..005) GO TO 30                                          PLOTS    1018
      IF (NNY.LE.5) GO TO 30                                            PLOTS    1019
      NC=NC+1                                                           PLOTS    1020
      NNK=NNK+1                                                         PLOTS    1021
   30 CONTINUE                                                          PLOTS    1022
      ENCODE (6,50,FMT)NC,NNK                                           PLOTS    1023
      ENCODE (10,FMT,OUT)YB                                             PLOTS    1024
      IF ((OUT.AND.MASK1).EQ.1L*) OUT=(OUT.AND.MASK2).OR.1L.            PLOTS    1025
C     THIS CHANGE SHOULD REPLACE * BY . AT LEFT OF FIELD                PLOTS    1026
C     WE COULD HAVE USED CALL PUT (1,OUT,1R.)                           PLOTS    1027
      IXT=IXL-ISZ(ISIZE)*(NC+.5)                                        PLOTS    1028
      IVS=IVSZ(ISIZE)/2                                                 PLOTS    1029
      CALL DLCH (IXT,IYB-IVS,NC,OUT,ISIZE)                              PLOTS    1030
      CALL TSP (IXL,IYB,1,1H+)                                          PLOTS    1031
      IF (NNY.LE.0) RETURN                                              PLOTS    1032
      NY=MIN0((IYB-IYT)/IVSZ(ISIZE),NNY)                                PLOTS    1033
      DY=(YT-YB)/NY+YT*1E-12                                            PLOTS    1034
      DDY=FLOAT(IYT-IYB)/NY                                             PLOTS    1035
      DO 40 I=1,NY                                                      PLOTS    1036
      YC=YB+I*DY                                                        PLOTS    1037
      IYC=IYB+I*DDY                                                     PLOTS    1038
      ENCODE (10,FMT,OUT)YC                                             PLOTS    1039
      CALL DLCH (IXT,IYC-IVS,NC,OUT,ISIZE)                              PLOTS    1040
   40 CALL TSP (IXL,IYC,1,1H+)                                          PLOTS    1041
      RETURN                                                            PLOTS    1042
C                                                                       PLOTS    1043
   50 FORMAT (2H(F,I1,1H.,I1,1H))                                       PLOTS    1044
      END                                                               PLOTS    1045
      SUBROUTINE SLLIN(NNY,NK)                                          PLOTS    1046
      COMMON /CJE07/ IXL,IXR,IYT,IYB,XL,XR,YT,YB                        PLOTS    1047
      DIMENSION FMT(14), OUT(2)                                         PLOTS    1048
      DATA (FMT(K),K=1,14)/6H(F7.0),6H(F8.1),6H(F9.2),7H(F10.3),7H(F11.4 PLOTS    1049
     1),7H(F12.5),7H(F13.6),8H(1PE7.0),8H(1PE8.1),8H(1PE9.2),9H(1PE10.3) PLOTS    1050
     2,9H(1PE11.4),9H(1PE12.5),9H(1PE13.6)/                             PLOTS    1051
      IF (NK.GT.6) GO TO 10                                             PLOTS    1052
      K=MIN0(6,MAX0(0,NK))+1                                            PLOTS    1053
      NC=K*6                                                            PLOTS    1054
      GO TO 20                                                          PLOTS    1055
   10 K=MIN0(16,MAX0(10,NK))-2                                          PLOTS    1056
      NC=K-1                                                            PLOTS    1057
   20 A=FMT(K)                                                          PLOTS    1058
      ENCODE (20,A,OUT)YB                                               PLOTS    1059
      IXT=IXL-12*NC-6                                                   PLOTS    1060
      CALL WLCH (IXT,IYB,NC,OUT,1)                                      PLOTS    1061
      CALL TSP (IXL,IYB,1,1H+)                                          PLOTS    1062
      IF (NNY.LE.0) RETURN                                              PLOTS    1063
      NY=MIN0(128,NNY)                                                  PLOTS    1064
      IYC=IYB                                                           PLOTS    1065
      DY=(YT-YB)/NY                                                     PLOTS    1066
      DDY=FLOAT(IYT-IYB)/NY                                             PLOTS    1067
      DO 30 I=1,NY                                                      PLOTS    1068
      YC=YB+I*DY                                                        PLOTS    1069
      IYC=IYB+I*DDY                                                     PLOTS    1070
      ENCODE (20,A,OUT)YC                                               PLOTS    1071
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      CALL WLCH (IXT,IYC,NC,OUT,1)                                      PLOTS    1072
   30 CALL TSP (IXL,IYC,1,1H+)                                          PLOTS    1073
      RETURN                                                            PLOTS    1074
      END                                                               PLOTS    1075
      SUBROUTINE SBLIN(NNY,NK)                                          PLOTS    1076
      COMMON /CJE07/ IXL,IXR,IYT,IYB,XL,XR,YT,YB                        PLOTS    1077
      DIMENSION FMT(12), OUT(2)                                         PLOTS    1078
      DATA (FMT(K),K=1,12)/2H(F,1H ,1H.,1H ,1H),8H(1PE7.0),8H(1PE8.1),9H PLOTS    1079
     1(1PE9.2),9H(1PE10.3),9H(1PE11.4),9H(1PE12.5),9H(1PE13.6)/         PLOTS    1080
      IF (NK.GT.9) GO TO 10                                             PLOTS    1081
      NC=MAX0(INT(ALOG10(AMAX1(ABS(YT),ABS(YB))))+1,1)                  PLOTS    1082
      IF (MIN0(YT,YB).LT.0) NC=NC+1                                     PLOTS    1083
      IF (NK.GT.0) NC=NC+1                                              PLOTS    1084
      NC=NC+NK                                                          PLOTS    1085
      ENCODE (10,40,FMT(2))NC                                           PLOTS    1086
      ENCODE (10,40,FMT(4))NK                                           PLOTS    1087
      K=1                                                               PLOTS    1088
      GO TO 20                                                          PLOTS    1089
   10 K=MIN0(16,MAX0(0,NK))-4                                           PLOTS    1090
      NC=K+1                                                            PLOTS    1091
   20 ENCODE (20,FMT(K),OUT)YB                                          PLOTS    1092
      CALL TSP (IXR,IYB,1,1H+)                                          PLOTS    1093
      CALL TCP (NC,OUT)                                                 PLOTS    1094
      IF (NNY.LE.0) RETURN                                              PLOTS    1095
      NY=MIN0(128,NNY)                                                  PLOTS    1096
      IYC=IYB                                                           PLOTS    1097
      DDY=FLOAT(IYT-IYB)/NY                                             PLOTS    1098
      DY=(YT-YB)/NY                                                     PLOTS    1099
      DO 30 I=1,NY                                                      PLOTS    1100
      YC=YB+I*DY                                                        PLOTS    1101
      IYC=IYB+I*DDY                                                     PLOTS    1102
      ENCODE (20,FMT(K),OUT)YC                                          PLOTS    1103
      CALL TSP (IXR,IYC,1,1H+)                                          PLOTS    1104
   30 CALL TCP (NC,OUT)                                                 PLOTS    1105
      RETURN                                                            PLOTS    1106
C                                                                       PLOTS    1107
   40 FORMAT (I2)                                                       PLOTS    1108
      END                                                               PLOTS    1109
      SUBROUTINE SBLIN(NNX,NK)                                          PLOTS    1110
      COMMON /CJE07/ IXL,IXR,IYT,IYB,XL,XR,YT,YB                        PLOTS    1111
      DIMENSION FMT(12), OUT(2)                                         PLOTS    1112
      DATA (FMT(K),K=1,12)/2H(F,1H ,1H.,1H ,1H),8H(1PE7.0),8H(1PE8.1),9H PLOTS    1113
     1(1PE9.2),9H(1PE10.3),9H(1PE11.4),9H(1PE12.5),9H(1PE13.6)/         PLOTS    1114
      IY=IYB                                                            PLOTS    1115
      IYDEL=12                                                          PLOTS    1116
      GO TO 10                                                          PLOTS    1117
      ENTRY STLIN                                                       PLOTS    1118
      IY=IYT                                                            PLOTS    1119
      IYDEL=-12                                                         PLOTS    1120
   10 IF (NK.GT.9) GO TO 20                                             PLOTS    1121
      NC=MAX0(INT(ALOG10(AMAX1(ABS(XL),ABS(XR)))+.00001)+1,1)           PLOTS    1122
      IF (MIN0(XL,XR).LT.0) NC=NC+1                                     PLOTS    1123
      IF (NK.GT.0) NC=NC+1                                              PLOTS    1124
      NC=NC+NK                                                          PLOTS    1125
      ENCODE (10,50,FMT(2))NC                                           PLOTS    1126
      ENCODE (10,50,FMT(4))NK                                           PLOTS    1127
      K=1                                                               PLOTS    1128
      GO TO 30                                                          PLOTS    1129
   20 K=MIN0(16,MAX0(10,NK))-4                                          PLOTS    1130
      NC=K+1                                                            PLOTS    1131
   30 ENCODE (20,FMT(K),OUT)XL                                          PLOTS    1132
      CALL TSP (IXL,IY,1,1H+)                                           PLOTS    1133
      IXTT=IXL-6*NC+6                                                   PLOTS    1134
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      IYC=IY+IYDEL                                                      PLOTS    1135
      CALL WLCH (IXTT,IYC,NC,OUT,1)                                     PLOTS    1136
      IF (NNX.LE.0) RETURN                                              PLOTS    1137
      NX=MIN0(NNX,128)                                                  PLOTS    1138
      IXC=IXL                                                           PLOTS    1139
      DDX=FLOAT(IXR-IXL)/NX                                             PLOTS    1140
      DX=(XR-XL)/NX                                                     PLOTS    1141
      DO 40 I=1,NX                                                      PLOTS    1142
      XC=XL+I*DX                                                        PLOTS    1143
      IXT=IXTT+I*DDX                                                    PLOTS    1144
      IXC=IXL+I*DDX                                                     PLOTS    1145
      ENCODE (20,FMT(K),OUT)XC                                          PLOTS    1146
      CALL TSP (IXC,IY,1,1H.)                                           PLOTS    1147
   40 CALL WLCH (IXT,IYC,NC,OUT,1)                                      PLOTS    1148
      RETURN                                                            PLOTS    1149
C                                                                       PLOTS    1150
   50 FORMAT (I2)                                                       PLOTS    1151
      END                                                               PLOTS    1152
      SUBROUTINE SBLOG                                                  PLOTS    1153
      COMMON /CJE07/ IXL,IXR,IYT,IYB,XL,XR,YT,YB                        PLOTS    1154
      DIMENSION XY(4), IXY(4)                                           PLOTS    1155
      EQUIVALENCE (XY,XL), (IXY,IXL)                                    PLOTS    1156
      DATA TEN/2H10/                                                    PLOTS    1157
      IY=IYB                                                            PLOTS    1158
      IYDEL=20                                                          PLOTS    1159
   10 IX=IXL                                                            PLOTS    1160
      IXDEL=-8                                                          PLOTS    1161
      I1=1                                                              PLOTS    1162
      I2=2                                                              PLOTS    1163
      GO TO 30                                                          PLOTS    1164
      ENTRY STLOG                                                       PLOTS    1165
      IY=IYT                                                            PLOTS    1166
      IYDEL=-12                                                         PLOTS    1167
      GO TO 10                                                          PLOTS    1168
      ENTRY SRLOG                                                       PLOTS    1169
      IX=IXR                                                            PLOTS    1170
      IXDEL=8                                                           PLOTS    1171
      GO TO 20                                                          PLOTS    1172
      ENTRY SLLOG                                                       PLOTS    1173
      IX=IXL                                                            PLOTS    1174
      IXDEL=-48                                                         PLOTS    1175
   20 IY=IYB                                                            PLOTS    1176
      IYDEL=0                                                           PLOTS    1177
      I1=4                                                              PLOTS    1178
      I2=3                                                              PLOTS    1179
   30 X1=XY(I1)                                                         PLOTS    1180
      X2=XY(I2)                                                         PLOTS    1181
      XMIN=AMIN1(X1,X2)                                                 PLOTS    1182
      XMAX=AMAX1(X1,X2)                                                 PLOTS    1183
      XMIN=AMIN1(AINT(XMIN),SIGN(AINT(ABS(XMIN)+.999),XMIN))            PLOTS    1184
      XMAX=AMAX1(AINT(XMAX),SIGN(AINT(ABS(XMAX)+.999),XMAX))            PLOTS    1185
      X1=XMIN                                                           PLOTS    1186
      X2=XMAX                                                           PLOTS    1187
      NY=ABS(X1-X2)                                                     PLOTS    1188
      IF (NY.NE.0) GO TO 40                                             PLOTS    1189
      YTT=X1+1.                                                         PLOTS    1190
      IF (X2.LT.X1) YTT=X1-1.                                           PLOTS    1191
      NY=1                                                              PLOTS    1192
      X1=YTT                                                            PLOTS    1193
   40 XY(I1)=X1                                                         PLOTS    1194
      XY(I2)=X2                                                         PLOTS    1195
      IXYV=XY(I1)                                                       PLOTS    1196
      NH=MAX1(ABS(XY(I1)),ABS(XY(I2)))                                  PLOTS    1197
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      NL=MIN1(XY(I1),XY(I2))                                            PLOTS    1198
      NC=MIN0(INT(ALOG10(FLOAT(NH))+.00001)+2,4)                        PLOTS    1199
      IF (NL.GE.0) GO TO 60                                             PLOTS    1200
      IF (IABS(NL).EQ.NH) GO TO 50                                      PLOTS    1201
      IF (INT(ALOG10(ABS(FLOAT(NL)))).LT.INT(ALOG10(FLOAT(NH)))) GO TO 6 PLOTS    1202
     10                                                                 PLOTS    1203
   50 NC=MIN0(NC+1,4)                                                   PLOTS    1204
   60 ENCODE (4,100,FMT)NC                                              PLOTS    1205
      NX=AMIN1(ABS(XY(I1)-XY(I2)),25.)                                  PLOTS    1206
      ENCODE (10,FMT,OUT)IXYV                                           PLOTS    1207
      CALL TSP (IX,IY,1,1H+)                                            PLOTS    1208
      IF ((I1.EQ.4).A.(IX.EQ.IXL)) IXDEL=IXDEL+8*(4-NC)                 PLOTS    1209
      IXC=IX+IXDEL                                                      PLOTS    1210
      IYC=IY+IYDEL                                                      PLOTS    1211
      IXX=IXC+8                                                         PLOTS    1212
      IYX=IYC-8                                                         PLOTS    1213
      CALL TSP (IXC,IYC,2,TEN)                                          PLOTS    1214
      CALL WRCH (IXX-8,IYX-12,4,OUT,1)                                  PLOTS    1215
      IF (NX.EQ.0) RETURN                                               PLOTS    1216
      IDXYV=ISIGN(1,IFIX(XY(I2)-XY(I1)))                                PLOTS    1217
      DO 80 I=1,NX                                                      PLOTS    1218
      IXYV=IXYV+IDXYV                                                   PLOTS    1219
      ENCODE (10,FMT,OUT)IXYV                                           PLOTS    1220
      IF (I1.EQ.1) GO TO 70                                             PLOTS    1221
      IYC=IY+IYDEL+(I*(IXY(I2)-IXY(I1)))/NX                             PLOTS    1222
      IYX=IYC-8                                                         PLOTS    1223
      CALL TSP (IX,IYC,1,1H+)                                           PLOTS    1224
      GO TO 80                                                          PLOTS    1225
   70 IXC=IX+IXDEL+(I*(IXY(I2)-IXY(I1)))/NX                             PLOTS    1226
      IXX=IXC+8                                                         PLOTS    1227
      CALL TSP (IXX,IY,1,1H+)                                           PLOTS    1228
   80 CALL TSP (IXC,IYC,2,TEN)                                          PLOTS    1229
      CALL WRCH (IXX-8,IYX-12,4,OUT,1)                                  PLOTS    1230
   90 CONTINUE                                                          PLOTS    1231
      RETURN                                                            PLOTS    1232
C                                                                       PLOTS    1233
  100 FORMAT (2H(I,I1,1H))                                              PLOTS    1234
      END                                                               PLOTS    1235
      SUBROUTINE PLNOW(FLUX,IX,JY,XPLT,YPLT,VECP,ILVECP,ITITLE)         PLOTS    1236
      LOGICAL ITOP,JTOP,NFOUND,IPR                                      PLOTS    1237
      COMMON /CNTRCOM/ ISYM(50),SCFAC                                   PLOTS    1238
      COMMON /CJE07/ IXL,IXR,IYT,IYB,XNM,XMX,YMX,YMN                    PLOTS    1239
      DIMENSION FLUX(1), XPLT(1), YPLT(1), VECP(1), ITITLE(1)           PLOTS    1240
      DATA TIGER/5LLARG1/                                               PLOTS    1241
C     LCP  LT  0      WE COMPUTE CONTOUR INTERVALS                      PLOTS    1242
C     LCP EQ  0      NO CONTOURS                                        PLOTS    1243
C     LCP GT 0      CONTOUR ROUTINE COMPUTES INTERVALS                 PLOTS    1244
C     PARAMETERS FOR COMPUTING REGIONS TO BE CONTOURED                  PLOTS    1245
      NCL=10                                                            PLOTS    1246
      LABELX=ITITLE(9)                                                  PLOTS    1247
      LABELY=ITITLE(10)                                                 PLOTS    1248
      LABELZ=ITITLE(11)                                                 PLOTS    1249
      LCP=-25                                                           PLOTS    1250
      FF=.04                                                            PLOTS    1251
      CINT=-1.0                                                         PLOTS    1252
      IGRID=5                                                           PLOTS    1253
      IMT=IX                                                            PLOTS    1254
      JMT=JY                                                            PLOTS    1255
      IMJMT=IMT*JMT                                                     PLOTS    1256
      SCALE=20.0                                                        PLOTS    1257
      ANGT=1.0471976                                                    PLOTS    1258
      ANGF=0.0                                                          PLOTS    1259
      AMULX=1.0                                                         PLOTS    1260
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      AMULX=YPLT(JY)/XPLT(IX)                                           PLOTS    1261
C     THIS SHOULD PRODUCE A SQUARE BASE FOR THE 3-D PLOT                PLOTS    1262
      AMULY=1.0                                                         PLOTS    1263
      IDXA=1                                                            PLOTS    1264
      IDXL=MAX0(IMT,JMT,21)                                             PLOTS    1265
      IDXB=IDXA+IDXL                                                    PLOTS    1266
      IDXC=IDXB+IDXL                                                    PLOTS    1267
      IDXD=IDXC+IDXL                                                    PLOTS    1268
      IDXE=IDXD+IDXL-1                                                  PLOTS    1269
      IF (IDXL.LE.ILVECP) GO TO 10                                      PLOTS    1270
      PRINT 190, IDXL,ILVECP                                            PLOTS    1271
      RETURN                                                            PLOTS    1272
C     COMPUTE ZERO ORIGIN.                                              PLOTS    1273
   10 CONTINUE                                                          PLOTS    1274
      XMIN=XPLT(1)                                                      PLOTS    1275
      XMAX=XPLT(IMT)                                                    PLOTS    1276
      YMIN=YPLT(1)                                                      PLOTS    1277
      YMAX=YPLT(JMT)                                                    PLOTS    1278
      TEMX=FLUX(1)                                                      PLOTS    1279
      TEMPM=TEMX                                                        PLOTS    1280
      DO 20 IDY=1,IMJMT                                                 PLOTS    1281
      TEMPI=FLUX(IDY)                                                   PLOTS    1282
      TEMX=AMAX1(TEMX,TEMPI)                                            PLOTS    1283
      TEMPM=AMIN1(TEMPM,TEMPI)                                          PLOTS    1284
C     END OF IDY LOOP.                                                  PLOTS    1285
   20 CONTINUE                                                          PLOTS    1286
      TEMP=0.0                                                          PLOTS    1287
      IF (TEMX.GT.TEMPM) TEMP=SCALE/(TEMX-TEMPM)                        PLOTS    1288
      IF (TEMP.EQ.0.0) GO TO 40                                         PLOTS    1289
C     SCALE VALUES TO BE PLOTTED                                        PLOTS    1290
      DO 30 IDY=1,IMJMT                                                 PLOTS    1291
      FLUX(IDY)=TEMP*FLUX(IDY)                                          PLOTS    1292
   30 CONTINUE                                                          PLOTS    1293
   40 CONTINUE                                                          PLOTS    1294
      ENCODE (20,230,ITITLE(5))XMIN,XMAX                                PLOTS    1295
      ENCODE (20,240,ITITLE(7))YMIN,YMAX                                PLOTS    1296
      CMAX=TEMX                                                         PLOTS    1297
      CMIN=TEMPM                                                        PLOTS    1298
      IF (TEMP.NE.0.0) CMAX=CMAX*TEMP                                   PLOTS    1299
      IF (TEMP.NE.0.0) CMIN=CMIN*TEMP                                   PLOTS    1300
      SCMAX=TEMX                                                        PLOTS    1301
      SCMIN=TEMPM                                                       PLOTS    1302
      IF (CMAX.LE.CMIN) GO TO 160                                       PLOTS    1303
C     RELATE R AND Z VALUES TO ORIGIN                                   PLOTS    1304
      DO 50 IDY=1,IMT                                                   PLOTS    1305
      XPLT(IDY)=XPLT(IDY)-XMIN                                          PLOTS    1306
   50 CONTINUE                                                          PLOTS    1307
      DO 60 IDY=1,JMT                                                   PLOTS    1308
      YPLT(IDY)=YPLT(IDY)-YMIN                                          PLOTS    1309
   60 CONTINUE                                                          PLOTS    1310
      PRINT 200, LABELZ                                                 PLOTS    1311
      CALL PLTXYZ (FLUX,XPLT,YPLT,IMT,JMT,ANGT,ANGF,AMULX,AMULY,VECP(IDX PLOTS    1312
     1A),VECP(IDXB),VECP(IDXC),VECP(IDXD),IRA,IRB,ICR,ICC)              PLOTS    1313
C     RESTORE R AND Z VALUES                                            PLOTS    1314
      DO 70 IDY=1,IMT                                                   PLOTS    1315
      XPLT(IDY)=XPLT(IDY)+XMIN                                          PLOTS    1316
   70 CONTINUE                                                          PLOTS    1317
      DO 80 IDY=1,JMT                                                   PLOTS    1318
      YPLT(IDY)=YPLT(IDY)+YMIN                                          PLOTS    1319
   80 CONTINUE                                                          PLOTS    1320
C     WRITE JOB IDENTIFICATION                                          PLOTS    1321
      CALL DLCH (154,992,4,4HJOB=,1)                                    PLOTS    1322
      CALL DLCH (206,992,10,ITITLE,1)                                   PLOTS    1323
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C     WRITE DATE                                                        PLOTS   1324
      CALL DLCH (400,992,5,5HDATE=,1)                                   PLOTS   1325
      CALL DLCH (464,992,10,ITITLE(2),1)                                PLOTS   1326
C     WRITE TD                                                          PLOTS   1327
      CALL DLCH (154,952,60,ITITLE(31),1)                               PLOTS   1328
C     WRITE FUNCTION RANGE                                              PLOTS   1329
      ENCODE (20,220,ITITLE(3))SCMIN,SCMAX                              PLOTS   1330
      CALL DLCH (696,952,7,7HRANGE--,1)                                 PLOTS   1331
      CALL DLCH (780,952,20,ITITLE(3),1)                                PLOTS   1332
C     WRITE X RANGE                                                     PLOTS   1333
      CALL DLCH (780,972,20,ITITLE(5),1)                                PLOTS   1334
C     WRITE Y RANGE                                                     PLOTS   1335
      CALL DLCH (780,992,20,ITITLE(7),1)                                PLOTS   1336
      CALL DLCH (154,972,60,ITITLE(12),1)                               PLOTS   1337
C     LABEL THE AXES                                                    PLOTS   1338
      IRA72=IRA-72                                                      PLOTS   1339
      IRA72=MAX0(IRA72,0)                                               PLOTS   1340
      CALL DLCH (ICC,IRA72,NCL,LABELX,1)                                PLOTS   1341
      CALL DLCH (ICB,IRB-11,NCL,LABELY,1)                               PLOTS   1342
      CALL DLCH (270,80,NCL,LABELZ,2)                                   PLOTS   1343
      CALL DLCH (200,4,5,TIGER,2)                                       PLOTS   1344
      CALL ADV (1)                                                      PLOTS   1345
      DIVIS=ABS(CMAX)                                                   PLOTS   1346
      IF (DIVIS.EQ.0.0) DIVIS=ABS(CMIN)                                 PLOTS   1347
      IF ((CMAX-CMIN)/DIVIS.LE.1.0E-6) GO TO 160                        PLOTS   1348
      IF (LCP.EQ.0) GO TO 160                                           PLOTS   1349
      IF (LCP.GT.0) GO TO 100                                           PLOTS   1350
C                                                                       PLOTS   1351
C     COMPUTE PLOT INTERVALS GIVEN FF AND NC                            PLOTS   1352
      NC=IABS(LCP)                                                      PLOTS   1353
      ANC=NC                                                            PLOTS   1354
      VNC=1.0/ANC                                                       PLOTS   1355
      VNCM=1.0/(ANC-1.0)                                                PLOTS   1356
      EONE=2.7182818                                                    PLOTS   1357
      ALPH=VNCM*(ANC*EXP(FF)-EONE)                                      PLOTS   1358
      BETA=ANC*VNCM*(EONE-EXP(FF))                                      PLOTS   1359
      CDIF=CMAX-CMIN                                                    PLOTS   1360
      DO 90 N=1,NC                                                      PLOTS   1361
      VECP(N)=CDIF*ALOG(ALPH+FLOAT(N)*VNC*BETA)+CMIN                    PLOTS   1362
   90 CONTINUE                                                          PLOTS   1363
      CMIN=(1.0-FF)*VECP(1)                                             PLOTS   1364
  100 CONTINUE                                                          PLOTS   1365
      II=0                                                              PLOTS   1366
      IM1=IMT                                                           PLOTS   1367
      IMX=1                                                             PLOTS   1368
      JM1=JMT                                                           PLOTS   1369
      JMX=1                                                             PLOTS   1370
      JTOP=.F.                                                          PLOTS   1371
      DO 140 J=1,JMT                                                    PLOTS   1372
      NFOUND=.T.                                                        PLOTS   1373
      ITOP=.F.                                                          PLOTS   1374
      DO 120 I=1,IMT                                                    PLOTS   1375
      II=II+1                                                           PLOTS   1376
      IF (FLUX(II).LT.CMIN) GO TO 120                                   PLOTS   1377
      NFOUND=.F.                                                        PLOTS   1378
      IF (ITOP) GO TO 110                                               PLOTS   1379
      ITOP=.T.                                                          PLOTS   1380
      IM1=MIN0(IM1,I)                                                   PLOTS   1381
      IMX=MAX0(IMX,I)                                                   PLOTS   1382
      GO TO 120                                                         PLOTS   1383
  110 IMX=MAX0(IMX,I)                                                   PLOTS   1384
  120 CONTINUE                                                          PLOTS   1385
      IF (NFOUND) GO TO 140                                             PLOTS   1386
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      IF (JTOP) GO TO 130                                               PLOTS    1387
      JTOP=.T.                                                          PLOTS    1388
      JM1=MIN0(JM1,J)                                                   PLOTS    1389
      GO TO 140                                                         PLOTS    1390
  130 JMX=MAX0(JMX,J)                                                   PLOTS    1391
  140 CONTINUE                                                          PLOTS    1392
C     IF NO REGION FOUND GO TO ERROR PRINT AND SKIP CONTOUR PLOT        PLOTS    1393
      IPR=.FALSE.                                                       PLOTS    1394
      IF (IM1.GE.IMX) IPR=.TRUE.                                        PLOTS    1395
      IF (JM1.GE.JMX) IPR=.TRUE.                                        PLOTS    1396
      IF (.NOT.IPR) GO TO 150                                           PLOTS    1397
      PRINT 210, IM1,IMX,JM1,JMX,SCMIN,SCMAX                            PLOTS    1398
      GO TO 160                                                         PLOTS    1399
  150 TOPX=XPLT(IMX)-XPLT(IM1)                                          PLOTS    1400
      TOPY=YPLT(JMX)-YPLT(JM1)                                          PLOTS    1401
      IJ=(JM1-1)*IX+IM1                                                 PLOTS    1402
      NJY=JMX-JM1+1                                                     PLOTS    1403
      NIX=IMX-IM1+1                                                     PLOTS    1404
C     TO PASS SCALE FACTOR VIA CNTRCOM TO CNTRJB FOR CONTOUR LABELS     PLOTS    1405
      SCFAC=TEMP                                                        PLOTS    1406
      CALL ADV (1)                                                      PLOTS    1407
      CALL CNTRJB (XPLT(IM1),NIX,YPLT(JM1),NJY,FLUX(IJ),IX,JY,ICP,CMIN,C PLOTS    1408
     1MAX,CINT,VECP,TOPX,TOPY,IGRID,IDRW,LABELX,10,LABELY,10)           PLOTS    1409
      KX=IXR+10                                                         PLOTS    1410
      KX=MAX0(KX,IXL+480)                                               PLOTS    1411
      KX=MIN0(KX,780)                                                   PLOTS    1412
C     WRITE JOB IDENTIFICATION                                          PLOTS    1413
      CALL DLCH (KX-168,30,4,4HJOB=,1)                                  PLOTS    1414
      CALL DLCH (KX-120,30,10,ITITLE,1)                                 PLOTS    1415
C     WRITE DATE                                                        PLOTS    1416
      CALL DLCH (KX+36,30,5,5HDATE=,1)                                  PLOTS    1417
      CALL DLCH (KX+96,30,10,ITITLE(2),1)                               PLOTS    1418
C     WRITE FUNCTION RANGE                                              PLOTS    1419
      CALL DLCH (KX-90,IDRW,7,7HRANGE=-,1)                              PLOTS    1420
      ENCODE (20,220,ITITLE(3))SCMIN,SCMAX                              PLOTS    1421
      CALL DLCH (KX,IDRW,20,ITITLE(3),1)                                PLOTS    1422
      IDRW1=IDRW+20                                                     PLOTS    1423
C     WRITE R AND Z RANGE                                               PLOTS    1424
      XMINC=XPLT(IM1)                                                   PLOTS    1425
      XMAXC=XPLT(IMX)                                                   PLOTS    1426
      ENCODE (20,230,ITITLE(27))XMINC,XMAXC                             PLOTS    1427
      CALL DLCH (KX,IDRW1,20,ITITLE(27),1)                              PLOTS    1428
      IDRW2=IDRW1+20                                                    PLOTS    1429
      YMINC=YPLT(JM1)                                                   PLOTS    1430
      YMAXC=YPLT(JMX)                                                   PLOTS    1431
      ENCODE (20,240,ITITLE(29))YMINC,YMAXC                             PLOTS    1432
      CALL DLCH (KX,IDRW2,20,ITITLE(29),1)                              PLOTS    1433
C     WRITE ID                                                          PLOTS    1434
      CALL DLCH (IXL,IDRW1,60,ITITLE(31),1)                             PLOTS    1435
      IDRW3=IDRW2+20                                                    PLOTS    1436
      CALL DLCH (IXL,IDRW3,60,ITITLE(12),1)                             PLOTS    1437
C     LABEL THE FUNCTION AXIS                                           PLOTS    1438
      CALL DLCH (110,30,10,LABEL7,1)                                    PLOTS    1439
      CALL DLCH (50,4,5,TIGER,2)                                        PLOTS    1440
      CALL ADV (1)                                                      PLOTS    1441
C     END OF IDX LOOP.                                                  PLOTS    1442
  160 CONTINUE                                                          PLOTS    1443
C     RESTORE FUNCTION VALUES                                           PLOTS    1444
      IF (TEMP.EQ.0.0) GO TO 180                                        PLOTS    1445
      TEMPI=1.0/TEMP                                                    PLOTS    1446
      DO 170 IDY=1,IMJMT                                                PLOTS    1447
  170 FLUX(IDY)=FLUX(IDY)*TEMPI                                         PLOTS    1448
  180 RETURN                                                            PLOTS    1449
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C                                                                       PLOTS    1450
  190 FORMAT (*0 NOT ENOUGH STORAGE AVAILABLE FOR PLOTTING*/20X,* REQUIRE PLOTS    1451
     1ED =*I6,4A,* AVAILABLE =*I6)                                      PLOTS    1452
  200 FORMAT (*      PLOT MADE OF *A10)                                 PLOTS    1453
  210 FORMAT (*0      ERROR IN CONTOUR VALUES--PLOTS CANNOT BE MADE*/*  PLOTS    1454
     1  IM1, IMX, JM1, JMX, SCMIN, SCMAX    *,4I5,1P2E14.6)             PLOTS    1455
  220 FORMAT (1X,1PE9.2,*,*,1PE9.2)                                     PLOTS    1456
  230 FORMAT (*X=*,F8.3,*, *,F8.3)                                      PLOTS    1457
  240 FORMAT (*Y=*,F8.3,*, *,F8.3)                                      PLOTS    1458
      END                                                               PLOTS    1459
      SUBROUTINE CNTRJB(X,NNX,Y,NNY,Z,NZX,NZY,NC,ZMN,ZMX,DLZ,ZPLAN,DMPX, PLOTS    1460
     1DMPY,IGRD,IDRW,LABELX,NXLBL,LABELY,NYLBL)                         PLOTS    1461
      COMMON /CJEO7/ IXL,IXR,IYT,IYB,XMN,XMX,YMX,YMN                    PLOTS    1462
      COMMON /CNTRCOM/ ISYM(50),SCFAC                                   PLOTS    1463
      DIMENSION XSCALE(2), YSCALE(2)                                    PLOTS    1464
      EQUIVALENCE (XMIN,XSCALE(1)), (XMAX,XSCALE(2))                    PLOTS    1465
      EQUIVALENCE (YMIN,YSCALE(1)), (YMAX,YSCALE(2))                    PLOTS    1466
      DIMENSION X(1), Y(1), Z(NZX,1), ZPLAN(1)                          PLOTS    1467
      DIMENSION FMT(2)                                                  PLOTS    1468
      LOGICAL TEST                                                      PLOTS    1469
      NOC=MIN0(IABS(NC),50)                                             PLOTS    1470
      ZMIN=ZMN                                                          PLOTS    1471
      ZMAX=ZMX                                                          PLOTS    1472
      DELZ=DLZ                                                          PLOTS    1473
      DMAPX=DMPX                                                        PLOTS    1474
      DMAPY=DMPY                                                        PLOTS    1475
      NOX=IABS(NNX)                                                     PLOTS    1476
      NOY=IABS(NNY)                                                     PLOTS    1477
      DO 10 I=1,50                                                      PLOTS    1478
   10 ISYM(I)=0                                                         PLOTS    1479
C     ESTABLISH SCALES                                                  PLOTS    1480
      XMIN=X(1)                                                         PLOTS    1481
      XMAX=X(NOX)                                                       PLOTS    1482
      YMIN=Y(1)                                                         PLOTS    1483
      YMAX=Y(NOY)                                                       PLOTS    1484
      FGRD=0.                                                           PLOTS    1485
      IF (IGRD.GT.0) FGRD=-IGRD                                         PLOTS    1486
      CALL PLOJB (XSCALE,YSCALE,2,1,1,1,FGRD,DMAPX,DMAPY,LABELX,NXLBL,LAB PLOTS    1487
     1ELY,NYLBL,-1)                                                     PLOTS    1488
      IF (NC.LT.0) GO TO 50                                             PLOTS    1489
      IF (NNX.LE.0) CALL MINM (Z,NZX,NOX,NOY,I,J,ZMIN)                  PLOTS    1490
      IF (NNY.LE.0) CALL MAXM (Z,NZX,NOX,NOY,I,J,ZMAX)                  PLOTS    1491
      IF (DELZ.GT.0) GO TO 20                                           PLOTS    1492
      DELZ=(ZMAX-ZMIN)/(NOC-1.)                                         PLOTS    1493
   20 IF (NZY.GT.0) GO TO 30                                            PLOTS    1494
      ZMAX=ZMAX-AMOD(ZMAX,DELZ)                                         PLOTS    1495
      ZMIN=ZMIN-AMOD(ZMIN,DELZ)                                         PLOTS    1496
      NOC=MIN0(NOC,IFIX((ZMAX-ZMIN)/DELZ+1.01))                         PLOTS    1497
   30 ZPLAN(1)=ZMIN                                                     PLOTS    1498
      DO 40 I=2,NOC                                                     PLOTS    1499
   40 ZPLAN(I)=ZPLAN(I-1)+DELZ                                          PLOTS    1500
   50 CONTINUE                                                          PLOTS    1501
      DO 80 NY=2,NOY                                                    PLOTS    1502
      IX=MOD(NY,2)                                                      PLOTS    1503
      DY=Y(NY)-Y(NY-1)                                                  PLOTS    1504
      DO 80 INX=2,NOX                                                   PLOTS    1505
      NX=INX                                                            PLOTS    1506
      IF (IX.NE.0) NX=NOX-INX+2                                         PLOTS    1507
      ZT1=Z(NX-1,NY-1)                                                  PLOTS    1508
      ZT2=Z(NX,NY-1)                                                    PLOTS    1509
      ZT3=Z(NX,NY)                                                      PLOTS    1510
      ZT4=Z(NX-1,NY)                                                    PLOTS    1511
      DX=X(NX)-X(NX-1)                                                  PLOTS    1512
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```
      IF (ABS(ZT3-ZT1)-ABS(ZT4-ZT2)) 70,60,60                           PLOTS    1513
   60 CALL TRCJB (X(NX),Y(NY),-DX,-DY,NOC,ZPLAN,ZT4,ZT3,ZT2)            PLOTS    1514
      CALL TRCJB (X(NX-1),Y(NY-1),DX,DY,NOC,ZPLAN,ZT2,ZT1,ZT4)          PLOTS    1515
      GO TO 80                                                          PLOTS    1516
   70 CALL TRCJB (X(NX-1),Y(NY),DX,-DY,NOC,ZPLAN,ZT3,ZT4,ZT1)           PLOTS    1517
      CALL TRCJB (X(NX),Y(NY-1),-DX,DY,NOC,ZPLAN,ZT1,ZT2,ZT3)           PLOTS    1518
   80 CONTINUE                                                          PLOTS    1519
   90 CONTINUE                                                          PLOTS    1520
      IDRW=IYB+40                                                       PLOTS    1521
      IDRW=MINO(IDRW,945)                                               PLOTS    1522
C     USE DLCH IF SPACE PERMITS                                         PLOTS    1523
C     DLCH USES 12SP/H.CHAR - 15SP /V.CHAR                              PLOTS    1524
C     TSP USES 8SP/H.CHAR - 12SP/V.CHAR                                 PLOTS    1525
      TEST=.F.                                                          PLOTS    1526
      ITOP=50                                                           PLOTS    1527
C     IXR = RIGHT BOUNDARY                                              PLOTS    1528
C     NOC = NUMBER OF CONTOURS                                          PLOTS    1529
C     ITOP = SPACES DOWN FROM TOP LEFT FOR LABEL                        PLOTS    1530
      ITST=IXR+142                                                      PLOTS    1531
      IF (ITST.GE.1024) TEST=.T.                                        PLOTS    1532
      ITST=NOC*15+ITOP                                                  PLOTS    1533
      IF (ITST.GE.1024) TEST=.T.                                        PLOTS    1534
      KX=IXR+10                                                         PLOTS    1535
      KC=KX+150                                                         PLOTS    1536
      IF (TEST) KC=KX+80                                                PLOTS    1537
      KY=ITOP                                                           PLOTS    1538
      DO 110 I=1,NOC                                                    PLOTS    1539
      ZTEM=ZPLAN(I)/SCFAC                                               PLOTS    1540
      ENCODE (10,120,FMT)ZTEM                                           PLOTS    1541
      IF (TEST) GO TO 100                                               PLOTS    1542
      CALL DLCH (KX,KY,10,FMT,1)                                        PLOTS    1543
      CALL DLCH (KC,KY,0,I,1)                                           PLOTS    1544
      KY=KY+25                                                          PLOTS    1545
      GO TO 110                                                         PLOTS    1546
  100 FMT(2)=SHIFT(I,54)                                                PLOTS    1547
      CALL TSP (KX,KY,11,FMT)                                           PLOTS    1548
      KY=KY+12                                                          PLOTS    1549
  110 CONTINUE                                                          PLOTS    1550
      RETURN                                                            PLOTS    1551
C                                                                       PLOTS    1552
  120 FORMAT (1PE9.2,1X)                                                PLOTS    1553
      END                                                               PLOTS    1554
      SUBROUTINE PLJB(X,Y,NPTS,INC,LNN,NSYM,C,XAA,YAA,LABELX,NXL,LABELY, PLOTS    1555
     1NYL,NZL)                                                          PLOTS    1556
      COMMON /CJE07/ IXL,IXR,IYT,IYB,XMN,XMX,YMX,YMN                    PLOTS    1557
      DIMENSION X(1), Y(1)                                              PLOTS    1558
      INTEGER GRIDF                                                     PLOTS    1559
      B=AMAX1(AMAX1(C,0.)*(LNN+1),0.)                                   PLOTS    1560
      LIN=LNN                                                           PLOTS    1561
      KSYM=IABS(NSYM)                                                   PLOTS    1562
      KINC=MAX0(IABS(INC),1)                                            PLOTS    1563
      MPTS=IABS(NPTS)                                                   PLOTS    1564
      XXA=ABS(XAA)                                                      PLOTS    1565
      YYA=ABS(YAA)                                                      PLOTS    1566
      NXN=IABS(NXL)                                                     PLOTS    1567
      NYN=IABS(NYL)                                                     PLOTS    1568
      GRIDF=AMAX1(1.,ABS(C))                                            PLOTS    1569
      IF (NSYM.LT.0) GO TO 130                                          PLOTS    1570
      CALL MAXV (X,KINC,MPTS,ISUB,XMX)                                  PLOTS    1571
      CALL MAXV (Y,KINC,MPTS,ISUB,YMX)                                  PLOTS    1572
      CALL MINV (X,KINC,MPTS,ISUB,XMN)                                  PLOTS    1573
      CALL MINV (Y,KINC,MPTS,ISUB,YMN)                                  PLOTS    1574
C     ALSO THE LOG AXES WILL BE FULL CYCLES.                            PLOTS    1575
```

```
C     IF XXA AND/OR YYA ARE NON-ZERO THE LENGTHS                        PLOTS   1576
C     WILL BE CONSIDERED AS RATIOS WHERE THE LONGEST                    PLOTS   1577
C     SIDE IS FITTED ON A 860 POINT LINE.                               PLOTS   1578
      IF (XXA.EQ.0) XXA=6.                                              PLOTS   1579
      IF (YYA.EQ.0) YYA=10.                                             PLOTS   1580
      IF (NPTS.LT.0) GO TO 20                                           PLOTS   1581
      IF (XMN.NE.XMX) GO TO 10                                          PLOTS   1582
      DXM=.001*ABS(XMX)                                                 PLOTS   1583
      IF (DXM.EQ.0) DXM=.0001                                           PLOTS   1584
      XMN=XMN-DXM                                                       PLOTS   1585
      XMX=XMX+DXM                                                       PLOTS   1586
   10 CALL ASCL (5,XMN,XMX,MAJX,MINX,KKX)                               PLOTS   1587
      GO TO 30                                                          PLOTS   1588
   20 XMN=ALOG10(XMN)                                                   PLOTS   1589
      XMX=ALOG10(XMX)                                                   PLOTS   1590
   30 IF (INC.LT.0) GO TO 50                                            PLOTS   1591
      IF (YMN.NE.YMX) GO TO 40                                          PLOTS   1592
      DYM=.001*ABS(YMX)                                                 PLOTS   1593
      IF (DYM.EQ.0) DYM=.0001                                           PLOTS   1594
      YMN=YMN-DYM                                                       PLOTS   1595
      YMX=YMX+DYM                                                       PLOTS   1596
   40 CALL ASCL (5,YMN,YMX,MAJY,MINY,KKY)                               PLOTS   1597
      GO TO 60                                                          PLOTS   1598
   50 YMN=ALOG10(YMN)                                                   PLOTS   1599
      YMX=ALOG10(YMX)                                                   PLOTS   1600
   60 IF (ISTGN(1,NYL).LT.0.AND.INC.GT.0) YYA=(YMX-YMN)/YYA             PLOTS   1601
      IF (ISTGN(1,NXL).LT.0.AND.NPTS.GT.0) XXA=(XMX-XMN)/XXA            PLOTS   1602
      MAKX=GRIDF*MAJX                                                   PLOTS   1603
      MAKY=GRIDF*MAJY                                                   PLOTS   1604
      FACT=860./AMAX1(XXA,YYA)                                          PLOTS   1605
      IXL=66                                                            PLOTS   1606
      IYT=50                                                            PLOTS   1607
      IXR=IXL+860.                                                      PLOTS   1608
      IYB=IYT+860.                                                      PLOTS   1609
      CALL FRAME (IXL,IXR,IYT,IYB)                                      PLOTS   1610
      IF (SIGN(1.,XAA).GT.0) GO TO 70                                   PLOTS   1611
      SWAP=XMN                                                          PLOTS   1612
      XMN=XMX                                                           PLOTS   1613
      XMX=SWAP                                                          PLOTS   1614
   70 IF (SIGN(1.,YAA).GT.0) GO TO 80                                   PLOTS   1615
      SWAP=YMN                                                          PLOTS   1616
      YMN=YMX                                                           PLOTS   1617
      YMX=SWAP                                                          PLOTS   1618
   80 CALL DGA (IXL,IXR,IYT,IYB,XMN,XMX,YMX,YMN)                        PLOTS   1619
      IF (NPTS.LT.0.AND.INC.LT.0) CALL DLGLG                            PLOTS   1620
      IF (NPTS.LT.0.AND.INC.GE.0) CALL DLGLN (MAKY)                     PLOTS   1621
      IF (NPTS.GE.0.AND.INC.LT.0) CALL DLNLG (MAKX)                     PLOTS   1622
      IF (NPTS.GE.0.AND.INC.GE.0) CALL DLNLN (MAKX,MAKY)                PLOTS   1623
      IF (NPTS.LT.0) GO TO 90                                           PLOTS   1624
      CALL SRLIN (MAJX,KKX)                                             PLOTS   1625
      GO TO 100                                                         PLOTS   1626
   90 CALL SRLOG                                                        PLOTS   1627
  100 IF (INC.LT.0) GO TO 110                                           PLOTS   1628
      CALL SLLIN (MAJY,KKY)                                             PLOTS   1629
      GO TO 120                                                         PLOTS   1630
  110 CALL SLLOG                                                        PLOTS   1631
  120 CALL EXL                                                          PLOTS   1632
      INXN=25                                                           PLOTS   1633
      IF (NXN.NE.0) CALL DLCH (MAX0(54,IXL+(IXR-IXL-12*NXN)/2),IYB+INXN, PLOTS   1634
     1INXN,LABELX,1)                                                    PLOTS   1635
      INCX=10                                                           PLOTS   1636
      IF (NYN.NE.0) CALL DLCV (INCX,MIN0(IYB+52,IYB-(IYB-IYT-12*NYN)/2), PLOTS   1637
     1INYN,LABELY,1)                                                    PLOTS   1638
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      CALL EXH                                                          PLOTS    1639
      IF (NZL.LT.0) GO TO 220                                           PLOTS    1640
C     PLOT POINTS AND/OR LINE                                           PLOTS    1641
  130 MPTS=MPTS*KINC                                                    PLOTS    1642
      DO 210 NXP=1,MPTS,KINC                                            PLOTS    1643
      XTWO=X(NXP)                                                       PLOTS    1644
      YTWO=Y(NXP)                                                       PLOTS    1645
      IF (NPTS.LT.0) XTWO=ALOG10(XTWO)                                  PLOTS    1646
      IF (INC.LT.0) YTWO=ALOG10(YTWO)                                   PLOTS    1647
      CALL CONVRT (XTWO,NXTWO,XMN,XMX,IXL,IXR)                          PLOTS    1648
      CALL CONVRT (YTWO,NYTWO,YMN,YMX,IYB,IYT)                          PLOTS    1649
      IF (NXP.EQ.1) GO TO 190                                           PLOTS    1650
      IF (LIN.GE.0) GO TO 180                                           PLOTS    1651
  140 IF (MOD(((NXP-1)/KINC),IABS(LIN)).NE.0) GO TO 150                 PLOTS    1652
      CALL EXL                                                          PLOTS    1653
      CALL DLCH (NXTWO,NYTWO,0,KSYM,1)                                  PLOTS    1654
      CALL EXH                                                          PLOTS    1655
      GO TO 200                                                         PLOTS    1656
  150 IF (B.EQ.0.) GO TO 200                                            PLOTS    1657
  160 DO 170 IB=1,4                                                     PLOTS    1658
  170 CALL PLT (NXTWO,NYTWO,42)                                         PLOTS    1659
      GO TO 200                                                         PLOTS    1660
  180 IF (B.EQ.0.) CALL DRV (NXONE,NYONE,NXTWO,NYTWO)                   PLOTS    1661
  190 IF (LIN.NE.0) GO TO 140                                           PLOTS    1662
      IF (B.NE.0.) GO TO 160                                            PLOTS    1663
  200 NYONE=NYTWO                                                       PLOTS    1664
      NXONE=NXTWO                                                       PLOTS    1665
  210 CONTINUE                                                          PLOTS    1666
  220 RETURN                                                            PLOTS    1667
      END                                                               PLOTS    1668
      SUBROUTINE TRCJB(X,Y,DX,DY,NOC,ZPLAN,ZX,ZV,ZY)                    PLOTS    1669
      COMMON /CNTRCOM/ ISYM(50),SCFAC                                   PLOTS    1670
      DIMENSION XP(2,50), YP(2,50), ZT(4), ZPLAN(1)                     PLOTS    1671
      ZT(1)=ZX                                                          PLOTS    1672
      ZT(2)=ZV                                                          PLOTS    1673
      ZT(3)=ZY                                                          PLOTS    1674
      ZT(4)=ZX                                                          PLOTS    1675
      ZTMIN=AMIN1(ZT(1),ZT(2),ZT(3))                                    PLOTS    1676
      ZTMAX=AMAX1(ZT(1),ZT(2),ZT(3))                                    PLOTS    1677
      IMIN=NOC+1                                                        PLOTS    1678
      IMAX=0                                                            PLOTS    1679
      DO 10 K=1,NOC                                                     PLOTS    1680
      J=NOC-K+1                                                         PLOTS    1681
      IF (ZPLAN(J).GE.ZTMIN) IMIN=J                                     PLOTS    1682
      IF (ZPLAN(K).LE.ZTMAX) IMAX=K                                     PLOTS    1683
   10 CONTINUE                                                          PLOTS    1684
      INT=IMAX-IMIN                                                     PLOTS    1685
      IF (INT.LT.0.OR.ZTMIN.EQ.ZTMAX) GO TO 130                         PLOTS    1686
      I2=1                                                              PLOTS    1687
      DO 110 K=1,3                                                      PLOTS    1688
      ZTMAX=AMAX1(ZT(K),ZT(K+1))                                        PLOTS    1689
      ZPMIN=AMIN1(ZT(K),ZT(K+1))                                        PLOTS    1690
      MIN=NOC+1                                                         PLOTS    1691
      MAX=0                                                             PLOTS    1692
      DO 20 J=1,NOC                                                     PLOTS    1693
      INZ=NOC-J+1                                                       PLOTS    1694
      IF (ZPLAN(INZ).GT.ZPMIN.OR.(ZPLAN(INZ).EQ.ZPMIN.AND.ZTMIN.EQ.ZPMIN PLOTS    1695
     1)) MIN=INZ                                                        PLOTS    1696
      IF (ZPLAN(J).LE.ZTMAX) MAX=J                                      PLOTS    1697
   20 CONTINUE                                                          PLOTS    1698
      INZ=MAX-MIN                                                       PLOTS    1699
      IF (INZ.LT.0.OR.ZTMAX.EQ.ZPMIN) GO TO 110                         PLOTS    1700
      IF (INZ-INT) 40,30,40                                             PLOTS    1701
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 30 GO TO (50,40), I2                                                   PLOTS    1702
 40 I2=1                                                                PLOTS    1703
    GO TO 60                                                            PLOTS    1704
 50 I2=2                                                                PLOTS    1705
 60 DO 100 J=MIN,MAX                                                    PLOTS    1706
    GO TO (70,80,90), K                                                 PLOTS    1707
 70 XP(I2,J)=X+DX*(ZPLAN(J)-ZT(2))/(ZT(1)-ZT(2))                        PLOTS    1708
    YP(I2,J)=Y                                                          PLOTS    1709
    GO TO 100                                                           PLOTS    1710
 80 XP(I2,J)=X                                                          PLOTS    1711
    YP(I2,J)=Y+DY*(ZPLAN(J)-ZT(2))/(ZT(3)-ZT(2))                        PLOTS    1712
    GO TO 100                                                           PLOTS    1713
 90 XP(I2,J)=X+DX*(ZPLAN(J)-ZT(3))/(ZT(1)-ZT(3))                        PLOTS    1714
    YP(I2,J)=Y+DY*(ZPLAN(J)-ZT(1))/(ZT(3)-ZT(1))                        PLOTS    1715
100 CONTINUE                                                            PLOTS    1716
110 CONTINUE                                                            PLOTS    1717
    DO 120 J=IMIN,IMAX                                                  PLOTS    1718
    ISYM(J)=ISYM(J)+1                                                   PLOTS    1719
    L=3                                                                 PLOTS    1720
    IF (MOD(ISYM(J),10).NE.1) L=0                                       PLOTS    1721
    CALL PLOB (XP(1,J),YP(1,J),2,1,L,-J,0,0,0,0,0,0,0,0)                PLOTS    1722
120 CONTINUE                                                            PLOTS    1723
130 RETURN                                                              PLOTS    1724
    END                                                                 PLOTS    1725
    SUBROUTINE PLTXYZ(F,X,Y,IX,JY,ANGT,ANGF,AMULX,AMULY,AA,AB,RA,RB,IR  PLOTS    1726
   1A,IRB,ICB,ICC)                                                      PLOTS    1727
    DIMENSION F(1), X(1), Y(1), AA(1), AB(1), RA(1), RB(1)               PLOTS    1728
    YT=SIN(ANGT)*AMULX                                                  PLOTS    1729
    XT=COS(ANGT)*AMULX                                                  PLOTS    1730
    YP=SIN(ANGF)*AMULY                                                  PLOTS    1731
    XP=COS(ANGF)*AMULY                                                  PLOTS    1732
    YTB=YT*X(IX)                                                        PLOTS    1733
    XTB=XT*X(IX)                                                        PLOTS    1734
    YPB=YP*Y(JY)                                                        PLOTS    1735
    XPB=XP*Y(JY)                                                        PLOTS    1736
    XA=XTB+XPB                                                          PLOTS    1737
    EA=0.                                                               PLOTS    1738
    EB=1000.                                                            PLOTS    1739
    DO 10 I=1,IX                                                        PLOTS    1740
    L=I                                                                 PLOTS    1741
    DO 10 J=1,JY                                                        PLOTS    1742
    E=F(L)-X(I)*YT-Y(J)*YP                                              PLOTS    1743
    EA=AMAX1(EA,E)                                                      PLOTS    1744
    EB=AMIN1(EB,E)                                                      PLOTS    1745
 10 L=L+IX                                                              PLOTS    1746
    YC=YTB+YPB                                                          PLOTS    1747
    IF (EB) 20,40,40                                                    PLOTS    1748
 20 DIF=YC+EB                                                           PLOTS    1749
    IF (DIF) 30,40,40                                                   PLOTS    1750
 30 YB=-DIF                                                             PLOTS    1751
    GO TO 50                                                            PLOTS    1752
 40 YB=0.                                                               PLOTS    1753
 50 YA=YC+YB+EA                                                         PLOTS    1754
    CALL DGA (123,1023,0,900,0,0,XA,YA,0,0)                             PLOTS    1755
    CALL FRAME (123,1023,0,900)                                         PLOTS    1756
    YD=YB+YTB                                                           PLOTS    1757
    IA=IX+1                                                             PLOTS    1758
    DO 60 I=1,IX                                                        PLOTS    1759
    L=IA-I                                                              PLOTS    1760
    AA(I)=XTB-XT*X(L)                                                   PLOTS    1761
    AB(I)=XPB+AA(I)                                                     PLOTS    1762
    RB(I)=YD-YT*X(L)                                                    PLOTS    1763
 60 RA(I)=YPB+RB(I)                                                     PLOTS    1764
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      CALL PLOT (IX,AA,1,RA,1,32,0)                                     PLOTS   1765
      CALL PLOT (IX,AB,1,RB,1,32,1)                                     PLOTS   1766
      YE=YB+YPB                                                         PLOTS   1767
      DO 70 J=1,JY                                                      PLOTS   1768
      AA(J)=XP*Y(J)                                                     PLOTS   1769
      AB(J)=XTB+AA(J)                                                   PLOTS   1770
      RA(J)=YE-YP*Y(J)                                                  PLOTS   1771
   70 RB(J)=YTB+RA(J)                                                   PLOTS   1772
      CALL PLOT (JY,AA,1,RA,1,32,1)                                     PLOTS   1773
      CALL PLOT (JY,AB,1,RB,1,32,0)                                     PLOTS   1774
      ZH=.05*EA                                                         PLOTS   1775
      YF=YC+YB                                                          PLOTS   1776
      DO 80 L=1,21                                                      PLOTS   1777
      AA(L)=XTB                                                         PLOTS   1778
      RA(L)=YF+ZH*FLOAT(L-1)                                            PLOTS   1779
   80 CONTINUE                                                          PLOTS   1780
      CALL PLOT (21,AA,1,RA,1,32,1)                                     PLOTS   1781
      DO 100 I=1,IX                                                     PLOTS   1782
      L=I                                                               PLOTS   1783
      DO 90 J=1,JY                                                      PLOTS   1784
      AA(J)=XTB-X(I)*XT+Y(J)*XP                                         PLOTS   1785
      RA(J)=YF-X(I)*YT-Y(J)*YP+F(L)                                     PLOTS   1786
   90 L=L+IX                                                            PLOTS   1787
      CALL PLOT (JY,AA,1,RA,1,42,1)                                     PLOTS   1788
  100 CONTINUE                                                          PLOTS   1789
      L=1                                                               PLOTS   1790
      DO 120 J=1,JY                                                     PLOTS   1791
      DO 110 I=1,IX                                                     PLOTS   1792
      AA(L)=XTB-X(I)*XT+Y(J)*XP                                         PLOTS   1793
      RA(L)=YF-X(I)*YT-Y(J)*YP+F(L)                                     PLOTS   1794
  110 L=L+1                                                             PLOTS   1795
      CALL PLOT (IX,AA,1,RA,1,42,1)                                     PLOTS   1796
  120 CONTINUE                                                          PLOTS   1797
      CA=22.+(XPB+.5*XTB)*113./XA                                       PLOTS   1798
      CA=AMIN1(CA,116.0)                                                PLOTS   1799
      CB=22.+XPB*56.5/XA                                                PLOTS   1800
      CC=XTB*113./XA                                                    PLOTS   1801
      RB=57.*(1.-(.5*YPB+YB)/YA)+1.                                     PLOTS   1802
      RA=57.*(1.-(.5*YTB+YB)/YA)+1.                                     PLOTS   1803
      TIY=RB*16.0-8.0                                                   PLOTS   1804
      IRB=IFIX(TIY)                                                     PLOTS   1805
      TIY=RA*16.0-8.0                                                   PLOTS   1806
      IRA=IFIX(TIY)                                                     PLOTS   1807
      TIX=CC*8.0-4.0                                                    PLOTS   1808
      ICC=IFIX(TIX)                                                     PLOTS   1809
      TIX=CB*8.0-4.0                                                    PLOTS   1810
      ICB=IFIX(TIX)                                                     PLOTS   1811
C     RETURN WITHOUT ADVANCE OF THE FRAME.                              PLOTS   1812
      RETURN                                                            PLOTS   1813
      END                                                               PLOTS   1814
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APPENDIX E

COMPARISON OF FRACTION IN COOLANT AND CUMULATIVE RELEASE AT TWO HOURS

Calculations for ^{131}I were made for the Ft. St. Vrain fuel model (MFUEL = 1) with an average age of 2.5 yr (AGE = 2.5) and the fuel was not aged (LAGE = F). A BISO-TRISO mixture (0.06, 0.04) was used (FRAC = 0.6). Six partitions of the core volume IC = 1, 5, 10, 25, 100, 200 and five partitions of the 20-h time period IT = 20, 40, 100, 300, 500 were used. The four temperature models SORS, CORCON, AYER, and AYER Fu-Cort (ITEMP = 1, 2, 3, 4) and the four equation models, Simplified Model Equation-Renormalized, Constant Release-Renormalized, Linear Release-Renormalized, Intact-Failed Self-Consistent fuel transition (NEQ = 1, 2, 3, 4) were used. The most sensitive test of these 320 calculations was the comparison of the fraction in the coolant and the cumulative release at 2-h time.

In Tables E.I through E.XXVIII we exhibit a summary of these results at 2 h. We note that the maximum variation between (IT, IC) of (100, 100) and 500,200) for the ^{131}I fraction release in the coolant is 20% for any temperature model, whereas the various temperature models differ by as much as a factor of 3.73 (NEQ = 4; ITEMP = 1,3; IT = 500, IC = 200).

A similar remark holds for the cumulative release where the maximum variation between (IT, IC) of (100,100) and (500,200) for the ^{131}I cumulative release is about 19%, whereas the various temperature models differ by as much as a factor of 3.03 (NEQ = 4, ITEMP = 1,3; IT = 100, IC = 100).

It should be noted that we are comparing the fraction at the 10^{-4} level and the release at less than the 1 Ci level here.

TABLE E.I

^{131}I FRACTION IN COOLANT x 10^4 at 2 h
ITEMP = 1, NEQ = 1, 2

IC \ IT	20	40	100	300	500
1	1.38	1.14	1.26	1.38	1.41
5	1.75	1.97	3.17	3.70	3.80
10	1.85	2.91	4.15	4.78	4.91
25	1.95	3.36	4.75	5.43	5.57
100	2.09	3.78	5.22	5.89	6.03
200	2.12	3.82	5.26	5.92	6.06

TABLE E.II

^{131}I FRACTION IN COOLANT x 10^4 at 2 h
ITEMP = 1, NEQ = 3

IC \ IT	20	40	100	300	500
1	1.38	1.14	1.26	1.38	1.41
5	1.75	1.97	3.17	3.70	3.80
10	1.85	2.91	4.15	4.78	4.91
25	1.95	3.36	4.75	5.43	5.57
100	2.09	3.78	5.22	5.89	6.03
200	2.12	3.81	5.26	5.92	6.06

TABLE E.III

^{131}I FRACTION IN COOLANT x 10^4 at 2 h
ITEMP = 1, NEQ = 4

IC \ IT	20	40	100	300	500
1	2.24	1.67	1.50	1.46	1.45
5	5.49	4.11	4.01	3.98	3.97
10	6.59	5.39	5.14	5.11	5.11
25	7.14	5.99	5.79	5.78	5.78
100	7.48	6.44	6.26	6.24	6.24
200	7.51	6.47	6.30	6.27	6.27

TABLE E.IV

^{131}I FRACTION IN COOLANT x 10^4 at 2 h

ITEMP = 2, NEQ = 1,2

IC \ IT	20	40	100	300	500
1	0.85	0.76	0.74	0.74	0.74
5	1.03	0.98	1.02	1.05	1.06
10	1.08	1.10	1.24	1.32	1.34
25	1.14	1.25	1.42	1.51	1.53
100	1.20	1.37	1.57	1.68	1.70
200	1.21	1.38	1.58	1.69	1.71

TABLE E.V

^{131}I FRACTION IN COOLANT x 10^4 at 2 h

ITEMP = 2, NEQ = 3

IC \ IT	20	40	100	300	500
1	0.85	0.76	0.74	0.74	0.74
5	1.03	0.98	1.02	1.05	1.06
10	1.08	1.10	1.24	1.32	1.34
25	1.14	1.25	1.42	1.51	1.53
100	1.20	1.37	1.57	1.68	1.70
200	1.21	1.38	1.58	1.69	1.71

TABLE E.VI

^{131}I FRACTION IN COOLANT x 10^4 at 2h

ITEMP = 2, NEQ = 4

IC \ IT	20	40	100	300	500
1	0.85	0.76	0.74	0.74	0.74
5	1.36	1.16	1.10	1.08	1.08
10	1.69	1.44	1.37	1.38	1.37
25	1.89	1.64	1.58	1.36	1.56
100	2.05	1.81	1.75	1.74	1.74
200	2.06	1.82	1.76	1.75	1.75

TABLE E.VII

^{131}I FRACTION IN COOLANT x 10^4 at 2 h
ITEMP = 3, NEQ = 1,2

IC \ IT	20	40	100	300	500
1	0.93	0.81	0.78	0.78	0.78
5	1.08	0.95	1.05	1.14	1.16
10	1.11	1.05	1.24	1.36	1.38
25	1.13	1.10	1.35	1.48	1.51
100	1.14	1.18	1.44	1.59	1.62
200	1.14	1.18	1.45	1.60	1.63

TABLE E.VIII

^{131}I FRACTION IN COOLANT x 10^4 at 2 h
ITEMP = 3, NEQ = 3

IC \ IT	20	40	100	300	500
1	0.93	0.81	0.78	0.78	0.78
5	1.08	0.95	1.05	1.14	1.16
10	1.11	1.05	1.24	1.36	1.38
25	1.13	1.10	1.35	1.48	1.51
100	1.14	1.18	1.44	1.59	1.62
200	1.14	1.18	1.45	1.60	1.63

TABLE E.IX

^{131}I FRACTION IN COOLANT x 10^4 at 2h
ITEMP = 3, NEQ = 4

IC \ IT	20	40	100	300	500
1	1.02	0.87	0.81	0.79	0.79
5	1.69	1.33	1.21	1.20	1.20
10	1.95	1.55	1.44	1.43	1.42
25	2.09	1.66	1.58	1.56	1.56
100	2.20	1.78	1.69	1.67	1.67
200	2.21	1.79	1.69	1.68	1.68

TABLE E.X

^{131}I FRACTION IN COOLANT x 10^4 at 2 h

ITEMP = 4, NEQ = 1,2

IC \ IT	20	40	100	300	500
1	0.94	0.84	0.81	0.81	0.81
5	1.25	1.41	1.94	2.20	2.26
10	1.26	1.48	2.07	2.36	2.42
25	1.27	1.55	2.15	2.45	2.51
100	1.28	1.59	2.20	2.51	2.57
200	1.28	1.59	2.20	2.51	2.57

TABLE E.XI

^{131}I FRACTION IN COOLANT x 10^4 at 2 h

ITEMP = 4, NEQ = 3

IC \ IT	20	40	100	300	500
1	0.94	0.84	0.81	0.81	0.81
5	1.25	1.41	1.94	2.20	2.26
10	1.26	1.48	2.07	2.36	2.42
25	1.27	1.55	2.15	2.45	2.51
100	1.28	1.59	2.20	2.51	2.57
200	1.28	1.59	2.20	2.51	2.57

TABLE E.XII

^{131}I FRACTION IN COOLANT x 10^4 at 2 h

ITEMP = 4, NEQ = 3

IC \ IT	20	40	100	300	500
1	0.97	0.86	0.82	0.81	0.81
5	3.12	2.46	2.37	2.35	2.34
10	3.30	2.62	2.53	2.51	2.51
25	3.40	2.73	2.63	2.61	2.61
100	3.47	2.79	2.69	2.67	2.67
200	3.47	2.80	2.69	2.67	2.67

TABLE E.XIII

^{131}I CUMULATIVE RELEASE (Ci) AT 2 h
ITEMP = 1, NEQ = 1

IT \ IC	20	40	100	300	500
1	0.187	0.125	0.114	0.114	0.115
5	0.238	0.195	0.220	0.238	0.244
10	0.251	0.264	0.284	0.309	0.316
25	0.265	0.299	0.325	0.355	0.363
100	0.282	0.332	0.362	0.393	0.401
200	0.286	0.335	0.364	0.395	0.403

TABLE E.XIV

^{131}I CUMULATIVE RELEASE (Ci) AT 2 h
ITEMP = 1, NEQ = 2

IT \ IC	20	40	100	300	500
1	0.187	0.125	0.114	0.114	0.115
5	0.238	0.195	0.220	0.238	0.244
10	0.251	0.264	0.284	0.309	0.316
25	0.265	0.299	0.325	0.335	0.363
100	0.282	0.332	0.362	0.393	0.401
200	0.286	0.335	0.364	0.395	0.402

TABLE E.XV

^{131}I CUMULATIVE RELEASE (Ci) AT 2 h
ITEMP = 1, NEQ = 3

IT \ IC	20	40	100	300	500
1	0.151	0.115	0.112	0.113	0.115
5	0.191	0.177	0.215	0.238	0.243
10	0.201	0.237	0.277	0.308	0.316
25	0.212	0.266	0.317	0.354	0.362
100	0.226	0.295	0.353	0.391	0.400
200	0.228	0.298	0.355	0.394	0.403

TABLE E.XVI

^{131}I CUMULATIVE RELEASE (Ci) AT 2 h
ITEMP = 1, NEQ = 4

IT \ IC	20	40	100	300	500
1	0.263	0.151	0.122	0.117	0.116
5	0.566	0.309	0.265	0.254	0.253
10	0.677	0.411	0.341	0.329	0.328
25	0.720	0.461	0.389	0.378	0.377
100	0.756	0.501	0.429	0.416	0.415
200	0.760	0.505	0.432	0.419	0.418

TABLE E.XVII

^{131}I CUMULATIVE RELEASE (Ci) AT 2 h
ITEMP = 2, NEQ = 1

IT \ IC	20	40	100	300	500
1	0.129	0.102	0.096	0.095	0.095
5	0.157	0.127	0.121	0.121	0.122
10	0.163	0.138	0.136	0.139	0.140
25	0.172	0.151	0.151	0.155	0.156
100	0.179	0.161	0.164	0.169	0.171
200	0.180	0.162	0.165	0.171	0.172

TABLE E.XVIII

^{131}I CUMULATIVE RELEASE (Ci) AT 2 h
ITEMP = 2, NEQ = 2

IT \ IC	20	40	100	300	500
1	0.129	0.102	0.096	0.095	0.095
5	0.157	0.127	0.121	0.121	0.122
10	0.163	0.138	0.136	0.139	0.140
25	0.172	0.151	0.151	0.155	0.156
100	0.179	0.161	0.164	0.169	0.171
200	0.180	0.162	0.165	0.171	0.172

TABLE E.XIX

^{131}I CUMULATIVE RELEASE (Ci) AT 2 h
ITEMP = 2, NEQ = 3

IT \ IC	20	40	100	300	500
1	0.115	0.099	0.095	0.095	0.095
5	0.139	0.122	0.120	0.121	0.122
10	0.145	0.132	0.135	0.139	0.140
25	0.152	0.144	0.149	0.155	0.156
100	0.158	0.154	0.162	0.169	0.171
200	0.159	0.155	0.163	0.170	0.172

TABLE E.XX

^{131}I CUMULATIVE RELEASE (Ci) AT 2 h
ITEMP = 2, NEQ = 4

IT \ IC	20	40	100	300	500
1	0.129	0.102	0.096	0.095	0.095
5	0.186	0.137	0.125	0.123	0.122
10	0.217	0.158	0.144	0.142	0.142
25	0.238	0.177	0.161	0.159	0.158
100	0.255	0.192	0.177	0.174	0.174
200	0.257	0.194	0.178	0.175	0.175

TABLE E.XXI

^{131}I CUMULATIVE RELEASE (Ci) at 2 h
ITEMP = 3, NEQ = 1

IC \ IT	20	40	100	300	500
1	0.132	0.099	0.089	0.088	0.087
5	0.152	0.113	0.107	0.108	0.108
10	0.157	0.121	0.116	0.119	0.120
25	0.159	0.125	0.123	0.127	0.128
100	0.160	0.131	0.129	0.133	0.135
200	0.161	0.131	0.129	0.134	0.135

TABLE E.XXII

^{131}I CUMULATIVE RELEASE (Ci) at 2 h
ITEMP = 3, NEQ = 2

IC \ IT	20	40	100	300	500
1	0.132	0.099	0.089	0.088	0.087
5	0.153	0.113	0.107	0.108	0.108
10	0.157	0.121	0.116	0.119	0.120
25	0.159	0.125	0.123	0.127	0.128
100	0.161	0.131	0.129	0.133	0.135
200	0.161	0.131	0.129	0.134	0.135

TABLE E.XXIII

^{131}I CUMULATIVE RELEASE (Ci) at 2 h
ITEMP = 3, NEQ = 3

IC \ IT	20	40	100	300	500
1	0.111	0.093	0.088	0.087	0.087
5	0.127	0.106	0.106	0.108	0.108
10	0.131	0.114	0.115	0.119	0.120
25	0.132	0.116	0.121	0.127	0.128
100	0.134	0.122	0.127	0.133	0.135
200	0.134	0.122	0.127	0.134	0.135

TABLE E.XXIV

^{131}I CUMULATIVE RELEASE (Ci) at 2 h
ITEMP = 3, NEQ = 4

IC \ IT	20	40	100	300	500
1	0.140	0.102	0.090	0.088	0.088
5	0.207	0.132	0.113	0.110	0.110
10	0.231	0.147	0.126	0.122	0.122
25	0.244	0.155	0.135	0.131	0.131
100	0.254	0.164	0.142	0.138	0.138
200	0.255	0.165	0.142	0.138	0.138

TABLE E.XXV

^{131}I CUMULATIVE RELEASE (Ci) AT 2 h
ITEMP = 4, NEQ = 1

IC \ IT	20	40	100	300	500
1	0.139	0.110	0.102	0.100	0.100
5	0.182	0.162	0.170	0.181	0.183
10	0.184	0.167	0.178	0.189	0.192
25	0.185	0.172	0.183	0.195	0.198
100	0.186	0.175	0.186	0.198	0.202
200	0.186	0.175	0.186	0.198	0.202

TABLE E.XXVI

^{131}I CUMULATIVE RELEASE (Ci) AT 2 h
ITEMP = 4, NEQ = 2

IC \ IT	20	40	100	300	500
1	0.139	0.110	0.102	0.100	0.100
5	0.182	0.162	0.170	0.181	0.183
10	0.184	0.167	0.178	0.189	0.192
25	0.186	0.172	0.183	0.195	0.198
100	0.186	0.175	0.186	0.198	0.202
200	0.186	0.175	0.186	0.198	0.202

TABLE E.XXVII

^{131}I CUMULATIVE RELEASE (Ci) AT 2 h
ITEMP = 4, NEQ = 3

IC \ IT	20	40	100	300	500
1	0.120	0.105	0.101	0.100	0.100
5	0.156	0.152	0.168	0.180	0.183
10	0.157	0.156	0.176	0.189	0.192
25	0.158	0.161	0.180	0.195	0.198
100	0.159	0.163	0.183	0.198	0.201
200	0.159	0.163	0.183	0.198	0.202

TABLE E.XXVIII

^{131}I CUMULATIVE RELEASE (Ci) AT 2 h
ITEMP = 4, NEQ = 4

IC \ IT	20	40	100	300	500
1	0.142	0.111	0.102	0.101	0.100
5	0.346	0.220	0.194	0.189	0.189
10	0.362	0.231	0.204	0.199	0.198
25	0.372	0.240	0.210	0.205	0.204
100	0.378	0.244	0.214	0.208	0.208
200	0.378	0.244	0.214	0.208	0.208

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