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# An Unsteady-State Material Balance Model for a Continuous Rotary Dissolver

B. E. Lewis



CONSOLIDATED FUEL REPROCESSING PROGRAM

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Consolidated Fuel Reprocessing Program

# AN UNSTEADY-STATE MATERIAL BALANCE MODEL FOR A CONTINUOUS ROTARY DISSOLVER


B. E. Lewis

Fuel Recycle Division


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## CONTENTS

# AN UNSTEADY-STATE MATERIAL BALANCE MODEL FOR A CONTINUOUS ROTARY DISSOLVER

B. E. Lewis
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## ABSTRACT

The unsteady-state continuous rotary dissolver material balance code (USSCRD) is a useful tool with which to study the performance of the rotary dissolver under a wide variety of operating conditions. The code does stepwise continuous material balance calculations around each dissolver stage and the digester tanks. Output from the code consists of plots and tabular information on the stagewise concentration profiles of $UO_2$, $PuO_2$, fission products, $Pu(NO_3)_4$, $UO_2(NO_3)_2$, fission product nitrates, $HNO_3$, $H_2O$, stainless steel, total particulate, and total fuel in pins. Other information about material transfers, stagewise liquid volume, material inventory, and dissolution performance is also provided. This report describes the development of the code, its limitations, key operating parameters, usage procedures, and the results of the analysis of several sets of operating conditions.

Of primary importance in this work was the estimation of the steady-state heavy metal inventory in a 0.5-t/d dissolver drum. Values ranging from ~12 to >150 kg of U+Pu were obtained for a variety of operating conditions. Realistically, inventories are expected to be near the lower end of this range. Study of the variation of operating parameters showed significant effects on dissolver product composition from intermittent solids feed. Other observations indicated that the cycle times for the digesters and shear feed should be closely coupled in order to avoid potential problems with off-specification product.

## 1. INTRODUCTION

Dissolution is a key step in reprocessing spent fuels from nuclear reactors. A continuous rotary dissolver for the dissolution of breeder reactor fuels is now under development at the Oak Ridge National Laboratory (ORNL). The continuous rotary dissolver provides increased agitation, more efficient rinsing, and a more uniform off-gas flow than the batch equipment used in the past. Before any equipment can be approved for use in a reprocessing plant, it must undergo extensive testing to ensure its reliability and safety. Criticality safety must also be ensured by calculations based on reasonable predictions of the stagewise concentrations of material in the dissolver and on criticality benchmark data. Analysis of the unsteady-state performance of the dissolver gives operators information on the time required to attain substantially steady-state operation and on the quality of the product produced during transient periods. The unsteady-state model can be used as a tool to evaluate alternative equipment designs and operating procedures by forecasting the consequences of various system perturbations.

Study of the unsteady-state operation of the dissolver is useful in determining sensitive operating and design parameters and specifying control systems and requirements for later processing steps. Using sensitivity analysis, it is possible to determine the probable effects of fluctuation of various parameters on product quality and system control.

### 1.1 Equipment Description

Continuous rotary dissolvers will be used in advanced reprocessing facilities for recovery of uranium and plutonium from spent breeder reactor fuels. The continuous dissolver, shown in Fig. 1, is a 0.5-t/d, compartmented, ~0.75-m-diam drum enclosed in a rectangular shroud (not shown). The drum is ~2.4 m long and has nine separate stages, or compartments. Liquid moves through the dissolver by gravity flow through the slots in the walls (shown in the cutaway in Fig. 1) separating each stage. A schematic diagram showing the flows through the dissolver is presented in Fig. 2. The liquid overflow from stage $i$ becomes the feed to stage $i - 1$. Sheared materials flow countercurrent to the liquid and are fed to the dissolver semicontinuously through two isolation valves. Sheared solids flow batchwise between dissolving stages and semicontinuously to the feed stage and from the rinse stage. Steam condensate enters stages 1 and 9 of the dissolver through the steam purge gaps between the stationary housing and rotating drum, and concentrated acid enters stage 8 through internal piping built into the drum walls.

The first eight stages are used for dissolution and contain concentrated nitric acid. The last stage contains dilute acid and is used as a rinse stage to further remove any dissolved fuel, concentrated acid, and particulates from the hulls before they are sent to waste disposal.

Each dissolving and rinse stage is ~25.4 cm long and can hold a liquid volume of ~8 L. Each dissolving stage contains a single baffle to provide agitation and a conical transfer duct for transfer of solids as the drum is rotated. The feed stage normally maintains a liquid

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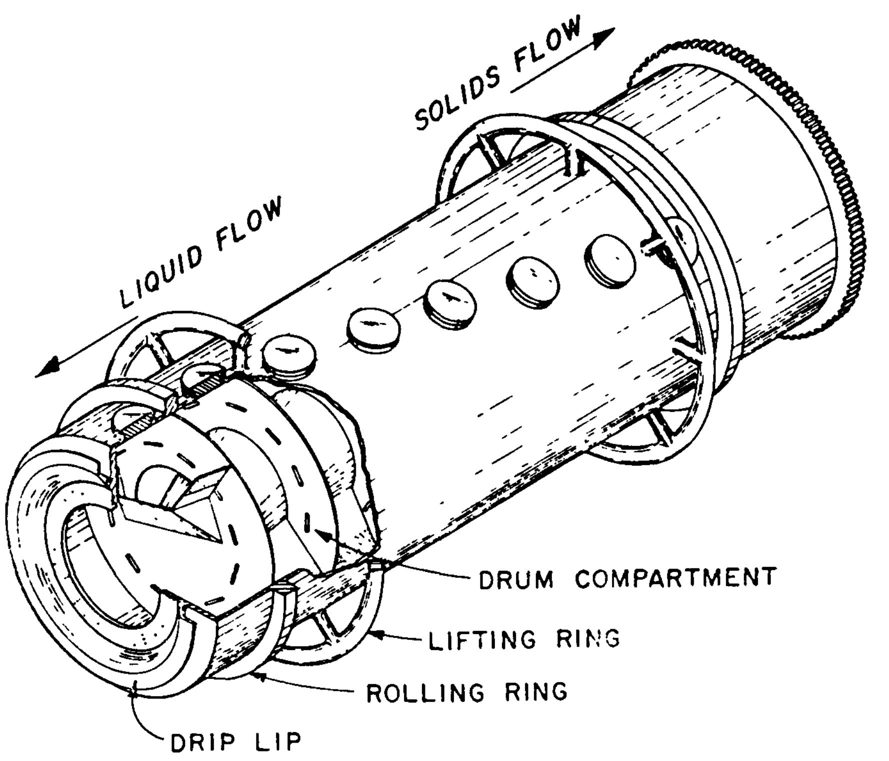


**Fig. 1. Cutaway view of the 0.5-t/d compartmented rotary dissolver drum.**

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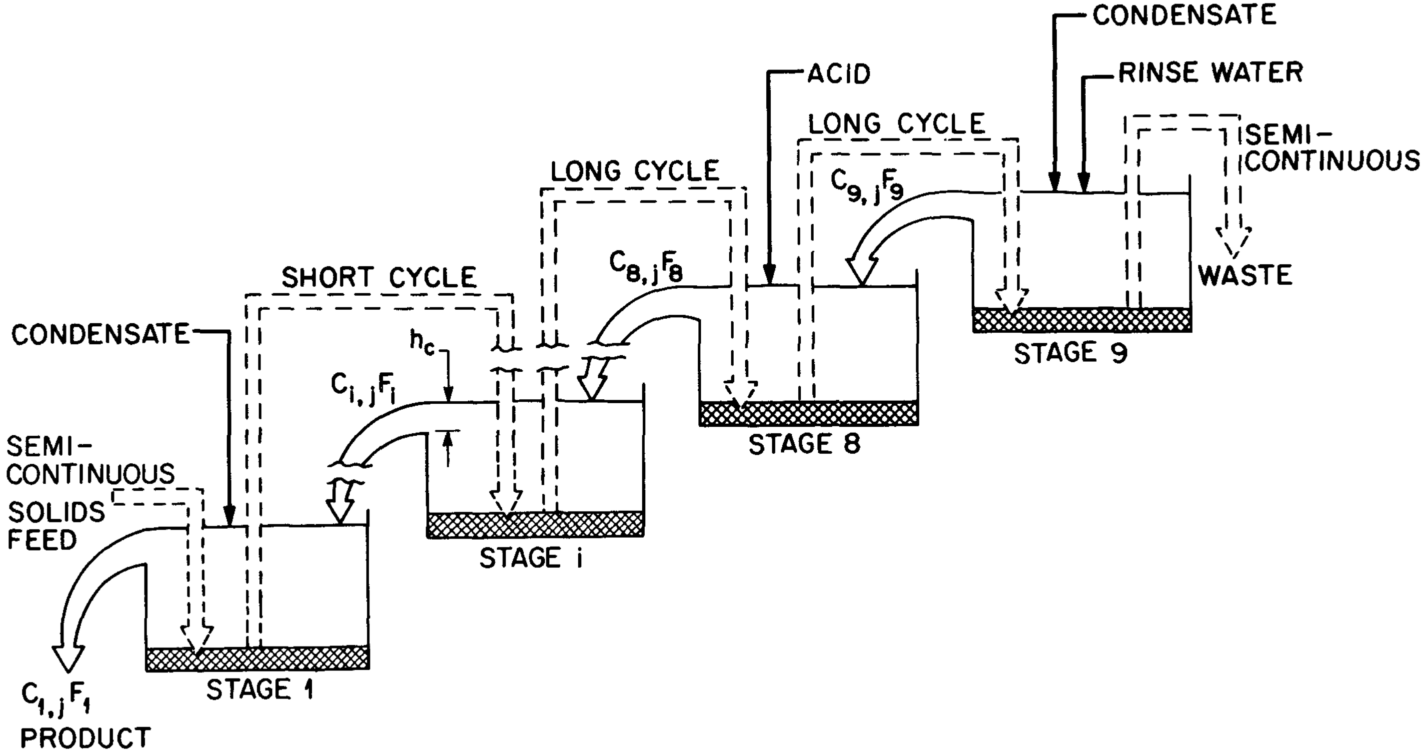


Fig. 2. Schematic diagram of material transfer through the rotary dissolver

volume of ~4.8 L and contains several small baffles, as does the rinse stage for rapid transfer of the fuel. Residence time of the sheared material in each dissolving stage is controlled by the time of forward rotation. To advance the sheared fuel to the next stage, reverse rotations are used.

## 1.2 Previous Dissolver Modeling

Some of the initial dissolver modeling work was based on experimental data related to the continuous spiral pellet dissolver shown in Fig. 3 (ref. 1). Data were taken on the nitric acid dissolution of $UO_2$, using beakers to simulate the countercurrent flow of the continuous spiral dissolver. A relatively simple continuous stirred tanks-in-series mathematical model was developed that predicted concentration profiles which were in reasonably good agreement with the experimental data.

The continuous stirred tanks model has also been used to describe the liquid flow characteristics in a 5-t/d scale, single-dissolving-stage, compartmented rotary dissolver shown in Fig. 4 (ref. 2). Tracer response data were used to evaluate the performance of the model.

The liquid flow through the 0.5-t/d dissolver shown in Fig. 1 was modeled similar to that in the 5-t/d dissolver, using the continuous stirred tanks-in-series approximation, modified to allow variations in stage volumes and flow between stages.[3] The predicted outlet response to step changes in acid and water flow rates to the 0.5-t/d dissolver was in good agreement with the experimental data. The internal design of the solids transfer mechanism of the 0.5-t/d dissolver is similar to that in the 5-t/d unit with the exception of liquid transfer. Liquid transfer in the 0.5-t/d dissolver occurs by gravity flow through slotted holes in the bulkheads between stages. In the 5-t/d unit, liquid flows by means of waterwheel-type scoops built into bulkheads.

## 1.3 The Unsteady-State Continuous Rotary Dissolver Material Balance Model (USSCRD)

This work has been concerned with the development of a mathematical model, incorporating what has been learned from past modeling efforts with what can be anticipated in actual operations with solids present. Past modeling efforts pertaining to the compartmented rotary dissolvers were primarily concerned with describing the liquid flow characteristics in the absence of solids transfers.

The unsteady-state continuous rotary dissolver material balance model (USSCRD) has been designed to provide detailed concentration profile data on stagewise solid- and liquid-phase inventories. The code predicts the concentrations of $UO_2(NO_3)_2$, $Pu(NO_3)_4$, fission product nitrates [$FP(NO_3)_{2.36}$], $HNO_3$, $H_2O$, $UO_2$, $PuO_2$, fission product oxides ($FPO_{1.18}$), and suspended-particulate size distributions, as well as the maximum concentration of each component and the time of occurence. The stage number and time required for completion of dissolution of fuel both in the sheared rods and in particulates are also determined. The code has been so structured that additional components may be included with a minimum of difficulty.

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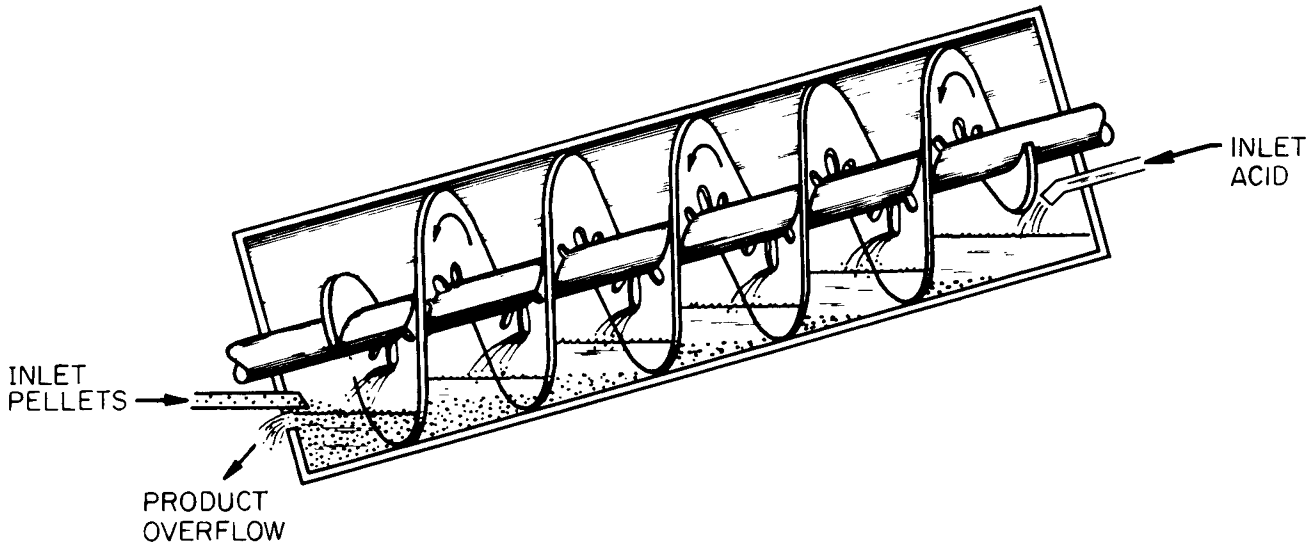


**Fig. 3. Continuous spiral pellet dissolver.**

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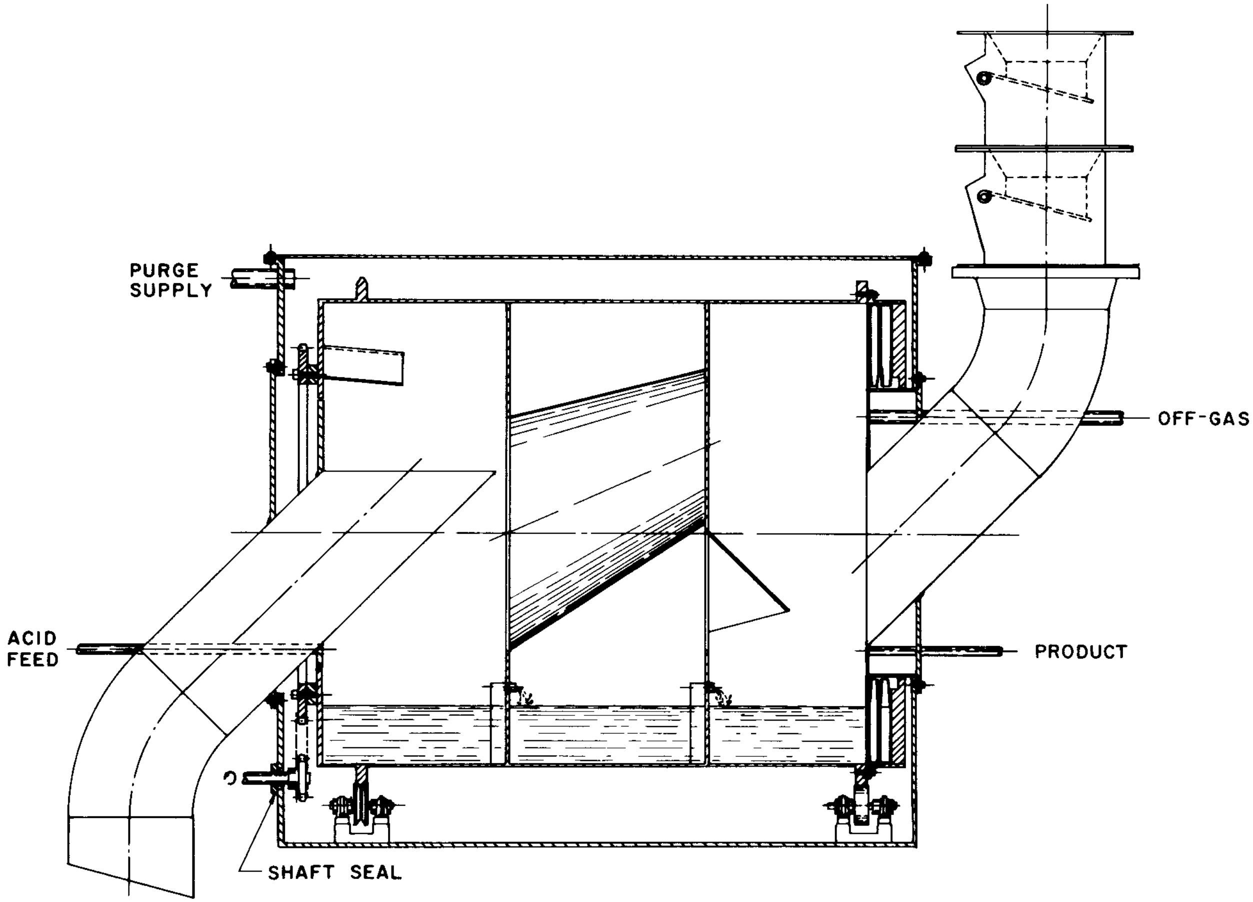


Fig. 4. Single-dissolving-stage, 5-t/d scale, compartmented rotary dissolver.

# 2. MATHEMATICAL DEVELOPMENT

The continuous rotary dissolver process is shown schematically in Fig. 2 as a series of mixing tanks, which is consistent with both past and current thinking. The diagram of a single-dissolving-stage process shown in Fig. 5 illustrates some of the details included in the model: liquid backmixing, particle release, mixing, and reaction.

## 2.1 Liquid Backmixing

As a result of the batchwise transfer of solids between stages, a small amount of backmixing (or carry-over) of solution, countercurrent to the normal fluid flow, is inherent in the operation of the dissolver. While other means of liquid backmixing have been considered improbable, the capability for a continuous backmixing stream has been included in the model as an option.

## 2.2 Particles

Particles are assumed to be released from the fuel pins as spheres with a lognormal distribution of sizes. The probability of a fuel particle having a size (diameter) between $x$ and $x + \Delta x$ is given by

$$P(x) = \overline{Q}\ \frac{\exp\left\{ -\left[\ln(x) - x_m\right]^2 / (2\sigma^2) \right\} \Delta x}{x\sigma} \quad . \tag{1}$$

The parameters $\overline{Q}$, $x_m$, and $\sigma$, defined in the Nomenclature (sect. 13), were determined from the analysis of particle size data from shearing ORNL Mark I, stainless-steel-clad prototype fuel assemblies.[4] Typical values of the parameters for 2.54-cm shear cut lengths are $\overline{Q} = 0.1100$, $x_m = 5.041$, and $\sigma = 1.510$. When considering only dislodged fuel, excluding hull fragments, the value of $\overline{Q}$ is equivalent to $1/\sqrt{2\pi}$.

A shrinking-spherical-particle model with chemical reaction control has been used to describe the reaction of particles.[5] Once particles have been released from the fuel, they can either flow with the liquid or be transported with the solids, depending on their size. Mudding tests in a 0.305-m-diam dissolver have shown that particles 200 to 500 $\mu$m in diameter have a tendency to accumulate until a certain inventory is established, at which point the particles transfer with the hulls.[6] Smaller particles (~20 $\mu$m diam) were removed with the normal liquid flows. For the purposes of the model, it has normally been assumed that particles $\geqslant$200 $\mu$m in diameter transfer with the hulls and particles $<$200 $\mu$m in diameter flow with the liquid.

To account for the effects on particle size of the transfer between stages and the shrinkage from reaction, the size distribution range was divided into 20 discrete size groups. Individual material balances on each size group were performed to determine whether the quantity of particles in each size group had increased or decreased as a result of stagewise transfers and interstage group transfers. Particle sizes were assumed to range from 0 to 2000 $\mu$m in diameter. An average size was determined for each size group in the distribution based

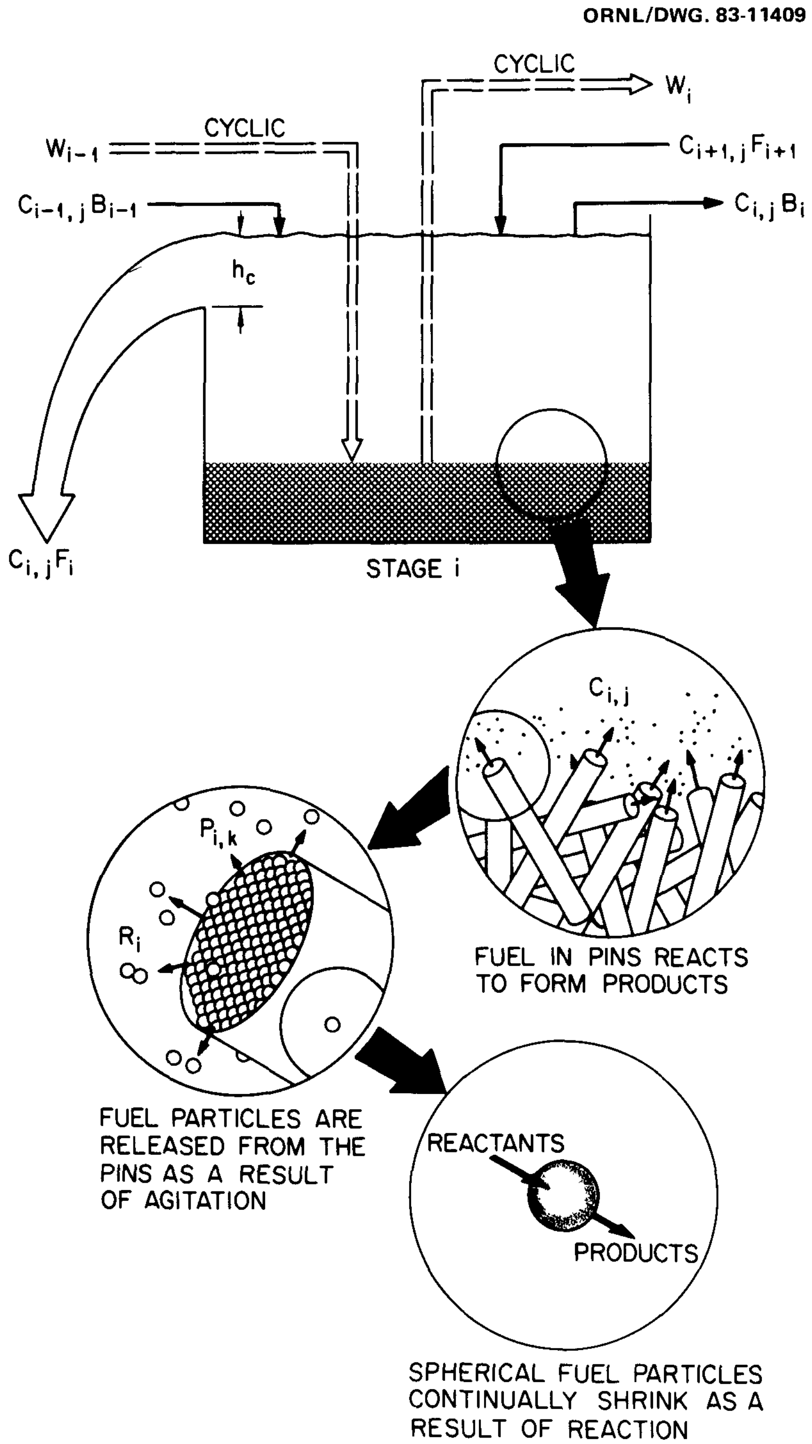


**Fig. 5. Detailed diagram of a typical stagewise dissolution process.**

on a weighted average of the results from the stagewise particle balances and the effects of chemical reaction. The average particle size from the mixing of several streams of particles of dissimilar sizes (hereafter referred to as "mixed streams") is calculated based on conservation of total mass and surface area. The total surface area, $A_{mix}$, of the particles in the mixed stream can be written in terms of particle mass and size as follows:

$$A_{mix} = \frac{M_k 4\pi (r_{mix,k})^2}{(4/3)\pi (r_{mix,k})^3 \rho_f} = \sum_{j=1}^{z} \frac{(\mu_k)_j 4\pi (r_{old,k})_j^2}{(4/3)\pi (r_{old,k})_j^3 \rho_f} , \quad (2)$$

where

$$M_k = \sum_{j=1}^{z} (\mu_k)_j \quad . \quad (3)$$

Equation (2) can be simplifed and solved for the average radius of the mixed stream for size group $k$ to give

$$r_{mix,k} = \frac{M_k}{\sum_{j=1}^{z} \frac{(\mu_k)_j}{(r_{old,k})_j}} \quad . \quad (4)$$

The effects of reaction on particle size are discussed in the section on reaction rates (Sect. 2.6).

Particles were assumed to enter the dissolver environment either by release from the fuel pins as a result of agitation and reaction (see Fig. 5) or as a part of the solid feed stream. The fraction of fines in the feed is a function of several variables, including the fuel makeup, irradiation history, and conditions in the preceding equipment. Goode and Stacy showed that the fraction of fines comminuted from various types of fuels irradiated in the Experimental Breeder Reactor II (EBR-II) ranged from 8 to 83% of the total.[7,8]

### 2.3 Mixing

Complete mixing of solids and liquids has been assumed to result from the continuous rotation of the drum and the agitation effects of its internals. Under this assumption, the acid concentration in the fuel pins is the same as that in the bulk liquid. However, if the complete mixing assumption is relaxed and we allow stagnant regions to exist in the fuel pins, then, as reaction proceeds, the probability of the acid in the fuel pins being less concentrated than the acid in the bulk increases. This feature has been designed into the model by allowing different reaction rates for particle and pin reactions.

## 2.4 Chemical Equations

The initial development of the material balance model was based on a continuous supply of oxidized fuel. The following chemical equations were used to describe the reactions of the oxidized fuel in nitric acid:

$$U_3O_8 + 7.35\ HNO_3 \rightleftarrows 3\ UO_2(NO_3)_2 + NO_2 + 0.35\ NO + 3.65\ H_2O\ , \quad (5)$$

$$PuO_2 + 4\ HNO_3 \rightarrow Pu(NO_3)_4 + 2\ H_2O\ , \quad (6)$$

and

$$FPO_{1.7} + 3.39\ HNO_3 \rightleftarrows FP(NO_3)_{3.39} + 1.7\ H_2O\ , \quad (7)$$

where FPO stands for fission product oxide and FP stands for fission product.

As can be seen in Eqs. (5), (6), and (7), water is produced and acid is consumed in each reaction. Nitric acid is produced by the reaction of $NO_2$ and $H_2O$, as shown in the overall reaction

$$3\ NO_2\ (g) + H_2O \rightarrow 2\ HNO_3 + NO\ (g)\ . \quad (8)$$

It has been assumed that all the $NO_2$ formed at $HNO_3$ concentrations less than 8 to 10 *M* reacts to form $HNO_3$ according to Eq. (8). At acid strengths greater than 8 to 10 *M*, none of the $NO_2$ produced reacts to form $HNO_3$.

The $NO_2$ conversion assumption is based on the following chemical equations for the dissolution of $UO_2$:

$$UO_2 + 2.7\ HNO_3 \rightleftarrows UO_2(NO_3)_2 + 0.7\ NO + 1.3\ H_2O\ , \quad (9)$$

$$UO_2 + 4\ HNO_3 \rightarrow UO_2(NO_3)_2 + 2\ NO_2 + 2\ H_2O\ . \quad (10)$$

Both reactions occur to some extent; however, Eq. (9) is predominant at low acid concentrations and Eq. (10) is predominant at $HNO_3$ concentrations greater than ~8 to 10 *M* (refs. 9, 10).

As a result of changes in program emphasis, the fuel oxidation step was eliminated from the process. This change required the substitution of chemical Eqs. (9) and (10) for Eq. (5) and estimation of the following fission product reaction equation for unoxidized fuel:

$$FPO_{1.18} + 2.36\ HNO_3 \rightarrow FP(NO_3)_{2.36} + 1.18\ H_2O \quad (11)$$

as a substitute for Eq. (7).

## 2.5 Material Balance Equations

The differential rate of change in mass of component $J$ in the liquid phase of stage $I$ due only to flow between stages may be written in terms of concentration $C$, primary flow $F$, and backmixing flow $B$ as follows:

$$\frac{d\,m_{I,J}}{dt} = C_{I+1,J}F_{I+1} - C_{I,J}F_I + C_{I-1,J}B_{I-1} - C_{I,J}B_I \quad . \tag{12}$$

Mass rate of change can also be expressed in terms of concentration and volume as

$$\frac{d\,m_{I,J}}{dt} = \frac{d(C_{I,J}V_I)}{dt} = C_{I,J}\frac{dV_I}{dt} + V_I\frac{dC_{I,J}}{dt} \quad . \tag{13}$$

Neglecting the change in volume with time due to reaction and mixing, and concentrating on gross volume changes due to solid/liquid transfers, the term $dV_I/dt$ can be expressed as a pseudoconstant,

$$\frac{dV_I}{dt} = D_I \quad , \tag{14}$$

which varies externally to the solution of Eq. (13). The value of $D_I$ varies according to the difference between the liquid flow in and out of a stage resulting from solids transfers and changes in feed rate. Combining Eqs. (12), (13), and (14), and rearranging and grouping like terms yields

$$V_I\frac{dC_{I,J}}{dt} = C_{I+1,J}F_{I+1} + C_{I-1,J}B_{I-1} - C_{I,J}(D_I + F_I + B_I) \quad . \tag{15}$$

To solve for $C_{I,J}$, let

$$A = D_I + F_I + B_I \quad , \tag{16}$$

and

$$G = C_{I+1,J}F_{I+1} + C_{I-1,J}B_{I-1} \quad . \tag{17}$$

Treating $A$ and $G$ as pseudo-steady-state constants, Eq. (15) may be written

$$V_I\frac{dC_{I,J}}{dt} = G - A\,C_{I,J} \quad . \tag{18}$$

Dividing through by $V_l$, integrating the resulting linear, first-order differential equation over an interval from time $t$ to $t + \Delta t$, and solving for $C_{i,j}$ gives

$$C_{i,j} = \frac{G}{A}\left[1 - \exp\left(\frac{-A\ \Delta t}{V_l}\right)\right] + C'_{i,j}\ \exp\left(\frac{-A\ \Delta t}{V_l}\right) . \qquad (19)$$

The general form of Eq. (19) is used to solve for the concentration of each compound, including particles in each stage of the dissolver. Only the definitions of the pseudoconstants $A$ and $G$ change as different compounds and stages are considered. The change in definition is primarily a result of the addition of various external feed streams (such as the acid feed to stage 8, rinse stream to stage 9, and condensate inleakage to stages 1 and 9) and particle flow considerations.

Once all the stagewise concentrations have been adjusted for the effects of liquid flow through the dissolver, it is necessary to correct the concentrations for dissolution of the fuel. Fuel dissolution occurs basically at two reaction sites — the fuel pin ends and particles in the bulk liquid. The primary difference in the two reaction sites is the amount of exposed surface area available for reaction.

For the dissolution of fuel from the pins, it is assumed that the pins have been sheared at an angle $\theta$ arbitrarily set at 45°. It is further assumed that there are hemispherical protrusions of fuel particle clusters on each end of a fuel pin, as shown in Fig. 6. The exposed

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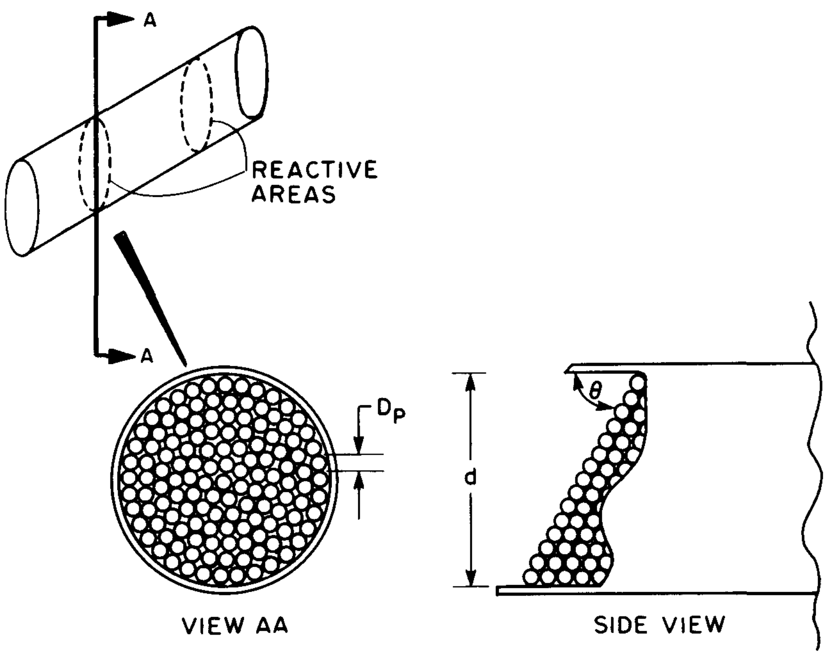


**Fig. 6. Idealized representation of exposed spherical clusters of fuel particles in a fuel pin.**

particle cluster area per fuel pin available for reaction, $A_{\text{pin}}$, is assumed to be constant while any fuel is present in the pin and is expressed

$$A_{\text{pin}} = d^2\ \pi/\sin(\theta)\quad . \tag{20}$$

The overall rate of dissolution of fuel from the fuel pins in stage $i$ due to reaction $R'_i$ is given by

$$R'_i = \alpha'_i\ A_{\text{pin}}\ N_i\quad , \tag{21}$$

where $N_i$ is the number of fuel pins in a stage and varies with time in stages 1, 2, and 9, but is constant in stages 3 through 8. Using Eq. (21), the mass of fuel dissolved from the pin can be calculated and deducted from the fuel inventory in the pins in stage $i$.

When fuel is dissolved from particles suspended in the bulk liquid in a stage, the overall rate of dissolution of fuel in the particles in stage $i$, $R_{i,k}$, must be expressed in terms of a particular particle size group, $k$:

$$R_{i,k} = \alpha_i\ \beta_k\ A_{\text{part},k}\quad . \tag{22}$$

$A_{\text{part},k}$ is the surface area of an idealized spherical particle in size group $k$ expressed as

$$A_{\text{part},k} = 4\pi(r_{\text{old},k}\ S)^2\quad , \tag{23}$$

where $S$ is the ratio of a pseudoradius of a particle (accounting for increased surface area due to porosity) to the actual particle radius. The ratio $S$ can also be defined in terms of the fractional increase in particle surface area due to porosity, $f$, as

$$S = \sqrt{f+1}\quad . \tag{24}$$

From Eq. (22), $\beta_k$ is the number of particles in size group $k$ before reaction and is given by

$$\beta_k = P_{i,k}\ V_i/\ [\ (4/3)\ \pi\ \rho_f\ (r_{\text{old},k})^3\ ]\quad , \tag{25}$$

where $P_{i,k}$ is the concentration of particles in size group $k$ in stage $i$ calculated using Eq. (19). Once the concentration of particles in each size group has been adjusted for the mass of material reacted during a time step, the new radius of each size group must be determined. Based on the amount of material disappearing during a time step of length $\Delta t$, the particle size group radius, corrected for reaction, is given by

$$r_{\text{new},k} = \left\{\left(r_{\text{old},k}\right)^3 - \left[R_{\text{i,k}}\ \Delta t/\ (4/3\ \pi\ \rho_f\ \beta_k)\right]\right\}^{1/3}\quad . \tag{26}$$

The particle size for each group varies between preset bounds, which are determined by the number of size groups and the specified maximum and minimum allowable particle sizes. Once the particle size group radii have been adjusted for reaction using Eq. (26), it must be determined whether or not the new radius is within the allowable range of sizes for the group. If the new radius lies outside the allowable range, the mass of particles remaining must be transferred from the old size group to the new group containing the adjusted radius. When all the group transfers have been accomplished, a new particle size distribution for each stage can be determined.

### 2.6 Reaction Rates

Basic reaction rate data for the $UO_2$-$PuO_2$ system in nitric acid at the boiling point is based on empirical rate equations developed by Uriarte and Rainey.[11] The empirical equations are functions of the acid concentration, theoretical fuel density, and fuel composition, and are used as follows [see Nomenclature (sect. 13) for definition of terms]:

$$k_{i,UO_2} = 0.480 \left(C_{i,HNO_3}\right)^2 e^{-0.091(T_d)} \quad , \tag{27}$$

$$k_{i,PuO_2} = 5.0\left(C_{i,HNO_3}\right)^4 e^{-0.27(T_d)} + 4 \times 10^4 \left(C_{i,HNO_3}\right)^4 \times \left(C_{i,HF}\right)^{1.4} e^{-0.27(T_d)} \quad , \tag{28}$$

$$k_{i,UO\text{-}PuO_2} = \left(k_{i,UO_2}\right)^{1-n} \left(k_{i,PuO_2}\right)^n \quad , \tag{29}$$

where

$$T_d = \frac{100\,\rho_f}{11.46\,(n) + 8.3\,(n-1)} \quad . \tag{30}$$

In the absence of hydrofluoric acid, Eq. (28) may be simply stated as follows:

$$k_{i,PuO_2} = 5.0\left(C_{i,HNO_3}\right)^4 e^{-0.27(T_d)} \quad . \tag{31}$$

In Eq. (29), as given by Uriarte and Rainey, $n$ is the mole fraction of only $PuO_2$ in the $UO_2$-$PuO_2$ solid solution. However, because of the presence of fission products in the irradiated fuel, $n$ has been assumed to be the sum of the mole fractions of both fission products and $PuO_2$ in the $UO_2$-$PuO_2$ fission product solid fuel solution. Uriarte and Rainey worked primarily with unirradiated fuels; however, they also stated that irradiated fuel (20% $PuO_2$–80% $UO_2$) dissolved about five times faster than unirradiated fuel. Therefore, a variable premultiplier has been included in the dissolution rate model to adjust the dissolution rates.

Uriarte and Rainey also reported on the effects of dissolved heavy metals on fuel dissolution. They found that the dissolution rate for $UO_2$ increased as the second power of the sum of the nitric acid and uranyl nitrate concentrations rather than nitric acid alone. This effect is believed to be due to the disassociation of uranyl nitrate, which provides additional $NO_3^-$ for dissolution. More recent work with mixed-oxide fuels has not supported these findings.[12] Therefore, the $NO_3^-$ enhancement from uranyl nitrate has not been included in the code, although its addition could be easily accomplished.

### 2.7 Liquid Flow

Flow between stages in the dissolver has been empirically modeled as flow over a weir[3] using

$$F_l = 0.9888\,(h_c)^{2.830} \quad . \tag{32}$$

The crest height, $h_c$, over the weir is calculated based on both the volume of liquid and volume of solids in a stage as shown in Fig. 7. Liquid volumes are determined by adding

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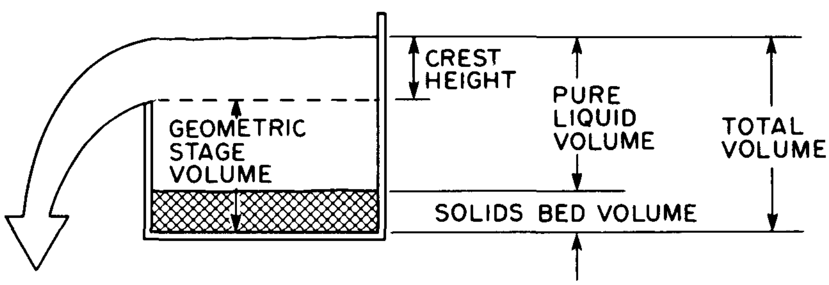


**Fig. 7. Physical components of liquid flow model.**

together the masses of all the liquid-phase components, dividing by the solution density, and making any necessary adjustments for differences between the flow rates in and out of the stage. Liquid densities for the dissolved fuel solutions are based on the concentrations of $UO_2(NO_3)_2$, $Pu(NO_3)_4$, and $HNO_3$ (ref. 13). The solution density at any temperature $\rho_T^{\ell}$ is determined by first calculating the density at 25°C using

$$\rho_{25}^{\ell} = 1.00125 + 0.3177\,[UO_2(NO_3)_2] + 0.22\,[Pu(NO_3)_4] + 0.03096\,[HNO_3] \quad , \tag{33}$$

where the brackets indicate molarity of the enclosed compound. Expressing molarity in terms of mass and density, Eq. (33) may be rewritten

$$\rho_{25}^{\ell} = \frac{1.00125}{1.0 - \left(\dfrac{0.3177\, m_{l,\mathrm{UN}} + 0.22\, m_{l,\mathrm{PN}} + 0.03096\, m_{l,\mathrm{HN}}}{T_{l,m}}\right)} \ . \tag{34}$$

The density at any other temperature may now be determined using

$$\rho_{T}^{\ell} = 1.0125\, \rho_{25}^{\ell} + 0.000145\, T - 0.0005\, T \rho_{25}^{\ell} - 0.0036 \ . \tag{35}$$

Solid volume calculations are based on the mass of material in a stage and the specific material densities. All solids in a stage consist of either stainless steel from the cladding, spent fuel in the pins, or loose particles.

Liquid flow through the 0.5-t/d Hot Experimental Facility (HEF) dissolver actually occurs as flow through slots in the bulkheads between stages (Fig. 1). At high liquid flows, the crest height in the weir flow equation becomes greater than the width of the overflow slot in the bulkhead. At this point, the overflow slot is flooded, and liquid flow begins to approximate flow through an orifice. No attempt has been made to model this phenomenon, since the higher flows are very transitory in nature. Instead, the weir flow equation is used exclusively. However, in order to avoid computational stability problems at the high liquid flows, an upper limit for the crest height term, approximately equivalent to the width of the slot, is utilized. The aforementioned stability problems occur when the flow rate is unbounded and the liquid volume in a stage is sufficiently low to lead to complete liquid depletion from the stage.

# 3. CODE DESCRIPTION AND OPERATION

The unsteady-state continuous rotary dissolver material balance code (USSCRD) is written in the FORTRAN programming language. There are over 4000 lines of code organized into 19 subroutines, a block data initialization routine, and a main supervisory program. The block data routine zeros most of the variables in the code and has a comprehensive table of nomenclature. All data are input through the supervisory program from an appropriate data file. Output from the code is also funneled through the supervisory program. The 19 subroutines perform the bulk of the calculations required for the unsteady-state material balance. Table 1 is a listing of the various sections of the code and their primary functions. The calling order column in Table 1 gives the order in which each of the program sections is executed during the unsteady-state analysis.

## 3.1 Data Input

The code requires ~83 different types of input data, much of which is needed to define the geometry of the dissolver, mode of operation, fuel characteristics, and feed streams. A summary of the input data is given in Table 2.

## 3.2 Output Summary

Output of data from the code is in four forms: hard copy from the line printer, microfiche, magnetic tape, and plots. The quantity of line printer output can be varied by changing PRDIST and PRTTIM. The output going to the line printer consists of a summary of the input data, material balance monitoring, particle size distribution monitoring, and total mass balance data at the end of the run. The microfiche data include all the line printer output plus component concentration monitoring and plot data. Everything written onto microfiche is also stored permanently on magnetic tape. Plot output consists of stagewise concentration profiles and particle size distributions for the dissolver and concentration histories for both digester tanks. Stagewise concentration history plots for stainless steel, fuel in pins, and fuel as particles are also provided. These plots are useful in monitoring the transfer of hulls through the dissolver and the completion of dissolution. A copy of the code input data files and typical output for various cases are given in the Appendixes.

## 3.3 Solution Procedure

The system of equations describing the stagewise continuous rotary dissolver process is solved stepwise in time. The order of the solution with respect to stages is not critical, since the presence of a backmixing term in each equation requires that iterative procedures be used to solve the equations. The family of equations and their respective pseudoconstants for a nine-stage dissolver are shown in Table 3. In the absence of the backmixing term in the definition of $G$, as presented in Eq. (17) and Table 3, the solution to the system of material balance equations is fully explicit when solved from stages 9 to 1. Including the continuous backmixing terms as well as considering the periodic external backmixing process during transfer of hulls necessitates the use of a fully implicit solution procedure

**Table 1. Primary functions of each section of USSCRD**

| Section name | Function | Calling order |
|---|---|---|
| BLOCK DATA | Initialization and definition | *a* |
| MAIN | Subroutine calls, input/output, and overall balance | *b* |
| TRANSF | Solid/liquid transfers including backmixing | 13 |
| PARTIC | Particle size group manipulation | 2 |
| SUBON | $UO_2(NO_3)_2$ concentration due to flow | 5 |
| SUBPN | $Pu(NO_3)_4$ concentration due to flow | 6 |
| SUBFN | $FP(NO_3)_{3\ 39}$ concentration due to flow | 7 |
| SUBHN | $HNO_3$ concentration due to flow | 8 |
| SUBH2 | $H_2O$ concentration due to flow | 9 |
| CHECK | Iteration convergence check | *c* |
| WEIGHT | Adjusts fuel mass and concentration due to reaction | 12 |
| RELEAS | Particle release rate from fuel pins | 3 |
| RATECK | Reaction rates | 4 |
| PLOT7 | General stagewise concentration profile plots | *d* |
| FREQUE | Particle birth size distribution | *a* |
| PLOTD | Stagewise particle size distribution plots | *d* |
| PLOT3 | Stagewise concentration profiles for fuel, particles, and stainless steel | *d* |
| TSTEP | Time step length adjustment | 1 |
| RXEQU | Uranium reaction equation determination | 10 |
| DIGEST | Digester tank model | 11 |
| DIGPLT | Digester tank history plots | *d* |

[a] Called once at beginning of execution
[b] Main supervisory program
[c] Called with each component balance routine
[d] Called once at end of execution

**Table 2. Input data summary definitions**

| Variable name | Definition |
|---|---|
| AAANG | Total number of particle size groups |
| AAANS | Total number of stages |
| ACDF | Fraction difference between bulk acid concentration and acid concentration in a fuel pin, can allow for reaction rate reduction while fuel is out of liquid |
| ACIDEF | Maximum $HNO_3$ concentration for acid deficiency (g/L) |
| AFIAT | Anticipation time for increased flow of acid feed to stage 8 (min) |
| AFRAT | Anticipation time for reduction of flow of acid feed to stage 8 (min) |
| AKSTOP | Upper limit for number of times concentration subroutines are called |
| ALIMO | Upper limit for number of iterations each time step for each subroutine |
| AMINFR | Multiplication factor to calculate the minimum time step |
| ANGLE | Drum angle (deg) |
| BAKMIX(I) | Mass of solution backmixed due to carry over on hulls from stage I (gram of solution per gram of hulls), hulls = hulls + shroud + wires + other |
| BASECT | Basic forward rotation time, not considering the lag time between forward and reverse (min) |
| BATTIM | Batch cycle time for shear to cut one fuel element and prepare for another (min) |
| CDEN8 | Density in external feed stream 8 at normal flow rate (g/L) |
| CH2OM8 | Water flow rate to stage 8 in acid feed stream at normal feed rate (kg/h) |
| CHNOM8 | $HNO_3$ flow rate to stage 8 in acid feed stream at normal feed rate (kg/h) |
| CONREL | Constant maximum total particle release rate for each stage (g/min) |
| CT1 | Cycle time for hull transfer from stage 1 (min) |
| DEN1, DEN9, DEN10 | Density of external feed streams to stages 1, 9, and 10, respectively (g/L), stage 10 is the same as 9 |
| DENSST | Metal density of stainless steel hulls, shrouds, and wires (g/L) |
| DEPTH(I) | Maximum liquid depth in stage I (cm) |
| DFP | Average density of fission products ($g/cm^3$) |
| DIA | Drum diameter (cm) |
| DP | Average particle diameter (cm) |
| DPUO2 | Density of $PuO_2$ ($g/cm^3$) |
| DREVS | Number of revolutions required to empty stage NS (solids exit stage) |
| DU3O8 | Density of $UO_2$ ($g/cm^3$) |
| FCSTG1, FCSTG9 | Fraction of condensate entering stages 1 and 9 |
| FEANG | Exposure angle for fuel in ends of fuel pin (deg) |
| FFINES | Fraction of input feed that is fines |
| FLAPTM | Cycle time for lower flapper valve in dissolver feed pipe (min) |
| FRMOFP | Mole fraction of fission products in homogeneous fuel |
| FRMOPU | Mole fraction of plutonium in homogeneous fuel |
| FRMOU3 | Mole fraction of uranium in homogeneous fuel |
| HC | Maximum time increment for calculations (min) |
| H2OM10 | Mass flow of water in external feed streams to stage 9 (kg/h) |
| HNOM10 | Mass flow of nitric acid in external feed stream to stage 9 (kg/h) |

**Table 2 (continued)**

| Variable name | Definition |
|---|---|
| PAR000 | Particle reaction rate on/off flag<br>0.0 – no particle reactions<br>1.0 – normal particle reactions |
| PCFP | Weight fraction of fission products in fuel pin |
| PCPUO2 | Weight fraction of $PuO_2$ in fuel pin |
| PCU3O8 | Weight fraction of $UO_2$ in fuel pin |
| PIN | Inside diameter of fuel pin (cm) |
| PIN000 | Pin reaction rate on/off flag<br>0.0 – no pin reactions<br>1.0 – normal pin reactions |
| PINLEN | Length of fuel pin (cm) |
| POW | Exponent for weir flow equation<br>flow (L/min) = TK* [crest height (cm)]**POW |
| PRDIST | Print time increment for particle size distribution (min) |
| PRINC | Base plotting time increment (min) |
| PRTTIM | Total run time between printouts (min) |
| RFACT | Correction factor for rate equations (A factor of 5.0 has been quoted by Uriarte and Rainey[11] for irradiated fuels.) |
| RHOAVE | Average density of solid fuel ($g/cm^3$) |
| RMAX | Maximum particle size radius ($\mu m$) |
| RMIN | Minimum particle size radius ($\mu m$) |
| RPM | Dissolver rotational speed (rpm) |
| RUN | Total run time (min) |
| RWASTE | Minimum particle size radius transferring with hulls ($\mu m$) |
| SDEN8 | Acid feed stream density at reduced flow (g/L) |
| SH2OM8 | Water flow in reduced acid feed stream flow to stage 8 (kg/h) |
| SHETIM | Time required to shear one fuel assembly into 2.54-cm lengths (min) |
| SHNOM8 | $HNO_3$ flow in reduced acid feed stream flow to stage 8 (kg/h) |
| SIZE | Plant capacity (t/d) |
| SLOTLM | Radial width of overflow slot (cm) |
| SPAREA | Ratio of pseudoradius of fuel particles to geometric radius, multiplication factor to account for particle area in excess of sphere area [SPAREA = DSQRT (*f*+1), where *f* is the fractional percent increase in surface area due to porous particles. SPAREA can be thought of as an area enhancement factor.] |
| STGLEN | Length of stage (cm) |
| TDIG | Time for digestion cycle in digester tank (min) |
| TEMP | Average dissolver temperature (°C) |
| TFILL | Input time for filling digester tank (min) |
| TH2OC | Total mass flow of $H_2O$ in condensate returned to stages 1 and 9 (kg/h) |
| THNO3C | Total mass flow of $HNO_3$ in condensate returned to stages 1 and 9 (kg/h) |
| TK | Term in weir flow equation (gives flow in L/h) |
| TMRFED | Mass feed rate of spent fuel, including stainless steel (kg/h) |

**Table 2 (continued)**

| Variable name | Definition |
|---|---|
| TMRSST | Mass feed rate of stainless steel (kg/h) |
| TOL | Tolerance between iterations in material balances |
| TRCT | Total reverse cycle time (min) |
| TTRAN | Transfer time for digester tank liquor (min) |
| V0(I) | Initial liquid volume in stage I (L) |
| ZNOPT3 | Concentration history plot flag<br>0 0 – no plots<br>1 0 – plots |
| ZNOPT7 | Concentration profile plot flag<br>0 0 – no plots<br>1 0 – plots |
| ZNOPTA | Total plot flags<br>0 0 – no plots<br>1 0 – plots |
| ZNOPTD | Digester plot flag<br>0 0 – no plots<br>1 0 – plots |
| ZNOPTP | Particle size distribution plot flag<br>0 0 – no plots<br>1 0 – plots |

**Table 3. A system of stagewise material balance equations for compound $j$ in a nine-stage continuous rotary dissolver**

| Stage No | Concentration equation | Pseudoconstants | |
|---|---|---|---|
| | | $A$ | $G$ |
| 9 | $C_{9,j} = \frac{G}{A}\left[1 - \exp\left(\frac{-A\,\Delta t}{V_9}\right)\right] + C'_{9,j}\exp\left(\frac{-A\,\Delta t}{V_9}\right)$ | $D_9 + F_9 + B_9$ | $C_{10,j}F_{10} + C_{8,j}B_8$ |
| $i$ | $C_{i,j} = \frac{G}{A}\left[1 - \exp\left(\frac{-A\,\Delta t}{V_i}\right)\right] + C'_{i,j}\exp\left(\frac{-A\,\Delta t}{V_i}\right)$ | $D_i + F_i + B_i$ | $C_{i+1,j}F_{i+1} + C_{i-1,j}B_{i-1}$ |
| 1 | $C_{1,j} = \frac{G}{A}\left[1 - \exp\left(\frac{-A\,\Delta t}{V_1}\right)\right] + C'_{1,j}\exp\left(\frac{-A\,\Delta t}{V_1}\right)$ | $D_1 + F_1 + B_1$ | $C_{2,j}F_2$ |

employing iterative techniques to solve for concentrations. The iteration technique used in the code assumes that the unknown concentrations for the first pass through the system of equations in Table 3 are the same as in the last time step. These values are substituted into the set of equations in Table 3 repeatedly until the solution converges. This entire process is repeated for each time step. For a sufficiently small time step, this is a reasonable procedure, leading quickly to convergence.

# 4. STANDARD CONDITIONS

A set of standard operating conditions was established so that the effects of variation of one or more of the variables in the model could be studied relative to a standard set of conditions. The effects being studied primarily relate to stagewise heavy metal and acid concentrations.

All solids and liquid flows, equipment designs, and operating conditions were based on the conceptual design requirements and specifications of the Consolidated Fuel Reprocessing Program (CFRP) Hot Experimental Facility (HEF). Fuel characteristics were based on Fast Flux Test Facility (FFTF) type 3.1 fuel, with the composition being the same as that given in the HEF design report. The reaction rate equations, liquid flow correlations, particle size distribution data, and density correlations were obtained from various studies on fuel chemistry and the dissolution of irradiated and unirradiated fuels described previously. Other parameters, such as specific surface area of the fuel and the minimum particle size transferring with the hulls, were estimated based on hot-cell experience.

The fraction of fines in the incoming fuel is highly variable, depending on the fuel history and treatment prior to dissolution. Hot-cell studies have indicated that when higher-burnup fuel is used, more fuel is released from the pins during shearing.[8] Amounts ranging from ~8 to 21% of the total were dislodged from the fuel pins as a result of shearing. Oxidation of the fuel prior to dissolution increased the amounts dislodged to ~60 to 83% of the total.

One adjustable parameter for which little information is available is the particle release rate. The particle release rate is the rate at which particles are released from the sheared fuel pins in the dissolver. Particles released from the pins have a much higher surface area exposed to the nitric acid than the fuel remaining in the sheared pins. The increased surface area has the effect of decreasing the time required for dissolution, which can produce a variety of results for stagewise inventories and concentration profiles. Some very early work with low-burnup EBR-II fuel reported the cumulative effects of reaction and particle release in terms of the incremental percentage of the total fuel loose in a basket dissolver as 24, 13, and 8% after 30, 60, and 90 min, respectively.[14] While these data are of limited usefulness here, they can be used as a guide in qualitatively choosing a reasonable particle release rate for the model. Additional data have recently been obtained from the dissolution of low-burnup (~0.2%) FFTF fuel, indicating essentially complete release of the fuel from the pins after ~30 min (ref. 15). Experiments are also being run using higher-burnup FFTF fuel; however, the results from this work are not yet available for use.

The input data for standard operating conditions are given in Table 4.

**Table 4 Standard conditions for input variables**

| Variable name | Operating condition input |
|---|---|
| AAANG | 20 0 |
| AAANS | 9 0 |
| ACDF | 1 0 |
| ACIDEF | 31 50 |
| AFIAT | 0 0 |
| AFRAT | 0 0 |
| AKSTOP | 500000 0 |
| ALIMO | 20 0 |
| AMINFR | 1 0 |
| ANGLE | 5 0 |
| BAKMIX(I) | 0 07 |
| BASECT | 30 0 |
| BATTIM | 180 00 |
| CDEN8 | 1300 0 |
| CH2OM8 | 47 45 |
| CHNOM8 | 40 08 |
| CONREL | 100 0 |
| CT1 | 0 001 |
| DEN1 | 951 0 |
| DEN9 | 951 0 |
| DEN10 | 1010 0 |
| DENSST | 8010 0 |
| DEPTH(I) | 8 7376 @ I = 1 11 4808 @ I = 2 9 |
| DFP | 12 10 |
| DIA | 76 20 |
| DP | 0 0010 |
| DPUO2 | 11 46 |
| DREVS | 20 0 |
| DU3O8 | 8 3 |
| FCSTG1 | 0 667 |
| FCSTG9 | 0 333 |
| FEANG | 45 0 |
| FFINES | 0 2 |
| FLAPTM | 0 0 |
| FRMOFP | 0 0990 |
| FRMOPU | 0 1999 |
| FRMOU3 | 0 2011 |
| HC | 0 02 |
| H2OM10 | 35 03 |
| HNOM10 | 1 140 |
| PAR000 | 1 0 |
| PCFP | 0 0520 |
| PCPUO2 | 0 2110 |
| PCU3O8 | 0 7370 |
| PIN | 0 4903 |
| PIN000 | 1 0 |
| PINLEN | 2 54 |
| POW | 2 830 |
| PRDIST | 399 99 |

**Table 4. (continued)**

| Variable name | Operating condition input |
|---|---|
| PRINC | 2 25 |
| PRTTIM | 0 9999 |
| RFACT | 5 000 |
| RHOAVE | 9 903 |
| RMAX | 1000 0 |
| RMIN | 0 0 |
| RPM | 3 0 |
| RUN | 400 0 |
| RWASTE | 200 0 |
| SDEN8 | 1300 0 |
| SH2OM8 | 47 45 |
| SHETIM | 180 0 |
| SHNOM8 | 40 08 |
| SIZE | 0 5 |
| SLOTLM | 3 810 |
| SPAREA | 1 0 |
| STGLEN | 25 4 |
| TDIG | 350 0 |
| TEMP | 108 0 |
| TFILL | 360 0 |
| TH2OC | 4 00 |
| THNO3C | 0 0 |
| TK | 0 9888 |
| TMRFED | 37 67 |
| TMRSST | 12 05 |
| TOL | 0 001 |
| TRCT | 2 0 |
| TTRAN | 10 0 |
| V0(I) | 4 8 @ I = 1, 8 00 @ I = 2    9 |
| ZNOPT3 | 1 |
| ZNOPT7 | 1 |
| ZNOPTA | 1 |
| ZNOPTD | 1 |
| ZNOPTP | 1 |

# 5. CRITICAL VARIABLES

Of the 83 different variables input to the code, only 12 were considered to be significantly questionable as to their assigned values. Nine of the 12 variables in question were chosen for more detailed analysis, using fractional factorial design techniques.[16] The three variables not included in the analysis either were considered to have little or no effect on the results of the model or were encompassed by the other variables. The nine variables chosen for more detailed analysis and their value ranges are listed in Table 5. A 12-run

**Table 5. Fractional factorial design variables**

| Variable name | Low value | Standard condition | High value |
|---|---|---|---|
| BAKMIX(I) | 0 0 | 0 07 | 0 50 |
| CONREL | 0 0 | 100 0 | 500 0 |
| DP | $1 \times 10^{-6}$ | $1 \times 10^{-3}$ | $1 \times 10^{-3}$ |
| FFINES | 0 0 | 0 06 | 1 0 |
| POW | 1 0 | 2 83 | 3 7 |
| RMAX | 500 0 | 1000 0 | 2000 0 |
| RWASTE | 100 0 | 200 0 | 500 0 |
| SPAREA | 1 0 | 1 0 | 10 0 |
| TK | 0 1 | 0 9888 | 2 0 |

screening design was chosen for the analysis. The values for each of the nine variables in each run of the screening design are indicated by a plus sign for a high value and a minus sign for a low value in Table 6.

**Table 6. Variable assignment schedule for 12-run screening design[a, b]**

| Run | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ | $X_{10}$ | $X_{11}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | + | + | – | + | + | + | – | – | – | + | – |
| 2 | + | – | + | + | + | – | – | – | + | – | + |
| 3 | – | + | + | + | – | – | – | + | – | + | + |
| 4 | + | + | + | – | – | – | + | – | + | + | – |
| 5 | + | + | – | – | – | + | – | + | + | – | + |
| 6 | + | – | – | – | + | – | + | + | – | + | + |
| 7 | – | – | – | + | – | + | + | – | + | + | + |
| 8 | – | – | + | – | + | + | – | + | + | + | – |
| 9 | – | + | – | + | + | – | + | + | + | – | – |
| 10 | + | – | + | + | – | + | + | + | – | – | – |
| 11 | – | + | + | – | + | + | + | – | – | – | + |
| 12 | – | – | – | – | – | – | – | – | – | – | – |

[a] $X_1$ = CONREL, $X_2$ = TK, $X_3$ = DP, $X_4$ = SPAREA, $X_5$ = BAKMIX(I), $X_6$ = RWASTE, $X_7$ = POW, $X_8$ = FFINES, $X_9$ = RMAX, $X_{10}$ = Dummy, $X_{11}$ = Dummy

[b] A plus sign indicates a high value, a minus sign indicates a low value

The range of the variables in the screening design was set primarily on the basis of maximum and minimum expected values for those variables where information was available. The high and low values for TK and POW were set based on operational stability of the code.

The unsteady-state model was initially developed to be used with voloxidized fuel, which involves the dissolution of $U_3O_8$ instead of $UO_2$. The 12-run screening design was done using the $U_3O_8$ dissolution model. The difference between the two dissolution models is not believed to have a significant impact on the results from the screening design.

The response variable for the screening design was the total amount of uranium and plutonium in the dissolver plus any amount leaving with the hulls. The results from the screening design are given in Table 7. The amount of material leaving the dissolver undissolved on the hulls is indicated in the comments section along with the percent material balance closure for the run.

Using dummy variables $X_{10}$ and $X_{11}$, an estimate of the total error in the response variable $s$ due to random errors and interaction effects can be obtained from

$$s = \sqrt{E(\sum_{i=1}^{\delta} \Delta_i^2)/4\delta} \quad . \tag{36}$$

The response error estimate is used to determine the confidence-interval width $Q$ for the main effect estimates by

$$Q = \pm t_v s / \sqrt{E/4} \quad . \tag{37}$$

Selected values for $t_\nu$ are given in Appendix D. Since the data used in this analysis are actually generated by a computer program, it is prudent to expect no random errors in replicate runs. Therefore, the response error estimate $s$ includes only interaction effects.

For a 95% confidence level with 11 degrees of freedom, the estimated confidence interval width $Q$ is 35,281. The confidence intervals for the factors in the screening design are given in Table 8. Refer to Table 2 for the definitions of the factors used hereafter.

Since all the factors in Table 8 except CONREL and FFINES include zero in the confidence interval, it can be stated that the remaining factors have no significant effect on the response variable at the 95% confidence level. This is also true for the 90% confidence level. Both CONREL and FFINES are related to the appearance of fuel particles in the dissolver solution. Of those factors deemed to be insignificant, the one most nearly significant, according to this analysis, SPAREA, is related to particle surface area.

This analysis has shown that increasing the particle release rate (CONREL) and the fraction of fines in the feed (FFINES) decreases heavy metal inventories and loss from the dissolver. It may also be stated that the heavy metal inventory may be decreased by increasing the effective particle surface area, although the analysis does not necessarily support this conclusion. Generally, these results indicate that, over the range studied, the factors having to do with fuel particles have the most significant effects on heavy metal inventory.

**Table 7. Results from 12-run screening design[a]**

| Run No. | Response[b] | CONREL | TK | DP | SPAREA | BAKMIX(I) | RWASTE | POW | FFINES | RMAX | $X_{10}$ | $X_{11}$ | Percent material balance closure/comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7,301 | + | + | – | + | + | + | – | – | – | + | – | 103 3/no loss |
| 2 | 18,518 | + | – | + | + | + | – | – | – | + | – | + | 103.5/no loss |
| 3 | 1,876 | – | + | + | + | – | – | – | + | – | + | + | 100.1/no loss |
| 4 | 23,114 | + | + | + | – | – | – | + | – | + | + | – | 96 0/1288 g loss |
| 5 | 6,924 | + | + | – | – | – | + | – | + | + | – | + | 98.9/571 g loss |
| 6 | 7,453 | + | – | – | – | + | – | + | + | – | + | + | 96.9/no loss |
| 7 | 115,780 | – | – | – | + | – | + | + | – | + | + | + | 99 9/49377 g loss |
| 8 | 13,634 | – | – | + | – | + | + | – | + | + | + | – | 102 3/445 g loss |
| 9 | 2,540 | – | + | – | + | + | – | + | + | + | – | – | 104.8/no loss |
| 10 | 1,214 | + | – | + | + | – | + | + | + | – | – | – | 100 3/no loss |
| 11 | 114,623 | – | + | + | – | + | + | + | – | – | – | + | 100 8/48922 g loss |
| 12 | 115,780 | – | – | – | – | – | – | – | – | – | – | – | 99.9/49377 g loss |
| Total | 428,757 | | | | | | | | | | | | |
| Average Response | 35,730 | | | | | | | | | | | | |
| | | 64,524 | 156,378 | 172,979 | 147,229 | 164,069 | 259,475 | 264,724 | 33,641 | 180,510 | 16,158 | 265,274 | |
| | | 364,233 | 272,379 | 255,778 | 281,528 | 264,288 | 169,282 | 164,033 | 395,116 | 248,247 | 259,599 | 163,583 | |
| Difference | | –299,709 | –116,001 | –82,799 | –134,299 | –100,619 | 90,193 | 100,691 | –361,475 | –67,736 | –90,440 | 101,591 | |
| Main effect | | –49,951 | – 19,333 | –13,800 | –22,383 | –16,770 | 15,032 | 16,782 | –60,246 | –11,289 | –15,073 | 16,932 | |

[a] A plus sign indicates a high value a minus sign indicates a low value $\Sigma+$ = sum of plus responses, $\Sigma-$ = sum of minus responses
[b] Total amount of uranium and plutonium in the dissolver plus any amount leaving with the hulls

**Table 8. Confidence intervals for factors in the screening design**

| Factor | 95% confidence interval |
|---|---|
| CONREL | −49,952 ± 35,281 |
| TK | −19,333 ± 35,281 |
| DP | −13,800 ± 35,281 |
| SPAREA | −22,384 ± 35,281 |
| BAKMIX(I) | −16,770 ± 35,281 |
| RWASTE | 15,032 ± 35,281 |
| POW | 16,782 ± 35,281 |
| FFINES | −60,246 ± 35,281 |
| RMAX | −11,289 ± 35,281 |
| $X_{10}$ | −15,073 ± 35,281 |
| $X_{11}$ | 16,932 ± 35,281 |

# 6. HEAVY METAL INVENTORY

The dissolution performance of a fuel depends on several factors and is not necessarily easy to predict. However, for a relatively homogeneous, irradiated, mixed-oxide fuel with $PuO_2$ composition less than ~35% under normal dissolver operating conditions, essentially complete dissolution can be expected in much less than the 4-h residence time the hulls experience in the rotary dissolver.[17,18] Variation of the appropriate parameters in the model can produce a wide variety of operating scenarios.

Several cases were outlined for study using the unsteady-state model. The primary goal of the study was to determine the maximum heavy metal holdup for both normal and abnormal operating conditions. Normal operating conditions are defined as those at which complete dissolution or removal of the fuel from the pins in the dissolver occurs. Under abnormal operating conditions, undissolved fuel is assumed to exit the dissolver with the hulls and/or accumulate in the drum in an eventually detectable manner.

## 6.1 Normal Operating Conditions

Definition of the terms for normal operating conditions was initially taken to be the same as given in Table 4. A summary of the output data from the code at these conditions is given in Appendix B. Please refer to Table 2 for definitions of all parameter names. The predicted U+Pu inventory at normal, or standard, operating conditions was ~12.1 kg. The parameters in Table 9 were varied individually over the indicated range to determine,

**Table 9. Parameter variation effects on U+Pu inventory relative to standard operating conditions**

| Parameter name | Range | Maximum normal predicted U+Pu holdup (kg) | Parameter value at maximum holdup |
|---|---|---|---|
| FFINES | 0–1.0 | 18.8 | 0 |
| CONREL | 0–600 | 21.0 | 0 g/min |
| SPAREA | 0.3–10.0 | 13.7 | 0.3 |
| TEMP | 85–110 | 12.1 | 110 °C |
| BAKMIX(I) | 0.0–0.5 | 12.1 | 0 and 0.5 g(solution)/g(hulls) |
| TH2OC | 1.0–16.0 | 12.35 | 16 kg/h |
| RWASTE | 1.0–800 | 12.9 | <50 μm |
| TK | 0.05–2.0 | 13.6 | 0.05 |
| RPM | 0.1–10 | 12.1 | 10 rpm |
| SHETIM | 10–180 | 46.6 | 40 min |
| RFACT | 0.5–50 | 21.5 | 0.5 |
| BASECT | 15–180 | 17.3 | 130.0 min |
| FLAPTM | 0–17 | 14.0 | 10 min |
| SLOTLM | 1.25–7.0 | 12.0 | <7 cm |

more precisely, their effect on the model's predicted U+Pu holdup relative to standard conditions. Parameter values were not varied to the extent of violating the assumption of complete dissolution or release of the fuel from the pins in the dissolver with no fuel leaving undissolved on the hulls. The effects of varying these parameters are further described in the text and figures that follow. A maximum normal heavy metal inventory of ~46.6 kg was predicted by variation of SHETIM. Other parameters indicating a potential for significant quantities of heavy metal holdup were CONREL, FFINES, FLAPTM, BASECT, RFACT, TK, and SPAREA. Plots of the values of each of these parameters vs predicted U+Pu inventory are given in Figs. 8 through 15.

The effect of SHETIM on inventory is related to the maximum number of complete shearing periods attainable in the specified run time and frequency. With a frequency of one assembly every 180 min and a run time of 400 min, a maximum of three complete 40-min shearing periods is attainable. Longer shearing periods would not allow the completion of the third fuel assembly in 400 min.

Decreasing the values of both CONREL and FFINES increases the heavy metal inventory in the dissolver. The reason for this is that fewer particles are available to flow from the dissolver to the digester tanks. Varying the particle size ratio, SPAREA, has the effect of changing the available area for particle dissolution. For small values of SPAREA, particle dissolution decreases to a relatively low level, rapidly increasing heavy metal inventories due to the accumulation of slowly dissolving particulates in the drum. At values of SPAREA $<0.3$, fuel exits the drum undissolved with the hulls.

The effect of FLAPTM on inventory is similar to that of SHETIM in that it is related to the number of complete flapper valve transfer cycles attainable in a specified run time. It also appears to be influenced by the quantity of material transferred each cycle. The larger the amount of fuel in a transfer, the less that will be dissolved due to depletion of the acid in the stage.

The effect of BASECT on inventory appears to be a direct function of the quantity of material present in a stage and transferring between stages during a specified run time. As BASECT increases, more material accumulates in the dissolver due to fewer solid transfers out of the dissolver over a set period of time. This effect reaches a maximum at ~130 min, probably due to interrelated effects from reaction rates, backmixing, and particle release in stages nearer the product outlet.

The effect of RFACT on inventory is relatively straightforward. As RFACT decreases and less material reacts, then less material is available to flow from the dissolver in the product stream, which implies that more material remains in the dissolver either in the pins or as loose powder.

Decreasing the value of flow equation parameter TK has the effect of slowing the flow of liquid through the dissolver. Lower rates of liquid flow lead to less material being removed from the dissolver and therefore higher heavy metal inventories.

The conditions producing the estimated maximum U+Pu inventory for each significant parameter from Table 9 were combined (Table 10) in an effort to determine the maximum normal heavy metal inventory resulting from synergistic effects. Based on the parameter values in Table 10, an estimated maximum normal U+Pu inventory of 145.7 kg was predicted. If the terms relating to physical operation of the dissolver and shear (BASECT, TK, SHETIM, and FLAPTM) are reset to their standard values, the predicted U+Pu inventory is 65.5 kg.

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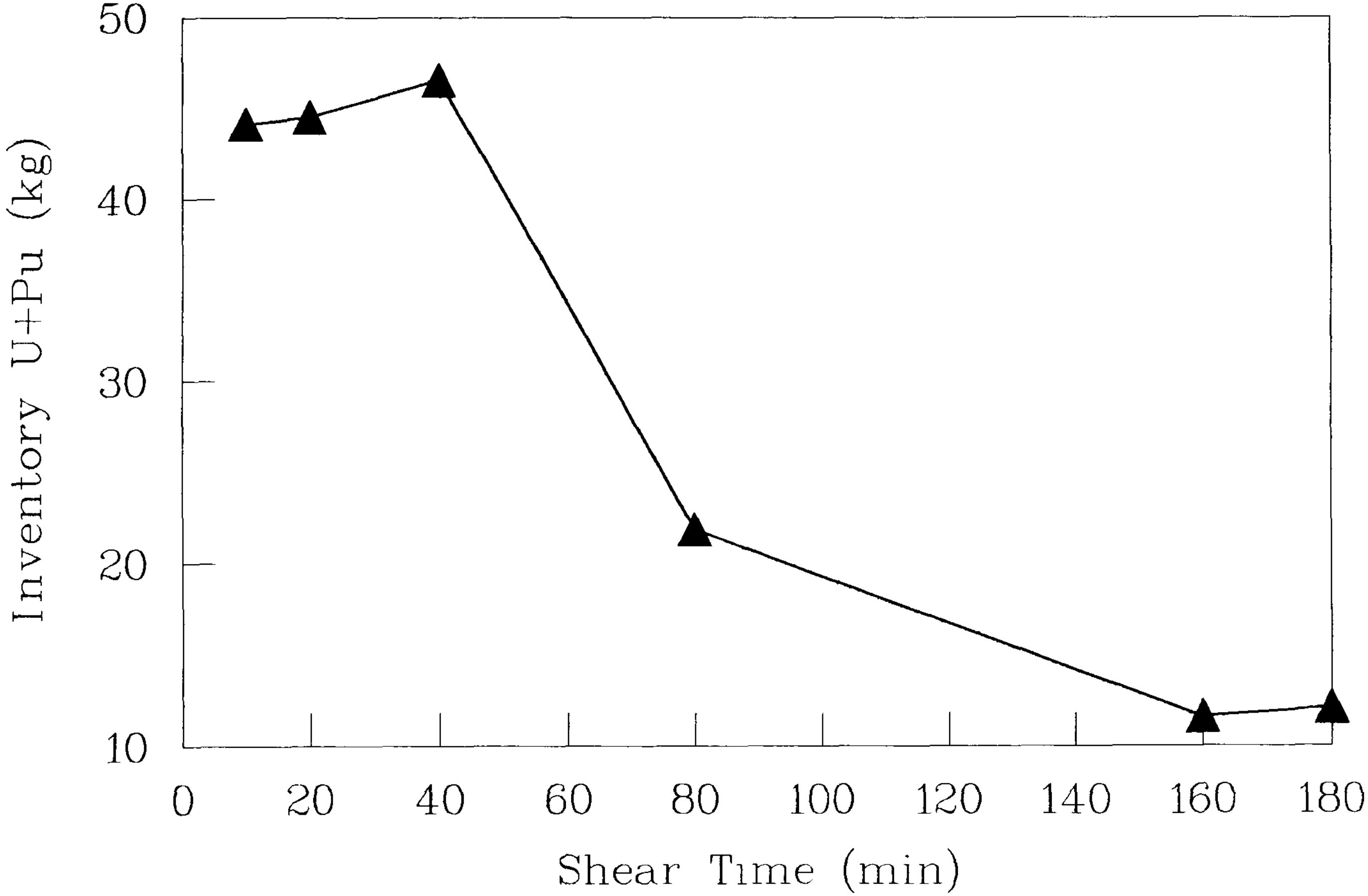


Fig. 8 Shear time vs inventory U+Pu

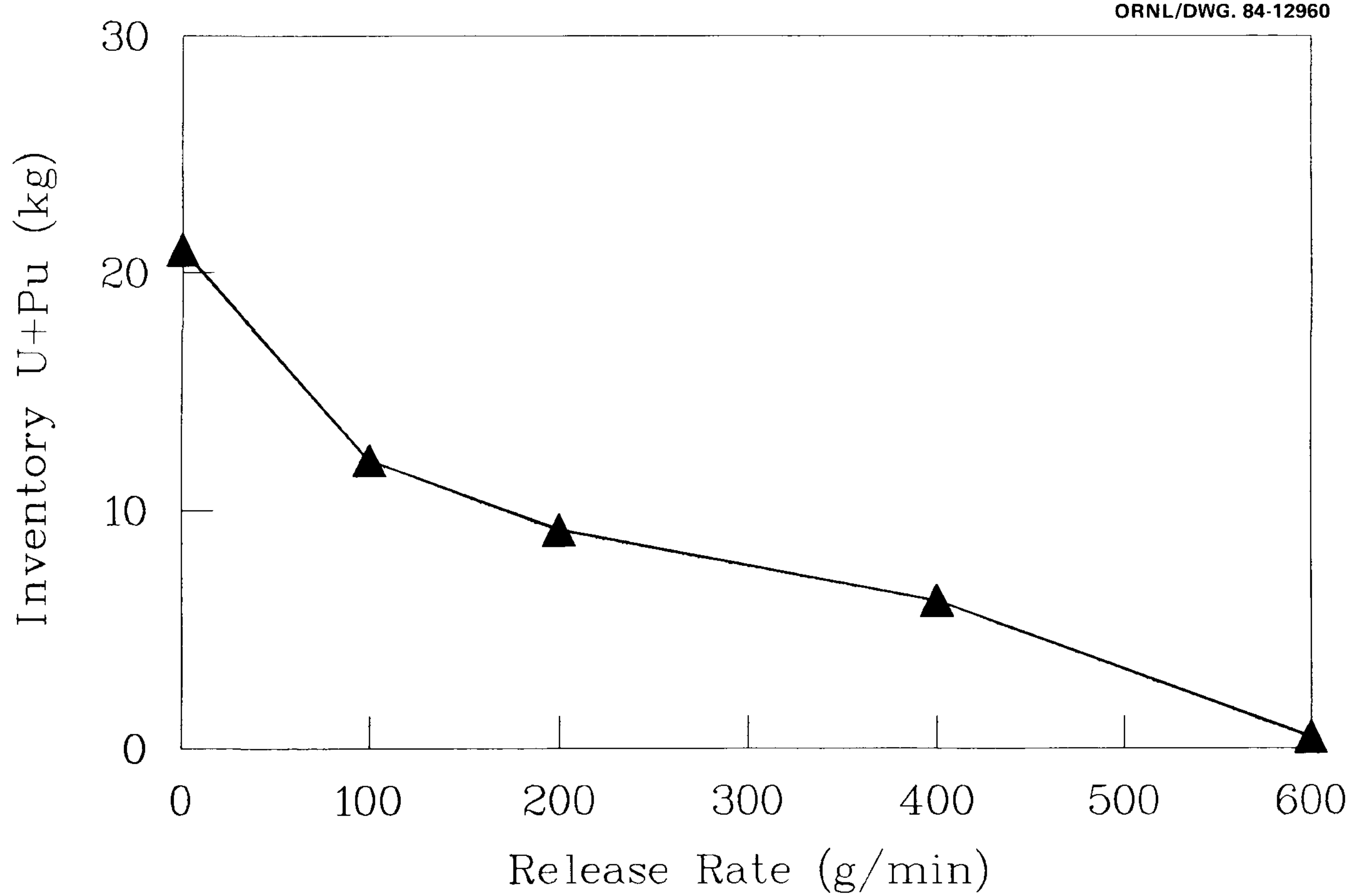


Fig. 9. Release rate vs inventory U+Pu

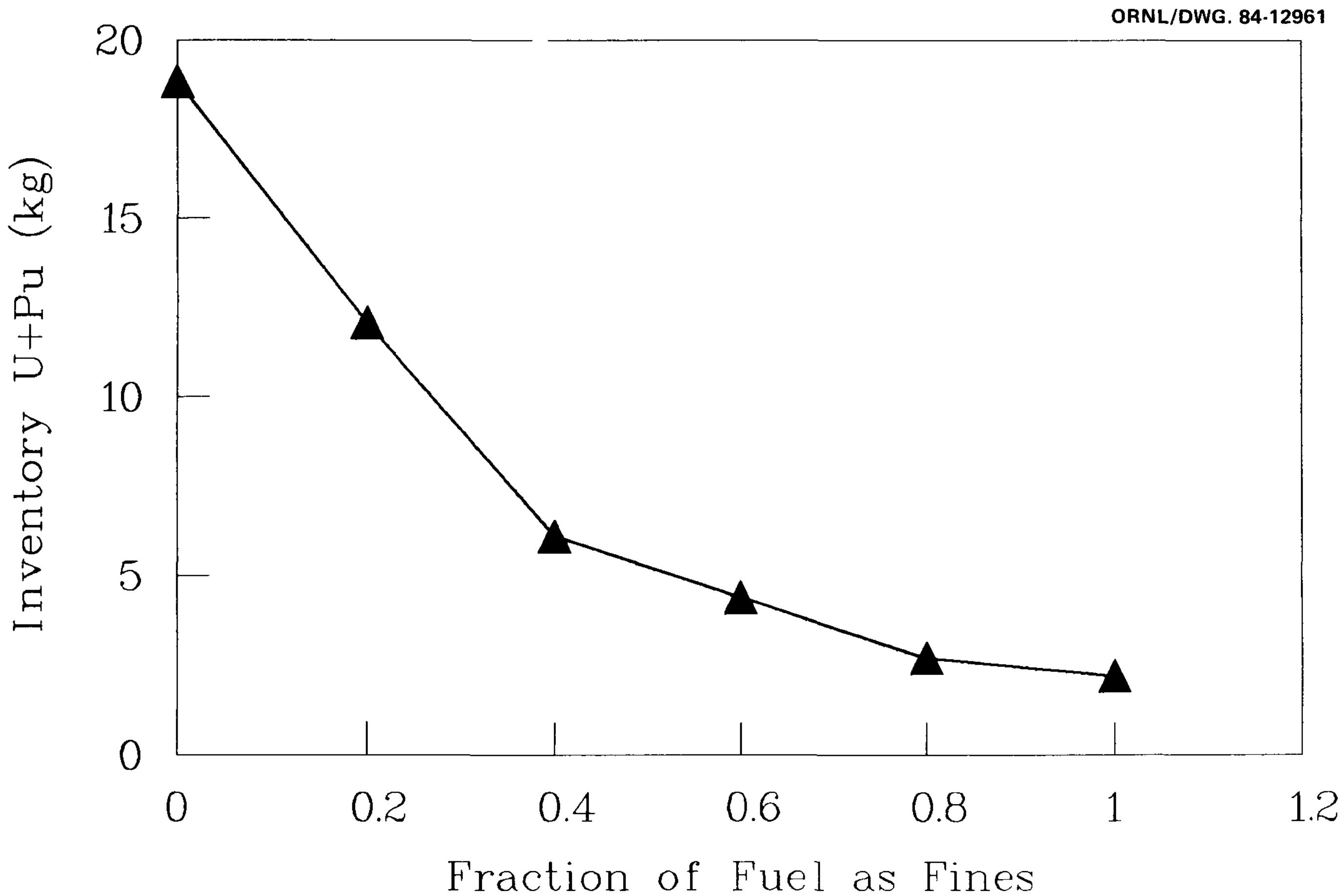


Fig. 10. Fraction of fuel as fines vs inventory U+Pu

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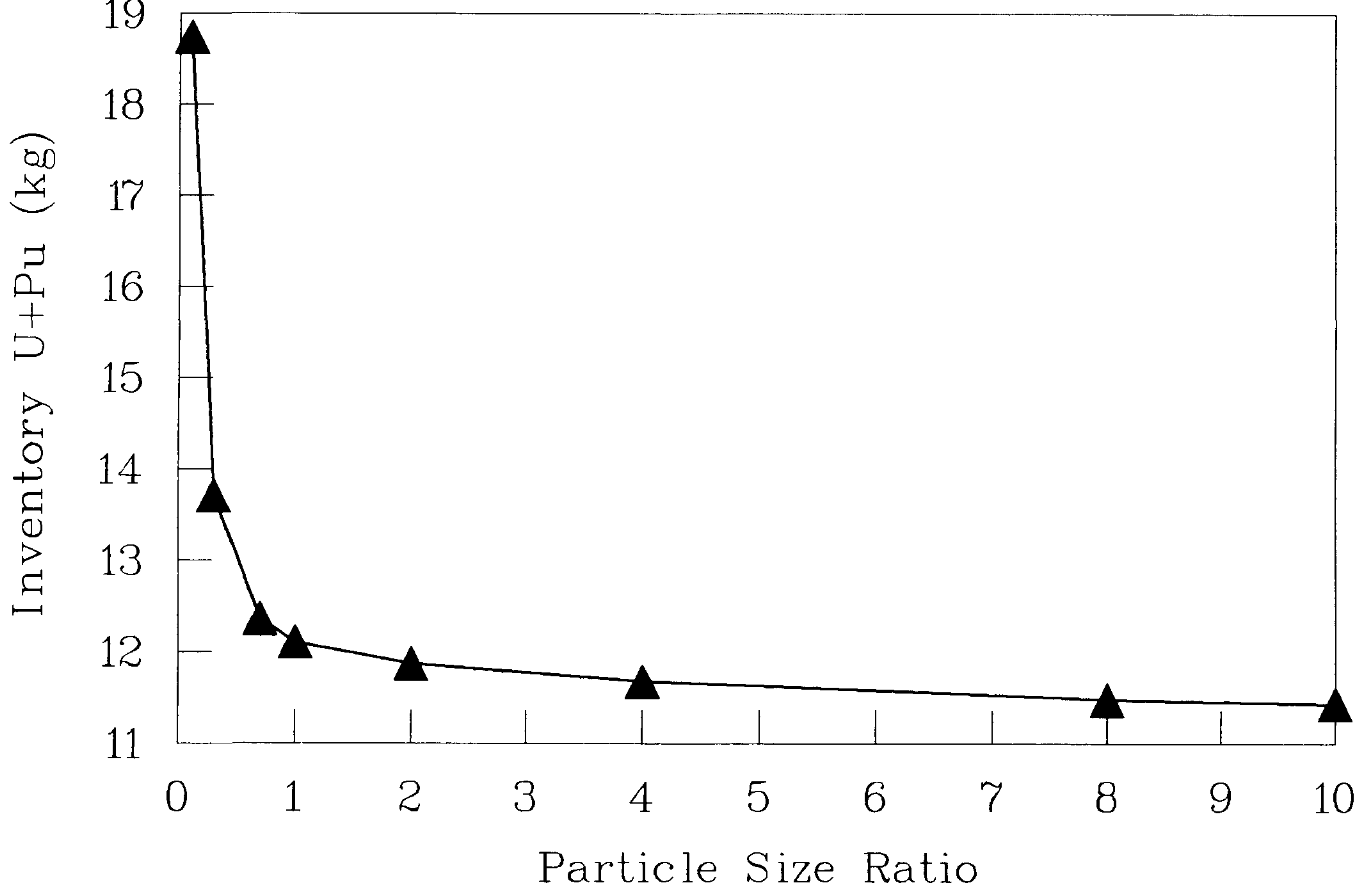


Fig. 11. Particle size ratio vs inventory U+Pu

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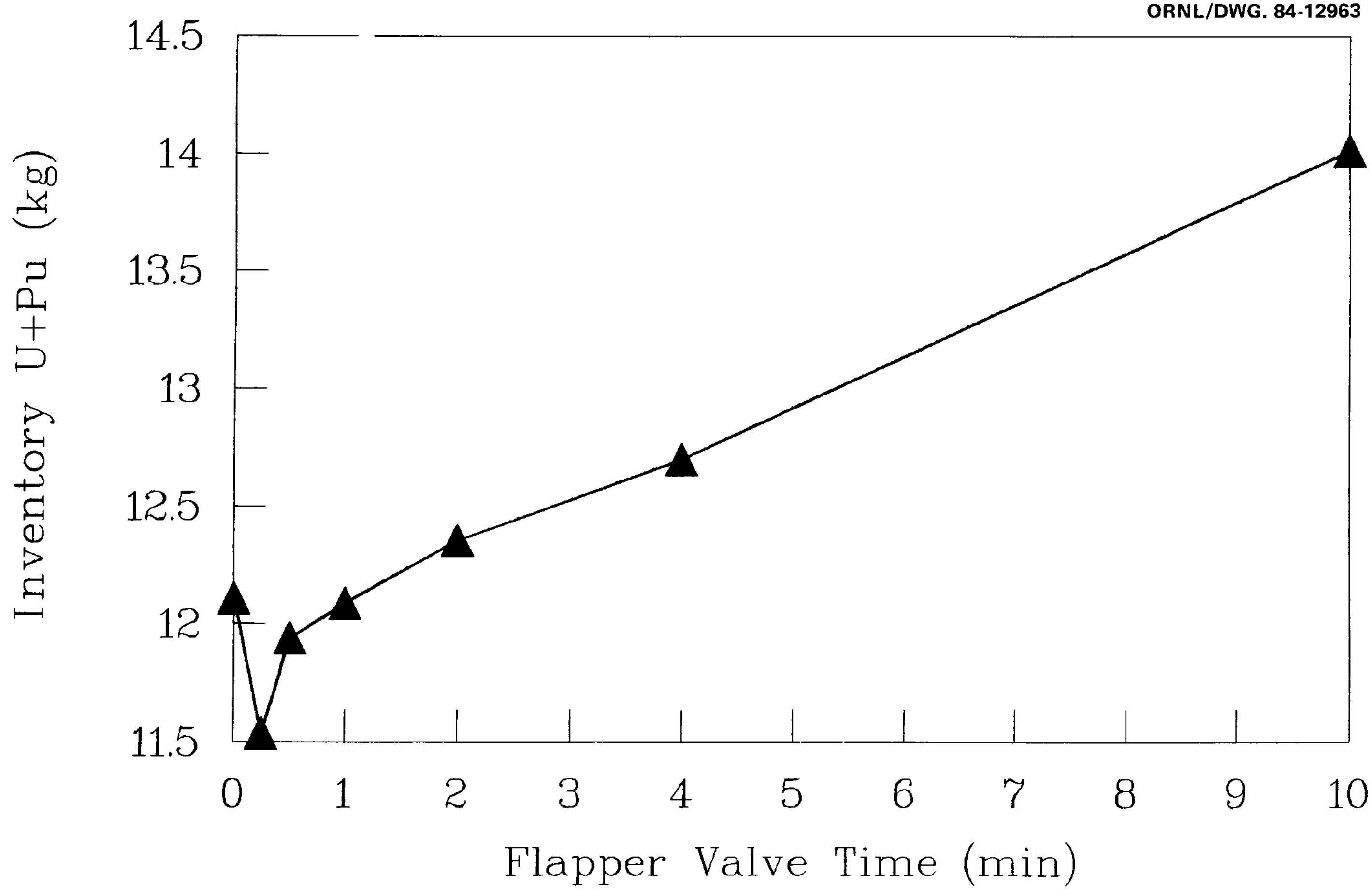


Fig. 12. Flapper valve time vs inventory U+Pu

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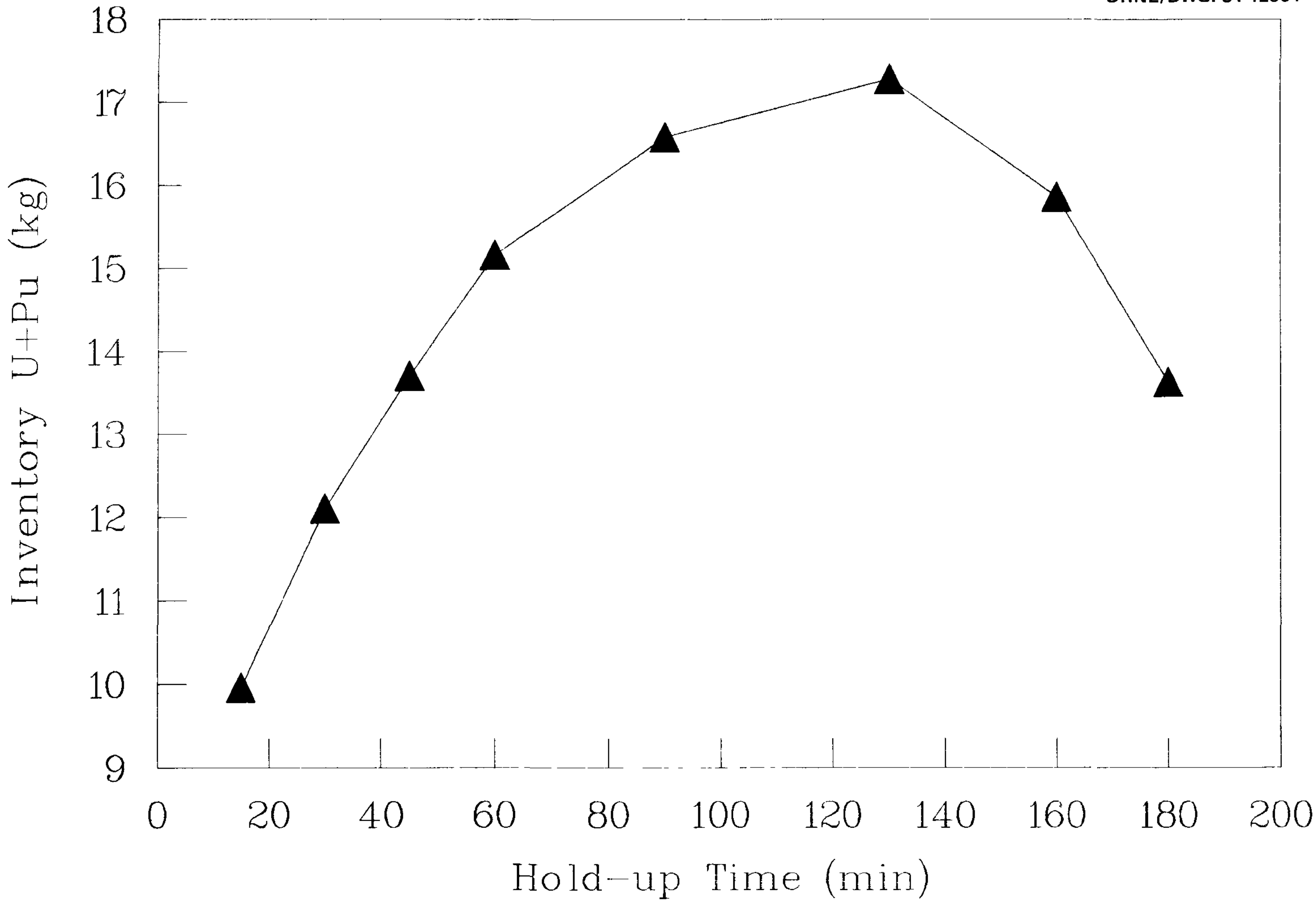


Fig. 13. Hold-up time vs inventory U+Pu

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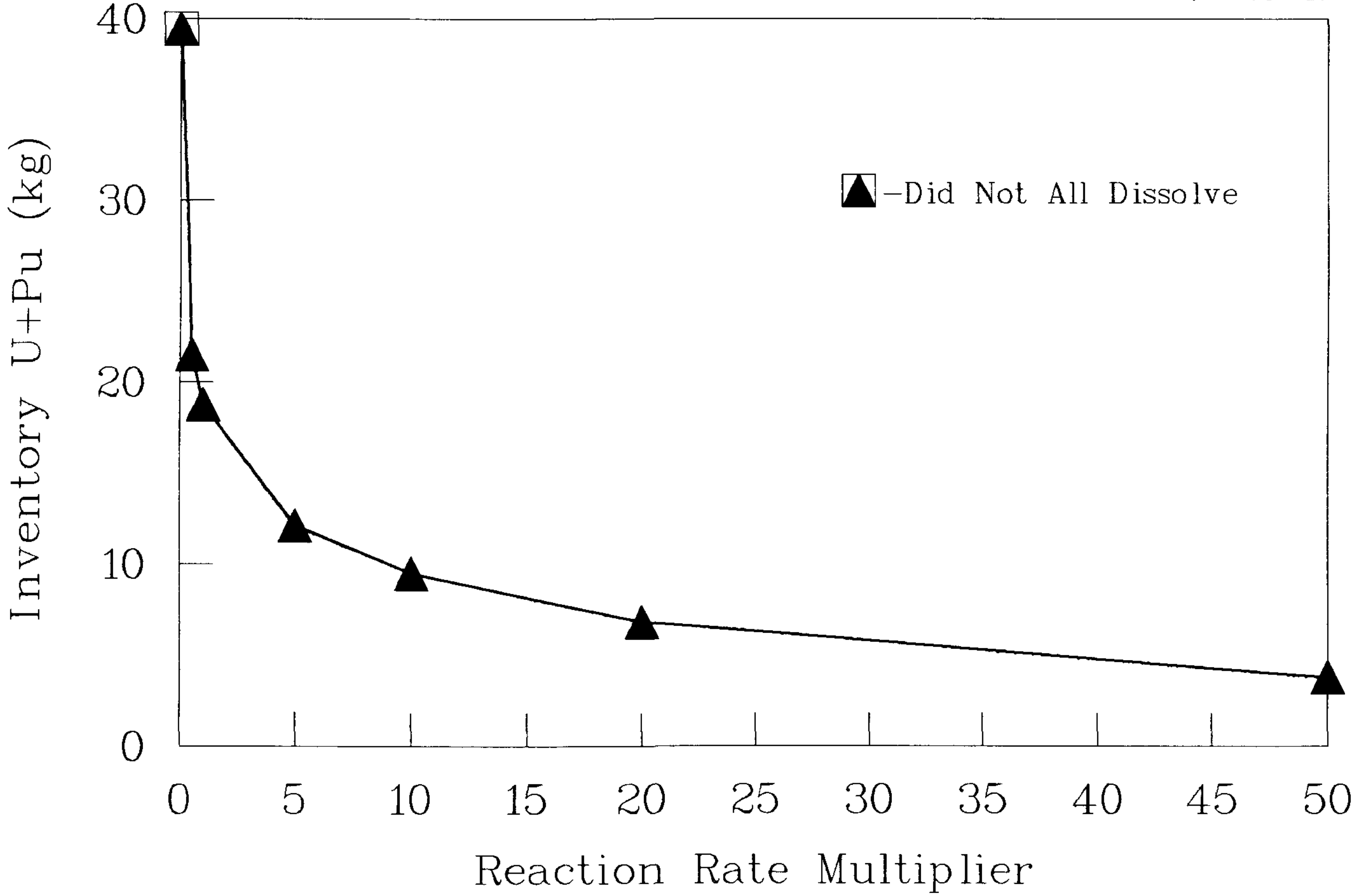


Fig. 14. Reaction rate multiplier vs inventory U+Pu

ORNL/DWG. 84-12966

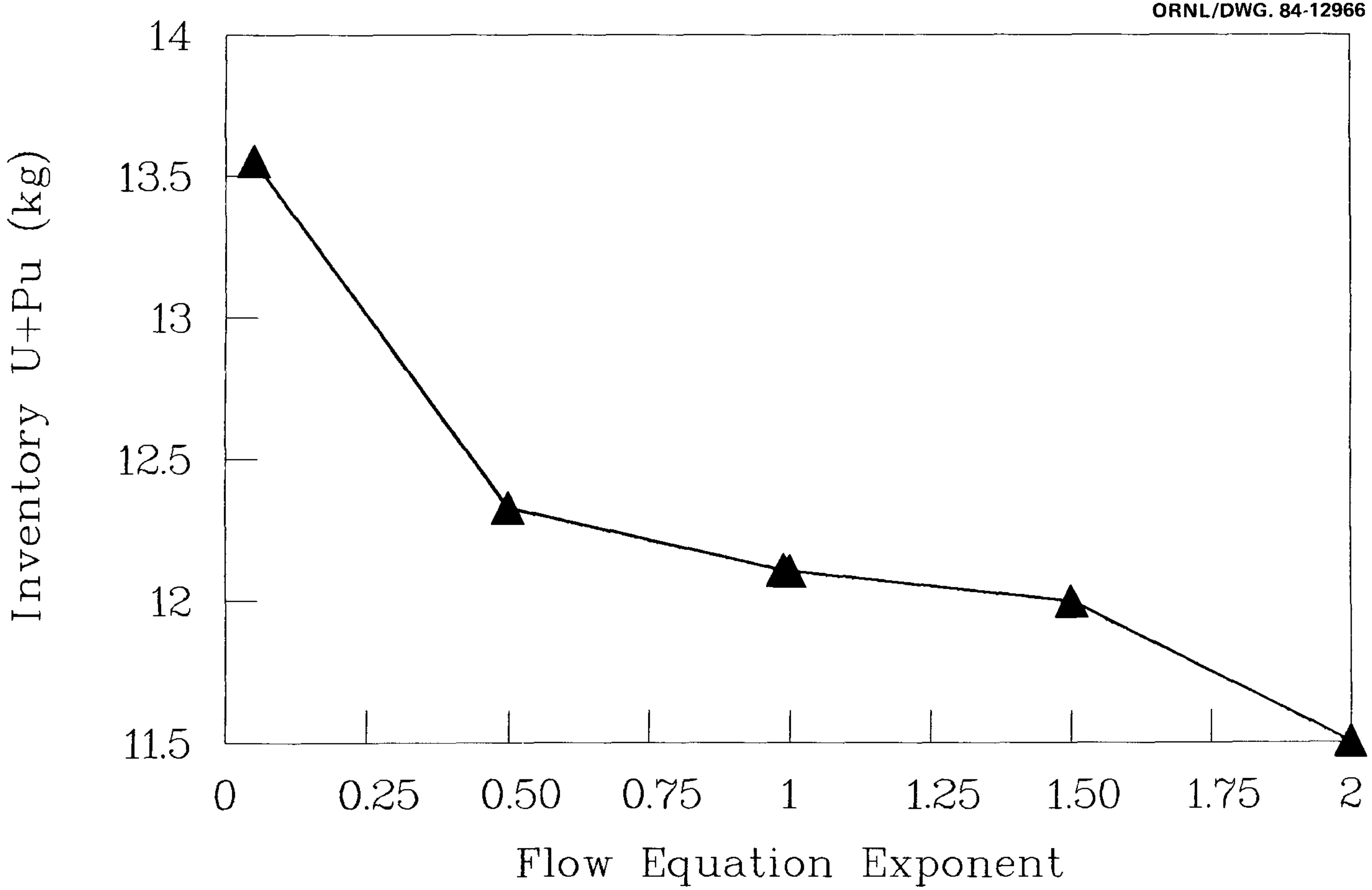


Fig. 15. Flow equation exponent vs inventory U+Pu

**Table 10. Parameter values in exception to standard conditions yielding the estimated maximum normal U+Pu inventory**

| Parameter name | Value |
|---|---|
| TK | 0.05 |
| RFACT | 0.5 |
| BASECT | 130 min |
| CONREL | 0 g/min |
| FFINES | 0 |
| FLAPTM | 10 min |
| SHETIM | 40 min |
| SPAREA | 0.3 |

These run conditions allow fuel to exit the dissolver with the hulls and therefore violate the assumptions of normal operation. However, this level of inventory represents the maximum inventory attributable to uncertainty in the parameters in the dissolver for which few data exist. If we include the effects of SHETIM on inventory, the predicted heavy metal inventory is 98.8 kg.

It is apparent that combination and variation of some of the parameters in Table 10 would create very unlikely situations and extremely high inventories for longer run times. For example, if fuel in pins (FFINES = 0) is continuously fed to the dissolver and is not allowed to transfer (large BASECT), react (RFACT = 0), or be released (CONREL = 0), then the heavy metal inventory will also continually increase. It is assumed here that such a situation would be detected within the 400-min run time of each case and has therefore not been explored with regard to inventory buildup for run times >400 min. However, for the 400-min run described, U+Pu inventories as high as 192.7 kg have been predicted for the assumed worst-case conditions.

## 6.2 Abnormal Operating Conditions

Abnormal operating conditions can result from a variety of scenarios. All abnormal operating conditions are eventually detectable and can be recovered from, assuming that reliable instrumentation and controls are provided. Abnormal heavy metal inventories in the dissolver basically arise due to problems in solids flow, liquid flow, or dissolution of the fuel. If it is assumed that no fuel dissolves or is released from the fuel pins and if all other conditions are normal, then the maximum inventory of U+Pu for a 0.5-t/d dissolver is ~83.3 kg, based solely on continuous solids flow and throughput. If >4 h of holdup or intermittent solids feed are allowed, the inventory increases proportionately with holdup time and number of complete solids feed cycles.

The maximum inventory of U+Pu in the drum for abnormal operating conditions, with the parameter values in Table 11 in exception to the standard conditions in Table 4,

**Table 11. Parameter values in exception to standard conditions yielding the estimated maximum abnormal U+Pu inventory**

| Parameter name | Value |
|---|---|
| CONREL | 0 g/min |
| FFINES | 0 |
| FLAPTM | 10 min |
| SHETIM | 40 min |
| SPAREA | 0.3 |
| RFACT | 0.0 |
| BASECT | 55.0 min |
| TK | 0.05 |

is 182.9 kg. It is very difficult to believe that the conditions described in Table 11 could ever occur due to the level of agitation in the rotary dissolver and the reactivity of $UO_2$ in nitric acid. If the fuel is released from the pins as a result of agitation or reaction, less inventory can be expected in the drum due to flow of material from the dissolver in the product stream.

### 6.3 Incredible Conditions

Several scenarios can be imagined in which catastrophic equipment failures could potentially lead to excessive U+Pu inventories in the dissolver; however, the probability of occurrence and nondetection of such failures is very low. One such failure has to do with limiting the liquid flow through the dissolver. If it is assumed that all conditions except liquid outflow are normal, very large heavy metal inventories, as indicated in Fig. 16, can be achieved. In all of the high-inventory points in Fig. 16, the volume of the acid feed stage was unrealistically large. If it is further assumed that the liquid flow to the feed stage can leak into the housing through a breach in the drum wall, then the inventories in Fig. 16 become slightly more believable. However, it is still unrealistic to assume that the cessation of liquid flow from the drum would go undetected.

ORNL/DWG. 84-12967

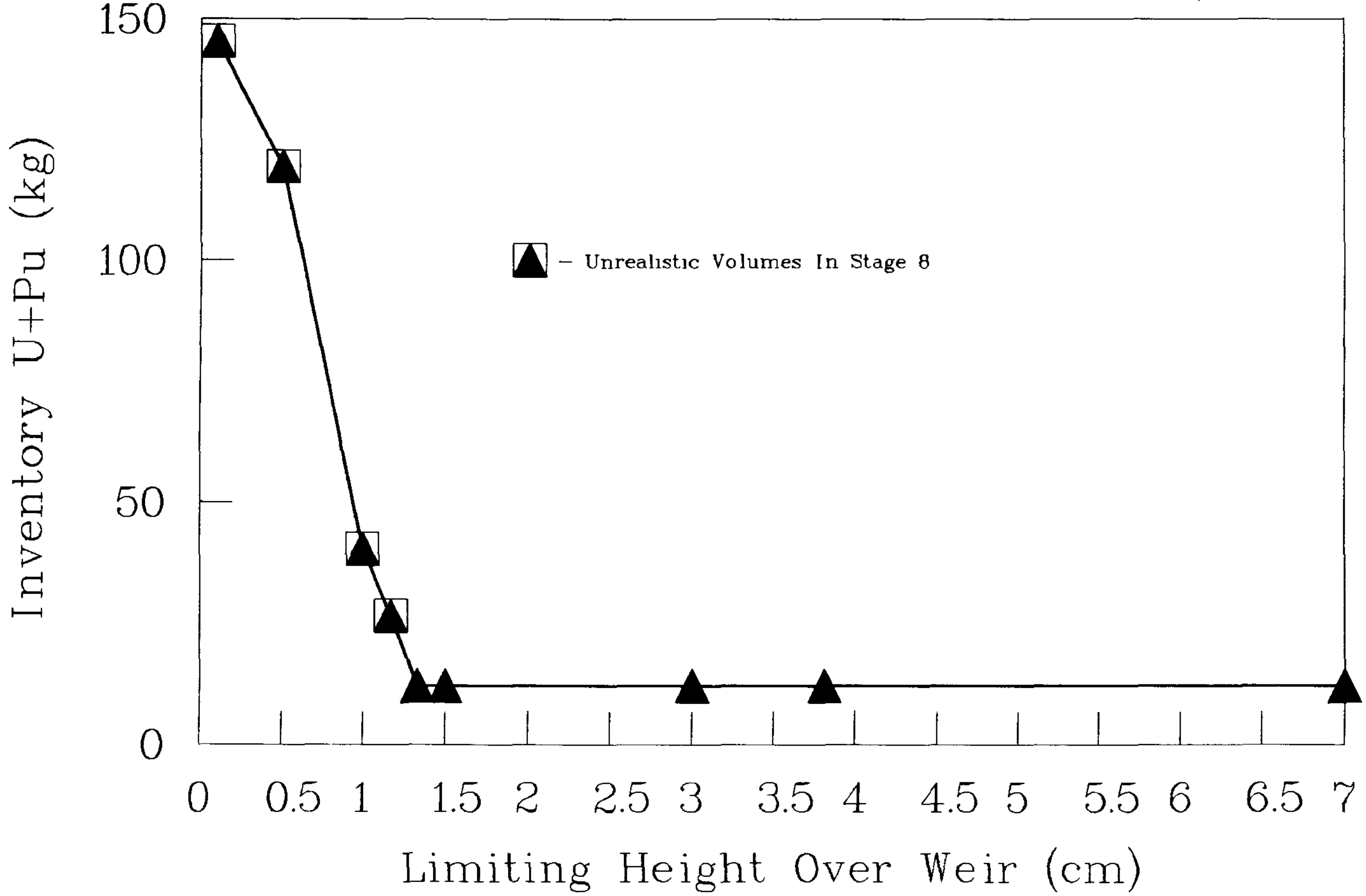


Fig. 16. Limiting height over weir vs inventory U+Pu

# 7. INTERMITTENT FEED

Solids feed to the dissolver is affected by two levels of discontinuity: (1) a primary effect from changing of fuel elements in the shear, and (2) a secondary effect due to the cyclic operation of the isolation valves between the shear and dissolver. Both of these effects have a significant impact on heavy metal inventory, as was shown in Sect. 6. Intermittent feed also has a significant effect on the concentration profiles of material in the dissolver. Concentration profiles for a case in which the only difference from standard conditions was intermittent feed of solids for 40 min out of every 180 min are given in Appendix C. Comparison of the stagewise profiles in Appendix B, at standard conditions, with those in Appendix C shows the large fluctuations in stagewise concentrations experienced during intermittent feeding. However, in both cases, any concentration fluctuations are smoothed out in the digester tanks. Fluctuations of the stagewise concentrations of heavy metals in the dissolver appear to be important only in choosing the proper concentration of excess soluble poison. Other considerations pertinent to intermittent solids feed are related to stagewise acid requirements. A sufficient quantity of $HNO_3$ must be available in each dissolver stage to support fuel dissolution and avoid plutonium polymerization. Acid deficiency does not appear to be a problem over the range of intermittent solids feed times studied (Table 12).

**Table 12. Intermittent solids feed times studied for a 180-min total cycle time**

| Feed time (min) | Time between feedings (min) |
|---|---|
| 10 | 170 |
| 20 | 160 |
| 40 | 140 |
| 80 | 100 |
| 160 | 20 |
| 180 | 0 |

# 8. PARTICLE SIZE DISTRIBUTION

The particle size distributions given for the runs in Appendixes B and C are fairly typical. The maximum particle size in stage 1 is indicative of a split in the particle size distribution, where the larger particles transfer with the hulls and the smaller particles flow with the liquid. The size distributions for the remaining stages reflect the disappearance of various sizes of particles. The disappearance of certain size groups is a net result of reaction and particle size group transfers. The shape of the size distributions continually changes as the chemical reactions proceed and particles of various sizes transfer into and out of a stage.

# 9. DIGESTER TANKS

The digester tanks receive liquid product and suspended particulates from the dissolver. The quantity of particulate entering the digester tanks is influenced by the same parameters that influence the inventory in the dissolver. A summary of the effect of variation of various parameters in the model on the quantity of fuel particles flowing to both digester tanks is shown in Table 13. All parameter names are defined in Table 2.

**Table 13. Parameter variation effects on the quantity of fuel flowing to the digester tanks relative to standard conditions for ~400 min of operation**

| Parameter name | Range of variation | Maximum fuel to digesters (kg) | Parameter value at maximum fuel to digester |
|---|---|---|---|
| FFINES | 0–1.0 | 13.5535 | 1.0 |
| CONREL | 0–600 | 5.325 | 600 g/min |
| SPAREA | 0.3–10.0 | 18.685 | 0.3 |
| TEMP | 85–110 | 3.3156 | 110 °C |
| BAKMIX(I) | 0.0–0.5 | 3.3787 | 0.5 g(solution)/g(hulls) |
| TH20C | 1.0–16.0 | 4.089 | 16.0 kg/h |
| RWASTE | 1–800 | 13.382 | 800 μm |
| TK | 0.05–2.0 | 3.4474 | 2.0 |
| RPM | 0.1–10 | 4.5839 | 0.1 rpm |
| SHETIM | 10–180 | 13.612 | 10 min |
| RFACT | 0.5–50 | 17.4 | 0.5 |
| BASECT | 15–180 | 3.79 | 180 min |
| FLAPTM | 0–17 | 5.2367 | 17.0 min |
| SLOTLM | 1.25–7.0 | 3.3108 | 1.50 cm |

Because of the large liquid holdup in each digester tank, concentration fluctuations in the dissolver product stream do not generally adversely affect tank concentrations. However, conditions can be described in which the heavy metal concentration in the digester tanks is abnormally low. These conditions involve delaying solids feed to the dissolver, resulting in the accumulation of only acid and water in the digester. Such conditions can occur when using intermittent solids feed if the beginning of the digester fill cycle does not correspond with the beginning of the shear feed cycle. A case was run in which solids feed to the dissolver was delayed 140 min, using an intermittent solid feed cycle of 40 min on, 140 min off. Digester tank concentrations at these conditions as well as standard conditions are listed in Table 14. This type of operation should be avoided, since it would require the handling of off-specification material.

**Table 14. Digester tank concentrations due to delayed solids feed to the dissolver**

| Component | Digester tank concentration with delayed feed (g/L) | Digester tank concentration with standard conditions (g/L) |
|---|---|---|
| $UO_2(NO_3)_2$ | 128 | 203 |
| $Pu(NO_3)_4$ | 45 | 72 |
| $HNO_3$ | 260 | 209 |
| U+Pu | 117 | 158 |

# 10. DEVELOPMENT CONCERNS AND LIMITATIONS

The dissolution of homogeneous spent fuels occurs fairly uniformly and can be described reasonably well using this model. However, the same spent fuels are likely to contain pockets of plutonium-rich materials, which do not readily dissolve. Such fuels would exhibit preferential dissolution of uranium, leaving a relatively insoluble plutonium-rich residue. The model in its present form does not have the capability for describing preferential dissolution.

Variation of the operating temperature in the code has no effect on the dissolution rate equations. Changing the operating temperature in the model affects only the solution densities and volumes. The dissolution rates of $UO_2$ at various temperatures and $HNO_3$ concentrations are well known.[19] Little or no data exist for the dissolution of $PuO_2$ and mixed oxides at temperatures other than boiling. Incorporation of temperature dependency rate data would give the code another dimension of flexibility.

The code has not yet been verified by any deliberate experimental dissolution of mixed-oxide fuels in a stagewise continuous manner. Hot-cell experimental data on batch-wise dissolutions that tend to support some of the results presented in this report do exist. However, experimental verification using a continuous rotary dissolver is desirable.

The present particle balance model has very limited provisions for the long-term holdup of specific ranges of particle sizes. Particle holdup in a stage is limited to the cycle time for the stage, since particles either transfer with the hulls or flow with the liquid. Therefore, the particle balance should be modified to allow for indefinite holdup of a specified range of particle sizes, as indicated by Holland et al.[6]

The code has been written for flexibility so that various components may be included for study. One such component not presently in the code is $Gd(NO_3)_3$. Since $Gd(NO_3)_3$ is a relatively inert species, it would simply flow through the system as a diluent. However, its inclusion would provide valuable information on $Gd(NO_3)_3$ losses on the scrap hulls and soluble poison requirements. Inclusion of other components in the model also introduces certain problems. The density correlation used to calculate solution volumes is a function of $UO_2(NO_3)_2$, $Pu(NO_3)_4$, and $HNO_3$. The density correlation already ignores the existence of fission products and insolubles; therefore, the addition of another major component such as $Gd(NO_3)_3$ would further serve to increase the uncertainty in calculated density values.

To more accurately describe the dissolution process, improvements in handling off-gases and evaporation must be included. The model presently employs some very broad assumptions in handling NO and $NO_2$ and makes no attempt to keep track of $I_2$, Kr, Xe, or evaporation. Tracking off-gases such as $I_2$ is important in order to ensure adequate removal from liquid streams. Monitoring evaporation is needed to allow for sufficient stage volume and flows to make up for losses.

The code is currently written to start execution from a set of initial conditions, many of which are internally set. This tends to limit the code's flexibility, since each run must start with the same set of internal conditions. From the standpoint of data output, plots, and run length, it would be desirable to modify the code to run from externally input initial conditions. This would enable extended runs to be studied and allow for the input of more diverse operating conditions.

# 11. CONCLUSIONS

The USSCRD model is a useful tool with which to study rotary dissolver performance under a variety of conditions. The model has not yet been verified by prototypic experimental dissolutions and therefore should not be used for obtaining absolute answers to stagewise concentration questions. However, the model can be used to determine the most likely ranges of concentrations and inventories.

From the many different cases run with the model, it can be concluded that the U+Pu inventory in the dissolver, for conditions in which no fuel exits the dissolver with the hulls, ranges from ~12 to 145 kg. Realistically, inventories are expected to be near the lower end of this range. For conditions in which fuel is allowed to leave the dissolver with the hulls, an estimated maximum U+Pu inventory of 183 kg was predicted. For unrealistic conditions in which no fuel dissolves and liquid flow is severely decreased, heavy metal inventories >150 kg were predicted.

Intermittent solids feed to the dissolver generally results in relatively large variations in stagewise concentrations, but the digester tanks tend to smooth out any fluctuations in the outlet concentrations from the dissolver. The cycle times for the digesters and shear feed should be closely coupled in order to avoid problems with off-specification fuel. The quantity of fines flowing to the digesters was found to be dependent on parameters similar to those that influence the heavy metal inventory in the dissolver.

# 12. ACKNOWLEDGMENTS

The author wishes to thank D. R. Beckwith, a cooperative education engineering student from Clemson University, for running the code and preparing many of the plots in this report. The author also thanks E. D. North and F. E. Weber for informative discussions on dissolver operation.

# 13. NOMENCLATURE

| | |
|---|---|
| $A, G$ | Pseudoconstants in material balance equations; defined in Eqs. (16) and (17) |
| $A_{mix}$ | Total surface area of the particles in the streams to be mixed ($\mu m^2$) |
| $A_{part,k}$ | Surface area of a spherical particle in size group $k$ ($cm^2$) |
| $A_{pin}$ | Reactive area per fuel pin ($cm^2$) |
| $B_i$ | Liquid backmixing flow rate from stage $i$ (L/min) |
| $C_{i,j}$ | Concentration of compound $j$ in stage $i$ at time $t + \Delta t$ (g/L) |
| $C'_{i,j}$ | Concentration of compound $j$ in stage $i$ at a time $t$ (g/L) |
| $D_i$ | $dV_i/dt$ |
| $D_p$ | Average particle cluster diameter (cm) |
| $d$ | Fuel pellet diameter (cm) |
| $E$ | Number of runs in screening design |
| $F_i$ | Liquid flow rate from stage $i$ (L/min) |
| $f$ | Fractional increase in particle surface area due to porous particles |
| $h_c$ | Crest height above weir in liquid flow equation (cm) |
| $k_{i,j}$ | Rate constant for the formation of compound $j$ in stage $i$ [g/(cm² · min)] |
| $M_k$ | Total mass of particles in size group $k$ in all streams to be mixed together (g) |
| $m_{i,j}$ | Mass of component $j$ in stage $i$ (g) |
| $m_{i,HN}$ | Mass of $HNO_3$ in stage $i$ (g) |
| $m_{i,PN}$ | Mass of $Pu(NO_3)_4$ in stage $i$ (g) |
| $m_{i,UN}$ | Mass of $UO_2(NO_3)_2$ in stage $i$ (g) |
| $N_i$ | Number of fuel pins in stage $i$ |
| $n$ | Mole fraction of $PuO_2$ and fission products in the $U_3O_8$-$PuO_2$ solid solution |
| $P_{i,k}$ | Concentration of particles in stage $i$ in size group $k$ (g/L) |
| $P(x)$ | Probability that a particle will have a size between $x$ and $x + \Delta x$ |
| $\bar{Q}$ | $1/\sqrt{2\pi}$ if only dislodged fuel is measured, or $(1/\sqrt{2\pi}) \times$ (fraction of fuel dislodged) $\times$ (weight of fuel)/(weight of fuel + hardware) |
| $Q$ | Confidence-interval width |
| $R'_i$ | Rate of disappearance of fuel from pins in stage $i$ due to reaction (g/min) |
| $R_i$ | Release rate of particles from fuel pins in stage $i$ (g/min) |
| $R_{i,k}$ | Overall rate of disappearance of fuel in particles of size group $k$ (g/min) |
| $r_{mix,k}$ | Average radius of particles in size group $k$ after combining streams ($\mu m$) |
| $r_{new,k}$ | Particle radius for size group $k$ after reaction for a time period $\Delta t$ ($\mu m$) |
| $r_{old,k}$ | Particle radius for size group $k$ before reaction ($\mu m$) |
| $S$ | Ratio of a pseudo particle radius that would account for increased particle surface area due to porosity over actual particle radius |
| $s$ | Response-variable total error estimate |
| $T_d$ | Percent theoretical density of a fuel pellet |

| | |
|---|---|
| $T_{i,m}$ | Total mass of solution in stage $i$ (g) |
| $t$ | Time (min) |
| $T$ | Temperature (°C) |
| $t_\nu$ | Student's $t$ statistic with $\nu$ degrees of freedom at the stated confidence level |
| $V_i$ | Liquid volume in stage $i$ (L) |
| $W_i$ | Mass of fuel transferring from stage $i$ (g) |
| $x$ | Particle size ($\mu$m) |
| $x_m$ | Estimated median of the natural logarithms of particle sizes |
| $z$ | Total number of streams to be mixed |

**Greek symbols**

| | |
|---|---|
| $\alpha_i'$ | Overall fuel pin reaction rate per unit area in stage $i$ [g/(min·cm$^2$)] |
| $\alpha_i$ | Overall fuel particle reaction rate per unit area in stage $i$ [g/(min·cm$^2$)] |
| $\beta_k$ | Number of particles in size group $k$ defined by Eq. (25) |
| $\theta$ | Shear cut angle (deg) |
| $\rho_f$ | Average fuel density (g/cm$^3$) |
| $\pi$ | 3.141592654 |
| $\sigma$ | Estimated standard deviation of the natural logarithms of particle sizes |
| $\Delta_i$ | Main effect of the $i$th dummy factor |
| $\Delta t$ | Length of a time step (min) |
| $\Delta x$ | Small change in particle size ($\mu$m) |
| $(\mu_k)_j$ | Mass of particles in size group $k$ in stream $j$ (g) |
| $\rho_T^\ell$ | Solution density at temperature $T$ (g/cm$^3$) |
| $\delta$ | Number of dummy factors |

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# APPENDIX A

## Program Listing

The computer printout, pages A-2 through A-75, is a listing of the unsteady-state continuous rotary dissolver material balance code, USSCRD. The code contains several comment statements that generally explain its operation. Table A.1 is an example input data file with the associated variable names. Table A.2 presents the job control language file used to execute the code.

```
C       PROGRAM : USSCRD
C       THIS PROGRAM DOES A STAGE-WISE MATERIAL BALANCE FOR A CONTINUOUS
C       ROTARY DISSOLVER.  THE COMPONENTS OF INTEREST ARE UO2(NO3)2,
C       UO2, PU(NO3)4, PUO2, HNO3, H2O, FISSION PRODUCTS(FP), AND
C       FP(NO3)3.39.  THE REACTION EQUATIONS ARE:
C               UO2+(8/3)HNO3=UO2(NO3)2+(2/3)NO+(4/3)H2O
C                       FOR HNO3<10M
C               UO2+4(HNO3)=UO2(NO3)2+2(NO2)+2(H2O)
C                       FOR HNO3>=10M
C               PUO2+4(HNO3)=PU(NO3)4+2(H2O)
C               FPO1.1776+2.3552(HNO3)=FP(NO3)2.3552+1.1776(H2O)
C
C        *******************************************************************
C       ********************************************************************
C       ****                                                            ****
C       ****                    DEFINITION OF TERMS                     ****
C       ****                                                            ****
C       ********************************************************************
C        *******************************************************************
C
C       AAANG---ENTERED NUMBER OF PARTICLE SIZE GROUPS.
C       AAANS---ENTERED NUMBER OF STAGES.
C       ACCPU---PLUTONIUM HOLD-UP.  G
C       ACCU---URANIUM HOLD-UP.  G
C       ACDF---FRACTION DIFFERENCE BETWEEN BULK ACID CONC AND
C               ACID CONC IN A FUEL PIN. CAN ALLOW FOR REACTION
C               RATE REDUCTION WHILE FUEL IS OUT OF LIQUID...
C       ACID---INITIAL HNO3 CONC IN STAGE 1  (MOLE/L)
C       ACIDEF---MAXIMUM HNO3 CONCENTRATION FOR ACID DEFICIENCY
C               DETECTION. (G/L)
C       ACTLEN---ACTUAL LIQUID SURFACE LENGTH. CM
C       ACTPA---ACTUAL PU ACCUMULATED IN DISSOLVER AT END OF RUN.(G)
C       ACTUA---ACTUAL U ACCUMULATED IN DISSOLVER AT END OF RUN. (G)
C       AFIAT---ACID FEED TO STAGE 8 FLOW INCREASE ANTICIPATION TIME. (MIN)
C       AFDAN---TIME OF LOW ACID FEED RATE DURING NO SHEAR FEED. (MIN)
C       AFDAS---TIME OF NORMAL ACID FEED RATE DURING SHEARING.(MIN)
C       AFRAT---ACID FEED TO STAGE 8 FLOW REDUCTION ANTICIPATION TIME. (MIN)
C       AKSTOP---UPPER LIMIT FOR NUMBER OF TIMES CONCENTRATION
C                SUBROUTINES ARE CALLED.
C       ALIMO---UPPER LIMIT FOR NUMBER OF ITERATIONS EACH TIME STEP FOR
C               EACH SUBROUTINE.
C       AMINFR---MULTIFICATION FACTOR TO CALCULATE THE MINIMUM TIME STEP.
C       ANEG---SOLUTION TO QUADRATIC EQUATION.
C       AN---DRUM ANGLE. (RAD)
C       ANFTIM---LENGTH OF TIME OF NO FUEL FEED. (MIN)
C       ANGLE---DRUM ANGLE. (DEG)
C       ANOVOX---CONVERSION FACTOR TO CONVERT CONTINUOUS FEED
C               RATES TO INSTANTANEOUS BATCH FEED RATES FROM
C               SHEAR TO DISSOLVER (SHEARING ONLY).
C       APOS---SOLUTION TO QUADRATIC EQUATION.
C       AS---PROJECTED HORIZONTIAL STAGE LIQUID SURFACE AREA.
C               CM**2
C       ATP(J)---GEOMETRIC SURFACE AREA OF A SINGLE PARTICLE IN
C               SIZE GROUP J.(CM**2)
C       AVEMOL---AVERAGE MOLECULAR WEIGHT OF FUEL. (G/MOLE)
C       B(I)---BACKMIX FLOW OF FLUID . (L/MIN)
```

```
C       BAKMIX(I)---MASS OF SOLUTION BACKMIXED DUE TO CARRY OVER ON
C               HULLS. (GRAM OF SOLUTICN/GRAM OF HULLS)
C               HULLS=HULLS+SHROUD+WIRES+OTHER.
C       BAKV(I)---VOLUME OF SOLUTION BACKMIXED DUE TO CARRY OVER ON
C               HULLS. (LITER)
C       BASECT---BASIC FORWARD ROTATION TIME, NOT CONSIDERING
C               THE LAG TIME BETWEEN FORWARD AND REVERSE. (MIN)
C       BATTIM---BATCH CYCLE TIME FOR SHEAR TO CUT ONE
C               FUEL ELEMENT AND PREPARE FOR ANOTHER.(MIN)
C       CDEN8---DENSITY IN EXTERNAL FEED STREAM 8 AT NORMAL FLOW RATE.(G/L)
C       CFINES---CONSTANT...INPUT MASS FEED RATE OF FINES TO STAGE 1
C               DURING SHEARING.  (G/MIN)
C       CFUEL---MASS OF FUEL FED DURING A TIME STEP H. (GRAMS)
C               ZERO WHEN NO FEED FROM SHEAR...
C       CH2OM8---WATER FLOW RATE TO STG 8 IN ACID FEED STREAM AT
C               NORMAL FEED RATE.(KG/HR)
C       CHNOM8---HNO3 FLOW RATE TO STG 8 IN ACID FEED STREAM AT
C               NORMAL FEED RATE.(KG/HR)
C       CO(I)---IDEAL LIQUID DENSITY IN STAGE I. G/L
C       CON---TOTAL FUEL SURFACE EXPOSURE AREA IN A FUEL PIN. (CM**2)
C               ASSUMES CUT ANGLE OF THETA RADIANS.
C       CONREL---CONSTANT MAXIMUM TOTAL PARTICLE RELEASE RATE FOR EACH
C               STAGE. (G/MIN)
C       COXXXN---CONSTANTS IN THE HNO3 MATERIAL BALANCE EQUATIONS.
C                WHERE XXX INDICATES THE COMPONENT THE CONSTANT
C                RELATES TO.
C       COXXXW---CONSTANTS IN THE H2O MATERIAL BALANCE EQUATIONS.
C                WHERE XXX INDICATES THE COMPONENT THE CONSTANT
C                RELATES TO.
C       CREL(I)---CONSTANT VALUE INPUT FOR PARTICLE RELEASE RATE
C               PER PIN FOR STAGE I.  (G/MIN/PIN)
C       CT---CYCLE TIME FOR HULL TRANSFER, INCLUDES LAG TIME
C               BETWEEN FORWARD AND REVERSE ROTATION. (MIN)
C       CT1---CYCLE TIME FOR HULL TRANSFER FROM STAGE 1. MIN
C       D25---DENSITY OF DISSOLVED FUEL SOLUTION AT 25 DEG C. (G/CC)
C       D25C1,D25C2,D25C3,D25C4---COEFFICIENTS OF 25 DEG C DENSITY CORRELATION
C       DEN1,DEN8,DEN9,DEN10---DENSITY OF EXTERNAL FEED STREAMS TO STAGES
C               1,8,9,AND 10 RESPECTIVELY.  (G/L)
C       DENSST---DENSITY OF STAINLESS STEEL HULLS, SHROUDS, AND WIRES.(G/L)
C       DEPTH(I)---MAXIMUM LIQUID DEPTH IN  STAGE. I CM
C       DFP---AVERAGE DENSITY FISSION PRODUCTS. (GRAM/CC)
C       DIA---DRUM DIAMETER. CM
C       DIFIAD---TIME BETWEEN OUTPUT OF ACID DEFICIENCY PRINT OUTS.(MIN)
C       DIGPAR---TOTAL MASS OF PARTICULATE FLOWING FROM DISSOLVER
C               STAGE 1 TO DIGESTER TANKS OVER TOTAL RUN TIME. (G)
C       DILUT1,DILUT9---TOTAL FLOW OF STEAM CONDENSATE INTO DISSOLVER
C                STAGES 1 AND 9. (L/MIN)
C       DISTM---TIME ACCUMULATOR FOR PARTICLE SIZE DISTRIBUTION
C               PRINT OUT.(MIN)
C       DP---AVERAGE PARTICLE DIAMETER, (CM).
C       DPUO2---DENSITY PUO2. (GRAM/CC)
C       DREVS---NUMBER OF REVOLUTIONS REQUIRED TO EMPTY STAGE NS.
C       DTFLG1 OR 2---TIME ACCUMULATOR FOR SOLIDS TRANSFER FROM
C               STAGE NS. (MIN)
C       DTRACT---ONE DIVIDED BY TOTAL TIME FOR SOLIDS
C               TRANSFER FROM STAGE NS.  (MIN**-1)
```

```
C        DU308---DENSITY UO2. (GRAM/CC)
C        DUMPT---TIME REQUIRED TO EMPTY STAGE NS. (MIN)
C        DV(I)---ARRAY HOLDING LIQUID VOLUME CHANGES PER TIME STEP.(L/MIN)
C        ETOTUF---TOTAL URANIUM FED TO FLAPPER VALVE OVER TOTAL RUN TIME. G
C        ETOTPF---TOTAL PLUTONIUM FED TO FLAPPER VALVE OVER TOTAL RUN TIME. G
C        ETSUM---TOTAL U PLUS PU FED TO THE FLAPPER VALVES.(G)
C        FCSTG1,FCSTG9---FRACTION OF CONDENSATE ENTERING STAGE 1 AND 9.
C        FEANG---EXPOSURE ANGLE FOR FUEL IN ENDS OF FUEL PIN. (DEGREE)
C        FEDRAT---FEED RATE OF SHEARED FUEL TO DISSOLVER. (GRAM/MIN)
C                 EXCLUDES HULLS....RATE DURING SHEARING ONLY...
C        FEDONE---ACCUMULATOR FOR FUEL IN PINS IN FLAPPER VALVE FEED TO
C                 STAGE 1. (G)
C        FFTIME---FRACTION OF TIME FUEL IS BEING SHEARED AND FED.
C        FFINES---FRACTION OF INPUT FEED RATE THAT IS FINES.
C        FINES---INPUT FEED RATE OF FINES. (GRAM/MIN)
C        FINESF---ACCUMULATOR FOR FINES IN FLAPPER VALVE FEED TO STAGE 1.(G)
C        FINESH---MASS OF FINES FED TO FLAPPER VALVE IN A TIME STEP. (G)
C        FL(I)---LIQUID FLOW FROM DISSOLVER STAGE I. (L/MIN)
C                 INCLUDES RINSE STAGE FEED...
C        FLAPTM---CYCLE TIME FOR LOWER FLAPPER VALVE IN DISSOLVER FEED PIPE.(MI
C        FLEXT(I)---VOLUMETRIC FLOW OF EXTERNAL FEED STREAM TO STAGE I.(L/MIN)
C        FLPHLU---HOLD UP OF U IN FLAPPER VALVES AT END OF RUN.(G)
C        FLTOS1---TOTAL FUEL FED FROM FLAPPER VALVE TO STAGE. (G)
C        FNMAX(I)---MAX CONC. OF FISSION PRODUCT NITRATES IN STAGE I. (G/L)
C        FP(I)---CONC. OF FISSION PRODUCTS IN STAGE I. (GRAM/L)
C        FPB(I)---CONC. OF FISSION PRODUCTS IN STAGE I BEFORE TIME T.
C                 (GRAM/L) AVERAGE.
C        FPK1(I)---RATE CONSTANT FOR THE FORMATION OF FISSION PRODUCT
C                NITRATES FROM SUSPENDED PARTICLES STAGE I.  (GRAM/CM**2 MIN)
C                AVERAGED.....
C        FPK2(I)---RATE CONSTANT FOR THE FORMATION OF FISSION PRODUCT
C                NITIATES FROM FUEL PINS STAGE I.  (GRAM/CM**2 MIN)  AVERAGED...
C                DIFFERENT FROM FPK1 DUE TO DIFFERENT HNO3 CONC IN PIN.
C        FPN(I)---CONC. FP(NO3)3.39 IN STAGE I. (GRAM/L)
C        FPNB(I)---CONC. FP(NO3)3.39 IN STAGE I BEFORE TIME T. (GRAM/L)
C        FREQ(I)---ARRAY CONTAINING THE FREQUENCY OF OCCURRANCE OF
C                 PARTICLES IN SIZE GROUP I.  BASED ON THE
C                 LOG NORMAL DISTRIBUTION OF WEIGHTS.
C        FRMOFP---MOLE FRACTION FISSION PRODUCTS IN HOMOGENEOUS FUEL.
C        FRMOPU---MOLE FRACTION PLUTONIUM IN HOMOGENEOUS FUEL.
C        FRMOU3---MOLE FRACTION URANIUM IN HOMOGENEOUS FUEL.
C        FUEL---WEIGHT OF FUEL ACCUMULATED IN FIRST STAGE IN FUEL
C                 PINS AFTER ONE MIN. G
C        FUELWT---MAXIMUM TOTAL FUEL WEIGHT IN STAGE 1 AT END OF CYCLE TIME.
C                 (GRAM)
C        FUPIN---NUMBER OF FUEL PINS ADDED TO FLAPPER VALVE EACH
C                 TIME STEP.
C        FO(I)---INITIAL DISSOLVER LIQUID FLOW RATES. (L/MIN)
C                 INCLUDES RINSE STAGE FEED ,ACID FEED AND STEAM COND.
C        HC---MAX TIME INCREMENT FOR CALCULATIONS. (MIN)
C        H---VARIABLE LENGTH TIME INCREMENT.  DEPENDS ON
C                 MINIMUM TIME TO COMPLETE DISSOLUTION.(MIN)
C        H2MAX(I)---MAX CONC. H2O IN STAGE I. (G/L)
C        H2O(I)---CONC. OF H2O IN STAGE I. (GRAM/L)
C        H2OB(I)---CONC. OF H2O IN STAGE I BEFORE TIME T.(GRAM/L)
C        H2OF(I)---CONC. OF H2O IN EXTERNAL FEED TO STAGE I.(GRAM/L)
```

```
C       H2OM1,H2CM8,H2CM9,H2OM10---MASS FLOW OF WATER IN EXTERNAL FEED
C               STREAMS TO STAGES 1,8,9,AND 10. (KG/HR)
C       HNMAX(I)---MAX CONC. OF HNO3 IN STAGE I. (G/L)
C       HNO3(I)---CONC. OF HNO3 IN STAGE I. (GRAM/L)
C       HNO3B(I)---CONC. OF HNO3 IN STAGE I BEFORE TIME T.(GRAM/L)
C       HNO3F(I)---CONC. OF HNO3 IN EXTERNAL FEED TO STAGE I.(GRAM/L)
C       HNO3M1,HNO3M8,HNO3M9,HNOM10---MASS FLOW OF NITRIC ACID IN EXTERNAL
C               FEED STREAM TO STAGES 1,8,9,AND 10.(KG/HR)
C       IAD---# OF ACID DEFICIENT CONDITIONS.
C       ION---1 OR 0.  USED TO TURN ON AND OFF THE
C               SOLIDS TRANSFER FROM STAGE NSM1 TO STAGE NS.
C       ITSAC---COUNTER FOR TIME STEP REDUCTIONS.
C       LIMO---ITERATION LIMITER.
C       MUM---NUMBER OF POINTS PLOTTED.
C       NS---NUMBER OF STAGES.
C       NSM1---NS-1
C       ONED---1.0D0-DTRACT.  USED AS THE FRACTION OF FUEL OR SOLUTION
C               NOT TRANSFERED OUT OF STAGE NS.
C       P1HC---MINIMUM TIME STEP. (MIN)
C       P(I,J)---FREE PARTICLE CONCENTRATION IN STAGE I OF PARTICLES IN SIZE
C               GROUP J.  (G/L)
C       PAR000---PARTICLE REACTION RATE ON/OFF FLAG.
C               0.0 -- NO PARTICLE REACTIONS
C               1.0 -- NORMAL PARTICLE REACTIONS
C       PART(I)---FREE PARTICLE CONCENTRATION IN STAGE I,  (G/L)
C       PARTP(I)---MASS OF PARTICLES DISSOLVED IN STAGE I.(G)
C       PB(I,J)---FREE PARTICLE CONCENTRATION IN STAGE I OF PARTICLES IN SIZE
C               GROUP J AT TIME T-H. (G/L)
C       PCFLTF---PERCENT OF TOTAL U FEED HELD UP IN FLAPPER VALVES.(%)
C       PCFP---WEIGHT FRACTION FISSION PRODUCTS IN FUEL PIN.
C       PCONT---TOTAL NUMBER OF TIMES ALL PARTICLE SIZE GROUPS WERE ZEROED
C               DUE TO GROUP TRANSFERS.
C       PCPUO2---WEIGHT FRACTION PUO2 IN FUEL PIN.
C       PCU308---WEIGHT FRACTION UO2 IN FUEL PIN.
C       PDIFP---PER CENT DIFFERENCE BETWEEN MASS OF PU ACTUALLY FED
C               AND THAT ACTUALLY REMOVED AND ACCUMULATED IN THE DISSOLVER.(%)
C       PIN000---PIN REACTION RATE ON/OFF FLAG.
C               0.0 -- NO PIN REACTIONS
C               1.0 -- NORMAL PIN REACTIONS
C       PIN---O.D. OF FUEL PELLET, (CM).
C       PINFED---ACCUMULATOR FOR NUMBER OF FUEL PINS FED TO
C               FLAPPER VALVE.
C       PINLEN---LENGTH OF FUEL PIN.  (CM)
C       PINMAS---MASS OF FUEL IN ONE PIN. G
C       PINOD---OUTSIDE DIAMETER OF FUEL PIN. (CM)
C       PINVOL---VOLUMN OF FUEL PIN.  (CM**3)
C       PLINC---COUNTER FOR PLOT DATA STORAGE.(MIN)
C       PLV(I)---PURE LIQUID VOLUME IN STAGE I CORRECTED FOR
C               NON-IDEALITY OF MIXING. (L)
C       PLVBT(I)---PURE LIQUID VOLUME IN STAGE I BEFORE BACKMIX
C               CORRECTION. (L)
C       PLVM(I)---MINIMUM VOLUME OF LIQUID IN A STAGE, EQUIVALENT
C               TO AMOUNT BACKMIXED ON HULLS. (L)
C       PM(J)---MASS OF A SINGLE PARTICLE IN SIZE GROUP J.(G)
C       PN(I)---CONC. OF PU(NO3)4 IN STAGE I. (GRAM/L)
C       PNB(I)---CONC. OF PU(NO3)4 IN STAGE I BEFORE TIME T.(GRAM/L)
```

```
C        PNK1(I)---RATE CONSTANT FOR THE FORMATATION OF PU(NO3)4 FROM
C                SUSPENDED PARTICLES STAGE I.  (GRAM/CM**2 MIN)
C        PNK2(I)---RATE CONSTANT FOR THE FORMATION OF PU(NO3)4 FROM FUEL
C                PINS STAGE I.  (GRAM/CM**2 MIN)
C                DIFFERENT FROM PNK1 DUE TO DIFFERENT HNO3 CONC IN PIN.
C        PNMAX(I)---MAX CONC. OF PU(NO3)4 IN STAGE I. (G/L)
C        POUTT---RUNNING TOTAL OF PU OUT OF STAGES 1 AND NS
C                 PLUS INVENTORIED IN DRUM. (G)
C        POW---EXPONENT FOR WEIR FLOW EQUATION.
C                 FLOW(L/MIN)=TK*(CREST HEIGHT(CM))**POW.
C        POWF---PU TRANSFERRED OUT OF STAGE NS UNDISSOLVED IN PINS
C                 DURING A TIME STEP.  (GRAMS)
C        PPERPU---CONSTANT IN TOTAL PU UNDISSOLVED CALC.
C        PPSTG(I)---NUMBER OF PINS IN EACH STAGE.
C        PRDIST---PRINT TIME INCREMENT FOR PARTICLE SIZE DISTRIBUTION.(MIN)
C        PRINC---BASE PLOTTING TIME INCREMENT. (MIN)
C        PRT---PRINT OUT TIME ACCUMULATOR. (MIN)
C        PRTTIM---TOTAL RUN TIME BETWEEN PRINT OUTS. (MIN)
C        PTFTFV---PERCENT TRANSFER OF U PLUS PU THRU FLAPPER VALVE. %
C        PUACC---TOTAL PU IN DISSOLVER. (G)
C        PUALL---TOTAL PU OUT PLUS HOLDUP. (G)
C        PUALLA---ACTUAL MASS OF PU REMOVED FROM DISSOLVER OVER TOTAL RUN
C                 PLUS HOLD-UP.(G)
C        PUDLIQ---TOTAL PU INVENTORY IN DRUM.(G)
C        PUIN---PLUTONIUM FEED. (G/MIN)
C        PUO2(I)---CONC. OF PUO2 IN STAGE I. (GRAM/L)
C        PUO2B(I)---CONC. OF PUO2 IN STAGE I BEFORE TIME T.(GRAM/L)
C        PUOUTF---PLUTONIUM FLOW OUT WITH FUEL, UNDISSOLVED. (G/MIN)
C        PUOUTO---TOTAL PLUTONIUM FLOW OUT. (G/MIN)
C        PUOUT1---PLUTONIUM FLOW OUT STAGE 1. (G/MIN)
C        PUPART---TOTAL PU IN PARTICLES UNDISSOLVED IN THE DISSOLVER
C                 AT END OF RUN TIME.  (G)
C        PUPINS---TOTAL PU UNDISSOLVED IN FUEL PINS AT END OF RUN (G).
C        QA,QB---CORD LENGTHS FOR STAGE AREA CALC.
C        QD---DIFFERENCE IN MIN AND MAX STAGE LIQUID HEIGHTS.
C        R(I)---RADIUS OF PARTICLES IN SIZE GROUP I FOR LOG NORMAL
C                 DISTRIBUTION. (MICRON)
C        RATMF---RFACT*RCON
C        RATE1(I)---COMBINED REACTION RATE FOR SUSPENDED UO2-PUO2 PARTICLES
C                 STAGE I.(URIARTE AND RAINEY).. (G/CM**2 MIN)
C        RATE2(I)---COMBINED REACTION RATE FOR UO2-PUO2 IN FUEL PINS.
C                 STAGE I.(URIARTE AND RAINEY)   (G/CM**2 MIN)
C        RCON---REACTION RATE CONSTANT.  (GRAM/(CM**2*MIN*(MOL/L)**(2+2*XPU)))
C        REL(I)---PARTICLE RELEASE RATE FROM FUEL PINS DUE TO AGITATION
C                 OF ALL PINS IN STAGE I  (GRAM/MIN).
C        REM---1.0-XPU
C        RFACT---CORRECTION FACTOR FOR RATE EQUATIONS.  A FACTOR OF 5.0 HAS BEE
C                 QUOTED IN THE URIARTE/RAINEY REPORT FOR IRRIADIATED FUELS..
C        RHOAVE---AVERAGE DENSITY OF SOLID FUEL. (GRAM/CC)
C        RHOC1,RHOC2,RHOC3,RHOC4---COEFFICIENTS OF AVERAGE LIQUID DENSITY
C                                  CORRELATION.
C        RHOLIQ(I)---AVERAGE DENSITY OF LIQUID IN STAGE I.  (GRAM/L)
C        RMAX---MAXIMUM PARTICLE SIZE RADIUS. (MICRON)
C        RMIN---MINIMUM PARTICLE SIZE RADIUS. (MICRON)
C        RMMAX(I)---MAX. RADIUS FOR SIZE GROUP I.(MICRON)
C        RMMIN(I)---MIN. RADIUS FOR SIZE GROUP I.(MICRON)
```

```
C       RMS(I,J)---WEIGHTED MEAN PARTICLE RADIUS IN SIZE GROUP J IN
C               STAGE I. (MICRON)
C       RPM---DISSOLVER ROTATIONAL SPEED.(REV/MIN)
C       RPOW---EXPONENT ON ACID CONC IN REACTION RATE EQUATION
C       RUN---TOTAL RUN TIME. (MIN)
C       RWASTE---MINIMUM PARTICLE SIZE RADIUS TRANSFERRING WITH HULLS. (MICRON
C       SALL---LIQUID DEPTH AT SHALLOW END. CM
C       SDEN8---ACID FEED STREAM DENSITY AT REDUCED FLOW. (G/L)
C       SHETIM---TIME REQUIRED TO SHEAR ONE FUEL ELEMENT INTO ONE
C               INCH LENGTHS. (MIN)
C       SH2OM8---WATER FLOW IN REDUCED ACID FEED STREAM FLOW TO STG 8.(KG/HR)
C       SHNOM8---HNO3 FLOW IN REDUCED ACID FEED STEAM FLOW TO STG 8.(KG/HR)
C       SIZE---PLANT CAPACITY. (TONNE-A-DAY)
C       SLOTLM---MAXIMUM HEIGHT FOR FLOW OVER WEIR (SLOT SIZE). (CM)
C       SMPUF1---TOTAL U IN PINS FED TO STAGE 1 FROM FLAPPER VALVES.(G)
C       SMFUF1---TOTAL U FINES FED TO STAGE 1 FROM FLAPPER VALVES.(G)
C       SPAREA---RATIO OF PSEUDO RADIUS OF FUEL PARTICLES
C               TO GEOMETRIC RADIUS.  MULTIPLICATION FACTOR TO ACCOUNT FOR
C               PARTICLE AREA IN EXCESS OF SPHERE AREA. SPAREA=DSQRT(F+1)
C               WHERE F IS THE FRACTIONAL PERCENT INCREASE IN SURFACE
C               AREA DUE TO POROUS PARTICLES.  SPAREA CAN BE THOUGHT OF
C               AS AN AREA ENHANCEMENT FACTOR.
C       SSSCT---VOLUME OF STAINLESS STEEL ADDED PER MINUTE OF SHEAR TIME.(L/MI
C       SSSCTH---VOLUME OF STAINLESS STEEL FED TO FLAPPER VALVE IN A
C               TIME STEP. (G)
C       SST(I)---VOLUME OF STAINLESS STEEL CLADDING, WIRES, AND SHROUD IN
C                IN STAGE I  (L)
C       SSTF---ACCUMULATOR FOR STAINLESS STEEL IN FLAPPER VALVE FEED TO
C               STAGE 1.(L)
C       SSTMSS(I)---MASS OF STAINLESS STEEL IN STAGE I. (G)
C       SSTVOL---MAXIMUM VOLUME OF STAINLESS STEEL IN A STAGE. (L)
C       STGLEN---DISSOLVER STAGE WIDTH. (CM)
C       SUBROUTINES :
C               BLOCK DATA---INITIALIZATION AND DEFINITION.
C               MAIN---SUBROUTINE CALLS,INPUT/OUTPUT,AND OVERALL BALANCE.
C               TRANSF---SOLID/LIQUID TRANSFERS INCLUDING BACKMIXING.
C               PARTIC---PARTICLE SIZE GROUP MANIPULATION.
C               SUBUN---UO2(NO3)2 CONC. DUE TO FLOW.
C               SUBPN---PU(NO3)4 CONC. DUE TO FLOW.
C               SUBFN---FP(NO3)3.39 CONC. DUE TO FLOW.
C               SUBHN---HNO3 CONC. DUE TO FLOW.
C               SUBH2---H2O CONC. DUE TO FLOW.
C               CHECK---ITERATION CHECKER.
C               WEIGHT---FUEL MASS AND CONC. ADJUSTER DUE REACTION.
C               RELEAS---PARTICLE RELEASE RATE FROM FUEL PINS.
C               RATECK---REACTION RATES.
C               PLOT7---STAGEWISE CONC. PROFILE PLOTER.
C               FREQUE---PARTICLE BIRTH SIZE DISTRIBUTION.
C               PLOTD---STAGEWISE PARTICLE SIZE DISTRIBUTION PLOTTER.
C               PLOT3---STAGEWISE CONC. PROFILES FOR FUEL,PARTICLES,AND SST.
C               TSTEP---TIME STEP LENGTH ADJUSTER.
C               RXEQU---U REACTION EQUATION CHOOSER.
C               DIGEST---DIGESTER TANK ACCUMULATOR MODEL.
C               DIGPLT---DIGESTER TANK HISTORY PLOTTER.
C       SUMFIN---SUM OF FUEL FED TO STAGE 9. (G)
C       SUMFLF---TOTAL FUEL FED AS FINES TO FLAPPER VALVES.(G)
```

```
C        SUMFLP---TOTAL FUEL FED IN PINS TO FLAPPER VALVES.(G)
C        SUMFOU---SUM OF FUEL TRANSFERED OUT STAGE 9. (G)
C        SUMHNO---SUM OF HNO3 DEPLETIONS FOR ENTIRE RUN (G).
C        SUMNEG---NEGATIVE SUM OF OVER DISSOLUTION OF FUEL IN PINS. (G)
C        SUMNEP---NEGATIVE SUM OF OVER DISSOLUTION OF PARTICLES
C                FROM TOTAL PARTICLE CALC IN WEIGHT. (G)
C        SUMOD---TOTAL NEGATIVE SUM OF OVER DISSOLUTION OF FUEL.(G)
C        SUMPIN---SUM OF PINS FED TO STAGE 9.
C        SUMPLV---SUM OF LIQUID VOLUME DEPLETIONS DUE TO CROWDING FROM
C                HULLS. (L)
C        SUMPOU---SUM OF PINS TRANSFERED OUT STAGE 9. (G)
C        T---CYCLE TIME ACCUMULATOR, STAGES 2-9.  (MIN)
C        T1---CYCLE TIME ACCUMULATOR, STAGE 1. (MIN).
C        T2---CYCLE TIME ACCUMULATOR, STAGE 1.  ACCOUNTS FOR
C                TIME OF NO FEED TO DISSOLVER.  (MIN)
C        TD1,TD2---DIGEST CYCLE TIME ACCUMULATOR FOR DIGESTER
C                TANKS 1 AND 2. (MIN)
C        TD---PER CENT THEORITICAL DENSITY OF FUEL .
C        TDIG---TIME FOR DIGESTION CYCLE IN DIGESTER TANK.(MIN)
C        TEMP---AVERAGE DISSOLVER TEMPERATURE.  DEGREE CENTIGRADE.
C        TF1,TF8,TF9,TF10---TOTAL MASS FLOW OF WATER AND ACID IN EXTERNAL FEED
C                STREAMS TO STAGES 1,8,9,AND 10. (KG/HR)
C        TFD1,TFD2---FILL TIME ACCUMULATOR FOR DIGESTER TANKS 1 AND 2.(MIN)
C        TFILL---INPUT TIME FOR FILLING DIGESTER TANK. (MIN)
C        TFMAX(I)---TIME OF MAX F.P.(NO3)3.39 CONC FOR STAGE I. (MIN)
C        TH2MX(I)---TIME OF MAX H2O CONC. FOR STAGE I. (MIN)
C        TH2OC---TOTAL MASS FLOW OF H2O IN CONDENSATE RETURNED TO STAGES
C                1 AND 9. (KG/HR)
C        THNMX(I)---TIME OF MAX HNO3 CONC. FOR STAGE I. (MIN)
C        THNO3C---TOTAL MASS FLOW OF HNO3 IN CONDENSATE RETURNED TO STAGES
C                1 AND 9.  (KG/HR)
C        THETA---EXPOSURE ANGLE FOR FUEL IN ENDS OF FUEL PINS.(RADIANS)
C        TIME---TOTAL RUN TIME ACCUMULATOR. (MIN)
C        TIMMIN---MINIMUM OF CT OR SHETIM. (MIN)
C        TK---WIER EQUATION CONSTANT. GIVES FLOW IN L/HR.
C        TM1,TM2---MASS ACCUMULATORS FOR DIGESTER TANKS 1 AND 2. (MIN)
C        TMOLD---RUN TIME AT LAST ACID DEFICIENCY PRINT OUT. (MIN)
C        TMRFED---MASS FEED RATE OF SPENT FUEL ,INCLUDING STAINLESS STEEL.
C                 (KG/HR)
C        TMRSST---MASS FEED RATE OF STAINLESS STEEL.  (KG/HR)
C        TNP---NUMBER OF FUEL PINS IN A STAGE.
C        TOCON1(I),T1CON---TOTAL NITRATE DISSAPPERING FROM PARTICLES.
C                 (G-HNO3/G-UO2)
C        TOCON2(I),T2CON---TOTAL NITRATE DISSAPPERING FROM PINS.
C                 (G-HNO3/G-UO2)
C        TOCOW1(I),T1COW---TOTAL H2O FORMED FOR PARTICLE REACTIONS.
C                 (G-H2O/G-UO2)
C        TOCOW2(I),T2COW---TOTAL H2O FORMED FROM PIN REACTIONS.
C                 (G-H2O/G-UO2)
C        TOL---TOLERANCE BETWEEN ITERATIONS IN MATERIAL BALANCES.
C        TOPUO---TOTAL PLUTONIUM OUT OVER TOTAL RUN TIME. G
C        TOPUOF---TOTAL PLUTONIUM (DISSOLVED AND UNDISSOLVED)
C                OUT OF RINSE STAGE.(G)
C        TOPUO1---TOTAL PLUTONIUM OUT OF STAGE 1. G
C        TOTPUI---TOTAL PLUTONIUM FED IN TO STAGE 1 OVER TOTAL RUN TIME.  G
C        TOTSST---TOTAL STAINLESS STEEL COLLECTED IN A STAGE OVER A
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C             TIME PERIOD LESS THAN OR EQUAL TO  MIN. (G)
C       TOTUI---TOTAL URANIUM FED IN TO STAGE 1 OVER TOTAL RUN TIME.G
C       TOTUO---TOTAL URANIUM OUT OVER TOTAL RUN TIME. G
C       TOTUOF---TOTAL URANIUM (DISSOLVED AND UNDISSOLVED)
C             OUT OF RINSE STAGE.(G)
C       TOTUO1---TOTAL URANIUM OUT OF STAGE 1. G
C       TPMAX(I)---TIME OF MAX PU(NO3)4 CONC. FOR STAGE I. (MIN)
C       TUMAX(I)---TIME OF MAX UO2(NO3)2 CONC. FOR STAGE I. (MIN)
C       TUPUS1---TOTAL U PLUS PU FED TO STAGE 1 FROM FLAPPER VALVES.(G)
C       TRCT---TOTAL REVERSE CYCLE TIME.  (MIN)
C       TTD1,TTD2---TRANSFER TIME ACCUMULATOR FOR DIGESTER
C             TANKS 1 AND 2. (MIN)
C       TTRAN---TRANSFER TIME FOR DIGESTER TANK LIQUOR. (MIN)
C       UACC---TOTAL U IN DISSOLVER. (G)
C       UALL---TOTAL U OUT PLUS HOLDUP. (G)
C       UALLA---ACTUAL U REMOVED FROM DISSOLVER OVER TOTAL RUN PLUS
C             HOLD-UP.(G)
C       UDIFP---PER CENT DIFFERENCE BETWEEN MASS OF U ACTUALLY FED AND
C             THAT ACTUALLY REMOVED AND ACCUMULATED IN THE DISSOLVER.(%)
C       UDLIQ--- TOTAL U INVENTORY IN DRUM.(G)
C       UIN---URANIUM FEED.(G/MIN)
C       UN(I)---CONC. OF UO2(NO3)2 IN STAGE I. (GRAM/L)
C       UNB(I)---CONC. OF UO2(NO3)2 IN STAGE I BEFORE TIME T.(GRAM/L)
C       UNK1(I)---RATE CONSTANT FOR THE FORMATION OF UO2(NO3)2 FROM
C            PARTICLES IN SUSPENSION STAGE I. (GRAM/CM**2 MIN)
C       UNK2(I)---RATE CONSTANT FOR THE FORMATION OF UO2(NO3)2 FROM FUEL
C            PINS, STAGE I. (GRAM/CM**2 MIN)
C            DIFFERENT FROM UNK1 DUE TO DIFFERENT HNO3 CONC IN PIN.
C       UNMAX(I)---MAX CONC. UO2(NO3)2 IN STAGE I. (G/L)
C       UOUTF---URANIUM FLOW OUT WITH FUEL, UNDISSOLVED.  (G/MIN)
C       UOUTT---RUNNING TOTAL U OUT OF STAGES 1 AND NS
C             PLUS INVENTORIED IN DRUM. (G)
C       UOUTO---TOTAL URANIUM FLOW OUT.  (G/MIN)
C       UOUT1---URANIUM FLOW OUT STAGE 1. (G/MIN)
C       UOWF---U TRANSFERRED OF OF STAGE NS UNDISSOLVED IN PINS
C             DURING A TIME STEP.  (GRAMS)
C       UPART---TOTAL U IN PARTICLES UNDISSOLVED IN DRUM AT END OF RUN.(G)
C       UPERU3---CONSTANT IN TOTAL URANIUM UNDISSOLVED CALC.
C             MOLE WEIGHT U/MOLE WEIGHT UO2 TIMES ONE.

C       UPERUN---MOLE WEIGHT U/MOLE WT UO2(NO3)2 TIME ONE.
C       UPINS---TOTAL U UNDISSOLVED IN FUEL PINS AT END OF RUN .(G)
C       U3O8(I)---CONC. OF UO2 IN STAGE I. (GRAM/L)
C       U3O8B(I)---CONC OF UO2 IN STAGE I BEFORE TIME T.(GRAM/L)
C       V(I)---TOTAL STAGE VOLUME. (L)
C       VD1,VD2---VOLUME ACCUMULATORS FOR DIGESTER TANKS 1 AND 2. (L)
C       VFULL---INPUT DIGESTER TANK CAPACITY.  BASED ON FILL TIME(TFILL)
C             AND DISSOLVER PRODUCT FLOW(FL(1)).  (L)
C       VIB(I)---PURE LIQUID VOLUME IN STAGE I AT TIME T-H. L
C       VOLFLO---VOLUME CORRECTION FACTOR BASED ON DIFFERENCES IN INLET AND
C              OUTLET FLOW RATES BETWEEN STAGES. (L)
C       VO(I)---INITIAL OR GEOMETRIC VOLUME OF LIQUID IN STAGE I. (L)
C       WMOLFP---AVERAGE MOLECULAR WEIGHT FISSION PRODUCT OXIDES.
C       WMOLPU---MOLECULAR WEIGHT PUO2. (GRAM/G-MOLE)
C       WMOLU3---MOLECULAR WEIGHT UO2. (GRAM/G-MOLE)
C       WMOLXX---MOLECULAR WEIGHT OF COMPOUND XX. (G/G-MOLE)
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C        WORKSP(I)---SCRATCH ARRAY USED IN PARTICLE DISTRIBUTION CALC.
C        WTFP(I)---WEIGHT OF F.P. REMAINING IN FUEL PINS IN STAGE I.(GRAMS)
C        WTFUEL(I)---TOTAL WEIGHT OF FUEL REMAINING IN PINS IN STAGE I. (GRAMS)
C        WTPUO2(I)---WEIGHT OF PUO2 REMAINING IN FUEL PINS IN STAGE I.(GRAMS)
C        WTU3O8(I)---WEIGHT OF UO2 REMAINING IN FUEL PINS IN STAGE I.(GRAMS)
C        XPU---COMBINED MOLE FRACTIONS OF PUO2 AND FP.
C        ZF---MOLECULAR WEIGHT RATIO OF FISSION PRODUCT NITRATE
C                TO FISSION PRODUCT OXIDE.
C        ZFCON---ZF*CON
C        ZNOPTA---TOTAL PLOT FLAG.
C                0.0 -- NO PLOTS
C                1.0 -- PLOTS
C        ZNOPTD---DIGESTER PLOT FLAG.
C                0.0 -- NO PLOTS
C                1.0 -- PLOTS
C        ZNOPTP---PARTICLE SIZE DISTRIBUTION PLOT FLAG.
C                0.0 -- NO PLOTS
C                1.0 -- PLOTS
C        ZNOPT3---CONCENTRATION HISTORY PLOT FLAG.
C                0.0 -- NO PLOTS.
C                1.0 -- PLOTS
C        ZNOPT7---CONCENTRATION PROFILE PLOT FLAG.
C                0.0 -- NO PLOTS
C                1.0 -- PLOTS
C        ZP---MOLECULAR WEIGHT RATIO OF PU(NO3)4 TO PUO2.
C        ZPCON---ZP*CON
C        ZQT(I)---ARRAY CONTAINING: DEXP(H*(-DENOM(I))/PLV(I)).
C        ZU---MOLECULAR WEIGHT RATIO OF UO2(NO3)2 TO UO2.
C        ZUCON---ZU*CON.
C        Z1MQT(I)---ARRAY CONTAINING 1.DO-ZQT(I).
C
C
C
C
C
C
C
C
C
C
         BLOCK DATA
         IMPLICIT REAL*8 (A-H,O-Z)
         COMMON/XX/ UN(20),PN(20),HNO3(20),H2O(20),UNB(20),OLD(20)
     $,PNB(20),HNO3B(20),H2OB(20),WTU3O8(20),WTPUO2(20),WTFP(20)
     $,WTFUEL(20),FPN(20),FPNB(20),DENOM(20),REL(20),CREL(20),LIMO
         COMMON /XXX/TOL,T,CT,V(20),VO(20),CT1,T1,H,PLV(20),HC,
     $T2,SUMNEG,SUMHNO,SUMNEP,ICP,ICPO,ITSAC
         COMMON/XXXX/B(20),U308(20),U3C8B(20),PART(20),RATE1(20),
     $PARTB(20),RATE2(20),PUO2(20),PUO2B(20),FP(20),FPB(20),
     $UNK1(20),PNK1(20),FPK1(20),FL(20),UNK2(20),PNK2(20),
     $FPK2(20),P(10,50),PB(10,50),NS
         COMMON/XXXXX/RMSC(2,50),TIME,PINVOL,RHOAVE,TD,XPU,REM,TNP,
     $RPOW,RCON,ACDF,PINOOO,PAROOO
         COMMON/PAR/FREQ(50),R(50),RMMIN(50),RMMAX(50),PP(10,50),
     $RMS(10,50),PARTP(20),PM(50),ATP(50),DR,PI,RMIN,RMAX,PCONT,
     $FTPIRO,FOURPI,NG
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      COMMON/DIG/DPLUN(2,200),DPLPN(2,200)
     $,PD(2,50),ATPD(2,50),PPD(2,50)
     $,DPLH2O(2,200),DPLHNO(2,200),DPLFPN(2,200),DPLPAR(2,200),
     $DPLTIM(200),DIGVOL(2,200),RUN,TFILL,VFULL,TTRAN,TDIG
     $,PLINC,VD1,VD2,TM1,TM2,TFD1,TFD2,TDPLOT,TTD1,TTD2,TD1,TD2,
     $D1UN,D2UN,D1PN,D2PN,D1H2O,D2H2O,D1HNO3,D2HNO3,
     $D1PART,D2PART,D1FPN,D2FPN,SUMD1,SUMD2,IPD,MUPIP
      COMMON /TRANZT/BAKMIX(20),SST(20),RHOLIQ(20),PLVBT(20)
     $,BAKV(20),SSTMSS(20),DTFLG1,DTFLG2,DTRACT,DUMPT,DENSST
     $,CFUEL,CFINES,SSSCT,FUPIN,OFFTIM,P1HC,TF,FLAPTM,
     $SSSCTH,FINESH,SSTF,FEDONE,FINESF,PINFED,NSM1
      COMMON/PERCNT/PCU308,PCPUO2,PCFP,SPAREA,DU308
     $,DPUO2,DFP,CCN,PINMAS,PPSTG(20),DV(20),RATMF,FEDRAT,ARATIO
     $,PCUPER,PCPPER,UOWF,POWF,PPERPN,UPERUN
      DATA UN,U308,PN,PUO2,HNO3,FP,H2O,B,U308B,PUO2B,FPB,UNB,PNB,
     $HNO3B,H2OB,WTPUO2,WTFP,WTU308,OLD,FL,V,VO,WTFUEL,
     $PART,FPN,FPNB,PLV,P,PB,FREQ,R,RMS,PARTB,DPLUN,DPLPN,DPLH2O,
     $DPLHNO,DPLFPN,DPLPAR,DPLTIM,DIGVOL,RATE1,RATE2,UNK1
     $,UNK2,PNK1,PNK2,FPK1,FPK2,REL,CREL,BAKMIX,SST,RHOLIQ,
     $PLVBT,BAKV,DENOM,DV,PPSTG,SSTMSS,PARTP,PM,ATP,PP
     $,PD,ATPD,PPD/6460*0.0D0/
      END
C
C
C
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION DEPTH(10),RASS(10),AS(20),PLVM(10)
     $,FO(10),VIB(20),CO(20),UNMAX(10),PNMAX(10)
     $,FNMAX(10),HNMAX(10),H2MAX(10),TUMAX(10),TPMAX(10)
     $,TFMAX(10),THNMX(10),TH2MX(10),UPA(10),PUPA(10)
     $,CO2(10),CO3(10)
      REAL*4 PLTIME(200)
      COMMON/DISSPL/PLU308(10,200),PLUN(10,200),PLPUO2(10,200),
     $PLPN(10,200),PLFP(10,200),PLH2O(10,200),PLHNO3(10,200)
     $,PLFPN(10,200),PLPART(10,200),PLWTT(10,200),PLSST(10,200)
      COMMON/XX/ UN(20),PN(20),HNO3(20),H2O(20),UNB(20),OLD(20)
     $,PNB(20),HNO3B(20),H2OB(20),WTU308(20),WTPUO2(20),WTFP(20)
     $,WTFUEL(20),FPN(20),FPNB(20),DENOM(20),REL(20),CREL(20),LIMO
      COMMON /XXX/TOL,T,CT,V(20),VO(20),CT1,T1,H,PLV(20),HC,
     $T2,SUMNEG,SUMHNO,SUMNEP,ICP,ICPO,ITSAC
      COMMON/XXXX/B(20),U308(20),U308B(20),PART(20),RATE1(20),
     $PARTB(20),RATE2(20),PUO2(20),PUO2B(20),FP(20),FPB(20),
     $UNK1(20),PNK1(20),FPK1(20),FL(20),UNK2(20),PNK2(20),
     $FPK2(20),P(10,50),PB(10,50),NS
      COMMON/XXXXX/RMSD(2,50),TIME,PINVOL,RHOAVE,TD,XPU,REM,TNP,
     $RPOW,RCON,ACDF,PIN000,PAR000
      COMMON/PERCNT/PCU308,PCPUO2,PCFP,SPAREA,DU308
     $,DPUO2,DFP,CCN,PINMAS,PPSTG(20),DV(20),RATMF,FEDRAT,ARATIO
     $,PCUPER,PCPPER,UOWF,POWF,PPERPN,UPERUN
      COMMON/EXTFED/HNO3F(10),H2OF(10),FLEXT(10),ACIDEF,IAD
      COMMON/CONSTN/COUN1N,COPN1N,COFP1N,COUN2N,COPN2N,COFP2N,
     $COUN1W,COPN1W,COFP1W,COUN2W,COPN2W,COFP2W
      COMMON/WTMCLE/WMOLU3,WMOLPU,WMOLFP,WMOLUN,WMOLPN,WMOLFN,
     $WMOLH2,WMOLHN,AVEMOL,JJPART,MMUN,NNPN,NNFP,MMHN,IIH2
      COMMON/PAR/FREQ(50),R(50),RMMIN(50),RMMAX(50),PP(10,50),
     $RMS(10,50),PARTP(20),PM(50),ATP(50),DR,PI,RMIN,RMAX,PCONT,
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     $FTPIPO,FOURPI,NG
        COMMON/SOLIDS/FINES,RWASTE,HDR,CUBE,NRW,NRWM1,NGPNRW,NGM1
     $,NRWM2
        COMMON/ZCONST/ZU,ZUCON,ZP,ZPCON,ZF,ZFCON,ZQT(10),Z1MQT(10)
     $,PCU3ZU,PCPUZP,PCFPZF,CU1NU3,CP1NPU,CF1NFP,CU1WU3,
     $CP1WPU,CF1WFP,CU2NU3,CP2NPU,CF2NFP,CU2WU3
     $,CP2WPU,CF2WFP,T1CON,T1COW,T2CON,T2COW,BW,BWC,BN,BNC
     $,EO3,FO3,TOCON1(10),TOCOW1(10),TOCON2(10),TOCOW2(10)
        COMMON/DIG/DPLUN(2,200),DPLPN(2,200)
     $,PD(2,50),ATPD(2,50),PPD(2,50)
     $,DPLH2O(2,200),DPLHNO(2,200),DPLFPN(2,200),DPLPAR(2,200),
     $DPLTIM(200),DIGVOL(2,200),RUN,TFILL,VFULL,TTRAN,TDIG
     $,PLINC,VD1,VD2,TM1,TM2,TFD1,TFD2,TDPLOT,TTD1,TTD2,TD1,TD2,
     $D1UN,D2UN,D1PN,D2PN,D1H2O,D2H2O,D1HNO3,D2HNO3,
     $D1PART,D2PART,D1FPN,D2FPN,SUMD1,SUMD2,IPD,MUPIP
        COMMON /TRANZT/BAKMIX(20),SST(20),RHOLIQ(20),PLVBT(20)
     $,BAKV(20),SSTMSS(20),DTFLG1,DTFLG2,DTRACT,DUMPT,DENSST
     $,CFUEL,CFINES,SSSCT,FUPIN,OFFTIM,P1HC,TF,FLAPTM,
     $SSSCTH,FINESH,SSTF,FEDONE,FINESF,PINFED,NSM1
        COMMON/SUMS/SUMFLP,SUMFLF,SUMFIN,SUMPIN,SUMFOU,SUMPOU
C
C
C       HALF TONNE-A-DAY DISSOLVER
C
C
C
C
C
C       FUEL CHARATERISTICS AND CONSTANTS...
C       FFTF TYPE 3.1 FUEL IS ASSUMED...
C               RWASTE TAKEN FROM NUCLEAR FUEL DISSOLUTION AND RINSING USING A
C               CONTINUOUS ROTARY DISSOLVER,  HOLLAND,RISER,HEIMDAL,AND
C               GRCENIER, ORNL/TM-5566.
C
C
        READ(5,1330)SIZE,PIN,PINLEN,RHCAVE,SPAREA,RWASTE
 1330   FORMAT(6(D10.4,1X))
        PI=4.D0*DATAN(1.0D0)
        PINVOL=PI*PIN*PIN*PINLEN/4.D0
        PINMAS=RHOAVE*PINVOL
C
C
C       FRACTIONAL FUEL COMPOSITION:
C               WEIGHT FRACTIONS
C               MOLE FRACTIONS
C
        READ(5,1330)PCU3O8,PCPUO2,PCFP,FRMCU3,FRMOPU,FRMOFP
C
C       COMPONENT DENSITIES AND
C       FLOW EQUATION CONSTANTS...
C       FROM ORNL/TM-7490, A MATHEMATICAL MODEL FOR LIQUID FLOW TRANSIENTS IN
C               A ROTARY DISSOLVER.  LEWIS AND WEBER
C
        READ(5,1330) DU3O8,DPUO2,DFP,DENSST,TK,POW
                REPOW=1.D0/POW
C
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C
C         PER CENT THEORITICAL FUEL DENSITY
C         COMBINED FISSION PROD MOLE FRACTION WITH PUO2...
                    XPU=FRMOPU+FRMCFP
                    REM=1.D0-XPU
                    TD=(RHOAVE*100.D0)/(XPU*DPUO2+REM*DU3O8)
C
C
C         ZERO MAXIMUM DETECTORS,ETC.
C
          DO 280 K=1,10
          TOCON1(K)=0.0D0
          TOCOW1(K)=0.0D0
          TOCON2(K)=0.0D0
          TOCOW2(K)=0.0D0
          UNMAX(K)=0.0D0
          PNMAX(K)=0.0D0
          FNMAX(K)=0.0D0
          HNMAX(K)=0.0D0
          H2MAX(K)=0.0D0
          TUMAX(K)=0.0D0
          TPMAX(K)=0.0D0
          TFMAX(K)=0.0D0
          THNMX(K)=0.0D0
          TH2MX(K)=0.0D0
280       CONTINUE
C
C         ZERO COUNTERS AND ACCUMULATORS...
C
                    FFI=0.0D0
                    TOTUO1=0.0D0
                    TOTUOF=0.0D0
                    TOPUO1=0.0D0
                    TOPUOF=0.0D0
                    TOTUI=0.0D0
                    TOTPUI=0.0D0
                    ETOTUF=0.0D0
                    ETOTPF=0.0D0
                    PRT=0.0D0
                    IDX=0
                    IAD=0
                    PLTM=0.0D0
                    T=0.0D0
                    T1=0.0D0
                    T2=0.0D0
                    TIME=0.0D0
                    DISTM=0.0D0
                    DIGPAR=0.0D0
                    DTFLG1=0.0D0
                    ICP=0
                    ICPO=0
                    FEDTIM=0.0D0
                    OFFTIM=0.0D0
                    SUMNEG=0.0D0
                    SUMHNO=0.0D0
                    SUMFLP=0.0D0
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      SUMFLF=0.0D0
      SUMPLV=0.0D0
      SUMNEP=0.0D0
      SUMFIN=0.0D0
      SUMPIN=0.0D0
      SUMFOU=0.0D0
      SUMPOU=0.0D0
      SUMD1=0.0D0
      SUMD2=0.0D0
      TMOLD=0.0D0
      TF=0.0D0
      SSTF=0.0D0
      FEDONE=0.0D0
      FINESF=0.0D0
      PINFED=0.0D0
      D1UN=0.0D0
      D2UN=0.0D0
      D1PN=0.0D0
      D2PN=0.0D0
      D1H2O=0.0D0
      D2H2O=0.0D0
      D1HNO3=0.0D0
      D2HNO3=0.0D0
      D1PART=0.0D0
      D2PART=0.0D0
      D1FPN=0.0D0
      D2FPN=0.0D0
      PCONT=0.0D0
      ITSAC=0
      JJPART=0
      MMUN=0
      NNPN=0
      NNFP=0
      MMHN=0
      IIH2=0
C
C
C        MOLECULAR WEIGHTS
C
      WMOLU3=270.05D0
      WMOLU=238.04D0
      WMOLP=239.172D0
      WMOLPU=271.17D0
      WMOLFP=135.34D0
      WMOLUN=394.02D0
      WMOLPN=487.21D0
      WMOLFN=328.22D0
      WMOLH2=18.02D0
      WMOLHN=63.02D0
      AVEMOL=PCU3O8*WMOLU3+PCPUO2*WMOLPU+PCFP*WMOLFP
C
C
C        ACID CONC CORRECTION FACTOR (ACDF) DUE TO DIFFERENCES IN
C        ACID CONC IN FUEL PINS AND BULK.
C        PRINT OUT AND RUN TIME CONSTANTS.
C
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```
C
C
      READ(5,1330)ACDF,PRTTIM,HC,RUN,PRINC,PRDIST
      READ(5,1370) ALIMO,AKSTOP,AMINFR,CTI
              LIMO=ALIMO
              KSTOP=AKSTOP
              P1HC=AMINFR*HC
              H=HC
              MUM=RUN/PRINC
              PLINC=PRINC-1.0D-4
C
C
C     DISSOLVER CHARATERISTICS
C
      READ(5,1370) TEMP,RPM,DREVS,FLAPTM
1350  FORMAT(3(D10.4,1X))
      DUMPT=DREVS/RPM
      DTRACT=1.D0/DUMPT
      READ(5,1360)(VO(I),I=1,5)
1360  FORMAT(5(D10.4,1X))
      READ(5,1360)(VO(I),I=6,10)
      READ(5,1360)(VO(I),I=11,15)
      READ(5,1360)(VO(I),I=16,20)
      DO 35 I=1,20
      BAKMIX(I)=0.0D0
      AS(I)=0.0D0
35    CONTINUE
C
C     NO INTERUPTIONS IN LIQUID FLOW ARE EXPERIENCED DURING REVERSE
C     ROTATION.  THE ACTUAL REVERSE IS ASSUMED TO BE INSTANTANIOUS.
C
      READ(5,1365) TRCT,BASECT,DIA,STGLEN,AAANS
1365  FORMAT(5(D10.4,1X))
      NS=AAANS
      NSM1=NS-1
      CT=BASECT+TRCT
C
C     MAXIMUM LIQUID DEPTHS.
C
      READ(5,1360)(DEPTH(I),I=1,5)
      READ(5,1360)(DEPTH(I),I=6,10)
      READ(5,1375) ANGLE
1375  FORMAT(D10.4)
      AN=ANGLE*PI/1.8D2
      QD=STGLEN*DSIN(AN)/DCOS(AN)
      ACTLEN=STGLEN/DCOS(AN)
      DO 210 K=1,NS
      QA=DSQRT(4.D0*DEPTH(K)*(DIA-DEPTH(K)))
      SALL=DEPTH(K)-QD
      QB=DSQRT(4.D0*SALL*(DIA-SALL))
      AS(K)=.5D0*(QA+QB)*ACTLEN
210   CONTINUE
C
C
C     ***    ZERO ARRAYS    ***
C
```

```
             DO 16 J1=1,10
      PLVM(J1)=0.0D0
      ZQT(J1)=0.0D0
      Z1MQT(J1)=0.0D0
      FO(J1)=0.0D0
      FLEXT(J1)=0.0D0
      H2OF(J1)=0.0D0
      HNO3F(J1)=0.0D0
             DO 16 J2=1,200
      PLTIME(J2)=0.0
      PLU3O8(J1,J2)=0.0D0
      PLUN(J1,J2)=0.0D0
      PLPUO2(J1,J2)=0.0D0
      PLPN(J1,J2)=0.0D0
      PLFP(J1,J2)=0.0D0
      PLHNO3(J1,J2)=0.0D0
      PLH2O(J1,J2)=0.0D0
      PLFPN(J1,J2)=0.0D0
      PLPART(J1,J2)=0.0D0
      PLWTT(J1,J2)=0.0D0
      PLSST(J1,J2)=0.0D0
16           CONTINUE
C
C     EXTERNAL FEED STREAM FLOWS..
C     FROM BECTAL FLOW SHEETS FOR HEF 4/18/80, DRAWING # 52-B-203
C     (FLOWSHEET DENSITIES HAVE BEEN USED BUT GADOLINUM NITRATE
C     HAS BEEN EXCLUDED FROM MASS FLOW RATES.)
C
      READ(5,1370)DEN1,CDEN8,DEN9,DEN10
1370  FORMAT(4(D10.4,1X))
      DEN8=CDEN8
      READ(5,1370) TH2OC,THNO3C,FCSTG1,FCSTG9
      H2OM1=TH2OC*FCSTG1
      HNO3M1=THNO3C*FCSTG1
      H2OM9=TH2OC*FCSTG9
      HNO3M9=THNO3C*FCSTG9
      TF1=H2OM1+HNO3M1
      TF9=H2OM9+HNO3M9
      READ(5,1370) CH2OM8,CHNOM8,H2OM10,HNOM10
      H2OM8=CH2OM8
      HNO3M8=CHNOM8
      TF8=H2OM8+HNO3M8
      TF10=H2OM10+HNOM10
      THOVSX=1000.D0/60.D0
      DILUT1=TF1*THOVSX/DEN1
      DILUT9=TF9*THOVSX/DEN9
      FLEXT(8)=TF8*THOVSX/DEN8
      FLEXT(1)=DILUT1
      FLEXT(9)=DILUT9
      F10=TF10*THOVSX/DEN10
      F9=F10+FLEXT(9)
      F2=F9+FLEXT(8)
      F1=F2+FLEXT(1)
      DO 185 K=2,NSM1
185   FO(K)=F2
      FO(1)=F1
```

```
      FO(9)=F9
      FO(10)=F10
C
C     INITIALIZATION OF BACKMIXING CARRYOVER ON HULLS.
C
      READ(5,1360)(BAKMIX(I),I=1,5)
      READ(5,1360)(BAKMIX(I),I=6,10)
      READ(5,1360)(BAKMIX(I),I=11,15)
      READ(5,1360)(BAKMIX(I),I=16,20)
      DO 20 J=1,20
20    FL(J)=F2
      FL(1)=F1
      FL(9)=F9
      FL(10)=F10
C
C
C     INITIAL STAGE CONCENTRATIONS....
C
C
      H2OF(8)=DEN8*H2OM8/TF8
      HNO3F(8)=DEN8*HNO3M8/TF8
      IF(TF1.LE.0.0D0) GOTO 4000
      H2OF(1)=DEN1*H2OM1/TF1
      HNO3F(1)=DEN1*HNO3M1/TF1
      GOTO 4010
4000  H2OF(1)=0.0D0
      HNO3F(1)=0.0D0
4010  IF(TF9.LE.0.0D0) GOTO 4050
      H2OF(9)=DEN9*H2OM9/TF9
      HNO3F(9)=DEN9*HNO3M9/TF9
      GOTO 4060
4050  H2OF(9)=0.0D0
      HNO3F(9)=0.0D0
4060  IF(TF10.LE.0.0D0) GOTO 4030
      HNO3(10)=DEN10*HNOM10/TF10
      H2O(10)=DEN10*H2OM10/TF10
      GOTO 4040
4030  H2O(10)=0.0D0
      HNO3(10)=0.0D0
4040  HNO3B(10)=HNO3(10)
      H2OB(10)=H2O(10)
      HNO3(9)=(HNO3(10)*FL(10)+HNO3F(9)*FLEXT(9))/FL(9)
      HNO3B(9)=HNO3(9)
      H2O(9)=(H2O(10)*FL(10)+H2OF(9)*FLEXT(9))/FL(9)
      H2OB(9)=H2O(9)
      HNO3(8)=(HNO3(9)*FL(9)+HNO3F(8)*FLEXT(8))/FL(8)
      HNO3B(8)=HNO3(8)
      H2O(8)=(H2O(9)*FL(9)+H2OF(8)*FLEXT(8))/FL(8)
      H2OB(8)=H2O(8)
      DO 10 K=2,7
      HNO3(K)=HNO3(8)
      H2O(K)=H2O(8)
10    CONTINUE
      HNO3(1)=(HNO3(2)*FL(2)+HNO3F(1)*FLEXT(1))/FL(1)
      HNO3B(1)=HNO3(1)
      H2O(1)=(H2OF(1)*FLEXT(1)+H2O(2)*FL(2))/FL(1)
```

```
      H2OB(1)=H2C(1)
C
C     REDUCED ACID FLOW PARAMATERS.
C
      READ(5,1370)SDEN8,SH2OM8,SHNOM8,SLOTLM
C
C     DIGESTER TANK VARIABLES :
C
              IPD=0
              VD1=0.0D0
              VD2=0.0D0
              TM1=0.0D0
              TM2=0.0D0
              TFD1=0.0D0
      READ(5,1350) TFILL,TTRAN,TDIG
              VFULL=TFILL*FL(1)
              TFD2=0.0D0
              TDPLOT=0.0D0
              TD1=0.0D0
              TD2=0.0D0
              TTD1=0.0D0
              TTD2=0.0D0
C
C     INITIAL REACTION RATES
C     REACTION RATE FOR U308 AS FUNCTION OF HNO3 CONC AND TD
C     BASED ON UO2 REACTION RATE.....??????.......
C
C
C
C
C     REACTION RATE FOR PUO2 AS FUNCTION OF HNO3 CONC AND TD
C     ASSUMES NO FLUORINE IN DISSOLVER.
C     FROM A REPORT BY RAINEY AND URIARTE PUBLISHED IN 1965.
C
C
C
C
C
      READ(5,1370) ACIDEF,RFACT,AFIAT,AFRAT
      ACID=HNO3(1)/WMOLHN
      RPOW=2.D0+2.D0*XPU
      RCON=((5.D3*DEXP((-.27D0)*TD))**XPU)*
     $((4.8D2*DEXP((-.091)*TD))**REM)
      RATMF=RFACT*RCON
              DO 220 K=1,NS
      RATE2(K)=RATMF*(ACID*ACDF)**RPOW
      RATE1(K)=RATMF*ACID**RPOW
      UNK1(K)=PCU308*RATE1(K)
      PNK1(K)=PCPUO2*RATE1(K)
      FPK1(K)=PCFP*RATE1(K)
      UNK2(K)=PCU308*RATE2(K)
      PNK2(K)=PCPUO2*RATE2(K)
      FPK2(K)=PCFP*RATE2(K)
220           CONTINUE
C
```

```
C        SOLID FLOWS AND QUANTITIES
C        HULLS,SHROUDS,AND WIPES VOLUMES...
C
         READ(5,1370) TMRFED,TMRSST,BATTIM,SHETIM
         ANOVOX=BATTIM/SHETIM
         FFTIME=SHETIM/BATTIM
         ANFTIM=BATTIM-SHETIM
         AFDAS=SHETIM-AFRAT
         AFDAN=ANFTIM-AFIAT
         FEDRAT=(TMRFED-TMRSST)*THOVSX*ANOVOX
         TIMMIN=SHETIM
         IF(SHETIM.GT.CT)TIMMIN=CT
         IF(SHETIM.LT.CT) GOTO 1740
         GOTO 1750
1740     ANIFS=CT/BATTIM
         INIFS=ANIFS
         BEEDIF=ANIFS-INIFS
         TMLEFT=BEEDIF*BATTIM
         TIMMIN=SHETIM*INIFS+TMLEFT
         IF(SHETIM.LT.TMLEFT)TIMMIN=SHETIM*INIFS+SHETIM
1750     CONTINUE
         FUELWT=TIMMIN*FEDRAT
         TNP=FUELWT/PINMAS
         TOTSST=TMRSST*THOVSX*TIMMIN*ANOVOX
         SSTVOL=TOTSST/DENSST
         READ(5,1330) FFINES,RMIN,RMAX,DP,TOL,AAANG
         NG=AAANG
         CFINES=FFINES*FEDRAT
         FINES=CFINES
         FUEL=(1.D0-FFINES)*FEDRAT
         READ(5,1370) CONREL,FEANG,PIN000,PAR000
         READ(5,1360)ZNOPTA,ZNOPTD,ZNOPTP,ZNOPT3,ZNOPT7
                  DO 195 J=1,NS
         REL(J)=CONREL
         CREL(J)=CONREL/TNP
195               CONTINUE
C
C        PARTICLE SIZE DISTRIBUTION INITIALIZATION.
C
                  CALL FREQUE
C
C
C        INITIAL AVERAGE PARTICLE DIAMETER(DP), USED IN CONSTANTS HEREAFTER.
C        FROM FFTF FUEL SPECS AND PHOTO OF RESIDUES..
C
C
C
C        CONSTANTS
C
C
         IF(RWASTE.GT.RMAX) GOTO 2200
         GOTO 2300
2200     WRITE(12,2400)
         WRITE(13,2400)
         WRITE(6,2400)
2400     FORMAT(//' DEFAULT RWASTE EQUAL TO RMAX...'/
```

```
     $' DATA FILE ENTRY OUT OF RANGE..'/' RWASTE = RMAX')
2300    NRW=(RWASTE-RMIN)/DR
        NRWM1=NRW-1
        NRWM2=NRW-2
        NGPNRW=NG+NRW
        NGM1=NG-1
        CUBE=1.D0/3.D0
        UPERU3=1.D0*WMOLU/WMOLU3
        PPERPU=WMOLP/WMOLPU
        UPERUN=WMOLU/WMOLUN
        PPERPN=WMOLP/WMOLPN
        THETA=FEANG*PI/180.D0
        CON=PIN*PIN*PI/(DSIN(THETA))
        ZU=1.D0*WMOLUN/WMOLU3
        ZUCON=ZU*CON
        ZP=WMOLPN/WMOLPU
        ZPCON=ZP*CON
        ZF=WMOLFN/WMOLFP
        ZFCON=ZF*CON
        BW=WMOLH2/WMOLU3
        BWC=CON*BW
        BN=WMOLHN/WMOLU3
        BNC=CON*BN
        E03=8.D0/3.D0
        F03=4.D0/3.D0
        COPN1N=4.D0*WMOLHN/WMOLPU
        COFP1N=2.3552D0*WMOLHN/WMOLFP
        COPN2N=4.D0*CON*WMOLHN/WMOLPU
        COFP2N=2.3552D0*CON*WMOLHN/WMOLFP
        COPN1W=2.D0*WMOLH2/WMOLPU
        COFP1W=1.1776D0*WMOLH2/WMOLFP
        COPN2W=2.D0*CON*WMOLH2/WMOLPU
        COFP2W=1.1776D0*CON*WMOLH2/WMOLFP
        PCU3ZU=PCU308*ZU
        PCPUZP=PCPUO2*ZP
        PCFPZF=PCFP*ZF
        CP1NPU=COPN1N*PCPUO2
        CF1NFP=COFP1N*PCFP
        CP1WPU=COPN1W*PCPUO2
        CF1WFP=COFP1W*PCFP
        CP2NPU=COPN2N*PCPUO2
        CF2NFP=COFP2N*PCFP
        CP2WPU=COPN2W*PCPUO2
        CF2WFP=COFP2W*PCFP
        T1CON=CP1NPU+CF1NFP
        T1COW=CP1WPU+CF1WFP
        T2CON=CP2NPU+CF2NFP
        T2COW=CP2WPU+CF2WFP
        DO 300 JJ=1,10
        TOCON1(JJ)=T1CON
        TOCON2(JJ)=T2CON
        TOCOW1(JJ)=T1COW
        TOCOW2(JJ)=T2COW
300     CONTINUE
        PCUPER=PCU308*UPERU3
        PCPPER=PCPUO2*PPERPU
```

```
      ARATIO=SPAREA*1.D-4
      DO 190 K=1,NS
      RASS(K)=1.D3/AS(K)
190   CONTINUE
      ROATT=RHOAVE*1.D3
      SSSCT=SSTVOL/TIMMIN
      D25C1=1.0012D0
      D25C2=0.3177D0/WMOLUN
      D25C3=0.22D0/WMOLPN
      D25C4=0.03096D0/WMOLHN
      RHOC1=1.0125D0*1.D3
      RHOC2=1.45D-4*TEMP*1.D3
      RHOC3=5.D-4*TEMP*1.D3
      RHOC4=3.6D-3*1.D3
      UFEEDC=FEDRAT*PCUPER
      PFEEDC=FEDRAT*PCPPER
      FOURPI=4.D0*PI
      FTPIRO=FOURPI*RHOAVE/3.D0
C
C     DENSITY INITIALIZATION
C
      DO 45 I=1,NS
      VIB(I)=VO(I)+AS(I)*((FL(I)/TK)**REPCW)/1.D3
      CO(I)=UN(I)+PN(I)+FPN(I)+H2O(I)+HNO3(I)
      COMA=CO(I)*VIB(I)/1.0D3
      D25=COMA-(D25C2*UN(I)+D25C3*PN(I)+D25C4*HNO3(I))*VIB(I)
      D25=COMA*D25C1/D25
      RHOLIQ(I)=RHOC1*D25+RHCC2-RHOC3*D25-RHOC4
      PLV(I)=CO(I)*VIB(I)/RHOLIQ(I)
      VIB(I)=PLV(I)
      V(I)=PLV(I)
45    CONTINUE
C
C     BACKMIX VOLUME INITIALIZATION.
C
      DO 225 J=1,NS
      BMCON=BAKMIX(J)*TCTSST
225   BAKV(J)=BMCCN/RHOLIQ(J)
C
C     INITIAL CALC FOR RELEASE RATE CUTPUT.
C
      T1=H
      WTFUEL(1)=FUELWT
      CALL RELEAS
      T1=0.0D0
      WTFUEL(1)=0.0D0
C
C
C     DATA OUTPUT
C
C
      WRITE(12,1000) PCU308,DU308,WMCLU3,PCPUO2,DPUO2,WMOLPU,PCFP,
     $DFP,WMOLFP
      WRITE(13,1000) PCU308,DU308,WMCLU3,PCPUO2,DPUO2,WMOLPU,PCFP,
     $DFP,WMOLFP
      WRITE(6,1000) PCU308,DU308,WMOLU3,PCPUO2,DPUO2,WMOLPU,PCFP,
```

```
     $DFP,WMOLFP
1000    FORMAT(' ',21X,'SPENT FUEL DATA'/' COMPONENT',5X,'WEIGHT FRAC',
     $'TION',5X,'DENSITY',5X,'MOLE WEIGHT'/35X,'(G/CC)',7X,'(G/G-MOLE)'/
     $3X,'UO2 ',10X,F10.4,7X,F10.6,4X,F10.4/3X,'PUO2',10X,F10.4,7X,
     $F10.6,4X,F10.4/3X,'F.P.',10X,F10.4,7X,F10.6,4X,F10.4)
        WRITE(12,1020) RHOAVE,DP,TNP,PIN,PINLEN,SPAREA,FFINES,CONREL
        WRITE(13,1020) RHOAVE,DP,TNP,PIN,PINLEN,SPAREA,FFINES,CONREL
        WRITE(6,1020) RHOAVE,DP,TNP,PIN,PINLEN,SPAREA,FFINES,CONREL
1020    FORMAT(/' AVERAGE FUEL DENSITY =',2X,F10.6,2X,
     $'G/CC'/' AVERAGE DIAMETER OF PARTICULATE=',2X,F10.6,
     $2X,'CM'/' TOTAL # FUEL PINS=',2X,F10.2/' DIAMETER OF FUEL',
     $' PELLET=',2X,F10.4,2X,'CM'/' LENGTH OF FUEL PIN=',2X,
     $F10.4,2X,'CM'/
     $' RATIO OF ACTUAL SURFACE AREA TO GEOMETRIC AREA=',2X,
     $1PD14.5/' FRACTION OF FUEL AS FINES=',
     $2X,1PD12.3/' FULL STAGE PARTICLE RELEASE RATE=',
     $2X,1PD14.5,2X,'G/MIN')
        WRITE(12,1010) TMRSST,SIZE,FEDRAT,FL(1),HNO3(1),H2O(1),RHOLIQ(1)
     $,TK,POW,SLOTLM
        WRITE(13,1010) TMRSST,SIZE,FEDRAT,FL(1),HNO3(1),H2O(1),RHOLIQ(1)
     $,TK,POW,SLOTLM
        WRITE(6,1010) TMRSST,SIZE,FEDRAT,FL(1),HNO3(1),H2O(1),RHOLIQ(1)
     $,TK,POW,SLOTLM
1010    FORMAT(' TOTAL MASS FEED RATE OF STAINLESS STEEL='
     $,2X,F12.2,2X,'KG/HR'//1X,F10.4,2X,'  TONNE-A-DAY THROUGHPUT'/
     $' FUEL FEED RATE=',2X,F10.4,2X,'G/MIN'//' LIQUID '
     $,'FLOW STG 1=',2X,F10.4,2X,'L/MIN'/' LIQUID FEED COMP. STG 1 :'/
     $13X,'HNO3',4X,'---',4X,F8.2,2X,'GRAM/L'/13X,'H2O',5X,'---',4X,
     $F8.2,2X,'GRAM/L'/' INITIAL DENSITY OF DISSOLVER LIQUID STG 1=',
     $2X,F12.4,2X,'G/L'/' COEFFICIENT OF WEIR FLOW EQUATION=',2X,
     $1PD14.4/' EXPONENT OF WEIR FLOW EQUATION=',2X,1PD14.4/
     $' LIMITING HEIGHT OVER WEIR (SLOT SIZE)=',2X,1PD15.4,
     $2X,'CM')
        WRITE(12,1030) V(1),NSM1,V(2),NS,V(9),NS,H
        WRITE(13,1030) V(1),NSM1,V(2),NS,V(9),NS,H
        WRITE(6,1030) V(1),NSM1,V(2),NS,V(9),NS,H
1030    FORMAT(//' STAGE',
     $' 1 INITIAL VOLUME=',2X,F10.2,2X,'L'/' STAGES 2-',I2,
     $' INITIAL VOLUME=',2X,F10.2,2X,'L'/' STAGE',I2,
     $' INITIAL VOLUME=',2X,F10.2,2X,'L'/
     $' NUMBER OF STAGES=',2X,I2/' MAXIMUM TIME INCREMENT='
     $,2X,F10.6,2X,'MIN')
        WRITE(12,1040) UNK1(1),UNK2(1),PNK1(1),PNK2(1),FPK1(1),FPK2(1)
        WRITE(13,1040) UNK1(1),UNK2(1),PNK1(1),PNK2(1),FPK1(1),FPK2(1)
        WRITE(6,1040) UNK1(1),UNK2(1),PNK1(1),PNK2(1),FPK1(1),FPK2(1)
1040    FORMAT(//14X,' INITIAL REACTION RATE CONSTANTS'/' COMPONENT',5X,
     $' PARTICULATE RATE',5X,' PIN RATE'/'    FORMED',11X,
     $'(G/MIN-CM**2)',5X,'(G/MIN-CM**2)'//' UO2(NO3)2',10X,
     $1PD12.5,5X,1PD12.5/'  PU(NO3)4',10X,1PD12.5,5X,1PD12.5/
     $' F.P. NIT.',10X,1PD12.5,5X,1PD12.5)
        WRITE(12,1060)RCON,RPOW,TD,TEMP,RWASTE,RMIN,RMAX,NG,FLAPTM
        WRITE(13,1060)RCON,RPOW,TD,TEMP,RWASTE,RMIN,RMAX,NG,FLAPTM
        WRITE(6,1060)RCON,RPOW,TD,TEMP,RWASTE,RMIN,RMAX,NG,FLAPTM
1060    FORMAT(/' REACTION RATE CONSTANT=',2X,1PD12.5,2X,
     $'(GRAM/(CM**2*MIN*(MOL/L)**(2+2*XPU))'/' REACTION RATE EXPONENT=',
     $2X,1PD12.5/' PERCENT THEORITICAL DENSITY=',2X,
```

```
     $2PD12.4/' INITIAL TEMPERATURE=',2X,3PD12.3,2X,'DEG C'/
     $' MINIMUM PARTICLE DIAMETER TRANSFERING WITH FUEL PINS=',
     $2X,1PD14.4,2X,'MICRON'/
     $' MINIMUM PARTICLE SIZE IN DISTRIBUTION='
     $,2X,1PD14.4,2X,'MICRON'/
     $' MAXIMUM PARTICLE SIZE IN DISTRIBUTION='
     $,2X,1PD14.4,2X,'MICRON'/' TOTAL # OF PARTICLE SIZE GROUPS='
     $,2X,I4/' FLAPPER VALVE CYCLE TIME=',2X,1PD10.4,2X,'MIN')
      WRITE(12,1050)RUN,CT1,NS,CT,TRCT,RPM,SHETIM,ANFTIM
      WRITE(13,1050)RUN,CT1,NS,CT,TRCT,RPM,SHETIM,ANFTIM
      WRITE(6,1050)RUN,CT1,NS,CT,TRCT,RPM,SHETIM,ANFTIM
1050  FORMAT(//' TOTAL RUN TIME=',2X,F10.2,2X,'MIN'/
     $' CYCLE TIME STG 1=',2X,F10.2,2X,'MIN'/' STAGES 2-',I2,
     $'  CYCLE TIME=',2X,F10.2,2X,'MIN'/' REVERSE CYCLE TIME',
     $2X,F10.2,2X,'MIN'/' RATE OF ROTATION=',
     $2X,F10.2,2X,'RPM'/' FEED TIME FROM SHEAR=',
     $2X,1PD15.4,2X,'MIN'/' ZERO FEED TIME=',
     $2X,1PD15.4,2X,'MIN')
      WRITE(12,1410) ACIDEF,RFACT,AFIAT,AFRAT,SDEN8,SH2OM8,SHNOM8
      WRITE(13,1410) ACIDEF,RFACT,AFIAT,AFRAT,SDEN8,SH2OM8,SHNOM8
      WRITE(6,1410) ACIDEF,RFACT,AFIAT,AFRAT,SDEN8,SH2OM8,SHNOM8
1410  FORMAT(//' ACID DEFICIENT CONCENTRATION FLAG=',2X,
     $1PD15.4,2X,'G-HNO3/L'/' REACTION RATE MULTIPLICATION FACTOR=',
     $2X,1PD15.4//' ACID FEED RATE INCREASE ANTICIPATION TIME=',
     $2X,1PD15.4,2X,'MIN'/
     $' ACID FEED RATE REDUCTION ANTICIPATION TIME=',
     $2X,1PD15.4,2X,'MIN'/' REDUCED ACID FEED RATE DENSITY=',
     $2X,1PD15.4,2X,'G/L'/' REDUCED ACID FEED H2O FLOW=',2X,
     $1PD15.4,2X,'KG/HR'/' REDUCED ACID FEED HNO3 FLOW=',2X,
     $1PD15.4,2X,'KG/HR')
      WRITE(12,2020)HNO3M8,HNO3F(8),H2OM8,H2OF(8),DEN8,TF8,HNO3M1,
     $HNO3F(1),H2OM1,H2OF(1),DEN1,TF1,HNO3M9,HNO3F(9),H2OM9,H2OF(9),
     $DEN9,TF9,HNOM10,HNO3F(10),H2OM10,H2O(10),DEN10,TF10
      WRITE(13,2020)HNO3M8,HNO3F(8),H2OM8,H2OF(8),DEN8,TF8,HNO3M1,
     $HNO3F(1),H2OM1,H2OF(1),DEN1,TF1,HNO3M9,HNO3F(9),H2OM9,H2OF(9),
     $DEN9,TF9,HNOM10,HNO3F(10),H2OM10,H2O(10),DEN10,TF10
      WRITE(6,2020)HNO3M8,HNO3F(8),H2OM8,H2OF(8),DEN8,TF8,HNO3M1,
     $HNO3F(1),H2OM1,H2OF(1),DEN1,TF1,HNO3M9,HNO3F(9),H2OM9,H2OF(9),
     $DEN9,TF9,HNOM10,HNO3F(10),H2OM10,H2O(10),DEN10,TF10
2020  FORMAT(//1X,20X,' EXTERNAL FEED STREAMS MASS FLOW RATES'
     $//1X,10X,'COMPONENT',14X,'DENSITY (G/L)',7X,'FLOW (KG/HR)'
     $,4X,'CONCENTRATION (G/L)'/' FEED HNO3 TO STAGE 8',31X,F10.2,8X
     $,F10.2/' FEED H2O TO STAGE 8',32X,F10.2,8X,F10.2/
     $' TOTAL FEED TO STAGE 8',11X,F10.2,9X,F10.2//
     $' CONDENSATE HNO3 TO STAGE 1',25X,F10.2,8X,F10.2/
     $' CONDENSATE H2O TO STAGE 1',26X,F10.2,8X,F10.2/
     $' TOTAL CONDENSATE TO STAGE 1',5X,F10.2,9X,F10.2//
     $' CONDENSATE HNO3 TO STAGE 9',25X,F10.2,8X,F10.2/
     $' CONDENSATE H2O TO STAGE 9',26X,F10.2,8X,F10.2/
     $' TOTAL CONDENSATE TO STAGE 9',5X,F10.2,9X,F10.2//
     $' RINSE HNO3 TO STAGE 9',30X,F10.2,8X,F10.2/
     $' RINSE H2O TO STAGE 9',31X,F10.2,8X,F10.2/
     $' TOTAL RINSE LIQUID TO STAGE 9',3X,F10.2,9X,F10.2)
      WRITE(12,2030) (I,BAKMIX(I),B(I),BAKV(I),PLV(I),I=1,NS)
      WRITE(13,2030) (I,BAKMIX(I),B(I),BAKV(I),PLV(I),I=1,NS)
      WRITE(6,2030) (I,BAKMIX(I),B(I),BAKV(I),PLV(I),I=1,NS)
```

```
2030    FORMAT(//1X,26X,'*** BACKMIXING DATA ***'//
       $' STAGE',10X,'PERIODIC',10X,'CONTINUOUS',10X,'MAXIMUM'
       $,10X,'INITIAL'/
       $'   #',11X,'BACKMIXING',9X,'BACKMIXING',10X,'QUANTITY'
       $,10X,'STAGE'/1X,14X,'WITH HULLS',
       $10X,'(L/MIN)',11X,'BACKMIXED',10X,'VOLUME'/1X,15X,'TRANSFER'
       $,31X,'(L)',15X,'(L)'/1X,11X,'(G SOLN / G HULLS)'/
       $5(I4,7X,1PD15.4,3X,1PD15.4,3X,1PD15.4,3X,1PD15.4/)//
       $1X,5X,'***  PLOTS REQUESTED  ***'/)
        IF(ZNOPTA.EQ.0.0D0) GOTO 2040
        IF(ZNOPTD.EQ.1.0D0) GOTO 2045
2063    IF(ZNOPTP.EQ.1.0D0) GOTO 2050
2065    IF(ZNOPT3.EQ.1.0D0) GOTO 2055
2073    IF(ZNOPT7.EQ.1.0D0) GOTO 2085
        GOTO 2095
2040    WRITE(6,2042)
        WRITE(12,2042)
        WRITE(13,2042)
2042    FORMAT(' NO PLOTS REQUESTED'/)
        GOTO 2095
2045    WRITE(6,2047)
        WRITE(12,2047)
        WRITE(13,2047)
2047    FORMAT(' DIGESTER CONCENTRATION PROFILES')
        GOTO 2063
2050    WRITE(6,2052)
        WRITE(12,2052)
        WRITE(13,2052)
2052    FORMAT(' PARTICLE SIZE DISRTIBUTIONS')
        GOTO 2065
2055    WRITE(6,2057)
        WRITE(12,2057)
        WRITE(13,2057)
2057    FORMAT(' CONCENTRATION HISTORIES')
        GOTO 2073
2085    WRITE(6,2088)
        WRITE(12,2088)
        WRITE(13,2088)
2088    FORMAT(' CONCENTRATION PROFILES')
2095    CONTINUE
C
C
C
C       BEGIN OF STEPWISE MATERIAL BALANCE.
C       IN ALL CALCULATIONS IT IS ASSUMED THAT SOLIDS ENTER
C       THE DISSOLVER AT STAGE 1 AND EXIT AT STAGE NS.  IT IS
C       ALSO ASSUMED THAT LIQUID ENTERS AT STAGE NS AND EXITS AT
C       STAGE 1, FLOWING COUNTERCURRENT TO THE SOLIDS.
C       INITIALLY THERE ARE NO SOLIDS IN THE DISSOLVER AND THE
C       ACID CONCENTRATION AND FLOWS ARE AT STEADY STATE.
C
C
C
        GO TO 800
850     CONTINUE
C
```

```
C        SET OFFTIM = H TO START WITH NC SOLIDS FEED TO DISSOLVER.
C        ALSO MUST SET CFUEL = 0.0D0 ....
C
C        OFFTIM=H
C        CFUEL=0.0D0
         DO 900 INC=1,KSTOP
C
C        TIME STEP LENGTH ADJUSTMENT TO AVOID OVER DISSCLUTION.
C
         CALL TSTEP
         IF(H.LT.P1HC) H=P1HC
C
C        INCREMENT COUNTERS
C
         TIME=TIME+H
         PLTM=PLTM+H
         T=T+H
         T1=T1+H
         DISTM=DISTM+H
C
C        ACID FEED CONTROL
C        ASSUMES INITIAL SOLIDS FEED OF NON ZERO VALUE
C
         IF(FEDTIM.GE.AFDAS) GOTO 3200
         IF(OFFTIM.GE.AFDAN) GOTO 3400
         IF(OFFTIM.GE.P1HC) GOTC 3200
         IF(TIME.LE.H.AND.OFFTIM.GE.P1HC) GOTO 3200
3400     DEN8=CDEN8
         HNO3M8=CHNCM8
         H2OM8=CH2OM8
         GOTO 3300
3200     DEN8=SDEN8
         HNO3M8=SHNCM8
         H2OM8=SH2OM8
C
C        SHEAR FEED CONTROL
C
3300     IF (OFFTIM.LT.P1HC) GOTO 500
         OFFTIM=OFFTIM+H
         IF (OFFTIM.GT.ANFTIM) GO TO 520
         GOTO 510
520      OFFTIM=0.0D0
         FEDTIM=H
         TCFUEL=FUEL
         GOTO 510
500      FEDTIM=FEDTIM+H
         IF (FEDTIM.GT.SHETIM) GOTO 450
         TCFUEL=FUEL
         GOTO 510
450      FEDTIM=0.0D0
         IF(BATTIM.EQ.SHETIM)GOTO 510
         OFFTIM=H
         TCFUEL=0.0D0
510      CTF8=(HNO3M8+H2OM8)/DEN8
         H2OF(8)=H2CM8/CTF8
         HNO3F(8)=HNO3M8/CTF8
```

```
      FLEXT(8)=CTF8*THOVSX
      CFUEL=TCFUEL*H
      SSSCTH=SSSCT*H
      FINESH=FINES*H
      FUPIN=(CFUEL+FINESH)/PINMAS
                        DO 2000 KD=1,NS
      U3O8(KD)=PART(KD)*PCU3C8
      PUO2(KD)=PART(KD)*PCPUC2
      FP(KD)=PART(KD)*PCFP
      CO(KD)=UN(KD)+PN(KD)+FPN(KD)+H2O(KD)+HNO3(KD)
      PLVM(KD)=BAKV(KD)
C
C     USE OLD VOLUME AND NEW CONC TO ESTIMATE NEW VOLUME...
C     ALSO USES OLD FLOWS TO DETERMINE VOLUME CORRECTION...
C
      KDP1=KD+1
      VOLFLO=(FLEXT(KD)+FL(KDP1)-FL(KD))*H
      PLV(KD)=CO(KD)*VIB(KD)/RHOLIQ(KD)+VOLFLO
C
C     PURE LIQUID VOLUME MUST NOT BE LESS THAN PLVM(I)...
C
C     WRITE(6,511)PLV(KD)
C511  FORMAT(5X,'PLV(KD)=',F15.7)
      IF(PLV(KD).LE.PLVM(KD)) GOTO 2100
      TEST=PLV(KD)+SST(KD)+(PART(KD)*PLV(KD)+WTFUEL(KD))
     $/RCATT-VO(KD)
      IF(TEST.LE.0.0D0) GO TO 2010
      CKOUT=TEST*RASS(KD)
      IF(CKOUT.GE.SLOTLM)CKOUT=SLOTLM
      FL(KD)=TK*(CKOUT)**POW
      GO TO 2060
C
C     ASSUMES NO INTERUPTION IN FLOW DUE SOLIDS TRANSFER.
C
2100  FL(KD)=0.0D0
      IF(PLV(KD).LE.0.0D0)SUMPLV=SUMPLV+PLV(KD)
      PLV(KD)=PLVM(KD)
      TEST=PLV(KD)+SST(KD)+(PART(KD)*PLV(KD)+WTFUEL(KD))
     $/RCATT-VO(KD)
      GOTO 2060
2010  FL(KD)=0.0D0
      TEST=0.0D0
2060  V(KD)=VO(KD)+TEST
      DV(KD)=(PLV(KD)-VIB(KD))/H
2000  CONTINUE
      DO 770 K=1,NS
      VIB(K)=PLV(K)
770   CONTINUE
      DO 200 KD=1,NS
      DENOM(KD)=DV(KD)+FL(KD)+B(KD)
      ZQT(KD)=DEXP(H*(-DENOM(KD))/PLV(KD))
      Z1MQT(KD)=1.D0-ZQT(KD)
C     WRITE(6,512)DV(KD),FL(KD),B(KD),DENOM(KD),PLV(KD),ZQT(KD)
C512  FORMAT(' ',6(5X,F15.7))
C     WRITE(6,513)TIME
C513  FORMAT(5X,F15.7)
```

```
200     CONTINUE
C
C
C
C       MATERIAL BALANCES CALC IN SUBROUTINES WITH VALUES TRANSFERED
C       THROUGH COMMONS.
C
C
        CALL PARTIC
        CALL SUBUN
        CALL SUBPN
        CALL SUBFN
        CALL SUBHN
        CALL SUBH2
C
C       CHOOSE PROPER UO2 REACTION EQUATION BASED ON HNO3 CONC.
C
        CALL RXEQU
C
        CALL DIGEST
C
C       CHECK WEIGHT OF UO2,PUO2,AND FP REMAINING IN FUEL
C       DETERMINE MAXIMUM CONCENTRATIONS AND ADJUST DENSITY
C       AND WEIGHT OF FUEL IN PINS.  ALSO CHECK FOR ACID DEFICIENCY.
C       ADJUST MASS OF PARTICLES REMAINING AFTER REACTION.
C
        IA=0
        CALL WEIGHT
C
C
C       SOLID/LIQUID TRANSFERS INCLUDING BACKMIXING.
C
C
                CALL TRANSF
        DO 15 I=1,NS
        IF(UNMAX(I).GE.UN(I)) GO TO 230
        UNMAX(I)=UN(I)
        TUMAX(I)=TIME
230     IF(PNMAX(I).GE.PN(I)) GO TO 240
        PNMAX(I)=PN(I)
        TPMAX(I)=TIME
240     IF(FNMAX(I).GE.FPN(I)) GO TO 260
        FNMAX(I)=FPN(I)
        TFMAX(I)=TIME
260     IF(HNMAX(I).GE.HNO3(I)) GO TO 270
        HNMAX(I)=HNO3(I)
        THNMX(I)=TIME
270     IF(H2MAX(I).GE.H2O(I)) GO TO 290
        H2MAX(I)=H2O(I)
        TH2MX(I)=TIME
290     CONTINUE
        WTU3O8(I)=WTFUEL(I)*PCU3O8
        WTPUO2(I)=WTFUEL(I)*PCPUO2
        WTFP(I)=WTFUEL(I)*PCFP
        U3O8(I)=PCU3O8*PART(I)
        PUO2(I)=PCPUO2*PART(I)
```

```
      FP(I)=PCFP*PART(I)
      COMA=(UN(I)+PN(I)+FPN(I)+H2O(I)+HNO3(I))*PLV(I)/1.0D3
      D25=COMA-(D25C2*UN(I)+D25C3*PN(I)+D25C4*HNO3(I))*PLV(I)
      D25=COMA*D25C1/D25
      RHOLIQ(I)=RHOC1*D25+RHOC2-RHOC3*D25-RHOC4
15    CONTINUE
C
C     ACID DEFICIENCY COUNTER...
C
      DO 1760 I=1,NSM1
      IF(HNO3(I).LT.ACIDEF) IA=IA+1
1760  CONTINUE
      IF(IA.GE.1) GOTO 1670
      GOTO 1660
1670  IAD=IAD+1
      DIFIAD=TIME-TMOLD
      IF(DIFIAD.GT.1.D0) GOTO 1680
      GOTO 1660
1680  TMOLD=TIME
      WRITE(12,1710)TIME,(HNO3(I),I=1,NS)
      WRITE(13,1710)TIME,(HNO3(I),I=1,NS)
      WRITE(6,1710)TIME,(HNO3(I),I=1,NS)
1710  FORMAT(/' TIME OF ACID DEFICIENCY=',2X,1PD15.4,2X,'MIN'
     $/' ACID CONC :',2X,9(1PD10.3,1X))
1660  IA=0
      PRT=PRT+H
C
C     PERIODIC DATA OUTPUT
C
      RUNM1=RUN-HC
      IF (TIME.GE.RUNM1) GOTO 838
      IF(PRT.GE.PRTTIM) GO TO 800
      GO TO 910
800   PRT=0.0D0
      GOTO 839
838   WRITE(13,840)TIME
      WRITE(13,820)
      WRITE(13,830)((UN(I),I=1,NS),(PN(I),I=1,NS),(FPN(I),I=1,NS),
     $(HNO3(I),I=1,NS),(H2O(I),I=1,NS),(U3O8(I),I=1,NS),
     $(PUO2(I),I=1,NS),(FP(I),I=1,NS),(PART(I),I=1,NS))
      WRITE(13,25)((WTU3O8(I),I=1,NS),(WTPUO2(I),I=1,NS),
     $(WTFP(I),I=1,NS),(WTFUEL(I),I=1,NS),(V(I),I=1,NS),
     $(PLV(I),I=1,NS),(SST(I),I=1,NS),(RHOLIQ(I),I=1,NS),
     $(FL(I),I=1,NS))
839   WRITE(12,840) TIME
      WRITE(6,840) TIME
840   FORMAT(///'  TIME INTO RUN : ',F10.4,2X,'MIN')
      WRITE(12,820)
      WRITE(6,820)
820   FORMAT(/46X,'*** STAGEWISE PROFILES ***'/' ',12X,106('-')/15X,
     $'STG 1',7X,'STG 2',7X,'STG 3',7X,'STG 4',7X,'STG 5',7X,'STG 6',
     $7X,'STG 7',7X,'STG 8',7X,'STG 9'/' ',12X,106('-')/
     $' COMPONENT',23X,'CONCENTRATION OF COMPONENTS DISSOLVED',
     $' IN LIQUID (G/L)'/' ',9('-'),22X,55('-')/)
      WRITE(12,830)((UN(I),I=1,NS),(PN(I),I=1,NS),(FPN(I),I=1,NS),
     $(HNO3(I),I=1,NS),(H2O(I),I=1,NS),(U3O8(I),I=1,NS),
```

```
     $(PUO2(I),I=1,NS),(FP(I),I=1,NS),(PART(I),I=1,NS))
        WRITE(6,830)((UN(I),I=1,NS),(PN(I),I=1,NS),(FPN(I),I=1,NS),
     $(HNO3(I),I=1,NS),(H2O(I),I=1,NS),(U3O8(I),I=1,NS),
     $(PUO2(I),I=1,NS),(FP(I),I=1,NS),(PART(I),I=1,NS))
830     FORMAT(' UO2(NO3)2',2X,9(1PD10.3,2X)/' PU(NO3)4',3X,
     $9(1PD10.3,2X)/' FP(NO3)3.39',9(1PE10.3,2X)/' HNO3',7X,
     $9(1PE10.3,2X)/' H2O',8X,9(1PD10.3,2X)/' ',118('-')/41X,
     $'CONCENTRATION OF SUSPENDED FINES (G/L)'/' ',39X,40('-')/' UO2 ',
     $7X,9(1PD10.3,2X)/' PUO2',7X,9(1PD10.3,2X)/' F.P.',7X,9(1PD10.3,2X)
     $/' TOTAL',6X,9(1PD10.3,2X)/' ',118('-'))
        WRITE(12,25)((WTU3O8(I),I=1,NS),(WTPUO2(I),I=1,NS),
     $(WTFP(I),I=1,NS),(WTFUEL(I),I=1,NS),(V(I),I=1,NS),
     $(PLV(I),I=1,NS),(SST(I),I=1,NS),(RHOLIQ(I),I=1,NS),
     $(FL(I),I=1,NS))
        WRITE(6,25)((WTU3O8(I),I=1,NS),(WTPUO2(I),I=1,NS),
     $(WTFP(I),I=1,NS),(WTFUEL(I),I=1,NS),(V(I),I=1,NS),
     $(PLV(I),I=1,NS),(SST(I),I=1,NS),(RHOLIQ(I),I=1,NS),
     $(FL(I),I=1,NS))
25      FORMAT(' ',40X,'QUANTITY UNDISSOLVED IN FUEL PINS (G)'/' ',
     $39X,39('-')/' UO2 ',7X,9(1PD10.3,2X)/' PUO2',7X,9(1PD10.3,2X)/
     $' F.P.',7X,9(1PD10.3,2X)/' TOTAL',6X,9(1PD10.3,2X)/' ',118('-')/
     $' ',53X,'VOLUME (L)'/' ',52X,12('-')/' TOTAL STAGE'
     $,9(1PD10.3,2X)/' LIQUID ONLY',9(1PD10.3,2X)/' STAINLESS',2X
     $9(1PD10.3,2X)/' ',118('-')/' ',52X,'DENSITY (G/L)'/' ',51X,
     $15('-')/' LIQUID',5X,9(1PD10.3,2X)/' ',118('-')/' ',49X,
     $'FLOW RATES (L/MIN)'/' ',48X,20('-')/' LIQUID',
     $5X,9(1PD10.3,2X)/' ',118('-')/)
910     CONTINUE
        IF(TIME.LT.P1HC) GO TO 911
        IF(PLTM.GE.PLINC) GO TO 911
        GO TO 912
911     PLTM=0.0D0
        IDX=IDX+1
        PLTIME(IDX)=TIME
        DO 912 IKE=1,NS
        PLU3O8(IKE,IDX)=U3O8(IKE)
        PLUN(IKE,IDX)=UN(IKE)
        PLPUO2(IKE,IDX)=PUO2(IKE)
        PLPN(IKE,IDX)=PN(IKE)
        PLFP(IKE,IDX)=FP(IKE)
        PLHNO3(IKE,IDX)=HNO3(IKE)
        PLH2O(IKE,IDX)=H2O(IKE)
        PLFPN(IKE,IDX)=FPN(IKE)
        PLPART(IKE,IDX)=PART(IKE)
        PLWTT(IKE,IDX)=WTFUEL(IKE)
        PLSST(IKE,IDX)=SSTMSS(IKE)
912     CONTINUE
                  IF(TIME.LT.P1HC)GOTO 850
C
C       TOTAL U AND PU FED TO STAGE 1.
C
        ION=1
        IF(OFFTIM.GT.P1HC)ION=0
        ETOTUF=ETOTUF+(FINESH+CFUEL)*ION*PCUPER
        ETOTPF=ETOTPF+(FINESH+CFUEL)*ION*PCPPER
C
```

```
C        TOTAL URANIUM AND PLUTCNIUM OUT OF STAGE 1..
C
         FUELOT=0.0D0
         DO 600 KNS=1,NRWM1
600      FUELOT=FUELOT+P(1,KNS)
         TOTU01=TOTU01+(FUELOT*PCUPER+UN(1)*UPERUN)*FL(1)*H
         TOPU01=TOPU01+(FUELOT*PCPPER+PN(1)*PPERPN)*FL(1)*H
         DIGPAR=DIGPAR+FUELOT*FL(1)*H
C
C        TOTAL U AND PU OUT OF STAGE NS...
C
         TOTUOF=TCTUOF+UOWF
         TOPUOF=TCPUOF+POWF
C
C
C        STAGE HOLDUPS
C
C
         UACC=0.0D0
         PUACC=0.0D0
         DO 2090 J=1,NS
         UACC=(U3O8(J)*PLV(J)+WTU3O8(J))*UPERU3+
      $UN(J)*UPERUN*PLV(J)+UACC
         PUACC=(PUO2(J)*PLV(J)+WTPUO2(J))*PPERPU+
      *PN(J)*PPERPN*PLV(J)+PUACC
2090     CONTINUE
         FFI=FFI+H
         IF(FFI.GE.1.0D0)GO TO 2070
         GO TO 2080
2070     FFI=0.0D0
         UOUTT=TOTU01+TOTUOF+UACC
         POUTT=TOPU01+TOPUOF+PUACC
         IF (FEDTIM.LE.P1HC) GOTO 400
         UFEED=UFEEDC*TIME
         PFEED=PFEEDC*TIME
         GOTO 420
400      UFEED=0.0D0
         PFEED=0.0D0
420      UDIFF=UOUTT-UFEED
         PDIFF=POUTT-PFEED
         WRITE(13,3100)
3100     FORMAT(/,6X,'TIME',12X,'U(OUT)',11X,'PU(OUT)',9X,
      $'U(FED)',10X,'PU(FED)',6X,'U(OUT)-U(FED)',2X,'PU(OUT)-PU(FED)')
         WRITE(13,3000)TIME,UOUTT,POUTT,UFEED,PFEED,UDIFF,PDIFF
3000     FORMAT(1X,7(1X,1PD15.5))
2080     CONTINUE
         RUNM1=RUN-HC
         IF(TIME.GE.RUNM1)GOTO 1140
         IF(DISTM.LT.PRDIST) GO TO 1120
1140     WRITE(6,1080)TIME
         WRITE(12,1080)TIME
1080     FORMAT(//' TIME =',2X,1PD10.3,2X,'MIN'/
      $' ',32X,'***   PARTICLE SIZE DISTRIBUTION',
      $' PROFILE DATA   ***'/' ',115('-')/' ',14X,
      $'STG 1',17X,'STG 2',17X,'STG 3',17X,'STG 4',17X,'STG 5'/
      $' GROUP',2X,'RADIUS'
```

```
     $,6X,'CONC',6X,'RADIUS',6X,'CONC',6X,
     $'RADIUS',6X,'CONC',6X,'RADIUS',6X,'CONC',6X,'RADIUS',6X,'CONC'
     $/'   #',3X,'(MICRON)',5X,'(G/L)',4X,'(MICRON)',5X'(G/L)',4X,
     $'(MICRON)',5X,'(G/L)',4X,'(MICRON)',5X,'(G/L)',4X,'(MICRON)'
     $5X,'(G/L)'/
     $' ',115('-')/)
      IF(TIME.GE.RUNM1) GOTO 1078
      GOTO 1079
1078  WRITE(13,1080)TIME
1079  DO 1090 M=1,NG
      WRITE(12,1100)M,(RMS(I,M),P(I,M),I=1,5)
      WRITE(6,1100)M,(RMS(I,M),P(I,M),I=1,5)
      IF (TIME.GE.RUNM1) GOTO 1101
      GOTO 1090
1101  WRITE(13,1100)M,(RMS(I,M),P(I,M),I=1,5)
1100  FORMAT(1X,I4,10(1X,1PD10.3))
1090  CONTINUE
      DO 1170 M=6,NS
      IF(PART(M).GT.0.0D0) GO TO 1190
1170  CONTINUE
      GO TO 1180
1190  WRITE(6,1110)
      WRITE(12,1110)
      IF (TIME.GE.RUNM1) GOTO 1210
      GOTO 1220
1210  WRITE(13,1110)
1220  CONTINUE
1110  FORMAT(///' ',32X,'***   PARTICLE SIZE DISTRIBUTION',
     $' PROFILE DATA   ***'/' ',115('-')/' ',14X,
     $'STG 6',17X,'STG 7',17X,'STG 8',17X,'STG 9'/
     $' GROUP',2X,'RADIUS'
     $,6X,'CONC',6X,'RADIUS',6X,'CONC',6X,
     $'RADIUS',6X,'CONC',6X,'RADIUS',6X,'CONC'
     $/'   #',3X,'(MICRON)',5X,'(G/L)',4X,'(MICRON)',5X'(G/L)',4X,
     $'(MICRON)',5X,'(G/L)',4X,'(MICRON)',5X,'(G/L)'/
     $' ',115('-')/)
      DO 1160 M=1,NG
      WRITE(12,1130)M,(RMS(I,M),P(I,M),I=6,NS)
      WRITE(6,1130)M,(RMS(I,M),P(I,M),I=6,NS)
      IF (TIME.GE.RUNM1) GOTO 1230
      GOTO 1240
1230  WRITE(13,1130)M,(RMS(I,M),P(I,M),I=6,NS)
1240  CONTINUE
1130  FORMAT(1X,I4,8(1X,1PD10.3))
1160  CONTINUE
1180  DISTM=0.0D0
1120  CONTINUE
      IF(TIME.GE.RUN) GO TO 1150
900   CONTINUE
      IF(TIME.GE.RUN) GO TO 1140
1150  TOTUO=TOTUC1+TOTUCF
      TOPUO=TOPUO1+TOPUCF
      UIN=FEDRAT*PCUPER*FFTIME
      PUIN=FEDRAT*PCPPER*FFTIME
      UOUT1=TOTUC1/TIME
      PUOUT1=TOPUO1/TIME
```

```
      UOUTF=TOTUOF/TIME
      PUOUTF=TOPUOF/TIME
      UOUTO=UOUT1+UOUTF
      PUOUTO=PUOUT1+PUOUTF
      FLTOS1=SUMFLP+SUMFLF
      TOTUI=FLTOS1*PCUPER
      TOTPUI=FLTOS1*PCPPER
      TUPUS1=TOTUI+TOTPUI
C
C     % TRANSFER THRU FLAPPER VALVE.
C
      ETSUM=ETOTUF+ETOTPF
      PTFTFV=TUPUS1*100.0D0/ETSUM
C
C     USE TOTAL TIME MATL. BAL. TO GET PROJECTED ACCUMULATION.
C
      ACCU=TOTUI-TOTUO
      ACCPU=TOTPUI-TOPUO
      UALL=TOTUO+ACCU
      PUALL=TOPUO+ACCPU
      UPART=0.0D0
      UPINS=0.0D0
      PUPART=0.0D0
      PUPINS=0.0D0
      UDLIQ=0.0D0
      PUDLIQ=0.0D0
      PINUMM=0.0D0
C
C     UNDISSOLVED HEAVY METALS IN PARTICLES OR PINS.
C
      DO 1075 L=1,NS
      UPINS=UPINS+(WTU308(L)*UPERU3)
      PUPINS=PUPINS+(WTPUO2(L)*PPERPU)
      UPART=UPART+(U308(L)*PLV(L)*UPERU3)
      PUPART=PUPART+(PUO2(L)*PLV(L)*PPERPU)
      UDLIQ=UDLIQ+PLV(L)*UN(L)*UPERUN
      PUDLIQ=PUDLIQ+PLV(L)*PN(L)*PPERPN
      PINUMM=PINUMM+PPSTG(L)
1075  CONTINUE
C
C     U FEED TO STG 1 FROM FLAPPER VALVES.
C
      SMPUF1=SUMFLP*PCUPER
      SMFUF1=SUMFLF*PCUPER
C
C     ACTUAL ACCUMULATION AT END OF RUN.
C
      ACTUA=UPINS+UPART+UDLIQ
      ACTPA=PUPINS+PUPART+PUDLIQ
C
C     ACTUAL MASS OUT OVER TOTAL RUN PLUS HOLD-UP.
C
      UALLA=TOTUO+ACTUA
      PUALLA=TOPUO+ACTPA
C
C     DIFFERENCE BETWEEN ACTUAL FEED AND ACTUAL MASS OUT PLUS HOLD-UP
```

```
C
         UDIFP=DABS(TOTUI-UALLA)*100.D0/TOTUI
         PDIFP=DABS(TOTPUI-PUALLA)*100.D0/TOTPUI
         PCUBAL=UALLA*100.D0/TOTUI
         PCPBAL=PUALLA*100.D0/TCTPUI
C
C        TOTAL U HOLD-UP IN FLAPPER VALVE AND % OF TOTAL FEED
C
         FLPHLU=(FEDONE+FINESF)*PCUPER
         PCFLTF=FLPHLU*1.D2/TOTUI
         SUMOD=SUMNEG+SUMNEP
C        WRITE(6,93)TOTUI,UALLA,TOTUO,ACTUA,UDIFP,PCUBAL
C    93  FORMAT(////,6(F20.10),////)
         WRITE(12,90) UIN,PUIN,UOUT1,PUCUT1,UOUTF,PUOUTF,UOUTO,PUOUTO
         WRITE(13,90) UIN,PUIN,UOUT1,PUCUT1,UCUTF,PUOUTF,UOUTO,PUOUTO
         WRITE(6,90) UIN,PUIN,UCUT1,PUOUT1,UOUTF,PUOUTF,UOUTO,PUOUTO
90       FORMAT(///15X,'  APPROXIMATE FLOWS'//
      $' APPROXIMATE U FEED RATE=',2X,
      $1PD15.4,2X,'G/MIN'/
      $' APPROXIMATE PU FEED RATE=',2X,1PD15.4,2X,'G/MIN'/
      $' TOTAL U FLOW OUT LIQUIC PHASE=',2X,1PD15.4,2X,'G/MIN'/
      $' TOTAL PU FLOW OUT LIQUID PHASE=',2X,1PD15.4,2X,'G/MIN'/
      $' TOTAL U FLOW UNDISSOLVED IN FUEL PINS=',2X,1PD15.4,2X,'G/MIN'/
      $' TOTAL PU FLOW UNDISSOLVED IN FUEL PINS=',2X,1PD15.4,2X,'G/MIN'
      $/' TOTAL U FLOW OUT=',2X,1PD15.4,2X,'G/MIN'/' TOTAL PU FLOW OUT=',
      $2X,1PD15.4,2X,'G/MIN')
         WRITE(12,95)TOTUI,TOTPUI,TOTUO1,TOPUO1,TOTUOF,TOPUOF,UPINS,
      $PUPINS,UPART,PUPART,DIGPAR,TOTUO,TOPUO
         WRITE(13,95)TOTUI,TOTPUI,TOTUO1,TOPUO1,TOTUOF,TOPUOF,UPINS,
      $PUPINS,UPART,PUPART,DIGPAR,TOTUO,TOPUO
         WRITE(6,95)TOTUI,TOTPUI,TOTUC1,TOPUC1,TOTUOF,TOPUOF,UPINS,
      $PUPINS,UPART,PUPART,DIGPAR,TOTUO,TOPUO
95       FORMAT(///15X,'TOTAL MASS BALANCE'//' TOTAL U FEED=',2X,
      $1PD15.4,2X,'G'/' TOTAL PU FEED=',2X,1PD15.4,2X,'G'/
      $' TOTAL U OUT STAGE 1=',2X,1PD15.4,2X,'G'/' TOTAL PU OUT STAGE 1='
      $,2X,1PD15.4,2X,'G'/
      $' TOTAL URANIUM FROM RINSE STAGE='
      $,2X,1PD15.4,2X,'G'/
      $' TOTAL PLUTCNIUM FROM RINSE STAGE='
      $,2X,1PD15.4,2X,'G'/' TOTAL U UNDISSOLVED IN FUEL PINS=',2X,
      $1PD15.4,2X,'G'/' TCTAL PU UNDISSCLVED IN FUEL PINS=',2X,
      $1PD15.4,2X,'G'/' TOTAL U IN PARTICLES UNDISSOLVED=',2X,
      $1PD15.4,2X,'G'/' TOTAL PU IN PARTICLES UNDISSOLVED=',2X,
      $1PD15.4,2X,'G'/' TOTAL SUSPENDED PARTICULATE TO DIGESTERS=',
      $2X,1PD15.4,2X,'G'/
      $' TOTAL U CUT OVER TOTAL RUN=',2X,1PD15.4,2X,'G'/
      $' TOTAL PU OUT OVER TOTAL RUN=',2X,1PD15.4,2X,'G')
         WRITE(12,1500)UDLIQ,PUDLIQ,SUMPLV,SMPUF1,SMFUF1,PINUMM
      $,PCONT,(PARTP(I),I=1,NS)
         WRITE(13,1500)UDLIQ,PUDLIQ,SUMPLV,SMPUF1,SMFUF1,PINUMM
      $,PCONT,(PARTP(I),I=1,NS)
         WRITE(6,1500)UDLIC,PUDLIQ,SUMPLV,SMPUF1,SMFUF1,PINUMM
      $,PCONT,(PARTP(I),I=1,NS)
1500     FORMAT(//' TOTAL U DISSOLVED IN LIQUID INVENTORY IN DISSOLVER=',
      $2X,1PD15.4,2X,'(G)'/
      $' TOTAL PU DISSOLVED IN LIQUID INVENTORY IN DISSOLVER='
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     $,2X,1PD15.4,2X,'(G)'/' CCRRECTED SUM OF LIQUID VOLUMES=',
     $2X,1PD15.4,2X,'(L)'/' TOTAL U IN PINS FED TO STAGE 1 FROM FLP='
     $,2X,1PD15.4,2X,'(G)'/' TCTAL U FINES FED TO STAGE 1 FROM FLP=',
     $2X,1PD15.4,2X,'(G)'/
     $' TOTAL NUMBER OF PINS REMAINING IN DISSOLVER='
     $,2X,1PD15.4/
     $' TOTAL NUMBER OF PARTICLE SIZE GROUP DEPLETION TRANSFERS='
     $,2X,1PD14.2//
     $36X,'*** MASS OF PARTICLES DISSOLVED IN EACH STAGE (G) ***'/
     $' ',12X,106('-')/15X,'STG 1',7X,'STG 2',7X,'STG 3',7X,'STG 4'
     $,7X,'STG 5',7X,'STG 6',7X,'STG 7',7X,'STG 8',7X,'STG 9'/
     $' ',12X,106('-')/' ',10X,9(2X,1PD10.3))
      WRITE(12,85) ACCU,ACCPU,UALL,PUALL,SUMNEG,SUMNEP,SUMOD,SUMHNO
     $,SUMFIN,SUMFOU,WTFUEL(9),SUMPIN,SUMPOU,PPSTG(9)
      WRITE(13,85) ACCU,ACCPU,UALL,PUALL,SUMNEG,SUMNEP,SUMOD,SUMHNO
     $,SUMFIN,SUMFOU,WTFUEL(9),SUMPIN,SUMPOU,PPSTG(9)
      WRITE(6,85) ACCU,ACCPU,UALL,PUALL,SUMNEG,SUMNEP,SUMOD,SUMHNO
     $,SUMFIN,SUMFOU,WTFUEL(9),SUMPIN,SUMPOU,PPSTG(9)
85    FORMAT(/' PROJECTED URANIUM HOLD-UP IN DISSOLVER=',2X,
     $1PD15.4,2X,'G'/' PROJECTED PLUTONIUM HOLD-UP IN DISSOLVER='
     $,2X,1PD15.4,2X,'G'/' PROJECTED TCTAL U OUT PLUS HOLD-UP='
     $,2X,1PD15.4,2X,'G'/
     $' PROJECTED TOTAL PU OUT PLUS HOLD-UP=',2X,1PD15.4,2X,'G'//
     $' CORRECTEC NEGATIVE SUM OF OVER DISSOLUTION FROM PINS=',2X
     $,1PD15.4,2X,'G'/
     $' CORRECTED NEGATIVE SUM OF OVER DISSOLUTION OF PARTICULATE=',
     $2X,1PD15.4,2X,'G'/' TCTAL CORRECTED OVER DISSOLUTION=',2X,
     $1PD15.4,2X,'G'/' SUM OF HNO3 DEPLETIONS=',2X,1PD15.4,
     $'G'/' TOTAL FUEL IN PINS FED TO STAGE 9=',2X,
     $1PD15.4,2X,'G'/' TCTAL FUEL IN PINS OUT OF STAGE 9=',2X,
     $1PD15.4,2X,'G'/' TOTAL FUEL IN PINS IN STAGE 9=',2X
     $,1PD15.4,2X,'G'/' TOTAL # PINS FED TO STAGE 9=',2X,
     $1PD15.4/' TOTAL # PINS CUT OF STAGE 9=',2X,1PD15.4/
     $' TOTAL # PINS IN STAGE 9=',2X,1PD15.4)
      WRITE(12,1420) ACTUA,ACTPA,UALLA,PUALLA,FLPHLU,UDIFP,PDIFP
     $,PCUBAL,PCPBAL,PCFLTF
      WRITE(13,1420) ACTUA,ACTPA,UALLA,PUALLA,FLPHLU,UDIFP,PDIFP
     $,PCUBAL,PCPBAL,PCFLTF
      WRITE(6,1420) ACTUA,ACTPA,UALLA,PUALLA,FLPHLU,UDIFP,PDIFP
     $,PCUBAL,PCPBAL,PCFLTF
1420  FORMAT(//' ACTUAL U HOLD-UP IN DISSOLVER=',2X,1PD15.4,2X,'G'/
     $' ACUTAL PU HOLD-UP IN DISSOLVER=',2X,1PD15.4,2X,'G'/
     $' ACTUAL U CUT PLUS DISSCLVER HOLD-UP=',2X,1PD15.4,2X,'G'/
     $' ACTUAL PU CUT PLUS DISSOLVER HOLD-UP=',2X,1PD15.4,2X,'G'/
     $' ACTUAL U HOLD-UP IN FLAPPER VALVES=',2X,1PD15.4,2X,'G'/
     $' % DIFF BETWEEN ACTUAL U FED AND U OUT PLUS HOLD-UP='
     $,2X,1PD15.4,2X,'%'/
     $' % DIFF BETWEEN ACTUAL PU FED AND PU OUT PLUS HOLD-UP='
     $,2X,1PD15.4,2X,'%'///
     $' U OUT OVER U FED PLUS HOLD-UP=',2X,1PD15.4,2X,'%'/
     $' PU OUT OVER PU FED PLUS HOLD-UP=',2X,1PD15.4,2X,'%'/
     $' % OF TOTAL U FEED IN FLAPPER VALVE HOLD-UP=',2X,
     $1PD15.4,2X,'%'/)
      WRITE(6,1800)ETOTUF,ETCTPF,ETSUM,TUPUS1,PTFTFV
      WRITE(12,1800)ETOTUF,ETOTPF,ETSUM,TUPUS1,PTFTFV
      WRITE(13,1800)ETOTUF,ETOTPF,ETSUM,TUPUS1,PTFTFV
```

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1800    FORMAT(//' TOTAL U FED TO FLAPPER VALVES=',2X
       $,1PD15.4,2X,'G'/' TCTAL PU FED TC FLAPPER VALVES=',2X,
       $1PD15.4,2X,'G'/
       $' TOTAL U PLUS PU FED TO FLAPPER VALVES=',2X,
       $1PD15.4,2X,'G'/
       $' TOTAL U PLUS PU FED TO STAGE 1 FROM FLAPPER VALVES='
       $,2X,1PD15.4,2X,'G'/
       $' PER CENT TRANSFER THRU FLAPPER VALVES=',
       $2X,1PD15.4,'%')
        WRITE(12,1070)IAD,(UNMAX(I),I=1,NS),(TUMAX(I),I=1,NS),
       $(PNMAX(I),I=1,NS),(TPMAX(I),I=1,NS),(FNMAX(I),I=1,NS)
       $,(TFMAX(I),I=1,NS),(HNMAX(I),I=1,NS),(THNMX(I),I=1,NS)
       $,(H2MAX(I),I=1,NS),(TH2MX(I),I=1,NS)
        WRITE(13,1070)IAD,(UNMAX(I),I=1,NS),(TUMAX(I),I=1,NS),
       $(PNMAX(I),I=1,NS),(TPMAX(I),I=1,NS),(FNMAX(I),I=1,NS)
       $,(TFMAX(I),I=1,NS),(HNMAX(I),I=1,NS),(THNMX(I),I=1,NS)
       $,(H2MAX(I),I=1,NS),(TH2MX(I),I=1,NS)
        WRITE(6,1070)IAD,(UNMAX(I),I=1,NS),(TUMAX(I),I=1,NS),
       $(PNMAX(I),I=1,NS),(TPMAX(I),I=1,NS),(FNMAX(I),I=1,NS)
       $,(TFMAX(I),I=1,NS),(HNMAX(I),I=1,NS),(THNMX(I),I=1,NS)
       $,(H2MAX(I),I=1,NS),(TH2MX(I),I=1,NS)
1070    FORMAT(//' NUMBER OF TIME STEPS WITH ACID DEFICIENT COND.=',
       $2X,I5//37X,'*** MAXIMUM PREDICTEC CONCENTRATIONS (G/L) ***'/
       $' ',12X,106('-')/15X,'STG 1',7X,'STG 2',7X,'STG 3',7X,'STG 4'
       $,7X,'STG 5',7X,'STG 6',7X,'STG 7',7X,'STG 8',7X,'STG 9'/
       $' ',12X,106('-')/' COMPONENT/TIME (MIN)'/' ',19('-')/
       $' UO2(NO3)2',2X,9(2X,1PD10.3)/' TIME',7X,9(2X,1PD10.3)/
       $' ',44X,30('-')/' PU(NO3)4',3X,9(2X,1PD10.3)/' TIME',7X,
       $9(2X,1PD10.3)/' ',44X,30('-')/' FP(NO3)1.18',9(2X,1PD10.3)/
       $' TIME',7X,9(2X,1PD10.3)/' ',44X,30('-')/' HNO3',7X,
       $9(2X,1PD10.3)/' TIME',7X,9(2X,1PD10.3)/' ',44X,30('-')/
       $' H2O',8X,9(2X,1PD10.3)/' TIME',7X,9(2X,1PD10.3)/' ',
       $44X,30('-')//)
        WRITE(12,1200) ITSAC,JJPART,MMUN,NNPN,NNFP,MMHN,IIH2
       $,SUMD1,SUMD2
        WRITE(13,1200) ITSAC,JJPART,MMUN,NNPN,NNFP,MMHN,IIH2
       $,SUMD1,SUMD2
        WRITE(6,1200) ITSAC,JJPART,MMUN,NNPN,NNFP,MMHN,IIH2
       $,SUMD1,SUMD2
1200    FORMAT(//' NUMBER OF TIME STEP REDUCTIONS=',2X,I6//
       $' MAXIMUM # ITERATIONS IN PARTIC=',2X,I6/
       $' MAXIMUM # ITERATIONS IN SUBUN=',3X,I6/
       $' MAXIMUM # ITERATIONS IN SUBPN=',3X,I6/
       $' MAXIMUM # ITERATIONS IN SUBFP=',3X,I6/
       $' MAXIMUM # ITERATIONS IN SUBHN=',3X,I6/
       $' MAXIMUM # ITERATIONS IN SUBH2=',3X,I6/
       $//' NEGATIVE SUM OF OVER DISSOLUTICN OF PARTICLES',
       $' IN DIGESTER # 1 =',2X,1PD15.4,2X,'G'/' NEGATIVE SUM OF',
       $' OVER DISSOLUTION OF PARTICLES IN DIGESTER # 2 =',
       $2X,1PD15.4,2X,'G')
C
C       REUSING OLD ARRAYS TO STORE STAGEWISE INVENTORIES...
C
        DO 3500 K=1,NS
        UNMAX(K)=UN(K)*PLV(K)
        PNMAX(K)=PN(K)*PLV(K)
```

```
      FNMAX(K)=FPN(K)*PLV(K)
      THNMX(K)=U308(K)*PLV(K)
      TH2MX(K)=PUO2(K)*PLV(K)
      TFMAX(K)=FP(K)*PLV(K)
      HNMAX(K)=HNO3(K)*PLV(K)
      H2MAX(K)=H2O(K)*PLV(K)
      TUMAX(K)=(UNMAX(K)*UPERUN+THNMX(K)*UPERU3)+
     $WTFUEL(K)*PCU308*UPERU3
      TPMAX(K)=(PNMAX(K)*PPERPN+TH2MX(K)*PPERPU)+
     $WTFUEL(K)*PCPUO2*PPERPU
      CO(K)=TUMAX(K)+TPMAX(K)
      UPA(K)=(THNMX(K)*UPERU3)/PLV(K)
      PUPA(K)=(TH2MX(K)*PPERPU)/PLV(K)
      DEPTH(K)=UNMAX(K)*UPERUN/PLV(K)
      RASS(K)=PNMAX(K)*PPERPN/PLV(K)
      AS(K)=DEPTH(K)+RASS(K)
      PLVM(K)=(WTFUEL(K)*PCU308*UPERU3)/PLV(K)
      VIB(K)=WTFUEL(K)*PCPUO2*PPERPU/PLV(K)
      CO2(K)=UPA(K)+PUPA(K)
      CO3(K)=PLVM(K)+VIB(K)
      FO(K)=HNO3(K)/WMOLHN
3500  CONTINUE
C
C     OUTPUT STAGEWISE MASS INVENTORIES...
C
      WRITE(6,3600)TIME
      WRITE(12,3600)TIME
      WRITE(13,3600)TIME
3600  FORMAT(///37X,'*** STAGEWISE MASS INVENTORY (G) AFTER ',F8.2
     $,' MINUTES ***'/
     $' ',12X,106('-')/15X,'STG 1',7X,'STG 2',7X,'STG 3',7X,'STG 4'
     $,7X,'STG 5',7X,'STG 6',7X,'STG 7',7X,'STG 8',7X,'STG 9'/
     $' ',12X,106('-')/' COMPONENT'/' ',10('-')/)
      WRITE(6,3700)(TUMAX(I),I=1,NS),(TPMAX(I),I=1,NS),
     $(CO(I),I=1,NS),(UNMAX(I),I=1,NS),(PNMAX(I),I=1,NS),
     $(FNMAX(I),I=1,NS),(HNMAX(I),I=1,NS),(H2MAX(I),I=1,NS),
     $(THNMX(I),I=1,NS),(TH2MX(I),I=1,NS),(TFMAX(I),I=1,NS)
      WRITE(6,3650)(DEPTH(I),I=1,NS),(UPA(I),I=1,NS),(PLVM(I),I=1,NS)
     $,(RASS(I),I=1,NS),(PUPA(I),I=1,NS),(VIB(I),I=1,NS)
     $,(AS(I),I=1,NS),(CO2(I),I=1,NS),(CO3(I),I=1,NS),
     $(FO(I),I=1,NS)
      WRITE(12,3700)(TUMAX(I),I=1,NS),(TPMAX(I),I=1,NS),
     $(CO(I),I=1,NS),(UNMAX(I),I=1,NS),(PNMAX(I),I=1,NS),
     $(FNMAX(I),I=1,NS),(HNMAX(I),I=1,NS),(H2MAX(I),I=1,NS),
     $(THNMX(I),I=1,NS),(TH2MX(I),I=1,NS),(TFMAX(I),I=1,NS)
      WRITE(12,3650)(DEPTH(I),I=1,NS),(UPA(I),I=1,NS),(PLVM(I),I=1,NS)
     $,(RASS(I),I=1,NS),(PUPA(I),I=1,NS),(VIB(I),I=1,NS)
     $,(AS(I),I=1,NS),(CO2(I),I=1,NS),(CO3(I),I=1,NS),
     $(FO(I),I=1,NS)
      WRITE(13,3700)(TUMAX(I),I=1,NS),(TPMAX(I),I=1,NS),
     $(CO(I),I=1,NS),(UNMAX(I),I=1,NS),(PNMAX(I),I=1,NS),
     $(FNMAX(I),I=1,NS),(HNMAX(I),I=1,NS),(H2MAX(I),I=1,NS),
     $(THNMX(I),I=1,NS),(TH2MX(I),I=1,NS),(TFMAX(I),I=1,NS)
      WRITE(13,3650)(DEPTH(I),I=1,NS),(UPA(I),I=1,NS),(PLVM(I),I=1,NS)
     $,(RASS(I),I=1,NS),(PUPA(I),I=1,NS),(VIB(I),I=1,NS)
     $,(AS(I),I=1,NS),(CO2(I),I=1,NS),(CO3(I),I=1,NS),
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     $(FO(I),I=1,NS)
3700    FORMAT(' URANIUM',4X,9(2X,1PD10.3)/' PLUTONIUM',2X,
     $9(2X,1PD10.3)/' U+PU',7X,9(2X,1PD10.3)/' ',44X,30('-')/
     $' UO2(NO3)2',2X,9(2X,1PD10.3)/' PU(NO3)4',3X,9(2X,1PD10.3)/
     $' FP(NO3)2.36',9(2X,1PD10.3)/' ',44X,30('-')/
     $' HNO3',7X,9(2X,1PD10.3)/' H2O',8X,9(2X,1PD10.3)/' ',44X,30('-')/
     $' UO2',8X,9(2X,1PD10.3)/' PUO2',7X,9(2X,1PD10.3)/
     $' FP(O)1.1776',9(2X,1PD10.3)/' ',44X,30('-')/
     $' ',44X,30('-'))
3650    FORMAT(//37X,'*** ADDITIONAL CONCENTRATION DATA ***'/
     $' U(G/L)LQ',3X,9(2X,1PD10.3)/' U(G/L)PT',3X,9(2X,1PD10.3)
     $/' U(G/L)PN',3X,9(2X,1PD10.3)/' PU(G/L)LQ',2X,9(2X,1PD10.3)
     $/' PU(G/L)PT',2X,9(2X,1PD10.3)/' PU(G/L)PN',2X,9(2X,1PD10.3)
     $/' U+PU(G/L)LQ',9(2X,1PD10.3)/' U+PU(G/L)PT',9(2X,1PD10.3)/
     $' U+PU(G/L)PN',9(2X,1PD10.3)/' HNO3(MOL/L)',9(2X,1PD10.3)/
     $' ',44X,30('-')//)
C
        IF (ZNOPTA.EQ.0.0) GOTO 5000
        CALL CALCMP
        IF (ZNOPT7.EQ.0.0) GOTO 5100
        CALL PLOT7(PLTIME,MUM,NS)
5100    IF (ZNOPTP.EQ.0.0) GOTO 5200
        CALL PLOTD(NS,FREQ,RMS,P,PART,RMIN,RMAX,NG)
5200    IF (ZNOPT3.EQ.0.0) GOTO 5300
        CALL PLOT3(PLTIME,MUM,NS)
5300    IF (ZNOPTD.EQ.0.0) GOTO 5400
        CALL DIGPLT
5400    CALL DONEPL
C
5000    STOP
        END
C
C
C
        SUBROUTINE TRANSF
        IMPLICIT REAL*8 (A-H,O-Z)
        COMMON/XX/ UN(20),PN(20),HNO3(20),H2O(20),UNB(20),OLD(20)
     $,PNB(20),HNO3B(20),H2OB(20),WTU3O8(20),WTPUO2(20),WTFP(20)
     $,WTFUEL(20),FPN(20),FPNB(20),DENCM(20),REL(20),CREL(20),LIMO
        COMMON /XXX/TOL,T,CT,V(20),VO(20),CT1,T1,H,PLV(20),HC,
     $T2,SUMNEG,SUMHNO,SUMNEP,ICP,ICPO,ITSAC
        COMMON/XXXX/B(20),U3O8(20),U3O8B(20),PART(20),RATE1(20),
     $PARTB(20),RATE2(20),PUO2(20),PUO2B(20),FP(20),FPB(20),
     $UNK1(20),PNK1(20),FPK1(20),FL(20),UNK2(20),PNK2(20),
     $FPK2(20),P(10,50),PB(10,50),NS
        COMMON/PERCNT/PCU3O8,PCPUO2,PCFP,SPAREA,DU3O8
     $,DPUO2,DFP,CCN,PINMAS,PPSTG(20),CV(20),RATMF,FEDRAT,ARATIO
     $,PCUPER,PCPPER,UOWF,POWF,PPERPN,UPERUN
        COMMON/PAR/FREQ(50),R(50),RMMIN(50),RMMAX(50),PP(10,50),
     $RMS(10,50),PARTP(20),PM(50),ATP(50),DR,PI,RMIN,RMAX,PCONT,
     $FTPIRO,FOURPI,NG
        COMMON/SOLIDS/FINES,RWASTE,HDR,CUBE,NRW,NRWM1,NGPNRW,NGM1
     $,NRWM2
        COMMON /TRANZT/BAKMIX(20),SST(20),RHOLIQ(20),PLVBT(20)
     $,BAKV(20),SSTMSS(20),DTFLG1,DTFLG2,DTRACT,DUMPT,DENSST
     $,CFUEL,CFINES,SSSCT,FUPIN,OFFTIM,P1HC,TF,FLAPTM,
```

```
     $SSSCTH,FINESH,SSTF,FEDONE,FINESF,PINFED,NSM1
        COMMON/SUMS/SUMFLP,SUMFLF,SUMFIN,SUMPIN,SUMFOU,SUMPOU
C
C
C        ******************************************************************
C       ********************************************************************
C       ****                                                           ****
C       ****    PARTICLES, HULLS, FUEL, AND SOLUTION BACKMIX TRANSFERS ****
C       ****                                                           ****
C       ********************************************************************
C        ******************************************************************
C
C
C       CT STAGE TRANSFERS HAVE PRIORITY OVER CT1 TRANSFERS
C       CT1 TRANSFERS HAVE PRICRITY OVER SOLIDS FEED...
C
C       ASSUME INSTANTANEOUS MIXING OF BACKMIXED LIQUIC CARRIED OVER
C       WITH HULLS.
C
C
C               BACKMIX VOLUME VALUE SETTER...
C
        JB=NS
        JBM1=NSM1
        DO 101 K=1,NS
        PLVBT(K)=PLV(K)
        SSTMSS(K)=SST(K)*DENSST
        BMCON=BAKMIX(K)*SSTMSS(K)
        BAKV(K)=BMCON/RHOLIQ(K)
101             CONTINUE
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                 C
C       SOLIDS TRANSFER RATE CCNTRCL FCR STAGE NS..               C
C                                                                 C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
        IF(T.GT.CT.OR.DTFLG1.GE.HC) GOTO 620
        GOTO 630
620     DTFLG1=DTFLG1+H
        IF (DTFLG1.GT.DUMPT) GOTO 640
        IF (DTFLG1.GT.H) GOTO 650
        WTFUEL(JB)=WTFUEL(JBM1)+WTFUEL(JB)
        SST(JB)=SST(JBM1)+SST(JB)
        PPSTG(JB)=PPSTG(JBM1)+PPSTG(JB)
        BAKVC=BAKV(JB)
        SSTCZ=SST(JB)
        PPSTGC=PPSTG(JB)
        SUMFIN=SUMFIN+WTFUEL(JB)
        SUMPIN=SUMPIN+PPSTGC
        ION=1
        GOTO 660
650     ION=0
660     IF(PPSTG(JB).LE.0.0D0) GOTO 640
        DTRCTH=DTRACT*H
        PPSTZ=PPSTGC*DTRCTH
        PPFRC=PPSTZ/PPSTG(JB)
        TPPS=PPSTG(JB)-PPSTZ
```

```
      IF(TPPS.LE.0.0D0) GOTO 10
      GOTO 20
C
C     FRACTIONAL ADJUSTMENT OF DTRCTH
C
10    DTRCTH=(1.D0+TPPS/PPSTZ)*DTRCTH
      PPSTZ=PPSTGC*DTRCTH
      PPFRC=PPSTZ/PPSTG(JB)
      TPPS=PPSTG(JB)-PPSTZ
20    PPSTG(JB)=TPPS
      PLV(JB)=PLV(JB)-BAKVC*DTRCTH+BAKV(JBM1)*ION
      DGUN=BAKV(JBM1)*UN(JBM1)*ION-BAKVC*DTRCTH*UN(JB)
      DGPN=BAKV(JBM1)*PN(JBM1)*ION-BAKVC*DTRCTH*PN(JB)
      DGFN=BAKV(JBM1)*FPN(JBM1)*ION-BAKVC*DTRCTH*FPN(JB)
      DGHN=BAKV(JBM1)*HNO3(JBM1)*ION-BAKVC*DTRCTH*HNO3(JB)
      DGH2=BAKV(JBM1)*H2O(JBM1)*ION-BAKVC*DTRCTH*H2O(JB)
      UN(JB)=(UN(JB)*PLVBT(JB)+DGUN)/PLV(JB)
      PN(JB)=(PN(JB)*PLVBT(JB)+DGPN)/PLV(JB)
      FPN(JB)=(FPN(JB)*PLVBT(JB)+DGFN)/PLV(JB)
      HNO3(JB)=(HNO3(JB)*PLVBT(JB)+DGHN)/PLV(JB)
      H2O(JB)=(H2O(JB)*PLVBT(JB)+DGH2)/PLV(JB)
      WTFUZ=WTFUEL(JB)*PPFRC
      WTFUEL(JB)=WTFUEL(JB)-WTFUZ
      SST(JB)=SST(JB)-SSTCZ*DTRCTH
      PLVRAT=PLVBT(JBM1)/PLV(JB)
      SUMFOU=SUMFOU+WTFUZ
      SUMPOU=SUMPOU+PPSTZ
C
C     ASSUME JBM1 TRANSFERS FIRST.
C     PARTICLE TRANSFERS DUE TO BACKMIXING
C
              SUMWT=0.0D0
              DO 670 JJ=1,NRWM1
      WTPJB=P(JB,JJ)*BAKVC*DTRCTH
      WTPJBM=P(JBM1,JJ)*BAKV(JBM1)*ION
      WTPTOT=P(JB,JJ)*PLVBT(JB)
      WTP=WTPJBM+WTPTOT
      IF(WTP)710,710,700
700   RMS(JB,JJ)=WTP/(WTPTOT/RMS(JB,JJ)+WTPJBM/RMS(JBM1,JJ))
      GO TO 680
710   RMS(JB,JJ)=R(JJ)
680   CONTINUE
      WTSUM=WTPJBM-WTPJB
      P(JB,JJ)=(P(JB,JJ)*PLVBT(JB)+WTSUM)/PLV(JB)
      SUMWT=SUMWT+WTSUM
670           CONTINUE
      PLVBO=PLVBT(JB)/PLV(JB)
      SUMPJ=0.0D0
      SUMAD=0.0D0
C
C     PARTICLES TRANSFERING WITH HULLS
C
              DO 690 KK=NRW,NG
      ADDPAR=P(JBM1,KK)*PLVRAT*ION
      SUMAD=SUMAD+ADDPAR
      PARFUZ=P(JB,KK)*PPFRC
```

```
      SUMPJ=SUMPJ+PARFUZ
      REMPAR=P(JB,KK)
      PJBTOT=ADDPAR+REMPAR
      IF(PJBTOT)370,370,380
380   RMS(JB,KK)=PJBTOT/(ADDPAR/RMS(JBM1,KK)+REMPAR/RMS(JB,KK))
      P(JB,KK)=PJBTOT-PARFUZ
      IF(P(JB,KK).LE.0.0D0) GOTO 370
      GOTO 690
370   RMS(JB,KK)=R(KK)
      P(JB,KK)=0.0D0
690          CONTINUE
      PART(JB)=(PART(JB)-SUMPJ)*PLVBO+SUMAC+(SUMWT/PLV(JB))
      OUT=WTFUZ+SUMPJ*PLV(JB)+WTPJB
      UOWF=OUT*PCUPER+BAKVC*CTRCTH*UN(JB)*UPERUN
      POWF=OUT*PCPPER+BAKVC*CTRCTH*PN(JB)*PPERPN
      GOTO 630
640   DTFLG1=0.0D0
      WTFUEL(JB)=0.0D0
      SST(JB)=0.0D0
      PPSTG(JB)=0.0D0
      UOWF=0.0D0
      POWF=0.0D0
630          TF=TF+H
C
C     SOLIDS FEED CONTROL
C     FLAPPER VALVE SIMULATION....
C
      IF(FLAPTM.LT.HC) GOTO 400
      IF(TF.GT.FLAPTM) GOTO 200
      ION=1
      IF(OFFTIM.GT.P1HC) ION=0
      SSTF=SSTF+SSSCTH*ION
      FEDONE=FEDONE+CFUEL*ION
      FINESF=FINESF+FINESH*ION
      PINFED=PINFED+FUPIN*ION
      GOTO 440
200   TF=TF-FLAPTM
      WTFUEL(1)=WTFUEL(1)+FEDONE
      SST(1)=SST(1)+SSTF
      PPSTG(1)=PPSTG(1)+PINFED
      PART(1)=(PART(1)*PLV(1)+FINESF)/PLV(1)
      SUMFLF=SUMFLF+FINESF
      SUMFLP=SUMFLP+FEDONE
             DO 220 J=1,NG
      ZWTPR=P(1,J)*PLV(1)
      ZWTAD=FINESF*FREQ(J)
      TZWTAD=ZWTPR+ZWTAD
      P(1,J)=(ZWTPR+ZWTAD)/PLV(1)
      IF(TZWTAD.LE.0.0D0) GOTO 225
      RMS(1,J)=TZWTAD/(ZWTPR/RMS(1,J)+ZWTAD/R(J))
      GOTO 220
225   RMS(1,J)=R(J)
220          CONTINUE
      ION=1
      IF(OFFTIM.GT.P1HC) ION=0
      TMFCT=TF/H
```

```
      SSTF=SSSCTH*TMFCT*ION
      FEDONE=CFUEL*TMFCT*ION
      FINESF=FINESH*TMFCT*ION
      PINFED=FUPIN*TMFCT*ION
      GO TO 440
400   ION=1
      IF(OFFTIM.GT.P1HC) ION=0
      FEDONE=CFUEL*ION
      FINESF=FINESH*ION
      WTFUEL(1)=WTFUEL(1)+FEDONE
      SST(1)=SST(1)+SSSCTH*ION
      PPSTG(1)=PPSTG(1)+FUPIN*ION
      PART(1)=(PART(1)*PLV(1)+FINESF)/PLV(1)
      SUMFLF=SUMFLF+FINESF
      SUMFLP=SUMFLP+FEDONE
              DO 410 J=1,NG
      ZWTPR=P(1,J)*PLV(1)
      ZWTAD=FINESF*FREQ(J)
      TZWTAD=ZWTPR+ZWTAD
      P(1,J)=(ZWTPR+ZWTAD)/PLV(1)
      IF(TZWTAD.LE.0.000) GOTO 415
      RMS(1,J)=TZWTAD/(ZWTPR/RMS(1,J)+ZWTAD/R(J))
      GOTO 410
415   RMS(1,J)=R(J)
410   CONTINUE
440   IF(T.GT.CT) GO TO 100
      IF(T1.GT.CT1) GO TO 30
      GOTO 40
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                           C
C     SOLIDS TRANSFER FROM STAGES 2 THROUGH NSM1            C
C                                                           C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
100   T=T-CT
                        DO 126 J=3,NSM1
      JB=NSM1-J+3
      JBM1=JB-1
      PLV(JB)=PLV(JB)-BAKV(JB)+BAKV(JBM1)
      DGUN=BAKV(JBM1)*UN(JBM1)-BAKV(JB)*UN(JB)
      DGPN=BAKV(JBM1)*PN(JBM1)-BAKV(JB)*PN(JB)
      DGFN=BAKV(JBM1)*FPN(JBM1)-BAKV(JB)*FPN(JB)
      DGHN=BAKV(JBM1)*HNO3(JBM1)-BAKV(JB)*HNO3(JB)
      DGH2=BAKV(JBM1)*H2O(JBM1)-BAKV(JB)*H2O(JB)
      UN(JB)=(UN(JB)*PLVBT(JB)+DGUN)/PLV(JB)
      PN(JB)=(PN(JB)*PLVBT(JB)+DGPN)/PLV(JB)
      FPN(JB)=(FPN(JB)*PLVBT(JB)+DGFN)/PLV(JB)
      HNO3(JB)=(HNO3(JB)*PLVBT(JB)+DGHN)/PLV(JB)
      H2O(JB)=(H2O(JB)*PLVBT(JB)+DGH2)/PLV(JB)
      WTFUEL(JB)=WTFUEL(JBM1)
      SST(JB)=SST(JBM1)
      PPSTG(JB)=PPSTG(JBM1)
      PLVRAT=PLVBT(JBM1)/PLV(JB)
C
C     ASSUME JBM1 TRANSFERS FIRST.
C     PARTICLE TRANSFERS DUE TO BACKMIXING
C
```

```
                SUMWT=0.0D0
                DO 102 JJ=1,NRWM1
        WTPJB=P(JB,JJ)*BAKV(JB)
        WTPJBM=P(JBM1,JJ)*BAKV(JBM1)
        WTPTOT=P(JB,JJ)*PLVBT(JB)
        WTP=WTPJBM+WTPTOT
        IF(WTP)310,310,300
300     RMS(JB,JJ)=WTP/(WTPTOT/RMS(JB,JJ)+WTPJBM/RMS(JBM1,JJ))
        GO TO 110
310     RMS(JB,JJ)=R(JJ)
110     CONTINUE
        WTSUM=WTPJBM-WTPJB
        P(JB,JJ)=(P(JB,JJ)*PLVBT(JB)+WTSUM)/PLV(JB)
        SUMWT=SUMWT+WTSUM
102             CONTINUE
        PLVBO=PLVBT(JB)/PLV(JB)
        SUMPJ=0.0D0
        SUMAD=0.0D0
C
C       PARTICLES TRANSFERING WITH HULLS
C
                DO 175 KK=NRW,NG
        ADDPAR=P(JBM1,KK)*PLVRAT
        SUMAD=SUMAD+ADDPAR
        SUMPJ=SUMPJ+P(JB,KK)
        P(JB,KK)=ADDPAR
        RMS(JB,KK)=RMS(JBM1,KK)
175             CONTINUE
        PART(JB)=(PART(JB)-SUMPJ)*PLVBO+SUMAD+(SUMWT/PLV(JB))
126     CONTINUE
                IF(T1.GT.CT1) GO TO 60
        WTFUEL(2)=0.0D0
        SST(2)=0.0D0
        PPSTG(2)=0.0D0
        PLV(2)=PLV(2)-BAKV(2)
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                               C
C       NO SOLIDS TRANSFER FROM STAGE 1.        C
C       ALL SOLIDS TRANSFERED FROM STAGE 2      C
C                                               C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
        JB=2
        PLVB2=PLVBT(2)/PLV(2)
        SUMPB2=0.0D0
C
C       PARTICLES TRANSFERRING DUE TO BACKMIXING.
C
                DO 103 JJ=1,NRWM1
        POUT2=P(2,JJ)*BAKV(2)
        P(2,JJ)=(P(2,JJ)*PLVBT(2)-POUT2)/PLV(2)
        SUMPB2=SUMPB2+POUT2
103             CONTINUE
        SUMPT2=0.0D0
C
C       PARTICLES TRANSFERRING WITH HULLS
C
```

```
                DO 130 KK=NRW,NG
                SUMPT2=SUMPT2+P(2,KK)
                PB(2,KK)=0.0D0
                P(2,KK)=0.0D0
                RMS(2,KK)=R(KK)
130             CONTINUE
        PART(2)=((PART(2)-SUMPT2)*PLVBT(2)-SUMPB2)/PLV(2)
        GO TO 40
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                 C
C       SOLIDS TRANSFER FROM STAGES 1 AND 2.      C
C                                                 C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
60              T1=T1-CT1
        PLV(2)=PLV(2)+BAKV(1)-BAKV(2)
        PLV(1)=PLV(1)-BAKV(1)
C
C       DO NOT NEED TO RECALCULATE STAGE 1 CONC SINCE
C       SOUP FROM SOUP LEAVES SOUP...
C
        DGUN=BAKV(1)*UN(1)-UN(2)*BAKV(2)
        DGPN=BAKV(1)*PN(1)-PN(2)*BAKV(2)
        DGFN=BAKV(1)*FPN(1)-FPN(2)*BAKV(2)
        DGHN=BAKV(1)*HNO3(1)-HNO3(2)*BAKV(2)
        DGH2=BAKV(1)*H2O(1)-H2O(2)*BAKV(2)
        UN(2)=(UN(2)*PLVBT(2)+DGUN)/PLV(2)
        PN(2)=(PN(2)*PLVBT(2)+DGPN)/PLV(2)
        FPN(2)=(FPN(2)*PLVBT(2)+DGFN)/PLV(2)
        HNO3(2)=(HNO3(2)*PLVBT(2)+DGHN)/PLV(2)
        H2O(2)=(H2O(2)*PLVBT(2)+DGH2)/PLV(2)
        WTFUEL(2)=WTFUEL(1)
        SST(2)=SST(1)
        PPSTG(2)=PPSTG(1)
        WTFUEL(1)=0.0D0
        SST(1)=0.0D0
        PPSTG(1)=0.0D0
        PLVRAT=PLVBT(1)/PLV(2)
        PLVB2=PLVBT(2)/PLV(2)
        PLVB1=PLVBT(1)/PLV(1)
                SUMPB1=0.0D0
                SUMPB2=0.0D0
C
C       PARTICLE CONCENTRATION DUE TO BACKMIXING
C
                DO 105 JJ=1,NRWM1
        POUT1=P(1,JJ)*BAKV(1)
        POUT2=P(2,JJ)*BAKV(2)
        WTP1=P(1,JJ)*PLVBT(1)
        WTP2=P(2,JJ)*PLVBT(2)
        WTP12=POUT1+WTP2
        IF(WTP12)320,320,330
330     RMS(2,JJ)=WTP12/(POUT1/RMS(1,JJ)+WTP2/RMS(2,JJ))
        GO TO 116
320     RMS(2,JJ)=R(JJ)
C
C       MEAN SIZES FOR STAGE 1 DOES NOT CHANGE.
```

```
C
116     CONTINUE
        WTSUM2=POUT1-POUT2
        P(2,JJ)=(WTP2+WTSUM2)/PLV(2)
        P(1,JJ)=(WTP1-POUT1)/PLV(1)
        SUMPB2=SUMPB2+WTSUM2
        SUMPB1=SUMPB1+POUT1
105             CONTINUE
        SUMPT1=0.0D0
        SUMPT2=0.0D0
        SUMAD=0.0D0
C
C       PARTICLE CONCENTRATION DUE TO HULLS TRANSFER
C
        DO 135 KK=NRW,NG
                ADDPAR=P(1,KK)*PLVRAT
                SUMAD=SUMAD+ADDPAR
                SUMPT2=SUMPT2+P(2,KK)
                P(2,KK)=ADDPAR
                RMS(2,KK)=RMS(1,KK)
                SUMPT1=SUMPT1+P(1,KK)
                P(1,KK)=0.0D0
                PB(1,KK)=0.0D0
                RMS(1,KK)=R(KK)
135     CONTINUE
        PART(2)=((PART(2)-SUMPT2)*PLVBT(2)+SUMPB2)/PLV(2)+SUMAD
        PART(1)=((PART(1)-SUMPT1)*PLVBT(1)-SUMPB1)/PLV(1)
        GO TO 40
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                               C
C       SOLIDS TRANSFER FROM STAGE 1 ONLY                       C
C       NO SOLIDS TRANSFER FROM STAGE 2.                        C
C                                                               C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
30      T1=T1-CT1
        PLV(2)=PLV(2)+BAKV(1)
        PLV(1)=PLV(1)-BAKV(1)
        JB=1
        DGUN=BAKV(JB)*UN(JB)
        DGPN=BAKV(JB)*PN(JB)
        DGFN=BAKV(JB)*FPN(JB)
        DGHN=BAKV(JB)*HNO3(JB)
        DGH2=BAKV(JB)*H2O(JB)
C
C       SOUP FROM SOUP LEAVES SOUP...
C
        JB=2
        UN(JB)=(UN(JB)*PLVBT(JB)+DGUN)/PLV(JB)
        PN(JB)=(PN(JB)*PLVBT(JB)+DGPN)/PLV(JB)
        FPN(JB)=(FPN(JB)*PLVBT(JB)+DGFN)/PLV(JB)
        HNO3(JB)=(HNO3(JB)*PLVBT(JB)+DGHN)/PLV(JB)
        H2O(JB)=(H2O(JB)*PLVBT(JB)+DGH2)/PLV(JB)
                SUMPB1=0.0D0
C
C       PARTICLE CONCENTRATION DUE TO BACKMIXING
C
```

```
          DO 104 JJ=1,NRWM1
      POUT1=P(1,JJ)*BAKV(1)
      WTP2=P(2,JJ)*PLVBT(2)
      WPTOT2=WTP2+POUT1
      IF(WPTOT2)340,340,350
350   RMS(2,JJ)=WPTOT2/(POUT1/RMS(1,JJ)+WTP2/RMS(2,JJ))
      GO TO 125
340   RMS(2,JJ)=R(JJ)
125   CONTINUE
      SUMPB1=SUMPB1+POUT1
      P(2,JJ)=(P(2,JJ)*PLVBT(2)+POUT1)/PLV(2)
      P(1,JJ)=(P(1,JJ)*PLVBT(1)-POUT1)/PLV(1)
104       CONTINUE
      WTFUEL(2)=WTFUEL(2)+WTFUEL(1)
      SST(2)=SST(2)+SST(1)
      PPSTG(2)=PPSTG(2)+PPSTG(1)
      WTFUEL(1)=0.0D0
      SST(1)=0.0D0
      PPSTG(1)=0.0D0
      PLVRAT=PLVBT(1)/PLV(2)
      PLVB2=PLVBT(2)/PLV(2)
      PLVB1=PLVBT(1)/PLV(1)
          SUMAD=0.0D0
          SUMPT1=0.0D0
C
C     PARTICLE CONCENTRATION DUE TO HULLS TRANSFER
C
      DO 140 KK=NRW,NG
          PS1=P(1,KK)*PLVBT(1)
          PS2=P(2,KK)*PLVBT(2)
          PSUM12=PS1+PS2
          IF(PSUM12)145,145,155
155       RMS(2,KK)=PSUM12/(PS1/RMS(1,KK)+PS2/RMS(2,KK))
          GO TO 165
145       RMS(2,KK)=R(KK)
165   CONTINUE
          ADDPAR=P(1,KK)*PLVRAT
          P(2,KK)=P(2,KK)*PLVB2+ADDPAR
          SUMAD=SUMAD+ADDPAR
          SUMPT1=SUMPT1+P(1,KK)
          P(1,KK)=0.0D0
          RMS(1,KK)=R(KK)
140   CONTINUE
          PART(2)=((PART(2)*PLVBT(2)+SUMPB1)/PLV(2))+SUMAD
          PART(1)=((PART(1)-SUMPT1)*PLVBT(1)-SUMPB1)/PLV(1)
C
C
C
C         PINS CONTINUE TO BE REMOVED FROM STAGE 1
C         EVEN AFTER SOLIDS FEED HAS STOPPED.
C
40    CONTINUE
          RETURN
          END
C
C
```

```
      SUBROUTINE PARTIC
                        IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/XX/ UN(20),PN(20),HNO3(20),H2O(20),UNB(20),OLD(20)
     $,PNB(20),HNO3B(20),H2OB(20),WTU3O8(20),WTPUO2(20),WTFP(20)
     $,WTFUEL(20),FPN(20),FPNB(20),DENOM(20),REL(20),CREL(20),LIMO
      COMMON /XXX/TOL,T,CT,V(20),VO(20),CT1,T1,H,PLV(20),HC,
     $T2,SUMNEG,SUMHNO,SUMNEP,ICP,ICPO,ITSAC
      COMMON/XXXX/B(20),U3O8(20),U3O8B(20),PART(20),RATE1(20),
     $PARTB(20),RATE2(20),PUO2(20),PUO2B(20),FP(20),FPB(20),
     $UNK1(20),PNK1(20),FPK1(20),FL(20),UNK2(20),PNK2(20),
     $FPK2(20),P(10,50),PB(10,50),NS
      COMMON/XXXXX/RMSD(2,50),TIME,PINVOL,RHOAVE,TD,XPU,REM,TNP,
     $RPOW,RCON,ACDF,PINOOO,PAROOO
      COMMON/PERCNT/PCU3O8,PCPUO2,PCFP,SPAREA,DU3O8
     $,DPUO2,DFP,CON,PINMAS,PPSTG(20),CV(20),RATMF,FEDRAT,ARATIO
     $,PCUPER,PCPPER,UOWF,POWF,PPERPN,UPERUN
      COMMON/WTMOLE/WMOLU3,WMOLPU,WMOLFP,WMOLUN,WMOLPN,WMOLFN,
     $WMOLH2,WMOLHN,AVEMOL,JJPART,MMUN,NNPN,NNFP,MMHN,IIH2
      COMMON/PAR/FREQ(50),R(50),RMMIN(50),RMMAX(50),PP(10,50),
     $RMS(10,50),PARTP(20),PM(50),ATP(50),CR,PI,RMIN,RMAX,PCONT,
     $FTPIRO,FOURPI,NG
      COMMON/SOLIDS/FINES,RWASTE,HDR,CUBE,NRW,NRWM1,NGPNRW,NGM1
     $,NRWM2
               DIMENSION TEMP(50),RTEMP(50),RREACT(50)
C
C     PARTICLE BALANCE
C
C                       DEFINITIONS
C
C     PP(I,J)---NUMBER OF PARTICLES IN SIZE GROUP J IN STAGE I IF REACTION
C              IS IGNORED.(G/L)
C     P(I,J)---CCNC OF PARTICLES IN SIZE GROUP J IN STAGE I IF
C              REACTION IS IGNORED. (G/L)
C
C
C     RECALCULATE RELEASE RATE DUE TO ADJUSTMENT OF TIME STEP.
C
               CALL RELEAS
                        DO 22 L=1,NS
               OLD(L)=PART(L)
               PARTB(L)=PART(L)
C
C     WEIGHT OF FUEL IN PINS ADJUSTED FOR RELEASE
C
               WTFUEL(L)=WTFUEL(L)-REL(L)*H
                        DO 22 M=1,NG
22                      PB(L,M)=P(L,M)
C
C     REACTION RATES RECALCULATED AFTER RELEASE OF FUEL FROM PINS
C
               CALL RATECK
                        DO 19 JJ=1,LIMC
      IF(JJ.GT.JJPART) JJPART=JJ
      IFLAG=0
C
C     STAGE 1 PARTICLE SIZE GROUPS NRW TO NG.
```

```
C
        I=1
        IP1=I+1
                HOP=H/PLV(I)
C
C       STAGE 1 PARTICLE SIZE GROUPS NRW TO NG
C
                        DO 30 JO=NRW,NG
        J=NGPNRW-JO
        A=REL(I)*FREQ(J)
        P(I,J)=PB(I,J)+A*HOP
30                      CONTINUE
C
C       STAGE 1 PARTICLE SIZE GROUPS 1 TO NRWM1.
C
        QTP=DEXP((-DENOM(I))*HOP)
        ONEQTP=1.D0-QTP
                        DO 65 JO=1,NRWM1
        J=NRW-JO
        A=FL(IP1)*P(IP1,J)+REL(I)*FREQ(J)
        IF(DENOM(I).EQ.0.0D0) GOTO 500
                P(I,J)=ONEQTP*A/DENOM(I)+PB(I,J)*QTP
        GOTO 65
500     P(I,J)=PB(I,J)
65                      CONTINUE
C
C       RADIUS DUE TO MIXING IN STAGE 1
C
        RELH=REL(I)*H
        FLVOL=H*FL(IP1)
                DO 610 J=1,NG
        PTCSTG=PB(I,J)*PLV(I)
        PTLOGN=RELH*FREQ(J)
        IF(J.GT.NRWM1) GOTO 556
        PTSTGB=PB(IP1,J)*FLVOL
        GOTO 558
556     PTSTGB=0.0D0
558     PTOTAL=PTLOGN+PTSTGB+PTCSTG
        PDEN=(PTLOGN/R(J)+PTSTGB/RMS(IP1,J)+PTCSTG/RMS(I,J))
        IF(PDEN.LE.0.0D0) GOTO 247
C
C       ADJUSTED RADIUS
C
        RMS(I,J)=PTOTAL/PDEN
        IF(RMS(I,J).LE.0.0D0)RMS(I,J)=R(J)
        GOTO 610
247     P(I,J)=0.0D0
        RMS(I,J)=R(J)
610     CONTINUE
C
C       STAGES 2 THROUGH NS PARTICLE SIZE GROUPS NRW TO NG.
C
                        DO 10 I=2,NS
        IP1=I+1
        IM1=I-1
                HOP=H/PLV(I)
```

```
                         DO 40  JO=NRW,NG
      J=NGPNRW-JO
      A=REL(I)*FREQ(J)
      P(I,J)=PB(I,J)+A*HOP
40                       CONTINUE
C
C     STAGES 2 THROUGH NS PARTICLE SIZE GROUPS 1 THROUGH NRWM1.
C
      QTP=DEXP((-DENOM(I))*HOP)
      ONEQTP=1.D0-QTP
                         DO 75  JO=1,NRWM1
      J=NRW-JO
      A=FL(IP1)*P(IP1,J)+REL(I)*FREQ(J)+B(IM1)*P(IM1,J)
      IF(DENOM(I).EQ.0.0D0) GOTO 530
              P(I,J)=ONEQTP*A/DENOM(I)+PB(I,J)*QTP
      GOTO 75
530   P(I,J)=PB(I,J)
75                       CONTINUE
C
C     RADIUS DUE TO MIXING IN STAGES 2 THRU NS
C
      RELH=REL(I)*H
      FLVOL=H*FL(IP1)
      BLVOL=H*B(IM1)
              DO 630 J=1,NG
      PTCSTG=PB(I,J)*PLV(I)
      PTLOGN=RELH*FREQ(J)
      IF(J.GT.NRWM1)GO TO 565
      PTSTGB=PB(IP1,J)*FLVOL
      PTBAK=PB(IM1,J)*BLVOL
      GOTO 555
565   PTSTGB=0.0D0
      PTBAK=0.0D0
555   PTOTAL=PTLOGN+PTSTGB+PTCSTG+PTBAK
      PDEN=(PTLOGN/R(J)+PTSTGB/RMS(IP1,J)+PTCSTG/RMS(I,J)
     $+PTBAK/RMS(IM1,J))
      IF(PDEN.LE.0.0D0) GOTO 140
C
C     ADJUSTED RADIUS
C
      RMS(I,J)=PTOTAL/PDEN
      IF(RMS(I,J).LE.0.0D0)RMS(I,J)=R(J)
      IF(RMS(I,J).GT.RMMAX(NG))GOTO 400
      GOTO 630
140   P(I,J)=0.0D0
      RMS(I,J)=R(J)
      GOTO 630
400   WRITE(13,420)TIME,I,J
420   FORMAT(/' TIME=',2X,1PD15.4,2X,I3,2X,I4)
      WRITE(13,410)PTCSTG,PTLOGN,PTSTGB,PTBAK,RELH,FLVOL,BLVOL
     $,RMS(I,J)
410   FORMAT(1X,8(1PD12.3,1X))
      RMS(I,J)=R(J)
630   CONTINUE
10                       CONTINUE
      IFLAG=0
```

```
      CALL CHECK(IFLAG,PART)
      IF(IFLAG.GT.1) GO TO 19
      GO TO 41
19                 CONTINUE
41    CONTINUE
                   DO 800 I=1,NS
      SUMPAR=0.0D0
                   DO 810 J=1,NG
      PTPLV=P(I,J)*PLV(I)
      PM(J)=FTPIRO*(RMS(I,J)*1.D-4)**3
C
C     ARATIO USED TO INCREASE SURFACE AREA ONLY...
C
      ATP(J)=FOURPI*(RMS(I,J)*ARATIO)**2
      PP(I,J)=PTPLV/PM(J)
810   SUMPAR=SUMPAR+PTPLV
800   PART(I)=SUMPAR
      RETURN
      END
C
C
C
      SUBROUTINE SUBUN
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/XX/ UN(20),PN(20),HNO3(20),H2O(20),UNB(20),OLD(20)
     $,PNB(20),HNO3B(20),H2OB(20),WTU3O8(20),WTPUO2(20),WTFP(20)
     $,WTFUEL(20),FPN(20),FPNB(20),DENOM(20),REL(20),CREL(20),LIMO
      COMMON /XXX/TOL,T,CT,V(20),VO(20),CT1,T1,H,PLV(20),HC,
     $T2,SUMNEG,SUMHNO,SUMNEP,ICP,ICPO,ITSAC
      COMMON/XXXX/B(20),U3O8(20),U3O8B(20),PART(20),RATE1(20),
     $PARTB(20),RATE2(20),PUO2(20),PUO2B(20),FP(20),FPB(20),
     $UNK1(20),PNK1(20),FPK1(20),FL(20),UNK2(20),PNK2(20),
     $FPK2(20),P(10,50),PB(10,50),NS
      COMMON/PERCNT/PCU3O8,PCPUO2,PCFP,SPAREA,DU3O8
     $,DPUO2,DFP,CON,PINMAS,PPSTG(20),CV(20),RATMF,FEDRAT,ARATIO
     $,PCUPER,PCPPER,UOWF,POWF,PPERPN,UPERUN
      COMMON/WTMOLE/WMOLU3,WMOLPU,WMOLFP,WMOLUN,WMOLPN,WMOLFN,
     $WMOLH2,WMOLHN,AVEMOL,JJPART,MMUN,NNPN,NNFP,MMHN,IIH2
      COMMON/ZCONST/ZU,ZUCON,ZP,ZPCON,ZF,ZFCON,ZQT(10),Z1MQT(10)
     $,PCU3ZU,PCPUZP,PCFPZF,CU1NU3,CP1NPU,CF1NFP,CU1WU3,
     $CP1WPU,CF1WFP,CU2NU3,CP2NPU,CF2NFP,CU2WU3
     $,CP2WPU,CF2WFP,T1CON,T1COW,T2CON,T2COW,BW,BWC,BN,BNC
     $,EO3,FO3,TOCON1(10),TOCOW1(10),TCCON2(10),TOCOW2(10)
C
C     UO2(NO3)2 BALANCE
C
      DO 400 K11=1,NS
      OLD(K11)=UN(K11)
400   UNB(K11)=UN(K11)
      DO 420 M=1,LIMO
      IF(M.GT.MMUN) MMUN=M
      IF(DENOM(1).EQ.0.0D0) GOTO 440
      A=UN(2)*FL(2)
      UN(1)=Z1MQT(1)*A/DENOM(1)+UNB(1)*ZQT(1)
      GOTO 450
440   UN(1)=UNB(1)
```

```
450     DO 410 J=2,NS
        IF(DENOM(J).EQ.0.0D0) GOTO 460
        JM1=J-1
        JP1=J+1
        A=UN(JP1)*FL(JP1)+UN(JM1)*B(JM1)
        UN(J)=Z1MQT(J)*A/DENOM(J)+UNB(J)*ZQT(J)
        GOTO 410
460     UN(J)=UNB(J)
410     CONTINUE
        IFLAG=0
        CALL CHECK(IFLAG,UN)
        IF(IFLAG.GT.1) GO TO 420
        GO TO 430
420     CONTINUE
430     CONTINUE
        RETURN
        END
C
C
C
        SUBROUTINE SUBPN
        IMPLICIT REAL*8 (A-H,O-Z)
        COMMON/XX/ UN(20),PN(20),HNO3(20),H2O(20),UNB(20),OLD(20)
     $,PNB(20),HNO3B(20),H2OB(20),WTU3C8(20),WTPUO2(20),WTFP(20)
     $,WTFUEL(20),FPN(20),FPNB(20),DENOM(20),REL(20),CREL(20),LIMO
        COMMON /XXX/TOL,T,CT,V(20),VO(20),CT1,T1,H,PLV(20),HC,
     $T2,SUMNEG,SUMHNO,SUMNEP,ICP,ICPO,ITSAC
        COMMON/XXXX/B(20),U3O8(20),U3O8B(20),PART(20),RATE1(20),
     $PARTB(20),RATE2(20),PUO2(20),PUO2B(20),FP(20),FPB(20),
     $UNK1(20),PNK1(20),FPK1(20),FL(20),UNK2(20),PNK2(20),
     $FPK2(20),P(10,50),PB(10,50),NS
        COMMON/PERCNT/PCU3O8,PCPUO2,PCFP,SPAREA,DU3O8
     $,DPUO2,DFP,CON,PINMAS,PPSTG(20),DV(20),RATMF,FEDRAT,ARATIO
     $,PCUPER,PCPPER,UOWF,POWF,PPERPN,UPERUN
        COMMON/WTMOLE/WMOLU3,WMOLPU,WMOLFP,WMOLUN,WMOLPN,WMOLFN,
     $WMOLH2,WMOLHN,AVEMOL,JJPART,MMUN,NNPN,NNFP,MMHN,IIH2
        COMMON/ZCONST/ZU,ZUCON,ZP,ZPCON,ZF,ZFCON,ZQT(10),Z1MQT(10)
     $,PCU3ZU,PCPUZP,PCFPZF,CU1NU3,CP1NPU,CF1NFP,CU1WU3,
     $CP1WPU,CF1WFP,CU2NU3,CP2NPU,CF2NFP,CU2WU3
     $,CP2WPU,CF2WFP,T1CON,T1COW,T2CON,T2COW,BW,BWC,BN,BNC
     $,EO3,FO3,TOCON1(10),TOCOW1(10),TOCON2(10),TOCOW2(10)
C
C       PU(NO3)4 BALANCE
C
        DO 500 K22=1,NS
        OLD(K22)=PN(K22)
500     PNB(K22)=PN(K22)
        DO 520 NN=1,LIMC
        IF(NN.GT.NNPN) NNPN=NN
        IF(DENOM(1).EQ.0.0D0) GOTO 540
        A=PN(2)*FL(2)
        PN(1)=Z1MQT(1)*A/DENOM(1)+PNB(1)*ZQT(1)
        GOTO 550
540     PN(1)=PNB(1)
550     DO 510 K=2,NS
        IF(DENOM(K).EQ.0.0D0) GOTO 560
```

```
      KP1=K+1
      KM1=K-1
      A=FL(KP1)*PN(KP1)+B(KM1)*PN(KM1)
      PN(K)=Z1MQT(K)*A/DENOM(K)+PNB(K)*ZQT(K)
      GOTO 510
560   PN(K)=PNB(K)
510   CONTINUE
      IFLAG=0
      CALL CHECK(IFLAG,PN)
      IF(IFLAG.GT.1) GO TO 520
      GO TO 530
520   CONTINUE
530   CONTINUE
      RETURN
      END
C
C
C
      SUBROUTINE SUBFN
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/XX/ UN(20),PN(20),HNO3(20),H2O(20),UNB(20),OLD(20)
     $,PNB(20),HNO3B(20),H2OB(20),WTU308(20),WTPUO2(20),WTFP(20)
     $,WTFUEL(20),FPN(20),FPNB(20),DENOM(20),REL(20),CREL(20),LIMO
      COMMON /XXX/TOL,T,CT,V(20),VO(20),CT1,T1,H,PLV(20),HC,
     $T2,SUMNEG,SUMHNO,SUMNEP,ICP,ICPO,ITSAC
      COMMON/XXXX/B(20),U308(20),U308B(20),PART(20),RATE1(20),
     $PARTB(20),RATE2(20),PUO2(20),PUO2B(20),FP(20),FPB(20),
     $UNK1(20),PNK1(20),FPK1(20),FL(20),UNK2(20),PNK2(20),
     $FPK2(20),P(10,50),PB(10,50),NS
      COMMON/PERCNT/PCU308,PCPUO2,PCFP,SPAREA,DU308
     $,DPUO2,DFP,CON,PINMAS,PPSTG(20),CV(20),RATMF,FEDRAT,ARATIO
     $,PCUPER,PCPPER,UOWF,POWF,PPERPN,UPERUN
      COMMON/WTMOLE/WMOLU3,WMOLPU,WMOLFP,WMOLUN,WMOLPN,WMOLFN,
     $WMOLH2,WMOLHN,AVEMOL,JJPART,MMUN,NNPN,NNFP,MMHN,IIH2
      COMMON/ZCONST/ZU,ZUCON,ZP,ZPCON,ZF,ZFCON,ZQT(10),Z1MQT(10)
     $,PCU3ZU,PCPUZP,PCFPZF,CU1NU3,CP1NPU,CF1NFP,CU1WU3,
     $CP1WPU,CF1WFP,CU2NU3,CP2NPU,CF2NFP,CU2WU3
     $,CP2WPU,CF2WFP,T1CON,T1COW,T2CON,T2COW,BW,BWC,BN,BNC
     $,EO3,FO3,TOCON1(10),TOCOW1(10),TOCON2(10),TOCOW2(10)
C
C     FP(NO3)3.39 BALANCE
C
      DO 550 K22=1,NS
      OLD(K22)=FPN(K22)
550   FPNB(K22)=FPN(K22)
      DO 570 NN=1,LIMO
      IF(NN.GT.NNFP)NNFP=NN
      IF(DENOM(1).EQ.0.0D0) GOTO 510
      A=FL(2)*FPN(2)
      FPN(1)=Z1MQT(1)*A/DENOM(1)+FPNB(1)*ZQT(1)
      GOTO 520
510   FPN(1)=FPNB(1)
520   DO 560 K=2,NS
      IF(DENOM(K).EQ.0.0D0) GOTO 530
      KP1=K+1
      KM1=K-1
```

```
      A=FL(KP1)*FPN(KP1)+B(KM1)*FPN(KM1)
      FPN(K)=Z1MQT(K)*A/DENOM(K)+FPNB(K)*ZQT(K)
      GOTO 560
530   FPN(K)=FPNB(K)
560   CONTINUE
      IFLAG=0
      CALL CHECK(IFLAG,FPN)
      IF(IFLAG.GT.1) GO TO 570
      GO TO 580
570   CONTINUE
580   CONTINUE
      RETURN
      END
C
C
C
      SUBROUTINE SUBHN
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/XX/ UN(20),PN(20),HNO3(20),H2O(20),UNB(20),OLD(20)
     $,PNB(20),HNO3B(20),H2OB(20),WTU3C8(20),WTPUO2(20),WTFP(20)
     $,WTFUEL(20),FPN(20),FPNB(20),DENOM(20),REL(20),CREL(20),LIMO
      COMMON /XXX/TOL,T,CT,V(20),VO(20),CT1,T1,H,PLV(20),HC,
     $T2,SUMNEG,SUMHNO,SUMNEP,ICP,ICPO,ITSAC
      COMMON/XXXX/B(20),U308(20),U308B(20),PART(20),RATE1(20),
     $PARTB(20),RATE2(20),PUO2(20),PUO2B(20),FP(20),FPB(20),
     $UNK1(20),PNK1(20),FPK1(20),FL(20),UNK2(20),PNK2(20),
     $FPK2(20),P(10,50),PB(10,50),NS
      COMMON/EXTFED/HNO3F(10),H2OF(10),FLEXT(10),ACIDEF,IAD
      COMMON/XXXXX/RMSD(2,50),TIME,PINVOL,RHOAVE,TD,XPU,REM,TNP,
     $RPCW,RCON,ACDF,PINOOO,PAROOO
      COMMON/CONSTN/COUN1N,COPN1N,COFP1N,COUN2N,COPN2N,COFP2N,
     $COUN1W,COPN1W,COFP1W,COUN2W,COPN2W,COFP2W
      COMMON/PERCNT/PCU308,PCPUO2,PCFP,SPAREA,DU308
     $,DPUO2,DFP,CON,PINMAS,PPSTG(20),DV(20),RATMF,FEDRAT,ARATIO
     $,PCUPER,PCPPER,UOWF,PCWF,PPERPN,UPERUN
      COMMON/WTMOLE/WMOLU3,WMOLPU,WMOLFP,WMOLUN,WMOLPN,WMOLFN,
     $WMOLH2,WMOLHN,AVEMOL,JJPART,MMUN,NNPN,NNFP,MMHN,IIH2
      COMMON/ZCONST/ZU,ZUCON,ZP,ZPCON,ZF,ZFCON,ZQT(10),Z1MQT(10)
     $,PCU3ZU,PCPUZP,PCFPZF,CU1NU3,CP1NPU,CF1NFP,CU1WU3,
     $CP1WPU,CF1WFP,CU2NU3,CP2NPU,CF2NFP,CU2WU3
     $,CP2WPU,CF2WFP,T1CON,T1COW,T2CON,T2COW,BW,BWC,BN,BNC
     $,EO3,FO3,TOCON1(10),TOCOW1(10),TOCON2(10),TOCOW2(10)
C
C
C     HNO3 BALANCE
C
      DO 600 K33=1,NS
      OLD(K33)=HNO3(K33)
600   HNO3B(K33)=HNO3(K33)
      DO 620 MM=1,LIMO
      IF(MM.GT.MMHN) MMHN=MM
      IF(DENOM(1).EQ.0.0D0) GOTO 640
      A=FL(2)*HNO3(2)+HNO3F(1)*FLEXT(1)
      HNO3(1)=Z1MQT(1)*A/DENOM(1)+HNO3B(1)*ZQT(1)
      GOTO 660
640   HNO3(1)=HNO3B(1)
```

```
660     DO 610 M=2,NS
        IF(DENOM(M).EQ.0.0D0) GOTO 670
        MP1=M+1
        MM1=M-1
        A=FL(MP1)*HNO3(MP1)+B(MM1)*HNO3(MM1)
     $+HNO3F(M)*FLEXT(M)
        HNO3(M)=Z1MQT(M)*A/DENOM(M)+HNO3B(M)*ZQT(M)
        GOTO 610
670     HNO3(M)=HNO3B(M)
610     CONTINUE
        IFLAG=0
        CALL CHECK(IFLAG,HNO3)
        IF(IFLAG.GT.1) GO TO 620
        GO TO 630
620     CONTINUE
C
C       NEGATIVE ACID CONC CORRECTOR...
C
630     DO 650 K=1,NS
        IF(HNO3(K))680,680,650
680     SUMHNO=SUMHNO+HNO3(K)*PLV(K)
        HNO3(K)=0.0D0
650     CONTINUE
        RETURN
        END
C
C
C
        SUBROUTINE SUBH2
        IMPLICIT REAL*8 (A-H,O-Z)
        COMMON/XX/ UN(20),PN(20),HNO3(20),H2O(20),UNB(20),OLD(20)
     $,PNB(20),HNO3B(20),H2OB(20),WTU3O8(20),WTPUO2(20),WTFP(20)
     $,WTFUEL(20),FPN(20),FPNB(20),DENOM(20),REL(20),CREL(20),LIMO
        COMMON /XXX/TOL,T,CT,V(20),VO(20),CT1,T1,H,PLV(20),HC,
     $T2,SUMNEG,SUMHNO,SUMNEP,ICP,ICPO,ITSAC
        COMMON/XXXX/B(20),U3O8(20),U3O8B(20),PART(20),RATE1(20),
     $PARTB(20),RATE2(20),PUO2(20),PUO2B(20),FP(20),FPB(20),
     $UNK1(20),PNK1(20),FPK1(20),FL(20),UNK2(20),PNK2(20),
     $FPK2(20),P(10,50),PB(10,50),NS
        COMMON/EXTFED/HNO3F(10),H2OF(10),FLEXT(10),ACIDEF,IAD
        COMMON/XXXXX/RMSD(2,50),TIME,PINVOL,RHOAVE,TD,XPU,REM,TNP,
     $RPOW,RCON,ACDF,PINOOO,PAROOO
        COMMON/CCNSTN/COUN1N,COPN1N,COFP1N,COUN2N,COPN2N,COFP2N,
     $COUN1W,COPN1W,COFP1W,COUN2W,COPN2W,COFP2W
        COMMON/PERCNT/PCU3O8,PCPUO2,PCFP,SPAREA,DU3O8
     $,DPUO2,DFP,CCN,PINMAS,PPSTG(20),DV(20),RATMF,FEDRAT,ARATIO
     $,PCUPER,PCPPER,UOWF,PCWF,PPERPN,UPERUN
        COMMON/WTMOLE/WMOLU3,WMOLPU,WMOLFP,WMOLUN,WMOLPN,WMOLFN,
     $WMOLH2,WMOLHN,AVEMOL,JJPART,MMUN,NNPN,NNFP,MMHN,IIH2
        COMMON/ZCONST/ZU,ZUCON,ZP,ZPCON,ZF,ZFCON,ZQT(10),Z1MQT(10)
     $,PCU3ZU,PCPUZP,PCFPZF,CU1NU3,CP1NPU,CF1NFP,CU1WU3,
     $CP1WPU,CF1WFP,CU2NU3,CP2NPU,CF2NFP,CU2WU3
     $,CP2WPU,CF2WFP,T1CON,T1COW,T2CON,T2COW,BW,BWC,BN,BNC
     $,EO3,FO3,TOCON1(10),TOCOW1(10),TOCON2(10),TOCOW2(10)
C
C
```

```
C       H2O BALANCE
C
C
        DO 700 K44=1,NS
        CLD(K44)=H2O(K44)
700     H2OB(K44)=H2O(K44)
        DO 720 II=1,LIMO
        IF(II.GT.IIH2) IIH2=II
        IF(DENOM(1).EQ.0.0D0) GOTO 760
        A=FL(2)*H2O(2)+H2OF(1)*FLEXT(1)
        H2O(1)=Z1MQT(1)*A/DENOM(1)+H2OB(1)*ZQT(1)
        GOTO 750
760     H2O(1)=H2OB(1)
750     CONTINUE
        DO 710 LI=2,NS
        IF(DENOM(LI).EQ.0.0D0) GOTO 770
        LIP1=LI+1
        LIM1=LI-1
        A=FL(LIP1)*H2O(LIP1)+B(LIM1)*H2O(LIM1)
     $+H2OF(LI)*FLEXT(LI)
        H2O(LI)=Z1MQT(LI)*A/DENOM(LI)+H2OB(LI)*ZQT(LI)
        GOTO 710
770     H2O(LI)=H2OB(LI)
710     CONTINUE
        IFLAG=0
        CALL CHECK(IFLAG,H2O)
        IF(IFLAG.GT.1) GO TO 720
        GO TO 730
720     CONTINUE
730     CONTINUE
        RETURN
        END
C
C
C
C
C
        SUBROUTINE CHECK(IFLAG,CONC)
        IMPLICIT REAL*8 (A-H,O-Z)
        COMMON/XX/ UN(20),PN(20),HNO3(20),H2O(20),UNB(20),OLD(20)
     $,PNB(20),HNO3B(20),H2OB(20),WTU308(20),WTPUO2(20),WTFP(20)
     $,WTFUEL(20),FPN(20),FPNB(20),DENOM(20),REL(20),CREL(20),LIMO
        COMMON /XXX/TOL,T,CT,V(20),VO(20),CT1,T1,H,PLV(20),HC,
     $T2,SUMNEG,SUMHNO,SUMNEP,ICP,ICPO,ITSAC
        COMMON/XXXX/B(20),U308(20),U308B(20),PART(20),RATE1(20),
     $PARTB(20),RATE2(20),PUO2(20),PUO2B(20),FP(20),FPB(20),
     $UNK1(20),PNK1(20),FPK1(20),FL(20),UNK2(20),PNK2(20),
     $FPK2(20),P(10,50),PB(10,50),NS
        DIMENSION CONC(20)
        DO 10 J=1,NS
        ERROR=DABS(OLD(J)-CONC(J))
        ABTOL=TOL*CLD(J)
        IF(ERROR.GT.ABTOL) GO TO 20
10      CONTINUE
        IFLAG=1
        RETURN
```

```
20      IFLAG=2
        DO 30 I=1,20
30      OLD(I)=CCNC(I)
        RETURN
        END
C
C
C
        SUBROUTINE WEIGHT
        IMPLICIT REAL*8 (A-H,O-Z)
        COMMON/XX/ UN(20),PN(20),HNO3(20),H2O(20),UNB(20),OLD(20)
     $,PNB(20),HNO3B(20),H2OB(20),WTU308(20),WTPUO2(20),WTFP(20)
     $,WTFUEL(20),FPN(20),FPNB(20),DENOM(20),REL(20),CREL(20),LIMO
        COMMON /XXX/TOL,T,CT,V(20),VO(20),CT1,T1,H,PLV(20),HC,
     $T2,SUMNEG,SUMHNO,SUMNEP,ICP,ICPO,ITSAC
        COMMON/XXXX/B(20),U3O8(20),U308B(20),PART(20),RATE1(20),
     *PARTB(20),RATE2(20),PUO2(20),PUO2B(20),FP(20),FPB(20),
     $UNK1(20),PNK1(20),FPK1(20),FL(20),UNK2(20),PNK2(20),
     $FPK2(20),P(10,50),PB(10,50),NS
        COMMON/XXXXX/RMSD(2,50),TIME,PINVOL,RHOAVE,TD,XPU,REM,TNP,
     $RPOW,RCON,ACDF,PINOOO,PAROOO
        COMMON/PERCNT/PCU308,PCPUO2,PCFP,SPAREA,DU308
     $,DPUO2,DFP,CCN,PINMAS,PPSTG(20),CV(20),RATMF,FEDRAT,ARATIO
     $,PCUPER,PCPPER,UOWF,POWF,PPERPN,UPERUN
        COMMON/ZCONST/ZU,ZUCON,ZP,ZPCON,ZF,ZFCON,ZQT(10),Z1MQT(10)
     *,PCU3ZU,PCPUZP,PCFPZF,CU1NU3,CP1NPU,CF1NFP,CU1WU3,
     $CP1WPU,CF1WFP,CU2NU3,CP2NPU,CF2NFP,CU2WU3
     $,CP2WPU,CF2WFP,T1CCN,T1CCW,T2CON,T2COW,BW,BWC,BN,BNC
     $,EC3,FO3,TOCCN1(10),TOCOW1(10),TCCON2(10),TOCOW2(10)
        COMMON/CCNSTN/COUN1N,CCPN1N,COFP1N,COUN2N,COPN2N,COFP2N,
     $COUN1W,COPN1W,COFP1W,COUN2W,COPN2W,COFP2W
        COMMON/PAR/FREQ(50),R(50),RMMIN(50),RMMAX(50),PP(10,50),
     $RMS(10,50),PARTP(20),PM(50),ATP(50),DR,PI,RMIN,RMAX,PCONT,
     $FTPIRO,FOURPI,NG
        COMMON/SCLIDS/FINES,RWASTE,HDR,CUBE,NRW,NRWM1,NGPNRW,NGM1
     $,NRWM2
        DIMENSION RTEMP(10,50)
C
C       QUANTITY REACTED FROM FUEL PINS DURING A TIME STEP
C       AMOUNT RELEASED IN DEDUCTED IN SUBROUTINE RELEAS...
C       UPDATE PARTICLE CONC FCR REACTION...
C
                DO 200 I=1,NS
        SUMPAR=0.0D0
                DO 360 J=1,NG
        K=NG-J+1
        PBBBV=P(I,K)*PLV(I)
        PRCT=RATE1(I)*PP(I,K)*ATP(K)*H
        P(I,K)=(PBBBV-PRCT)/PLV(I)
        PPTIM=PP(I,K)
        IF(P(I,K).LE.0.0D0) GOTO 150
        GOTO 160
150     SUMNEP=SUMNEP+P(I,K)*PLV(I)
        PRCT=PBBBV
        P(I,K)=0.0C0
        PPTIM=0.0D0
```

```
      RMS(I,K)=R(K)
C
C     CONCENTRATION ADJUSTMENT FOR DISSOLUTION OF PARTICLES.
C
160   HXP=PRCT/PLV(I)
      PARTP(I)=PARTP(I)+PRCT
      UN(I)=(UN(I)+HXP*PCU3ZU)
      PN(I)=(PN(I)+HXP*PCPUZP)
      FPN(I)=(FPN(I)+HXP*PCFPZF)
      HNO3(I)=HNO3(I)-HXP*TOCON1(I)
               IF(HNO3(I).LT.0.0D0)HNO3(I)=0.0D0
      H2O(I)=H2O(I)+HXP*TOCOW1(I)
      IF(P(I,K).LE.0.0D0) GOTO 300
      RMS(I,K)=(((RMS(I,K)*1.D-4)**3-PRCT/
     $(FTPIRO*PP(I,K)))**CUBE)/1.D-4
      GOTO 350
300   RMS(I,K)=R(K)
      P(I,K)=0.0D0
350   RTEMP(I,K)=RMS(I,K)
      PP(I,K)=PPTIM
360   CONTINUE
C
C     PARTICLE SIZE GROUP TRANSFERS...
C
      DO 305 K=1,NGM1
      KP1=K+1
               DO 185 J1=KP1,NG
      IF(RMS(I,J1).GE.RMMIN(K).AND.RMS(I,J1).LE.RMMAX(K))GOTO 190
      GOTO 185
190   TOTPAR=P(I,K)+P(I,J1)
      PCONT=PCONT+1.D0
      IF(TOTPAR.LE.0.0D0)GOTO 195
      RTEMP(I,K)=TOTPAR/(P(I,K)/RTEMP(I,K)+P(I,J1)/RTEMP(I,J1))
      P(I,K)=TOTPAR
      P(I,J1)=0.0D0
      RTEMP(I,J1)=R(J1)
      GOTO 185
195   P(I,J1)=0.0D0
      RTEMP(I,J1)=R(J1)
      P(I,K)=0.0D0
      RTEMP(I,K)=R(K)
185   CONTINUE
305   CONTINUE
               DO 400 J=1,NG
      RMS(I,J)=RTEMP(I,J)
      SUMPAR=SUMPAR+P(I,J)
400   CONTINUE
      PART(I)=SUMPAR
C
C     PIN REACTIONS...
C
      RCT=RATE2(I)*CON*PPSTG(I)*H
      OLDWT=WTFUEL(I)
      WTFUEL(I)=WTFUEL(I)-RCT
      IF(WTFUEL(I).LE.0.0D0) GO TO 110
      GOTO 120
```

```
110     SUMNEG=SUMNEG+WTFUEL(I)
        RCT=OLDWT
        WTFUEL(I)=0.0D0
120     IF(OLDWT.GT.0.0D0.AND.WTFUEL(I).LE.0.0D0) GO TO 10
        GO TO 20
10      IF(IFLG10.EQ.10) GO TO 90
        GO TO 100
9C      TPERCT=DABS(T-TSTG)
        IF(TPERCT.LE.0.33333D0) GO TO 20
1C0     TSTG=T
        ICP=ICP+1
        TOTDIS=TIME
        IDISP=I
        WRITE(13,30) TOTDIS,IDISP,TSTG,ICP
        WRITE(6,30) TOTDIS,IDISP,TSTG,ICP
30      FORMAT(/' TIME INTO RUN=',F12.4,' MIN'/
       $' DISSOLUTION OF FUEL IN PINS COMPLETEC IN STAGE',1X,I3,
       $' AFTER ',F12.4,' MINUTES INTO CYCLE.'/
       $' THIS IS THE ',I4,' FUEL DISSAPPEARANCE CYCLE.'/)
C
C       CONCENTRATION ADJUSTMENTS FOR DISSOLUTION FROM FUEL PINS.
C
20      HXPIN=RCT/PLV(I)
        UN(I)=UN(I)+HXPIN*PCU3ZU
        PN(I)=PN(I)+HXPIN*PCPUZP
        FPN(I)=FPN(I)+HXPIN*PCFPZF
        HNO3(I)=HNC3(I)-HXPIN*TOCON2(I)
                IF(HNO3(I).LT.0.0D0)HNC3(I)=0.0D0
        H2O(I)=H2O(I)+HXPIN*TOCOW2(I)
        IF(PART(I).LE.0.0D0) GOTO 130
        GOTO 140
130     PART(I)=0.0D0
140     IF(PARTB(I).GT.0.0D0.AND.PART(I).LE.0.0D0) GO TC 40
        GO TO 50
40      IF(IFLG10.EQ.10) GO TO 70
        GO TO 80
7C      TPERCT=DABS(T-TPSTG)
        IF(TPERCT.LE.0.33333D0) GO TO 50
80      TPSTG=T
        TOPDIS=TIME
        IPDISP=I
        ICPO=ICPC+1
        WRITE(13,60) TOPDIS,IPDISP,TPSTG,ICPO
        WRITE(6,60) TOPDIS,IPDISP,TPSTG,ICPC
6C      FORMAT(/' TIME INTO RUN=',F12.4,' MIN'/
       $' DISSOLUTION OF LOOSE FUEL PARTICLES COMPLETED IN STAGE'
       $,1X,I3,' AFTER',F12.4,' MINUTES INTO CYCLE.'/
       $' THIS IS THE ',I4,' FUEL DISSAPPEARANCE CYCLE.'/)
50      IFLG10=10
200             CONTINUE
        RETURN
        END
C
C
C
        SUBROUTINE RELEAS
```

```
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/XX/ UN(20),PN(20),HNO3(20),H2O(20),UNB(20),OLD(20)
     $,PNB(20),HNO3B(20),H2OB(20),WTU308(20),WTPUO2(20),WTFP(20)
     $,WTFUEL(20),FPN(20),FPNB(20),DENOM(20),REL(20),CREL(20),LIMO
      COMMON /XXX/TOL,T,CT,V(20),VO(20),CT1,T1,H,PLV(20),HC,
     $T2,SUMNEG,SUMHNO,SUMNEP,ICP,ICPO,ITSAC
      COMMON/XXXX/B(20),U308(20),U308B(20),PART(20),RATE1(20),
     $PARTB(20),RATE2(20),PUO2(20),PUO2B(20),FP(20),FPB(20),
     $UNK1(20),PNK1(20),FPK1(20),FL(20),UNK2(20),PNK2(20),
     $FPK2(20),P(10,50),PB(10,50),NS
      COMMON/XXXXX/RMSD(2,50),TIME,PINVOL,RHOAVE,TD,XPU,REM,TNP,
     $RPOW,RCON,ACDF,PINOOO,PAROOO
      COMMON/PERCNT/PCU308,PCPUO2,PCFP,SPAREA,DU308
     $,DPUO2,DFP,CON,PINMAS,PPSTG(20),CV(20),RATMF,FEDRAT,ARATIO
     $,PCUPER,PCPPER,UOWF,POWF,PPERPN,UPERUN
C
C
C
              DO 70 ISTG=1,NS
      STG=DFLOAT(ISTG)
      IF(WTFUEL(ISTG).LE.0.0D0) GO TO 10
      IF(ISTG.EQ.1) GO TO 40
      GO TO 50
40    TID=T1
      GO TO 30
5C    TID=CT*(STG-2.0D0)+T+CT1
C
C
C     FACTOR OF 1 IN RELEASE RATE EQUATION TO INCREASE RATE...
C
C
C30   CONST=WTFUEL(ISTG)/1.D2
C     REL(ISTG)=1.D0*(.2795D0/(TID**.2044D0))*CONST
30    REL(ISTG)=CREL(ISTG)*PPSTG(ISTG)
      RELWTM=WTFUEL(ISTG)/H
      IF(REL(ISTG).GT.RELWTM) GOTO 60
      GO TO 20
60    REL(ISTG)=RELWTM
      GOTO 20
10    REL(ISTG)=0.0D0
20    CONTINUE
70    CONTINUE
      RETURN
      END
C
C
C
      SUBROUTINE RATECK
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/XX/ UN(20),PN(20),HNO3(20),H2O(20),UNB(20),OLD(20)
     $,PNB(20),HNO3B(20),H2OB(20),WTU3C8(20),WTPUO2(20),WTFP(20)
     $,WTFUEL(20),FPN(20),FPNB(20),DENOM(20),REL(20),CREL(20),LIMO
      COMMON /XXX/TOL,T,CT,V(20),VO(20),CT1,T1,H,PLV(20),HC,
     $T2,SUMNEG,SUMHNO,SUMNEP,ICP,ICPO,ITSAC
      COMMON/XXXX/B(20),U308(20),U308B(20),PART(20),RATE1(20),
     $PARTB(20),RATE2(20),PUO2(20),PUO2B(20),FP(20),FPB(20),
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```
      $UNK1(20),PNK1(20),FPK1(20),FL(20),UNK2(20),PNK2(20),
      $FPK2(20),P(10,50),PB(10,50),NS
         COMMON/XXXXX/RMSD(2,50),TIME,PINVOL,RHOAVE,TD,XPU,REM,TNP,
      $RPOW,RCON,ACDF,PIN000,PAR000
         COMMON/PERCNT/PCU308,PCPUO2,PCFP,SPAREA,DU308
      $,DPUO2,DFP,CON,PINMAS,PPSTG(20),DV(20),RATMF,FEDRAT,ARATIO
      $,PCUPER,PCPPER,UOWF,POWF,PPERPN,UPERUN
C
C
C        REACTION RATE FOR U308 AS FUNCTION OF HNO3 CONC AND TD
C        BASED ON UO2 REACTION RATE.....??????.......
C
C
C
C
C        REACTION RATE FOR PUO2 AS FUNCTION OF HNO3 CONC AND TD
C        ASSUMES NO FLUORINE IN DISSOLVER.
C        FROM A REPORT BY RAINEY AND URIATE PUBLISHED IN 1965.
C
C
C
C
                DO 70 IST=1,NS
         A=HNO3(IST)/63.02D0
         IF(A.LE.0.0D0) GO TO 50
         IF(WTFUEL(IST).LE.0.0D0) GO TO 10
         IF(PIN000.LT.1.0D0) GOTO 80
         RATE2(IST)=RATMF*(A*ACDF)**RPOW
         GOTO 20
80       RATE2(IST)=0.0D0
         GO TO 20
10       RATE2(IST)=0.0D0
20       IF(TIME.LE.H) GO TO 60
         IF(PART(IST).LE.0.0D0) GO TO 30
60       IF(PAR000.LT.1.0D0) GOTO 90
         RATE1(IST)=RATMF*A**RPOW
         GOTO 40
90       RATE1(IST)=0.0D0
         GO TO 40
30       RATE1(IST)=0.0D0
         GO TO 40
50       RATE1(IST)=0.0D0
         RATE2(IST)=0.0D0
40       UNK1(IST)=PCU308*RATE1(IST)
         PNK1(IST)=PCPUO2*RATE1(IST)
         FPK1(IST)=PCFP*RATE1(IST)
         UNK2(IST)=PCU308*RATE2(IST)
         PNK2(IST)=PCPUO2*RATE2(IST)
         FPK2(IST)=PCFP*RATE2(IST)
70              CONTINUE
         RETURN
         END
C
C
         SUBROUTINE FREQUE
         IMPLICIT REAL*8 (A-H,O-Z)
```

```
      COMMON/XXXX/B(20),U308(20),U308B(20),PART(20),RATE1(20),
     $PARTB(20),RATE2(20),PUO2(20),PUO2B(20),FP(20),FPB(20),
     $LNK1(20),PNK1(20),FPK1(20),FL(20),UNK2(20),PNK2(20),
     $FPK2(20),P(10,50),PB(10,50),NS
      COMMON/PERCNT/PCU308,PCPUO2,PCFP,SPAREA,DU308
     $,DPUO2,DFP,CON,PINMAS,PPSTG(20),DV(20),RATMF,FEDRAT,ARATIO
     $,PCUPER,PCPPER,UOWF,POWF,PPERPN,UPERUN
      COMMON/PAR/FREQ(50),R(50),RMMIN(50),RMMAX(50),PP(10,50),
     $RMS(10,50),PARTP(20),PM(50),ATP(50),DR,PI,RMIN,RMAX,PCONT,
     $FTPIRO,FOURPI,NG
      COMMON/SOLIDS/FINES,RWASTE,HDR,CUBE,NRW,NRWM1,NGPNRW,NGM1
     $,NRWM2
      COMMON/XXXXX/RMSD(2,50),TIME,PINVOL,RHOAVE,TD,XPU,REM,TNP,
     $RPCW,RCON,ACDF,PIN000,PAR000
C
C     PARTICLE DISTRIBUTION INITIALIZATION ROUTINE...
C
C     DISTRIBUTION DATA IS FOR SHEARED ,UNVOLOXIDIZED, UNIRRIDIATED
C     FUEL.  TAKEN FROM SUBCONTRACT REPORT NUREG/CR-0866,
C     ORNL/NUREG-60 BY DAVIS,WEST, AND STACY OCTOBER 1979
C
      DR=(RMAX-RMIN)/NG
      HDR=DR/2.D0
      R(1)=RMIN+HDR
      RMMIN(1)=R(1)-HDR
      RMMAX(1)=R(1)+HDR
      SUM=0.0D0
              DO 10 I=2,NG
              R(I)=R(I-1)+DR
              RMMIN(I)=R(I)-HDR
10            RMMAX(I)=R(I)+HDR
      CM=5.041D0
      S=1.510D0
      RS1=1.D0/S
C     RSQPI=1.D0/(2.D0*PI)**.5D0
      RSQPI=0.11D0
      RS2=RS1/(2.D0*S)
      COMFA=RSQPI*DR/S
              DO 20 I=1,NG
      Q10=DLOG(R(I))-CM
      FREQ(I)=COMFA*(DEXP(Q10*(-Q10)*RS2))/R(I)
      SUM=SUM+FREQ(I)
20    CONTINUE
      WRITE(6,30) SUM
30    FORMAT(//' INTEGRATED FREQUENCY DISTRIBUTION=',2X,1PD12.5)
      SUM1=0.0D0
C
C     NORMALIZED FREQUENCY DISTRIBUTION FOR PRESENT PARTICLE
C     SIZE RANGE
C
      DO 40 J=1,NG
      FREQ(J)=FREQ(J)/SUM
      PM(J)=FTPIRO*(R(J)*1.D-4)**3
      ATP(J)=FOURPI*(R(J)*ARATIO)**2
40    SUM1=SUM1+FREQ(J)
      NSP1=NS+1
```

```
      DO 60 I=1,NSP1
      DO 60 J=1,NG
      RMS(I,J)=R(J)
60    CONTINUE
      DO 70 I=1,2
      DO 70 J=1,NG
      RMSD(I,J)=R(J)
70    CONTINUE
      WRITE(6,50) SUM1
50    FORMAT(' NORMALIZED INTEGRATED FREQUENCY DISTRIBUTION=',
     $2X,1PD12.5//)
      RETURN
      END
C
C     TIME STEP ADJUSTER
C
      SUBROUTINE TSTEP
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/XX/ UN(20),PN(20),HNO3(20),H2O(20),UNB(20),OLD(20)
     $,PNB(20),HNO3B(20),H2OB(20),WTU3O8(20),WTPUO2(20),WTFP(20)
     $,WTFUEL(20),FPN(20),FPNB(20),DENCM(20),REL(20),CREL(20).LIMO
      COMMON /XXX/TOL,T,CT,V(20),VO(20),CT1,T1,H,PLV(20),HC,
     $T2,SUMNEG,SUMHNO,SUMNEP,ICP,ICPO,ITSAC
      COMMON/PERCNT/PCU3O8,PCPUO2,PCFP,SPAREA,DU3O8
     $,DPUO2,DFP,CON,PINMAS,PPSTG(20),CV(20),RATMF,FEDRAT,ARATIO
     $,PCUPER,PCPPER,UOWF,POWF,PPERPN,UPERUN
      COMMON/XXXX/B(20),U3O8(20),U3O8B(20),PART(20),RATE1(20),
     $PARTB(20),RATE2(20),PUO2(20),PUO2B(20),FP(20),FPB(20),
     $UNK1(20),PNK1(20),FPK1(20),FL(20),UNK2(20),PNK2(20),
     $FPK2(20),P(10,50),PB(10,50),NS
      SHORTM=HC
      CALL RATECK
      CALL RELEAS
      DO 10 I=1,NS
      IZE=I
      IF(WTFUEL(IZE).LE.0.0D0) GOTO 10
      REACT=(RATE2(IZE)*CON*PPSTG(IZE)+REL(IZE))*HC
      DELWT=WTFUEL(IZE)-REACT
      IF(DELWT.LE.0.0D0) GOTO 20
      STTM=HC
      GOTO 10
20    STTM=WTFUEL(IZE)*HC/REACT
      ITSAC=ITSAC+1
      IF(STTM.LT.SHORTM) SHORTM=STTM
10    CONTINUE
      H=SHORTM
      RETURN
      END
C
C     UO2 REACTION RATE CHOISE
C
C
      SUBROUTINE RXEQU
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/PERCNT/PCU3O8,PCPUO2,PCFP,SPAREA,DU3O8
     $,DPUO2,DFP,CON,PINMAS,PPSTG(20),CV(20),RATMF,FEDRAT,ARATIO
```

```
     $,PCUPER,PCPPER,UOWF,POWF,PPERPN,UPERUN
      COMMON/CCNSTN/COUN1N,CCPN1N,COFP1N,COUN2N,COPN2N,COFP2N,
     $COUN1W,COPN1W,COFP1W,COUN2W,COPN2W,COFP2W
      COMMON/XX/ UN(20),PN(20),HNO3(20),H2O(20),UNB(20),OLD(20)
     $,PNB(20),HNO3B(20),H2OB(20),WTU3O8(20),WTPUO2(20),WTFP(20)
     $,WTFUEL(20),FPN(20),FPNB(20),DENOM(20),REL(20),CREL(20),LIMO
      COMMON/WTMOLE/WMOLU3,WMOLPU,WMOLFP,WMOLUN,WMOLPN,WMOLFN,
     $WMOLH2,WMOLHN,AVEMOL,JJPART,MMUN,NNPN,NNFP,MMHN,IIH2
      COMMON/ZCONST/ZU,ZUCON,ZP,ZPCON,ZF,ZFCON,ZQT(10),Z1MQT(10)
     $,PCU3ZU,PCPUZP,PCFPZF,CU1NU3,CP1NPU,CF1NFP,CU1WU3,
     $CP1WPU,CF1WFP,CU2NU3,CP2NPU,CF2NFP,CU2WU3
     $,CP2WPU,CF2WFP,T1CCN,T1CCW,T2CON,T2COW,BW,BWC,BN,BNC
     $,EO3,FO3,TOCON1(10),TOCOW1(10),TCCON2(10),TOCOW2(10)
      DO 500 I=1,10
      A=HNO3(I)/WMOLHN
      IF (A.GE.10.0D0) GOTO 100
      COUN1N=EO3*BN
      COUN2N=EO3*BNC
      COUN1W=FO3*BW
      COUN2W=FO3*BWC
      GOTO 200
100   COUN1N=4.D0*BN
      COUN2N=4.D0*BNC
      COUN1W=2.D0*BW
      COUN2W=2.D0*BWC
200   CU2WU3=COUN2W*PCU3O8
      CU1NU3=COUN1N*PCU3O8
      CU2NU3=CCUN2N*PCU3O8
      CU1WU3=CCUN1W*PCU3O8
      TOCON1(I)=T1CON+CU1NU3
      TOCON2(I)=T2CON+CU2NU3
      TOCOW1(I)=T1COW+CU1WU3
      TOCOW2(I)=T2COW+CU2WU3
500   CONTINUE
      RETURN
      END
C
C
C     DIGESTER TANK MODEL
C
C
      SUBROUTINE DIGEST
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/XX/ UN(20),PN(20),HNO3(20),H2O(20),UNB(20),OLD(20)
     $,PNB(20),HNO3B(20),H2OB(20),WTU3O8(20),WTPUO2(20),WTFP(20)
     $,WTFUEL(20),FPN(20),FPNB(20),DENOM(20),REL(20),CREL(20),LIMO
      COMMON /XXX/TOL,T,CT,V(20),VO(20),CT1,T1,H,PLV(20),HC,
     $T2,SUMNEG,SUMHNO,SUMNEP,ICP,ICPO,ITSAC
      COMMON/XXXX/B(20),U3O8(20),U3O8B(20),PART(20),RATE1(20),
     $PARTB(20),RATE2(20),PUO2(20),PUO2B(20),FP(20),FPB(20),
     $UNK1(20),PNK1(20),FPK1(20),FL(20),UNK2(20),PNK2(20),
     $FPK2(20),P(10,50),PB(10,50),NS
      COMMON/XXXXX/RMSD(2,50),TIME,PINVOL,RHOAVE,TD,XPU,REM,TNP,
     $RPCW,RCON,ACDF,PINOOO,PAROOO
      COMMON/SCLIDS/FINES,RWASTE,HDR,CUBE,NRW,NRWM1,NGPNRW,NGM1
     $,NRWM2
```

```
      COMMON/PAR/FREQ(50),R(50),RMMIN(50),RMMAX(50),PP(10,50),
     $RMS(10,50),PARTP(20),PM(50),ATP(50),DR,PI,RMIN,RMAX,PCONT,
     $FTPIRO,FOURPI,NG
      COMMON/PERCNT/PCU308,PCPUO2,PCFP,SPAREA,DU308
     $,DPUO2,DFP,CON,PINMAS,PPSTG(20),CV(20),RATMF,FEDRAT,ARATIO
     $,PCUPER,PCPPER,UOWF,POWF,PPERPN,UPERUN
      COMMON/DIG/DPLUN(2,200),DPLPN(2,200)
     $,PD(2,50),ATPD(2,50),PPD(2,50)
     $,DPLH2O(2,200),DPLHNO(2,200),DPLFPN(2,200),DPLPAR(2,200),
     $DPLTIM(200),DIGVOL(2,200),RUN,TFILL,VFULL,TTRAN,TDIG
     $,PLINC,VD1,VD2,TM1,TM2,TFD1,TFD2,TOPLOT,TTD1,TTD2,TD1,TD2,
     $D1UN,D2UN,D1PN,D2PN,D1H2O,D2H2O,D1HNO3,D2HNO3,
     $D1PART,D2PART,D1FPN,D2FPN,SUMD1,SUMD2,IPD,MUPIP
      COMMON/ZCONST/ZU,ZUCON,ZP,ZPCON,ZF,ZFCON,ZQT(10),Z1MQT(10)
     $,PCU3ZU,PCPUZP,PCFPZF,CU1NU3,CP1NPU,CF1NFP,CU1WU3,
     $CP1WPU,CF1WFP,CU2NU3,CP2NPU,CF2NFP,CU2WU3
     $,CP2WPU,CF2WFP,T1CON,T1COW,T2CON,T2COW,BW,BWC,BN,BNC
     $,E03,F03,TOCON1(10),TOCOW1(10),TOCON2(10),TOCOW2(10)
      COMMON/WTMOLE/WMOLU3,WMOLPU,WMOLFP,WMOLUN,WMOLPN,WMOLFN,
     $WMOLH2,WMOLHN,AVEMOL,JJPART,MMUN,NNPN,NNFP,MMHN,IIH2
      DIMENSION RTEMPD(2,50),SUMPAR(2)
C
C     FILL DIGESTER # 1
C
      FLH=FL(1)*H
      IF(TFD1.GE.TFILL.OR.VD1.GE.VFULL) GOTO 10
      IFLG1=0
      TFD1=TFD1+H
      VD1=VD1+FLH
      IF(VD1.LE.0.0D0)GOTO 20
      D1UN=D1UN+UN(1)*FLH
      D1PN=D1PN+PN(1)*FLH
      D1FPN=D1FPN+FPN(1)*FLH
      D1H2O=D1H2O+H2O(1)*FLH
      D1HNO3=D1HNO3+HNO3(1)*FLH
                      DO 200 K=1,NRWM1
      PMENT=P(1,K)*FLH
      D1PART=D1PART+PMENT
      PDIN1=PD(1,K)*VD1
      PTOT1=PDIN1+PMENT
      PD(1,K)=PTOT1/VD1
      IF(PTOT1.LE.0.0D0)GOTO 300
      RMSD(1,K)=PTOT1/(PMENT/RMS(1,K)+PDIN1/RMSD(1,K))
      GOTO 200
300   RMSD(1,K)=R(K)
      PD(1,K)=0.0D0
200                   CONTINUE
      TM1=TM1+D1UN+D1PN+D1FPN+D1H2O+D1HNO3+D1PART
      CD1UN=D1UN/VD1
      CD1PN=D1PN/VD1
      CD1FPN=D1FPN/VD1
      CD1H2O=D1H2O/VD1
      CD1HNO=D1HNO3/VD1
      CD1PAR=D1PART/VD1
      GOTO 20
C
```

```
C       DIGEST CYCLE FOR DIGESTER # 1
C
10      IF(IFLG1.NE.10) GOTO 25
        GOTO 35
25      TTRAT1=VD1/TTRAN
        TRTM1=TM1/TTRAN
        VF1=VD1
        IF(VD1.LE.0.0D0)GOTO 35
        CD1UN=D1UN/VD1
        CD1PN=D1PN/VD1
        CD1FPN=D1FPN/VD1
        CD1H2O=D1H2O/VD1
        CD1HNO=D1HNO3/VD1
        CD1PAR=D1PART/VD1
        IFLG1=10
35      TD1=TD1+H
        IF(TD1.GT.TDIG) GOTO 30
        GOTO 20
C
C       EMPTY DIGESTER # 1
C
30      TTD1=TTD1+H
        IF(TTD1.GT.TTRAN) GOTO 40
        IF(VD1.LE.0.0D0)GOTO 20
        VD1=VD1-TTRAT1*H
        TM1=TM1-TRTM1*H
        GOTO 20
40      TD1=0.0D0
        TTD1=0.0D0
        TFD1=0.0D0
        TM1=0.0D0
        VD1=0.0D0
C
C       FILL DIGESTER # 2
C
20      IF(TIME.LE.TFILL) GOTO 110
        IF(TFD2.GE.TFILL.OR.VD2.GE.VFULL)GOTO 60
        TFD2=TFD2+H
        VD2=VD2+FLH
        IFLG2=0
        IF(VD2.LE.0.0D0)GOTO 70
        D2UN=D2UN+UN(1)*FLH
        D2PN=D2PN+PN(1)*FLH
        D2FPN=D2FPN+FPN(1)*FLH
        D2H2O=D2H2O+H2O(1)*FLH
        D2HNO3=D2HNO3+HNO3(1)*FLH
                              DO 350 K=1,NRWM1
        PMENT=P(1,K)*FLH
        D2PART=D2PART+PMENT
        PDIN2=PD(2,K)*VD2
        PTOT2=PDIN2+PMENT
        PD(2,K)=PTOT2/VD2
        IF(PTOT2.LE.0.0D0)GOTO 360
        RMSD(2,K)=PTOT2/(PMENT/RMS(1,K)+PDIN2/RMSD(2,K))
        GOTO 350
360     RMSD(2,K)=R(K)
```

```
      PD(2,K)=0.0D0
350                 CONTINUE
      TM2=TM2+D2UN+D2PN+D2FPN+D2H2O+D2HNO3+D2PART
      CD2UN=D2UN/VD2
      CD2PN=D2PN/VD2
      CD2FPN=D2FPN/VD2
      CD2H2O=D2H2O/VD2
      CD2HNO=D2HNO3/VD2
      CD2PAR=D2PART/VD2
      GOTO 70
C
C     DIGEST CYCLE FOR DIGESTER # 2
C
60    IF(IFLG2.NE.10) GOTO 63
      GOTO 100
63    TTRAT2=VD2/TTRAN
      TRTM2=TM2/TTRAN
      VF2=VD2
      IF(VD2.LE.0.0D0)GOTO 80
      CD2UN=D2UN/VD2
      CD2PN=D2PN/VD2
      CD2FPN=D2FPN/VD2
      CD2H2O=D2H2O/VD2
      CD2HNO=D2HNO3/VD2
      CD2PAR=D2PART/VD2
      IFLG2=10
100   TD2=TD2+H
      IF(TD2.GT.TDIG) GOTO 80
      GOTO 70
C
C     EMPTY DIGESTER # 2
C
80    TTD2=TTD2+H
      IF(TTD2.GT.TTRAN) GOTO 90
      IF(VD2.LE.0.0D0)GOTO 70
      VD2=VD2-TTRAT2*H
      TM2=TM2-TRTM2*H
      GOTO 70
90    TD2=0.0D0
      TTD2=0.0D0
      TFD2=0.0D0
      TM2=0.0D0
      VD2=0.0D0
      GOTO 70
110   CD2UN=0.0D0
      CD2PN=0.0D0
      CD2FPN=0.0D0
      CD2H2O=0.0D0
      CD2HNO=0.0D0
      CD2PAR=0.0D0
C
C     CONCENTRATION ADJUSTMENT DUE TO REACTION
C
C     REACTION RATE DETERMINATION
C
70    A1=CD1HNO/63.02D0
```

```
      A2=CD2HNC/63.02D0
      IF(D1PART.LE.0.0D0) GOTO 400
      RATED1=RATMF*A1**RPOW
      GOTO 410
400   RATED1=0.0D0
410   IF(D2PART.LE.0.0D0) GOTO 420
      RATED2=RATMF*A2**RPOW
      GOTO 430
420   RATED2=0.0D0
430   CONTINUE
C
C     DISSOLUTICN CORRECTION
C
      AD1=CD1HNO/WMOLHN
      IF(AD1.GE.10.0D0) GOTO 210
      TD1CN1=T1CCN+E03*BN
      TD1CW1=T1CCW+F03*BW
      GOTO 220
210   TD1CN1=T1CON+4.D0*BN
      TD1CW1=T1COW+2.D0*BW
220   AD2=CD2HNC/WMOLHN
      IF(AD2.GE.10.0D0)GOTO 230
      TD2CN1=T1CON+E03*BN
      TD2CW1=T1COW+F03*BW
      GOTO 240
230   TD2CN1=T1CON+4.0D0*BN
      TD2CW1=T1CCW+2.0D0*BW
240   CONTINUE
                           DC 490 J=1,NRWM1
      IF(VD1.LE.0.0D0)GCTO 500
      PDIM1=PD(1,J)*VD1
      PMD1=FTPIRC*(RMSD(1,J)*1.D-4)**3
      ATPD(1,J)=FCURPI*(RMSD(1,J)*ARATIO)**2
      PPD(1,J)=PDIM1/PMD1
      PRCTD1=RATED1*PPD(1,J)*ATPD(1,J)*H
      PD(1,J)=(PDIM1-PRCTD1)/VD1
      PPDTIM=PPD(1,J)
      IF(PD(1,J).LE.0.0D0)GOTO 460
      GOTO 470
460   SUMD1=SUMD1+PD(1,J)
      PRCTD1=PDIM1
      PD(1,J)=0.0D0
      PPDTIM=0.0D0
      RMSD(1,J)=R(J)
C
C     CONCENTRATION ADJUSTMENT FOR DIGESTER # 1
C
470   HXP1=PRCTD1/VD1
      CD1UN=CD1UN+HXP1*PCU3ZU
      D1UN=CD1UN*VD1
      CD1PN=CD1PN+HXP1*PCPUZP
      D1PN=CD1PN*VD1
      CD1FPN=CD1FPN+HXP1*PCFPZF
      D1FPN=CD1FPN*VD1
      CD1HNO=CD1HNO-HXP1*TD1CN1
      D1HNO3=CD1HNO*VD1
```

```
      CD1H2O=CD1H2O+HXP1*TD1CW1
      D1H2O=CD1H2O*VD1
      IF(PD(1,J).LE.0.0D0) GCTO 480
      RMSD(1,J)=(((RMSD(1,J)*1.D-4)**3-PRCTD1/(FTPIRO*PPD(1,J)))
     $**CUBE)/1.D-4
      GOTO 550
480   RMSD(1,J)=R(J)
      PD(1,J)=0.0D0
550   PPD(1,J)=PPDTIM
500   IF(VD2.LE.0.0D0) GOTO 450
      PDIM2=PD(2,J)*VD2
      PMD2=FTPIRC*(RMSD(2,J)*1.D-4)**3
      ATPD(2,J)=FCURPI*(RMSD(2,J)*ARATIO)**2
      PPD(2,J)=PDIM2/PMD2
      PPDTIM=PPD(2,J)
      PRCTD2=RATED2*PPD(2,J)*ATPD(2,J)*H
      PD(2,J)=(PDIM2-PRCTD2)/VD2
      IF(PD(2,J).LE.0.0D0) GCTO 510
      GOTO 520
510   SUMD2=SUMD2+PD(2,J)
      PRCTD2=PDIM2
      PD(2,J)=0.0D0
      PPDTIM=0.0D0
      RMSD(2,J)=R(J)
C
C
C     CONCENTRATION ADJUSTMENT FOR DIGESTER # 2
C
C
520   HXP2=PRCTD2/VD2
      CD2UN=CD2UN+HXP2*PCU3ZU
      D2UN=CD2UN*VD2
      CD2PN=CD2PN+HXP2*PCPUZP
      D2PN=CD2PN*VD2
      CD2FPN=CD2FPN+HXP2*PCFPZF
      D2FPN=CD2FPN*VD2
      CD2HNO=CD2HNO-HXP2*TD2CN1
      D2HNO3=CD2HNO*VD2
      CD2H2O=CD2H2O+HXP2*TD2CW1
      D2H2O=CD2H2O*VD2
      IF(PD(2,J).LE.0.0D0) GOTO 530
      RMSD(2,J)=(((RMSD(2,J)*1.D-4)**3-PRCTD2/(FTPIRO*PPD(2,J)))
     $**CUBE)/1.D-4
      GOTO 560
530   RMSD(2,J)=R(J)
      PD(2,J)=0.0D0
560   PPD(2,J)=PPDTIM
450   RTEMPD(1,J)=RMSD(1,J)
      RTEMPD(2,J)=RMSD(2,J)
490                      CONTINUE
C
C     PARTICLE SIZE GROUP TRANSFERS...
C
                         DO 610 I=1,2
      SUMPAR(I)=0.0D0
                         DO 620 K=1,NRWM2
```

```
      KP1=K+1
                        DO 630 J=KP1,NRWM1
      IF(RMSD(I,J).GE.RMMIN(K).AND.RMSD(I,J).LE.RMMAX(K)) GOTO 640
      GOTO 630
640   TOTPAR=PD(I,K)+PD(I,J)
      IF(TOTPAR.LE.0.0D0) GO TO 650
      RTEMPD(I,K)=TOTPAR/(PD(I,K)/RTEMPD(I,K)+PD(I,J)/RTEMPD(I,J))
      PD(I,K)=TOTPAR
      PD(I,J)=0.0D0
      RTEMPD(I,J)=R(J)
      GOTO 630
650   PD(I,J)=0.0D0
      RTEMPD(I,J)=R(J)
      PD(I,K)=0.0D0
      RTEMPD(I,K)=R(K)
630                     CONTINUE
620                     CONTINUE
                        DO 700 J=1,NRWM1
      RMSD(I,J)=RTEMPD(I,J)
      SUMPAR(I)=SUMPAR(I)+PD(I,J)
700                     CONTINUE
610                     CONTINUE
      D1PART=SUMPAR(1)*VD1
      CD1PAR=SUMPAR(1)
      D2PART=SUMPAR(2)*VD2
      CD2PAR=SUMPAR(2)
      TDPLOT=TDPLOT+H
      IF(TDPLOT.GT.PLINC) GOTO 15
      GOTO 800
15    IPD=IPD+1
      DPLUN(1,IPD)=CD1UN
      DPLPN(1,IPD)=CD1PN
      DPLFPN(1,IPD)=CD1FPN
      DPLH2O(1,IPD)=CD1H2O
      DPLHNO(1,IPD)=CD1HNO
      DPLPAR(1,IPD)=CD1PAR
      DPLTIM(IPD)=TIME
      DIGVOL(1,IPD)=VD1
      DPLUN(2,IPD)=CD2UN
      DPLPN(2,IPD)=CD2PN
      DPLFPN(2,IPD)=CD2FPN
      DPLH2O(2,IPD)=CD2H2O
      DPLHNO(2,IPD)=CD2HNO
      DPLPAR(2,IPD)=CD2PAR
      DPLTIM(IPD)=TIME
      DIGVOL(2,IPD)=VD2
      MUPIP=IPD
      TDPLOT=0.0D0
800   CONTINUE
      RETURN
      END
C
C
C
      SUBROUTINE PLOT7(PLTIME,MUM,NS)
      REAL*8 PLU308,PLUN,PLPUO2,PLPN,PLFP,PLH2O,PLHNO3,PLFPN
```

```
      $,DPLUN,DPLPN,SUMD1,SUMD2,PD,ATPD,PPD
      $,DPLH2O,DPLHNO,DPLFPN,DPLPAR,
      $DPLTIM,DIGVOL,RUN,TFILL,VFULL,TTRAN,TDIG
      $,PLINC,VD1,VD2,TM1,TM2,TFD1,TFD2,TDPLOT,TTD1,TTD2,TD1,TD2
       DIMENSION PLTIME(200),PL1(200),PL2(200),
      $PL3(200),PL4(200),PL5(200),PL6(200),PL7(200),ATITLE(10),IPAK(250)
      $,ATNUM(9),PL8(200)
       COMMON/DISSPL/PLU308(10,200),PLUN(10,200),PLPUO2(10,200),
      $PLPN(10,200),PLFP(10,200),PLH2O(10,200),PLHNO3(10,200)
      $,PLFPN(10,200),PLPART(10,200),PLWTT(10,200),PLSST(10,200)
       COMMON/DIG/DPLUN(2,200),DPLPN(2,200)
      $,PD(2,50),ATPD(2,50),PPD(2,50)
      $,DPLH2O(2,200),DPLHNO(2,200),DPLFPN(2,200),DPLPAR(2,200),
      $DPLTIM(200),DIGVOL(2,200),RUN,TFILL,VFULL,TTRAN,TDIG
      $,PLINC,VD1,VD2,TM1,TM2,TFD1,TFD2,TDPLOT,TTD1,TTD2,TD1,TD2,
      $D1UN,D2UN,D1PN,D2PN,D1H2O,D2H2O,D1HNO3,D2HNO3,
      $D1PART,D2PART,D1FPN,D2FPN,SUMD1,SUMD2,IPD,MUPIP
       DATA ATITLE/'CONC','ENTR','ATIC','N PR','OFIL','E FO',
      $'P ST','AGE ','    ','   $'/,ATNUM/' 1 ',' 2 ',' 3 ',' 4 ',
      $' 5 ',' 6 ',' 7 ',' 8 ',' 9 '/
       XTI=RUN+10.D0
       STI=XTI/10.
       DO 17 J3=1,200
       PL1(J3)=0.0
       PL2(J3)=0.0
       PL3(J3)=0.0
       PL4(J3)=0.0
       PL5(J3)=0.0
       PL5(J3)=0.0
       PL6(J3)=0.0
       PL7(J3)=0.0
       PL8(J3)=0.0
17     CONTINUE
       CALL COMPLX
       CALL PHYSOR(.625,.75)
       DO 1001 IPLT=1,NS
       ATITLE(9)=ATNUM(IPLT)
       CALL TITLE(ATITLE,-100,'TIME(MIN)$',100,
      $'CONC. UO2, PUO2, AND F.P. (GRAM/L)$',100,8.5,6.5)
       CALL YTICKS(10)
       CALL XTICKS(5)
       CALL XINTAX
       CALL BLNK1(0.0,1.9345,4.3125,6.5,3)
       IDUMMY=LINEST(IPAK,250,70)
       CALL LINES('UO2 $',IPAK,1)
       CALL LINES('PUO2$',IPAK,2)
       CALL LINES('PU(NO3)4$',IPAK,4)
       CALL LINES('F.P.$',IPAK,3)
       CALL LINES('UO2(NO3)2$',IPAK,5)
       CALL LINES('FP(NO3)2.36$',IPAK,6)
       CALL LINES('HNO3$',IPAK,7)
       CALL LINES('H2O$',IPAK,8)
       U308MX=0.0
       UNMXP=0.0
       DO 1002 JAK=1,MUM
       PL1(JAK)=PLU308(IPLT,JAK)
```

```
      PL2(JAK)=PLPUO2(IPLT,JAK)
      PL3(JAK)=PLPN(IPLT,JAK)
      PL4(JAK)=PLFP(IPLT,JAK)
      PL5(JAK)=PLUN(IPLT,JAK)
      PL6(JAK)=PLHNO3(IPLT,JAK)
      PL7(JAK)=PLH2O(IPLT,JAK)
      PL8(JAK)=PLFPN(IPLT,JAK)
      WRITE(6,1003)PLTIME(JAK),PL1(JAK),PL2(JAK),PL3(JAK),PL4(JAK),
     $PL5(JAK),PL6(JAK),PL7(JAK),PL8(JAK)
1003  FORMAT(2X,9(1PE12.5,1X))
      IF(U308MX.LT.PL1(JAK))U308MX=PL1(JAK)
      IF(UNMXP.LT.PL5(JAK)) UNMXP=PL5(JAK)
1002  CONTINUE
      IF(U308MX.LE..01) GOTO 100
      U308MX=U308MX+10.
      IU308=U308MX/10.
      U308MX=IU308*10.
      U308IN=U308MX/10.
      GOTO 200
100   U308MX=10.
      U308IN=1.0
200   IF(UNMXP.LE..01) GOTO 300
      UNMXP=UNMXP+50.
      IUNMXP=UNMXP/50.
      UNMXP=IUNMXP*50.
      UNMXPI=UNMXP/10.
      GOTO 400
300   UNMXP=100.
      UNMXPI=10.
400   CALL GRAF(0.0,STI,XTI,0.0,U308IN,U308MX)
      CALL FRAME
      CALL CURVE(PLTIME,PL1,MUM,2)
      CALL CURVE(PLTIME,PL2,MUM,2)
      CALL CURVE(PLTIME,PL4,MUM,2)
      CALL YGRAXS(0.0,UNMXPI,UNMXP,6.5,
     $'CONC. UO2(NO3)2, PU(NO3)2, AND FP(NO3)2.3552 (GRAM/L)$'
     $,-100,8.5,0.0)
      CALL CURVE(PLTIME,PL3,MUM,2)
      CALL CURVE(PLTIME,PL5,MUM,2)
      CALL CURVE(PLTIME,PL8,MUM,2)
      CALL YGRAXS(0.0,100.,1000.,6.5,'CONC. HNO3 AND H2O (GRAM/L)$',
     $-100,9.125,0.0)
      CALL CURVE(PLTIME,PL6,MUM,2)
      CALL CURVE(PLTIME,PL7,MUM,2)
      CALL RESET('BLNK1')
      CALL LEGEND(IPAK,8,.125,4.44)
      IIPLT=IPLT
      CALL ENDPL(IIPLT)
1001  CONTINUE
      RETURN
      END
C
C
C
      SUBROUTINE PLOTD(NS,FREQ,RMS,P,PART,RMIN,PMAX,NG)
      REAL*8 FREQ(50),RMS(10,50),P(10,50),PART(20),RMIN,RMAX
```

```
      DIMENSION FQ(50),RAD(50),DTITLE(11),ANUM(9)
      DATA DTITLE/'PART','ICLE',' SIZ','E DI','STRI','BUTI','ON F',
     $'OR S','TAGE','    ','   $'/,ANUM/' 1 ',' 2 ',' 3 ',
     $' 4 ',' 5 ',' 6 ',' 7 ',' 8 ',' 9 '/
C
C
      IMARK=0
      IF(NG.LE.100) IMARK=1
      DO 20 IPLT=1,NS
      IPRT=10
      FQMAX=0.0
      IF(PART(IPLT).LE.0.0D0) GO TO 20
      DO 30 J=1,NG
      FQ(J)=P(IPLT,J)/PART(IPLT)
      RAD(J)=RMS(IPLT,J)
      IF(FQ(J).GT.FQMAX) FQMAX=FQ(J)
      IF(IPRT.LT.10) GO TO 50
      IPRT=1
      WRITE(6,40)J,RAD(J),FQ(J)
4C    FORMAT(I5,5X,1PE13.6,5X,1PE13.6)
50    IPRT=IPRT+1
30    CONTINUE
      FQMAX=1.2*FQMAX
      IFQMAX=FQMAX*100.
      FQMAX=IFQMAX/100.
      IF(FQMAX.LE.0.0) FQMAX=0.2
      FQINC=FQMAX/10.
      DTITLE(10)=ANUM(IPLT)
      RMIN4=RMIN
      RMAX4=RMAX
      RINC=(RMAX4-RMIN4)/10.
      CALL COMPLX
      CALL TITLE(DTITLE,-100,'PARTICLE RADIUS (MICRON)$',100,
     *'NORMALIZED FREQUENCY$',100,8.5,6.5)
      CALL YTICKS(10)
      CALL XTICKS(10)
      CALL XINTAX
      CALL GRAF(RMIN4,RINC,RMAX4,0.0,FQINC,FQMAX)
      CALL FRAME
      CALL CURVE(RAD,FQ,NG,IMARK)
      IIPLT=IPLT
      CALL ENDPL(IIPLT)
      CALL RESET('ALL')
20    CONTINUE
      RETURN
      END
C
C
      SUBROUTINE PLOT3(PLTIME,MUM,NS)
      REAL*8 PLU308,PLUN,PLPUO2,PLPN,PLFP,PLH2O,PLHNO3,PLFPN
     *,PLPART,PLWTT,PLSST,DPLUN,DPLPN,SUMD1,SUMD2,PD,ATPD,PPD
     $,DPLH2O,DPLHNO,DPLFPN,DPLPAR,
     $DPLTIM,DIGVOL,RUN,TFILL,VFULL,TTRAN,TDIG
     *,PLINC,VD1,VD2,TM1,TM2,TFD1,TFD2,TDPLOT,TTD1,TTD2,TD1,TD2
      DIMENSION PLTIME(200),PL1(200),PL2(200),PL3(200)
```

```
     $,ATITLE(10),IPAK(250),ATNUM(9)
        COMMON/DISSPL/PLU308(10,200),PLUN(10,200),PLPUO2(10,200),
     $PLPN(10,200),PLFP(10,200),PLH2O(10,200),PLHNO3(10,200)
     $,PLFPN(10,200),PLPART(10,200),PLWTT(10,200),PLSST(10,200)
        COMMON/DIG/DPLUN(2,200),DPLPN(2,200)
     $,PD(2,50),ATPD(2,50),PPD(2,50)
     $,DPLH2O(2,200),DPLHNO(2,200),DPLFPN(2,200),DPLPAR(2,200),
     $CPLTIM(200),DIGVOL(2,200),RUN,TFILL,VFULL,TTRAN,TDIG
     $,PLINC,VD1,VD2,TM1,TM2,TFD1,TFD2,TDPLOT,TTD1,TTD2,TD1,TD2,
     $D1UN,D2UN,D1PN,D2PN,D1H2C,D2H2O,D1HNO3,D2HNO3,
     $D1PART,D2PART,D1FPN,D2FPN,SUMD1,SUMD2,IPD,MUPIP
        DATA ATITLE/'CONC','ENTR','ATIC','N HI','STOP','Y FO',
     $'R ST','AGE ','    ','   $'/,ATNUM/' 1 ',' 2 ',' 3 ',' 4 ',
     $' 5 ',' 6 ',' 7 ',' 8 ',' 9 '/
        XTI=RUN+10.D0
        STI=XTI/10.
        IPLT=0
        NSM1=NS-1
        DO 17 J3=1,200
        PL1(J3)=0.0
        PL2(J3)=0.0
        PL3(J3)=0.0
17      CONTINUE
        CALL COMPLX
        CALL PHYSOR(.625,.75)
1005    IPLT=IPLT+1
        YSMAX=0.0
        YPMAX=0.0
        YWMAX=0.0
        DO 1002 JAK=1,MUM
        PL1(JAK)=PLWTT(IPLT,JAK)
        PL2(JAK)=PLPART(IPLT,JAK)
        PL3(JAK)=PLSST(IPLT,JAK)
        IF(PL1(JAK).GT.YWMAX) YWMAX=PL1(JAK)
        IF(PL2(JAK).GT.YPMAX) YPMAX=PL2(JAK)
        IF(PL3(JAK).GT.YSMAX) YSMAX=PL3(JAK)
        WRITE(6,1003)PLTIME(JAK),PL1(JAK),PL2(JAK),PL3(JAK)
1003    FORMAT(2X,4(1PE12.5,1X))
1002    CONTINUE
        YWMAX=YWMAX+20.
        IYWMAX=YWMAX/20.
        YWMAX=IYWMAX*20.
        YWINC=YWMAX/5.
        YPMAX=YPMAX+20.
        IYPMAX=YPMAX/20.
        YPMAX=IYPMAX*20.
        YPINC=YPMAX/5.
        YSMAX=YSMAX+20.
        IYSMAX=YSMAX/20.
        YSMAX=IYSMAX*20.
        YSINC=YSMAX/5.
        ATITLE(9)=ATNUM(IPLT)
        CALL TITLE(ATITLE,-100,'TIME(MIN)$',100,
     $'MASS OF UNDISSOLVED FUEL IN PINS (GRAM)$',100,8.5,6.5)
        CALL YTICKS(5)
        CALL XTICKS(5)
```

```
      CALL XINTAX
      CALL BLNK1(0.0,2.5,5.375,6.5,3)
      IDUMMY=LINEST(IPAK,250,70)
      CALL LINES('FUEL IN PINS$',IPAK,1)
      CALL LINES('FREE PARTICLES$',IPAK,2)
      CALL LINES('STAINLESS STEEL$',IPAK,3)
      CALL FRAME
      CALL GRAF(0.0,STI,XTI,0.0,YWINC,YWMAX)
      CALL CURVE(PLTIME,PL1,MUM,2)
      CALL YGRAXS(0.0,YPINC,YPMAX,6.5,
     $'CCNC. OF FREE PARTICLES (GRAM/L)$'
     $,-100,8.5,0.0)
      CALL CURVE(PLTIME,PL2,MUM,2)
      CALL YGRAXS(0.0,YSINC,YSMAX,6.5,
     $'MASS OF STAINLESS STEEL (GRAM)$',
     $-100,9.125,0.0)
      CALL CURVE(PLTIME,PL3,MUM,2)
      CALL RESET('BLNK1')
      CALL LEGEND(IPAK,3,.125,5.525)
100   IIPLT=IPLT
      CALL ENDPL(IIPLT)
1001  IF(IPLT.GT.NSM1) GOTO 1010
      GOTO 1005
1010  RETURN
      END
C
C
C
      SUBROUTINE DIGPLT
      REAL*8 DPLUN,DPLPN,DPLH2O,DPLHNO,DPLFPN
     $,DPLPAR,DPLTIM,DIGVOL,RUN,TFILL,VFULL,TTRAN,TDIG
     $,PLINC,VD1,VD2,TM1,TM2,TFD1,TFD2,TDPLOT,TTD1,TTD2,TD1,TD2
     $,D1UN,D2UN,D1PN,D2PN,D1H2O,D2H2O,D1HNO3,D2HNO3,
     $D1PART,D2PART,D1FPN,D2FPN,SUMD1,SUMD2,PD,ATPD,PPD
      DIMENSION PLTME(200),PL1(200),PL2(200),PL3(200)
     $,PL4(200),PL5(200),ATITLE(8),ATNUM(2),IPAK(250)
      COMMON/DIG/DPLUN(2,200),DPLPN(2,200)
     $,PD(2,50),ATPD(2,50),PPD(2,50)
     $,DPLH2O(2,200),DPLHNO(2,200),DPLFPN(2,200),DPLPAR(2,200),
     $DPLTIM(200),DIGVOL(2,200),RUN,TFILL,VFULL,TTRAN,TDIG
     $,PLINC,VD1,VD2,TM1,TM2,TFD1,TFD2,TDPLOT,TTD1,TTD2,TD1,TD2,
     $D1UN,D2UN,D1PN,D2PN,D1H2O,D2H2O,D1HNO3,D2HNO3,
     $D1PART,D2PART,D1FPN,D2FPN,SUMD1,SUMD2,IPD,MUPIP
      DATA ATITLE/'DIGE','STER',' TAN','K # ','    ',
     $' HIS','TORY','   $'/,ATNUM/' 1  ',' 2  '/
      XTI=RUN+10.D0
      STI=XTI/10.
      ALV=0.0
      AMP=0.0
      HMM=0.0
      DO 17 J3=1,200
      PL1(J3)=0.0
      PL2(J3)=0.0
      PL3(J3)=0.0
      PL4(J3)=0.0
      PL5(J3)=0.0
```

```
17      CONTINUE
        CALL COMPLX
        CALL PHYSOR(.625,.75)
        DO 1001 IPLT=1,2
        IF(TFILL.GT.RUN.AND.IPLT.EQ.2) GOTO 1001
        ATITLE(5)=ATNUM(IPLT)
        CALL TITLE(ATITLE,-100,'TIME(MIN)$',100,
     $' VOLUME (L)$'
     $,100,8.5,6.5)
        CALL YTICKS(10)
        CALL XTICKS(5)
        CALL XINTAX
        CALL BLNK1(0.0,1.75,4.9375,6.5,3)
        IDUMMY=LINEST(IPAK,250,70)
        CALL LINES('VOLUME$',IPAK,1)
        CALL LINES('UO2(NO3)2$',IPAK,2)
        CALL LINES('PU(NO3)4$',IPAK,3)
        CALL LINES('HNO3$',IPAK,4)
        CALL LINES('PARTICLES$',IPAK,5)
        CALL FRAME
        DO 1002 JAK=1,MUPIP
        PL1(JAK)=DPLUN(IPLT,JAK)
        PL2(JAK)=DPLPN(IPLT,JAK)
        PL3(JAK)=DPLHNO(IPLT,JAK)
        PL4(JAK)=DIGVOL(IPLT,JAK)
        PLTME(JAK)=DPLTIM(JAK)
        PL5(JAK)=DPLPAR(IPLT,JAK)
        IF(ALV.LT.PL4(JAK)) ALV=PL4(JAK)
        IF(AMP.LT.PL5(JAK)) AMP=PL5(JAK)
        IF(HMM.LT.PL1(JAK)) HMM=PL1(JAK)
        IF(HMM.LT.PL3(JAK)) HMM=PL3(JAK)
        WRITE(6,1003)PLTME(JAK),PL1(JAK),PL2(JAK),PL3(JAK),PL4(JAK)
     $,PL5(JAK)
1003    FORMAT(2X,6(1PE12.5,1X))
1002    CONTINUE
        ALV=ALV+20.
        IALV=ALV/20.
        ALV=20.*IALV
        ALINC=ALV/10.
        AMP=AMP+20.
        IAMP=AMP/20.
        AMP=20.*IAMP
        AMINC=AMP/10.
        HMM=HMM+20.
        IHMM=HMM/20.
        HMM=IHMM*20.
        HMMINC=HMM/10.
        CALL GRAF(0.0,STI,XTI,0.0,ALINC,ALV)
        CALL CURVE(PLTME,PL4,MUPIP,2)
        CALL YGRAXS(0.0,HMMINC,HMM,6.5,
     $' CONC. UO2(NO3)2, PU(NO3)4, AND HNO3 (G/L)$'
     $,-100,8.5,0.0)
        CALL CURVE(PLTME,PL1,MUPIP,2)
        CALL CURVE(PLTME,PL2,MUPIP,2)
        CALL CURVE(PLTME,PL3,MUPIP,2)
        CALL YGRAXS(0.0,AMINC,AMP,6.5,
```

```
     $'PARTICLE CONCENTRATION (G/L)$',-100,9.125,0.0)
      CALL CURVE(PLTME,PL5,MUPIP,2)
      CALL RESET('BLNK1')
      CALL LEGEND(IPAK,5,.125,5.125)
      IIPLT=IPLT
      CALL ENDPL(IIPLT)
 1001 CONTINUE
      RETURN
      END
```

Table A.1. Data file for standard conditions with variable names

| Data file | | | | | | Variable names |
|---|---|---|---|---|---|---|
| 0 5000 | 0 4903 | 2 54 | 9 903 | 1 000 | 200 0 | SIZE, PIN, PINLEN, RHOAVE, SPAREA, RWASTE |
| 0 7370 | 0 2110 | 0 0520 | 0 7011 | 0 1999 | 0 0990 | PCU3O8, PCPUO2, PCFP, FRMOU3, FRMOPU, FRMOFP |
| 8 300 | 11 460 | 12 100 | 8010 00 | 0 9888 | 2 830 | DU3O8, DPUO2, DFP, DENSST, TK, POW |
| 1 000 | 0 9999 | 0 0200 | 400 00 | 2 250 | 399 99 | ACDF, PRTTIM, HC, RUN, PRINC, PRDIST |
| 20 0 | 500000 0 | 0 1 | 0 001 | | | ALIMO, AKSTOP, AMINFR, CT1 |
| 108 0 | 3 00 | 20 0 | 00 000 | | | TEMP, RPM, DREVS, FLAPTIM |
| 4 800 | 8 000 | 8 000 | 8 000 | 8 000 | | VO(1), VO(2), VO(3), VO(4), VO(5) |
| 8 000 | 8 000 | 8 000 | 8 000 | 8 000 | | VO(1), VO(6), VO(7), VO(8), VO(9), VO(10) |
| 0 0 | 0 0 | 0 0 | 0 0 | 0 0 | | VO(1), VO(11), VO(12), VO(13), VO(14), VO(15) |
| 0 0 | 0 0 | 0 0 | 0 0 | 0 0 | | VO(1), VO(16), VO(17), VO(18), VO(19), VO(20) |
| 2 0 | 30 00 | 76 20 | 25 40 | 9 000 | | TRCT, BASECT, DIA, STGLEN, AAANS |
| 8 7376 | 11 4808 | 11 4808 | 11 4808 | 11 4808 | | DEPTH(1), DEPTH(2), DEPTH(3), DEPTH(4), DEPTH(5) |
| 11 4808 | 11 4808 | 11 4808 | 11 4808 | 11 4808 | | DEPTH(1), DEPTH(6), DEPTH(7), DEPTH(8), DEPTH(9), DEPTH(10) |
| 5 000 | | | | | | ANGLE |
| 951 00 | 1300 00 | 951 00 | 1010 00 | | | DEN1, CDEN8, DEN9, DEN10 |
| 4 000 | 0 0 | 0 667 | 0 333 | | | TH2OC, THNO3C, FCSTG1, FCSTG9 |
| 47 45 | 40 08 | 35 03 | 1 140 | | | CH2OM8, CHNOM8, H2OM10 |
| 0 0700 | 0 0700 | 0 0700 | 0 0700 | 0 0700 | | BAKMIX(1), BAKMIX(2), BAKMIX(3), BAKMIX(4), BAKMIX(5) |
| 0 0700 | 0 0700 | 0 0700 | 0 0700 | 0 0700 | | BAKMIX(1), BAKMIX(6), BAKMIX(7), BAKMIX(8), BAKMIX(9), BAKMIX(10) |
| 0 0700 | 0 0700 | 0 0700 | 0 0700 | 0 0700 | | BAKMIX(1), BAKMIX(11), BAKMIX(12), BAKMIX(13), BAKMIX(14), BAKMIX(15) |
| 0 0700 | 0 0700 | 0 0700 | 0 0700 | 0 0700 | | BAKMIX(1), BAKMIX(16), BAKMIX(17), BAKMIX(18), BAKMIX(19), BAKMIX(20) |
| 1300 00 | 47 45 | 40 08 | 3 810 | | | SDEN8, SH2OM8, SHNOM8, SLOTLM |
| 360 00 | 10 00 | 350 00 | | | | TFILL, TTRAN, TDIG |
| 31 50 | 5 000 | 00 00 | 00 00 | | | ACIDEF, RFACT, AFIAT, AFRAT |
| 37 67 | 12 05 | 180 00 | 180 0 | | | TMRFED, TMRSST, BATTIM, SHETIM |
| 0 20 | 0 0 | 1000 0 | 0 001000 | 0 0010 | 20 00 | FFINES, RMIN, RMAX, DP, TOL, AAANG |
| 100 0 | 45 0 | 1 0 | 1 0 | | | CONREL, FEANG, PINOOO, PAROOO |
| 1 00 | 1 00 | 1 00 | 1 00 | 1 00 | 1 00 | ZNOPTA, ZNOPTD, ZNOPTP, ZNOPT3, ZNOPT7 |

**Table A.2. Job control language required for various code options, where xxx = identifier, +++++ = charge number, and ooooo = tape number**

| Job control language | Purpose |
|---|---|
| //xxxUS244 JOB (+++++,TAPE,17), 'B. E LEWIS, 7601',TIME=(20,30)<br>/*JOBPARM LINES=80 | Job setup |
| //*NOTES THIS IS JOB 1 OF 1 | Note to operator |
| //*PLOT TYPE=CAL925,INK=(BLACK/L),NUMBER=29,PAPER=600 | Set up plotter |
| /*ROUTE XEQ STANDBY | Run on standby system |
| /*ROUTE PRINT LOCAL<br>//EXEC FORTHCLG,PLOT=DISS,PARM.FORT='XREF',REGION FORT=600K,<br>//PARM.GO='EU=–1,DUMP=1',REGION GO=600K | Job setup continued, with link to display and cross reference listing |
| //FORT SYSPRINT DD DUMMY | Suppress printout of source code |
| //FORT SYSIN DD *<br>=USSCRD<br>/*<br>//LKED.SYSIN DD *<br>/* | Link to code |
| //GO.FT06F001 DD SYSOUT=Q | Output unit 6 to microfiche |
| //GO.FT13F001 DD SYSOUT=A | Output unit 13 to printer |
| //GO FT12F001 DD UNIT=TAPE62,VOL=SER=Xooooo,<br>//DISP=(NEW,KEEP),LABEL=(21,SL,,),DSN=USSCRD.DATA<br>//DCB=(RECFM=FB,LRECL=120,BLKSIZE=4080,DEN=4)<br>//GO.FT54F001 DD DDNAME=PLOTTAPE<br>//GO.PLOTTAPE DD UNIT=TAPE16,DSN=xxx DISS,<br>//LABEL=(,SL),DISP=(NEW,KEEP),<br>//DCB=(DEN=3,RECFM=VS,LRECL=364,BLKSIZE=368) | Output unit 12 to tape |
| //GO.FT05F001 DD*<br>=USS DAT | Link to data file |
| /*<br>//<br>ENDINPUT | End |

# APPENDIX B

## Code Output for Standard Operating Conditions

The following output is for the list of standard conditions given in Table 4 of the body of this report. The initial output summarizes all input data. The quantity of output following the initial input summary data is controlled by changing the specified frequency in the input data. The final run summary gives code performance factors, maximum concentrations, and inventory data. Other output includes stagewise concentration profiles, concentration histories, particle size distribution, and digester concentration profiles. An index of the tables and figures containing this output is given in Table B.1.

**Table B.1. Index of tables and figures contained in this appendix**

| Location | Type of output |
|---|---|
| Table B.2. | Summary of input data |
| Table B.3. | Uranium/plutonium material balance closure |
| Table B.4. | Stagewise data for concentrations, volume, density, and flow rates |
| Table B.5. | Stagewise particle size distribution data |
| Table B.6. | Run summary data |
| Figs. B.1–B.9 | Stagewise concentration profiles |
| Figs. B.10–B.13 | Stagewise particle size distribution |
| Figs. B.14–B.22 | Concentration histories |
| Figs. B.23–B.24 | Digester tank concentration profiles |

## Table B.2. Summary of input data

SPENT FUEL DATA

| COMPONENT | WEIGHT FRACTION | DENSITY (G/CC) | MOLE WEIGHT (G/G-MOLE) |
|---|---|---|---|
| UO2 | 0.7370 | 8.300000 | 270.0500 |
| PUO2 | 0.2110 | 11.460000 | 271.1700 |
| F.P. | 0.0520 | 12.100000 | 135.3400 |

AVERAGE FUEL DENSITY = 9.903000 G/CC
AVERAGE DIAMETER OF PARTICULATE= 0.001000 CM
TOTAL # FUEL PINS= 2877.16
DIAMETER OF FUEL PELLET= 0.4903 CM
LENGTH OF FUEL PIN= 2.5400 CM
RATIO OF ACTUAL SURFACE AREA TO GEOMETRIC AREA= 1.00000D 00
FRACTION OF FUEL AS FINES= 2.000D-01
FULL STAGE PARTICLE RELEASE RATE= 1.00000D 02 G/MIN
TOTAL MASS FEED RATE OF STAINLESS STEEL= 12.05 KG/HR

0.5000 TONNE-A-DAY THROUGHPUT
FUEL FEED RATE= 427.0000 G/MIN

LIQUID FLOW STG 1= 1.7891 L/MIN
LIQUID FEED COMP. STG 1 :
HNO3 --- 383.98 GRAM/L
H2O --- 805.60 GRAM/L
INITIAL DENSITY OF DISSOLVER LIQUID STG 1= 1152.5684 G/L
COEFFICIENT OF WEIR FLOW EQUATION= 9.8880D-01
EXPONENT OF WEIR FLOW EQUATION= 2.8300D 00
LIMITING HEIGHT OVER WEIR (SLOT SIZE)= 3.8100D 00 CM

STAGE 1 INITIAL VOLUME= 6.43 L
STAGES 2- 8 INITIAL VOLUME= 9.95 L
STAGE 9 INITIAL VOLUME= 9.33 L
NUMBER OF STAGES= 9
MAXIMUM TIME INCREMENT= 0.020000 MIN

INITIAL REACTION RATE CONSTANTS

| COMPONENT FORMED | PARTICULATE RATE (G/MIN-CM**2) | PIN RATE (G/MIN-CM**2) |
|---|---|---|
| UO2(NO3)2 | 7.37934D-02 | 7.37934D-02 |
| PU(NO3)4 | 2.11268D-02 | 2.11268D-02 |
| F.P. NIT. | 5.20659D-03 | 5.20659D-03 |

REACTION RATE CONSTANT= 1.83123D-04 (GRAM/(CM**2*MIN*(MOL/L)**(2+2*XPU))
REACTION RATE EXPONENT= 2.59780D 00
PERCENT THEORITICAL DENSITY= 10.7123D 01
INITIAL TEMPERATURE= 108.0000D 00 DEG C
MINIMUM PARTICLE DIAMETER TRANSFERING WITH FUEL PINS= 2.00000D 02 MICRON
MINIMUM PARTICLE SIZE IN DISTRIBUTION= 0.0 MICRON
MAXIMUM PARTICLE SIZE IN DISTRIBUTION= 1.00000D 03 MICRON
TOTAL # OF PARTICLE SIZE GROUPS= 20
FLAPPER VALVE CYCLE TIME= 0.0 MIN

TOTAL RUN TIME= 400.00 MIN
CYCLE TIME STG 1= 0.00 MIN
STAGES 2- 9 CYCLE TIME= 32.00 MIN
REVERSE CYCLE TIME 2.00 MIN
RATE OF ROTATION= 3.00 RPM
FEED TIME FROM SHEAR= 1.8000D 02 MIN
ZERO FEED TIME= 0.0 MIN

ACID DEFICIENT CONCENTRATION FLAG= 3.1500D 01 G-HNO3/L
REACTION RATE MULTIPLICATION FACTOR= 5.0000D 00

ACID FEED RATE INCREASE ANTICIPATION TIME= 0.0 MIN
ACID FEED RATE REDUCTION ANTICIPATION TIME= 0.0 MIN
REDUCED ACID FEED RATE DENSITY= 1.3000D 03 G/L
REDUCED ACID FEED H2O FLOW= 4.7450D 01 KG/HR
RECUCED ACID FEED HNO3 FLOW= 4.0080D 01 KG/HR

**Table B.2 (continued)**

EXTERNAL FEED STREAMS MASS FLOW RATES

| COMPONENT | DENSITY (G/L) | FLOW (KG/HR) | CONCENTRATION (G/L) |
|---|---|---|---|
| FEED HNO3 TO STAGE 8 | | 40.08 | 595.27 |
| FEED H2O TO STAGE 8 | | 47.45 | 704.73 |
| TOTAL FEED TO STAGE 8 | 1300.00 | 87.53 | |
| CONDENSATE HNO3 TO STAGE 1 | | 0.0 | 0.0 |
| CONDENSATE H2O TO STAGE 1 | | 2.67 | 951.00 |
| TOTAL CONDENSATE TO STAGE 1 | 951.00 | 2.67 | |
| CONDENSATE HNO3 TO STAGE 9 | | 0.0 | 0.0 |
| CONDENSATE H2O TO STAGE 9 | | 1.33 | 951.00 |
| TOTAL CONDENSATE TO STAGE 9 | 951.00 | 1.33 | |
| RINSE HNO3 TO STAGE 9 | | 1.14 | 0.0 |
| RINSE H2O TO STAGE 9 | | 35.03 | 978.17 |
| TOTAL RINSE LIQUID TO STAGE 9 | 1010.00 | 36.17 | |

*** BACKMIXING DATA ***

| STAGE # | PERIODIC BACKMIXING WITH HULLS TRANSFER (G SOLN / G HULLS) | CONTINUOUS BACKMIXING (L/MIN) | MAXIMUM QUANTITY BACKMIXED (L) | INITIAL STAGE VOLUME (L) |
|---|---|---|---|---|
| 1 | 7.00000D-02 | 0.0 | 3.90320D-01 | 6.43340D 00 |
| 2 | 7.00000D-02 | 0.0 | 3.88760D-01 | 9.94730D 00 |
| 3 | 7.00000D-02 | 0.0 | 3.88760D-01 | 9.94730D 00 |
| 4 | 7.00000D-02 | 0.0 | 3.88760D-01 | 9.94730D 00 |
| 5 | 7.00000D-02 | 0.0 | 3.88760D-01 | 9.94730D 00 |
| 6 | 7.00000D-02 | 0.0 | 3.88760D-01 | 9.94730D 00 |
| 7 | 7.00000D-02 | 0.0 | 3.88760D-01 | 9.94730D 00 |
| 8 | 7.00000D-02 | 0.0 | 3.88760D-01 | 9.94730D 00 |
| 9 | 7.00000D-02 | 0.0 | 4.56130D-01 | 9.32690D 00 |

*** PLOTS REQUESTED ***

DIGESTER CONCENTRATION PROFILES
PARTICLE SIZE DISRTIBUTIONS
CONCENTRATION HISTORIES
CONCENTRATION PROFILES

## Table B.3. Uranium/plutonium material balance closure

| TIME | U(OUT) | PU(OUT) | U(FED) | PU(FED) | U(OUT)-U(FED) | PU(OUT)-PU(FED) |
|---|---|---|---|---|---|---|
| 2.56964D 02 | 7.13202D 04 | 2.04310D 04 | 7.12810D 04 | 2.04198D 04 | 3.91515D 01 | 1.12157D 01 |
| 2.57984D 02 | 7.16032D 04 | 2.05121D 04 | 7.15640D 04 | 2.05009D 04 | 3.91896D 01 | 1.12266D 01 |
| 2.59004D 02 | 7.18841D 04 | 2.05926D 04 | 7.18469D 04 | 2.05819D 04 | 3.71780D 01 | 1.05504D 01 |
| 2.60024D 02 | 7.21654D 04 | 2.06732D 04 | 7.21299D 04 | 2.06630D 04 | 3.55365D 01 | 1.01801D 01 |

TIME INTO RUN= 260.2421 MIN
DISSOLUTION OF FUEL IN PINS COMPLETED IN STAGE 4 AFTER 4.2421 MINUTES INTO CYCLE.
THIS IS THE 6 FUEL DISSAPPEARANCE CYCLE.

| TIME | U(OUT) | PU(OUT) | U(FED) | PU(FED) | U(OUT)-U(FED) | PU(OUT)-PU(FED) |
|---|---|---|---|---|---|---|
| 2.61042D 02 | 7.24465D 04 | 2.07537D 04 | 7.24122D 04 | 2.07439D 04 | 3.42895D 01 | 9.82288D 00 |
| 2.62062D 02 | 7.27285D 04 | 2.08345D 04 | 7.26951D 04 | 2.08249D 04 | 3.33946D 01 | 9.56653D 00 |
| 2.63082D 02 | 7.30107D 04 | 2.09153D 04 | 7.29781D 04 | 2.09060D 04 | 3.26364D 01 | 9.34932D 00 |
| 2.64102D 02 | 7.32930D 04 | 2.09962D 04 | 7.32610D 04 | 2.09870D 04 | 3.19550D 01 | 9.15412D 00 |
| 2.65122D 02 | 7.35754D 04 | 2.10771D 04 | 7.35440D 04 | 2.10681D 04 | 3.14451D 01 | 9.00833D 00 |
| 2.66142D 02 | 7.38578D 04 | 2.11580D 04 | 7.38269D 04 | 2.11491D 04 | 3.08714D 01 | 8.84370D 00 |
| 2.67162D 02 | 7.41400D 04 | 2.12388D 04 | 7.41099D 04 | 2.12302D 04 | 3.00969D 01 | 8.62183D 00 |
| 2.68182D 02 | 7.44220D 04 | 2.13196D 04 | 7.43928D 04 | 2.13112D 04 | 2.91901D 01 | 8.36205D 00 |
| 2.69202D 02 | 7.47039D 04 | 2.14004D 04 | 7.46758D 04 | 2.13923D 04 | 2.81923D 01 | 8.07622D 00 |
| 2.70222D 02 | 7.49859D 04 | 2.14811D 04 | 7.49587D 04 | 2.14734D 04 | 2.71531D 01 | 7.77852D 00 |
| 2.71242D 02 | 7.52677D 04 | 2.15619D 04 | 7.52416D 04 | 2.15544D 04 | 2.60741D 01 | 7.46942D 00 |

## Table B.3 (continued)

```
TIME INTO RUN=     272.0821 MIN
DISSOLUTION OF LOOSE FUEL PARTICLES COMPLETED IN STAGE   4 AFTER      16.0821 MINUTES INTO CYCLE.
THIS IS THE    6 FUEL DISSAPPEARANCE CYCLE.
```

| TIME | U(OUT) | PU(OUT) | U(FED) | PU(FED) | U(OUT)-U(FED) | PU(OUT)-PU(FED) |
|---|---|---|---|---|---|---|
| 2.72262D 02 | 7.55496D 04 | 2.16426D 04 | 7.55246D 04 | 2.16355D 04 | 2.49656D 01 | 7.15188D 00 |

| TIME | U(OUT) | PU(OUT) | U(FED) | PU(FED) | U(OUT)-U(FED) | PU(OUT)-PU(FED) |
|---|---|---|---|---|---|---|
| 2.73282D 02 | 7.58314D 04 | 2.17233D 04 | 7.58075D 04 | 2.17165D 04 | 2.38324D 01 | 6.82725D 00 |

| TIME | U(OUT) | PU(OUT) | U(FED) | PU(FED) | U(OUT)-U(FED) | PU(OUT)-PU(FED) |
|---|---|---|---|---|---|---|
| 2.74302D 02 | 7.61131D 04 | 2.18041D 04 | 7.60905D 04 | 2.17976D 04 | 2.26576D 01 | 6.49069D 00 |

**Table B.4. Stagewise data for concentrations, volume, density, and flow rates**

| COMPONENT | STG 1 | STG 2 | STG 3 | STG 4 | STG 5 | STG 6 | STG 7 | STG 8 | STG 9 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | CONCENTRATION OF COMPONENTS DISSOLVED IN LIQUID (G/L) | | | | | |
| UO2(NO3)2 | 2.285D 02 | 2.115D 02 | 1.488D 02 | 1.089D 01 | 7.107D-04 | 4.648D-08 | 3.062D-12 | 1.995D-16 | 1.043D-19 |
| PU(NO3)4 | 8.056D 01 | 7.456D 01 | 5.246D 01 | 3.838D 00 | 2.506D-04 | 1.639D-08 | 1.080D-12 | 7.034D-17 | 3.678D-20 |
| FP(NO3)3.39 | 2.680D 01 | 2.480D 01 | 1.745D 01 | 1.277D 00 | 8.335D-05 | 5.451D-09 | 3.591D-13 | 2.340D-17 | 1.224D-20 |
| HNO3 | 1.956D 02 | 2.171D 02 | 2.654D 02 | 3.739D 02 | 3.835D 02 | 3.856D 02 | 3.870D 02 | 3.857D 02 | 3.514D 01 |
| H2O | 7.541D 02 | 7.518D 02 | 7.591D 02 | 7.740D 02 | 7.746D 02 | 7.736D 02 | 7.729D 02 | 7.736D 02 | 9.537D 02 |
| | | | | CONCENTRATION OF SUSPENDED FINES (G/L) | | | | | |
| UO2 | 3.310D 00 | 1.880D 01 | 1.150D 01 | 9.202D-08 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PUO2 | 9.477D-01 | 5.382D 00 | 3.294D 00 | 2.635D-08 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| F.P. | 2.336D-01 | 1.326D 00 | 8.117D-01 | 6.493D-09 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL | 4.492D 00 | 2.551D 01 | 1.561D 01 | 1.249D-07 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | | QUANTITY UNDISSOLVED IN FUEL PINS (G) | | | | | |
| UO2 | 0.0 | 3.522D 03 | 3.656D 03 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PUO2 | 0.0 | 1.008D 03 | 1.047D 03 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| F.P. | 0.0 | 2.485D 02 | 2.580D 02 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL | 0.0 | 4.779D 03 | 4.961D 03 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | | VOLUME (L) | | | | | |
| TOTAL STAGE | 6.287D 00 | 9.683D 00 | 9.656D 00 | 9.644D 00 | 9.644D 00 | 9.644D 00 | 9.644D 00 | 9.643D 00 | 9.136D 00 |
| LIQUID ONLY | 6.284D 00 | 8.777D 00 | 8.339D 00 | 8.841D 00 | 8.841D 00 | 8.841D 00 | 8.841D 00 | 8.841D 00 | 9.136D 00 |
| STAINLESS | 0.0 | 4.015D-01 | 8.028D-01 | 8.023D-01 | 8.024D-01 | 8.023D-01 | 8.024D-01 | 8.024D-01 | 0.0 |
| | | | | DENSITY (G/L) | | | | | |
| LIQUID | 1.285D 03 | 1.280D 03 | 1.243D 03 | 1.164D 03 | 1.158D 03 | 1.159D 03 | 1.160D 03 | 1.159D 03 | 9.888D 02 |
| | | | | FLOW RATES (L/MIN) | | | | | |
| LIQUID | 1.984D 00 | 1.925D 00 | 1.841D 00 | 1.801D 00 | 1.801D 00 | 1.801D 00 | 1.801D 00 | 1.801D 00 | 6.337D-01 |

## Table B.5. Stagewise particle size distribution data

TIME = 4.000D 02 MIN

*** PARTICLE SIZE DISTRIBUTION PROFILE DATA ***

| GROUP # | STG 1 RADIUS (MICRON) | STG 1 CONC (G/L) | STG 2 RADIUS (MICRON) | STG 2 CONC (G/L) | STG 3 RADIUS (MICRON) | STG 3 CONC (G/L) | STG 4 RADIUS (MICRON) | STG 4 CONC (G/L) | STG 5 RADIUS (MICRON) | STG 5 CONC (G/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.847D 01 | 1.215D 00 | 1.580D 01 | 1.181D-01 | 1.588D 01 | 1.825D-01 | 1.034D 01 | 1.249D-07 | 2.500D 01 | 0.0 |
| 2 | 6.974D 01 | 1.308D 00 | 7.655D 01 | 1.574D 00 | 5.081D 01 | 7.648D-01 | 7.500D 01 | 0.0 | 7.500D 01 | 0.0 |
| 3 | 1.025D 02 | 1.968D 00 | 1.434D 02 | 2.628D 00 | 1.283D 02 | 1.930D 00 | 1.250D 02 | 0.0 | 1.250D 02 | 0.0 |
| 4 | 1.750D 02 | 0.0 | 1.955D 02 | 2.659D 00 | 1.687D 02 | 2.645D-01 | 1.750D 02 | 0.0 | 1.750D 02 | 0.0 |
| 5 | 2.250D 02 | 0.0 | 2.485D 02 | 2.359D 00 | 2.047D 02 | 1.680D 00 | 2.250D 02 | 0.0 | 2.250D 02 | 0.0 |
| 6 | 2.750D 02 | 0.0 | 2.747D 02 | 2.447D-02 | 2.685D 02 | 1.609D 00 | 2.750D 02 | 0.0 | 2.750D 02 | 0.0 |
| 7 | 3.250D 02 | 0.0 | 3.005D 02 | 2.103D 00 | 3.284D 02 | 1.423D 00 | 3.250D 02 | 0.0 | 3.250D 02 | 0.0 |
| 8 | 3.750D 02 | 0.0 | 3.513D 02 | 1.915D 00 | 3.862D 02 | 1.281D 00 | 3.750D 02 | 0.0 | 3.750D 02 | 0.0 |
| 9 | 4.250D 02 | 0.0 | 4.017D 02 | 1.747D 00 | 4.439D 02 | 1.212D 00 | 4.250D 02 | 0.0 | 4.250D 02 | 0.0 |
| 10 | 4.750D 02 | 0.0 | 4.521D 02 | 1.594D 00 | 4.727D 02 | 2.725D-02 | 4.750D 02 | 0.0 | 4.750D 02 | 0.0 |
| 11 | 5.250D 02 | 0.0 | 5.024D 02 | 1.455D 00 | 5.056D 02 | 1.085D 00 | 5.250D 02 | 0.0 | 5.250D 02 | 0.0 |
| 12 | 5.750D 02 | 0.0 | 5.527D 02 | 1.338D 00 | 5.654D 02 | 9.609D-01 | 5.750D 02 | 0.0 | 5.750D 02 | 0.0 |
| 13 | 6.250D 02 | 0.0 | 6.075D 02 | 1.426D 00 | 6.295D 02 | 9.783D-01 | 6.250D 02 | 0.0 | 6.250D 02 | 0.0 |
| 14 | 6.750D 02 | 0.0 | 6.685D 02 | 1.355D 00 | 6.952D 02 | 7.982D-01 | 6.750D 02 | 0.0 | 6.750D 02 | 0.0 |
| 15 | 7.250D 02 | 0.0 | 7.322D 02 | 1.149D 00 | 7.238D 02 | 5.632D-03 | 7.250D 02 | 0.0 | 7.250D 02 | 0.0 |
| 16 | 7.750D 02 | 0.0 | 7.935D 02 | 8.689D-01 | 7.608D 02 | 5.548D-01 | 7.750D 02 | 0.0 | 7.750D 02 | 0.0 |
| 17 | 8.250D 02 | 0.0 | 8.233D 02 | 2.209D-02 | 8.184D 02 | 3.883D-01 | 8.250D 02 | 0.0 | 8.250D 02 | 0.0 |
| 18 | 8.750D 02 | 0.0 | 8.511D 02 | 5.810D-01 | 8.857D 02 | 3.877D-01 | 8.750D 02 | 0.0 | 8.750D 02 | 0.0 |
| 19 | 9.250D 02 | 0.0 | 9.021D 02 | 3.917D-01 | 9.203D 02 | 2.011D-02 | 9.250D 02 | 0.0 | 9.250D 02 | 0.0 |
| 20 | 9.750D 02 | 0.0 | 9.516D 02 | 1.991D-01 | 9.610D 02 | 5.662D-02 | 9.750D 02 | 0.0 | 9.750D 02 | 0.0 |

## Table B.6. Run summary data

APPROXIMATE FLOWS

APPROXIMATE U FEED RATE= 2.7740D 02 G/MIN
APPROXIMATE PU FEED RATE= 7.9466D 01 G/MIN
TOTAL U FLOW OUT LIQUID PHASE= 2.5408D 02 G/MIN
TOTAL PU FLOW OUT LIQUID PHASE= 7.2785D 01 G/MIN
TOTAL U FLOW UNDISSOLVED IN FUEL PINS= 0.0 G/MIN
TOTAL PU FLOW UNDISSOLVED IN FUEL PINS= 0.0 G/MIN
TOTAL U FLOW OUT= 2.5408D 02 G/MIN
TOTAL PU FLOW OUT= 7.2785D 01 G/MIN

TOTAL MASS BALANCE

TOTAL U FEED= 1.1096D 05 G
TOTAL PU FEED= 3.1787D 04 G
TOTAL U OUT STAGE 1= 1.0163D 05 G
TOTAL PU OUT STAGE 1= 2.9115D 04 G
TOTAL URANIUM FROM RINSE STAGE= 0.0 G
TOTAL PLUTONIUM FROM RINSE STAGE= 0.0 G
TOTAL U UNDISSOLVED IN FUEL PINS= 6.3273D 03 G
TOTAL PU UNDISSOLVED IN FUEL PINS= 1.8126D 03 G
TOTAL U IN PARTICLES UNDISSOLVED= 2.4834D 02 G
TOTAL PU IN PARTICLES UNDISSOLVED= 7.1143D 01 G
TOTAL SUSPENDED PARTICULATE TO DIGESTERS= 3.1913D 03 G
TOTAL U OUT OVER TOTAL RUN= 1.0163D 05 G
TOTAL PU OUT OVER TOTAL RUN= 2.9115D 04 G

TOTAL U DISSOLVED IN LIQUID INVENTORY IN DISSOLVER= 2.7967D 03 (G)
TOTAL PU DISSOLVED IN LIQUID INVENTORY IN DISSOLVER= 8.0116D 02 (G)
CORRECTED SUM OF LIQUID VOLUMES= 0.0 (L)
TOTAL U IN PINS FED TO STAGE 1 FROM FLP= 8.8769D 04 (G)
TOTAL U FINES FED TO STAGE 1 FROM FLP= 2.2192D 04 (G)
TOTAL NUMBER OF PINS REMAINING IN DISSOLVER= 1.8704D 04
TOTAL NUMBER OF PARTICLE SIZE GROUP DEPLETION TRANSFERS= 1.15D 04

*** MASS OF PARTICLES DISSOLVED IN EACH STAGE (G) ***

| STG 1 | STG 2 | STG 3 | STG 4 | STG 5 | STG 6 | STG 7 | STG 8 | STG 9 |
|---|---|---|---|---|---|---|---|---|
| 1.833D 04 | 2.992D 04 | 3.686D 04 | 4.393D 03 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

PROJECTED URANIUM HOLD-UP IN DISSOLVER= 9.3285D 03 G
PROJECTED PLUTONIUM HOLD-UP IN DISSOLVER= 2.6723D 03 G
PROJECTED TOTAL U OUT PLUS HOLD-UP= 1.1096D 05 G
PROJECTED TOTAL PU OUT PLUS HOLD-UP= 3.1787D 04 G

CORRECTED NEGATIVE SUM OF OVER DISSOLUTION FROM PINS= -3.0615D 00 G
CORRECTED NEGATIVE SUM OF OVER DISSOLUTION OF PARTICULATE= -5.3778D 00 G
TOTAL CORRECTED OVER DISSOLUTION= -8.4393D 00 G

## Table B.6 (continued)

```
SUM OF HNO3 DEPLETIONS=        0.0        G
TOTAL FUEL IN PINS FED TO STAGE 9=       0.0          G
TOTAL FUEL IN PINS OUT OF STAGE 9=       0.0          G
TOTAL FUEL IN PINS IN STAGE 9=       0.0          G
TOTAL # PINS FED TO STAGE 9=        1.7261D 04
TOTAL # PINS OUT OF STAGE 9=        1.7239D 04
TOTAL # PINS IN STAGE 9=        0.0

ACTUAL U HOLD-UP IN DISSOLVER=        9.3723D 03  G
ACUTAL PU HOLD-UP IN DISSOLVER=        2.6849D 03  G
ACTUAL U OUT PLUS DISSOLVER HOLD-UP=        1.1101D 05  G
ACTUAL PU OUT PLUS DISSOLVER HOLD-UP=        3.1800D 04  G
ACTUAL U HOLD-UP IN FLAPPER VALVES=        5.5479D 00  G
% DIFF BETWEEN ACTUAL U FED AND U OUT PLUS HOLD-UP=        3.9463D-02  %
% DIFF BETWEEN ACTUAL PU FED AND PU OUT PLUS HOLD-UP=        3.9463D-02  %

U OUT OVER U FED PLUS HOLD-UP=        1.0004D 02  %
PU OUT OVER PU FED PLUS HOLD-UP=        1.0004D 02  %
% OF TOTAL U FEED IN FLAPPER VALVE HOLD-UP=        4.9999D-03  %

TOTAL U FED TO FLAPPER VALVES=        1.1096D 05  G
TOTAL PU FED TO FLAPPER VALVES=        3.1787D 04  G
TOTAL U PLUS PU FED TO FLAPPER VALVES=        1.4275D 05  G
TOTAL U PLUS PU FED TO STAGE 1 FROM FLAPPER VALVES=        1.4275D 05  G
PER CENT TRANSFER THRU FLAPPER VALVES=        1.00000D 02%

NUMBER OF TIME STEPS WITH ACID DEFICIENT COND.=        0
```

*** MAXIMUM PREDICTED CONCENTRATIONS (G/L) ***

| COMPONENT/TIME (MIN) | STG 1 | STG 2 | STG 3 | STG 4 | STG 5 | STG 6 | STG 7 | STG 8 | STG 9 |
|---|---|---|---|---|---|---|---|---|---|
| UO2(NO3)2 | 2.421D 02 | 2.275D 02 | 1.844D 02 | 1.035D 02 | 1.889D-02 | 1.227D-06 | 7.984D-11 | 5.175D-15 | 3.235D-19 |
| TIME | 3.845D 02 | 2.880D 02 | 2.944D 02 | 2.922D 02 | 2.880D 02 | 3.200D 02 | 3.520D 02 | 3.840D 02 | 3.840D 02 |
| PU(NO3)4 | 8.533D 01 | 8.021D 01 | 6.500D 01 | 3.649D 01 | 6.659D-03 | 4.326D-07 | 2.815D-11 | 1.825D-15 | 1.141D-19 |
| TIME | 3.845D 02 | 2.880D 02 | 2.944D 02 | 2.922D 02 | 2.880D 02 | 3.200D 02 | 3.520D 02 | 3.840D 02 | 3.840D 02 |
| FP(NO3)1.18 | 2.839D 01 | 2.668D 01 | 2.162D 01 | 1.214D 01 | 2.215D-03 | 1.439D-07 | 9.363D-12 | 6.070D-16 | 3.794D-20 |
| TIME | 3.845D 02 | 2.880D 02 | 2.944D 02 | 2.922D 02 | 2.880D 02 | 3.200D 02 | 3.520D 02 | 3.840D 02 | 3.840D 02 |
| HNO3 | 3.733D 02 | 3.816D 02 | 3.816D 02 | 3.846D 02 | 3.854D 02 | 3.860D 02 | 3.874D 02 | 3.934D 02 | 4.600D 01 |
| TIME | 2.000D-02 | 2.000D-02 | 2.000D-02 | 3.840D 02 | 3.766D 02 | 3.711D 02 | 3.651D 02 | 3.594D 02 | 3.520D 02 |
| H2O | 7.830D 02 | 7.833D 02 | 7.824D 02 | 7.814D 02 | 7.822D 02 | 7.822D 02 | 7.822D 02 | 7.854D 02 | 9.565D 02 |
| TIME | 2.000D-02 | 3.204D 01 | 3.206D 01 | 9.604D 01 | 1.280D 02 | 1.600D 02 | 1.920D 02 | 2.249D 02 | 4.000D-02 |

## Table B.6 (continued)

NUMBER OF TIME STEP REDUCTIONS= 18

MAXIMUM # ITERATIONS IN PARTIC= 1
MAXIMUM # ITERATIONS IN SUBUN= 2
MAXIMUM # ITERATIONS IN SUBPN= 2
MAXIMUM # ITERATIONS IN SUBFP= 2
MAXIMUM # ITERATIONS IN SUBHN= 2
MAXIMUM # ITERATIONS IN SUBH2= 2

NEGATIVE SUM OF OVER DISSOLUTION OF PARTICLES IN DIGESTER # 1 = -6.0985D-08 G
NEGATIVE SUM OF OVER DISSOLUTION OF PARTICLES IN DIGESTER # 2 = 0.0 G

*** STAGEWISE MASS INVENTORY (G) AFTER 400.01 MINUTES ***

| COMPONENT | STG 1 | STG 2 | STG 3 | STG 4 | STG 5 | STG 6 | STG 7 | STG 8 | STG 9 |
|---|---|---|---|---|---|---|---|---|---|
| URANIUM | 8.858D 02 | 4.371D 03 | 4.057D 03 | 5.815D 01 | 3.796D-03 | 2.483D-07 | 1.636D-11 | 1.066D-15 | 5.759D-19 |
| PLUTONIUM | 2.538D 02 | 1.252D 03 | 1.162D 03 | 1.666D 01 | 1.087D-03 | 7.112D-08 | 4.685D-12 | 3.053D-16 | 1.650D-19 |
| U+PU | 1.140D 03 | 5.623D 03 | 5.219D 03 | 7.480D 01 | 4.884D-03 | 3.194D-07 | 2.104D-11 | 1.371D-15 | 7.408D-19 |
| UO2(NO3)2 | 1.436D 03 | 1.856D 03 | 1.241D 03 | 9.625D 01 | 6.284D-03 | 4.110D-07 | 2.707D-11 | 1.764D-15 | 9.532D-19 |
| PU(NO3)4 | 5.062D 02 | 6.544D 02 | 4.374D 02 | 3.393D 01 | 2.215D-03 | 1.449D-07 | 9.544D-12 | 6.219D-16 | 3.360D-19 |
| FP(NO3)2.36 | 1.684D 02 | 2.177D 02 | 1.455D 02 | 1.129D 01 | 7.369D-04 | 4.819D-08 | 3.175D-12 | 2.069D-16 | 1.118D-19 |
| HNO3 | 1.229D 03 | 1.905D 03 | 2.213D 03 | 3.306D 03 | 3.391D 03 | 3.410D 03 | 3.421D 03 | 3.410D 03 | 3.211D 02 |
| H2O | 4.738D 03 | 6.598D 03 | 6.330D 03 | 6.843D 03 | 6.849D 03 | 6.839D 03 | 6.833D 03 | 6.840D 03 | 8.713D 03 |
| UO2 | 2.080D 01 | 1.650D 02 | 9.594D 01 | 8.136D-07 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PUO2 | 5.955D 00 | 4.724D 01 | 2.747D 01 | 2.329D-07 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FP(O)1.1776 | 1.468D 00 | 1.164D 01 | 6.769D 00 | 5.740D-08 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

*** ADDITIONAL CONCENTRATION DATA ***

| | STG 1 | STG 2 | STG 3 | STG 4 | STG 5 | STG 6 | STG 7 | STG 8 | STG 9 |
|---|---|---|---|---|---|---|---|---|---|
| U(G/L)LQ | 1.380D 02 | 1.278D 02 | 8.989D 01 | 6.577D 00 | 4.294D-04 | 2.808D-08 | 1.850D-12 | 1.205D-16 | 5.303D-20 |
| U(G/L)PT | 2.918D 00 | 1.657D 01 | 1.014D 01 | 8.112D-08 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| U(G/L)PN | 0.0 | 3.537D 02 | 3.865D 02 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PU(G/L)LQ | 3.955D 01 | 3.660D 01 | 2.575D 01 | 1.884D 00 | 1.230D-04 | 8.044D-09 | 5.299D-13 | 3.453D-17 | 1.806D-20 |
| PU(G/L)PT | 8.359D-01 | 4.747D 00 | 2.905D 00 | 2.324D-08 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PU(G/L)PN | 0.0 | 1.013D 02 | 1.107D 02 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| U+PU(G/L)LQ | 1.776D 02 | 1.644D 02 | 1.156D 02 | 8.461D 00 | 5.524D-04 | 3.613D-08 | 2.380D-12 | 1.551D-16 | 8.108D-20 |
| U+PU(G/L)PT | 3.754D 00 | 2.132D 01 | 1.305D 01 | 1.044D-07 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| U+PU(G/L)PN | 0.0 | 4.550D 02 | 4.972D 02 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| HNO3(MOL/L) | 3.103D 00 | 3.445D 00 | 4.212D 00 | 5.933D 00 | 6.086D 00 | 6.119D 00 | 6.140D 00 | 6.120D 00 | 5.576D-01 |

ORNL/DWG. 84-12968

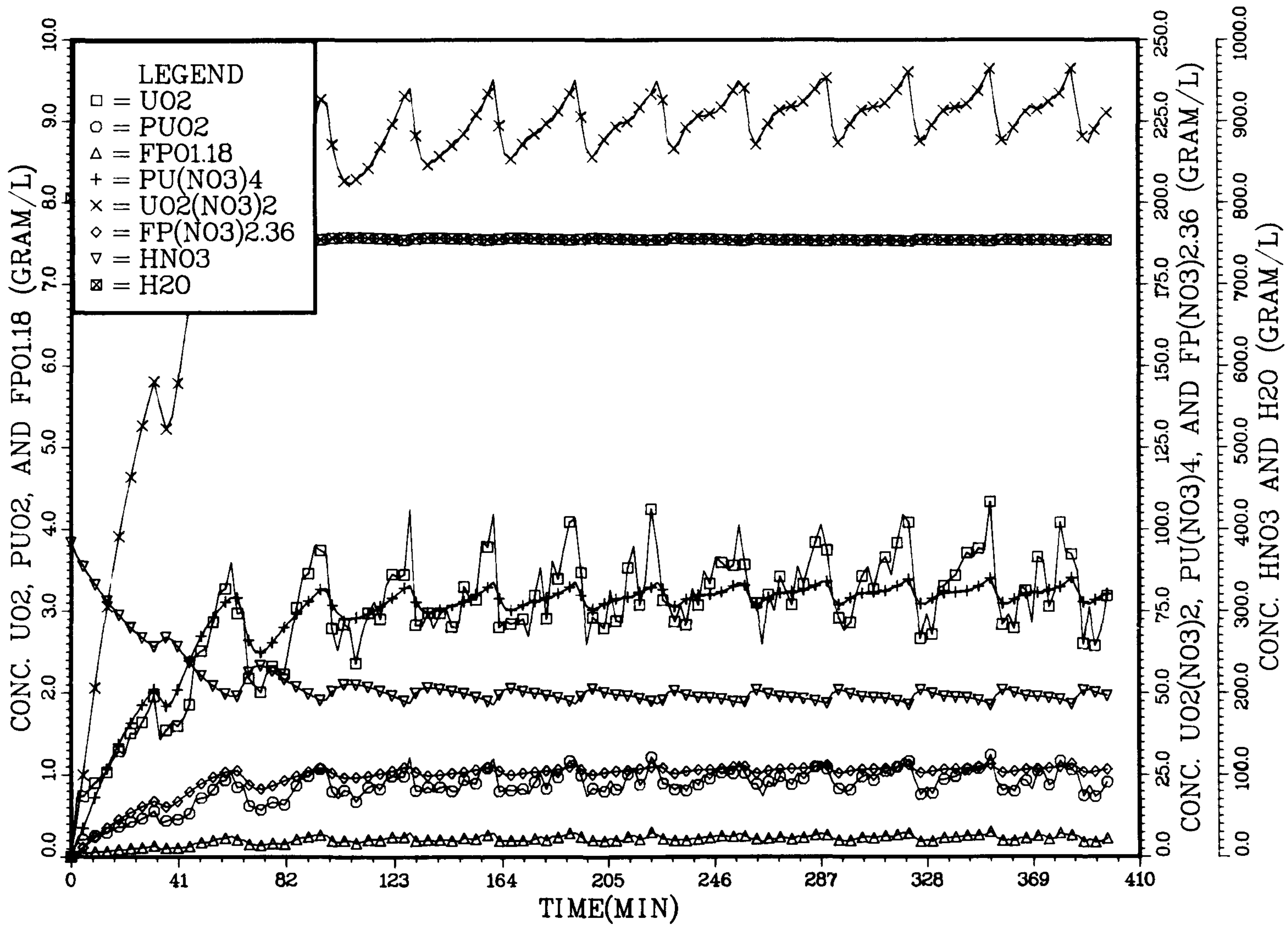


Fig. B.1. Concentration profile for stage 1

ORNL/DWG. 84-12969

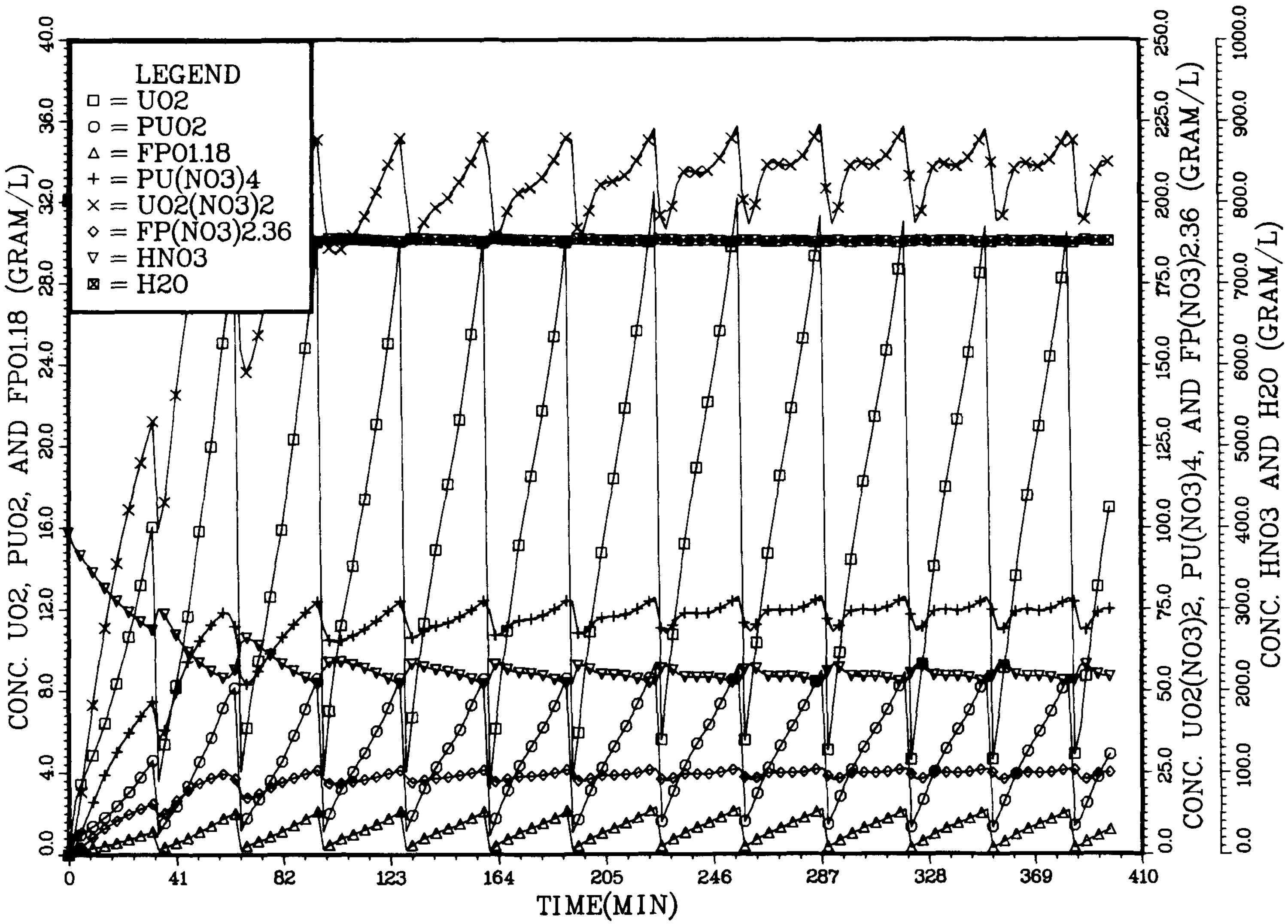


Fig. B.2. Concentration profile for stage 2

ORNL/DWG. 84-12970

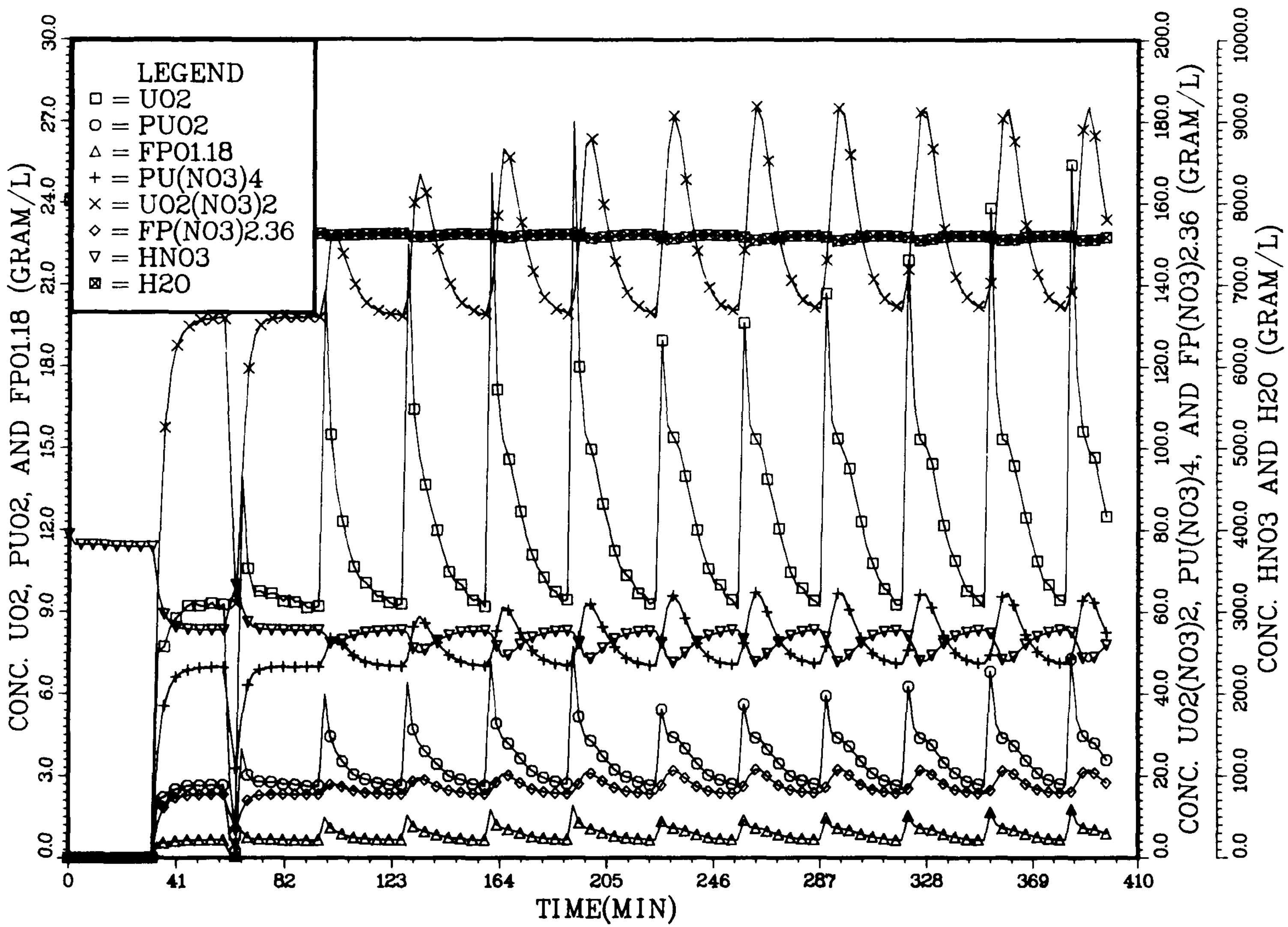


Fig. B.3. Concentration profile for stage 3

ORNL/DWG. 84-12971

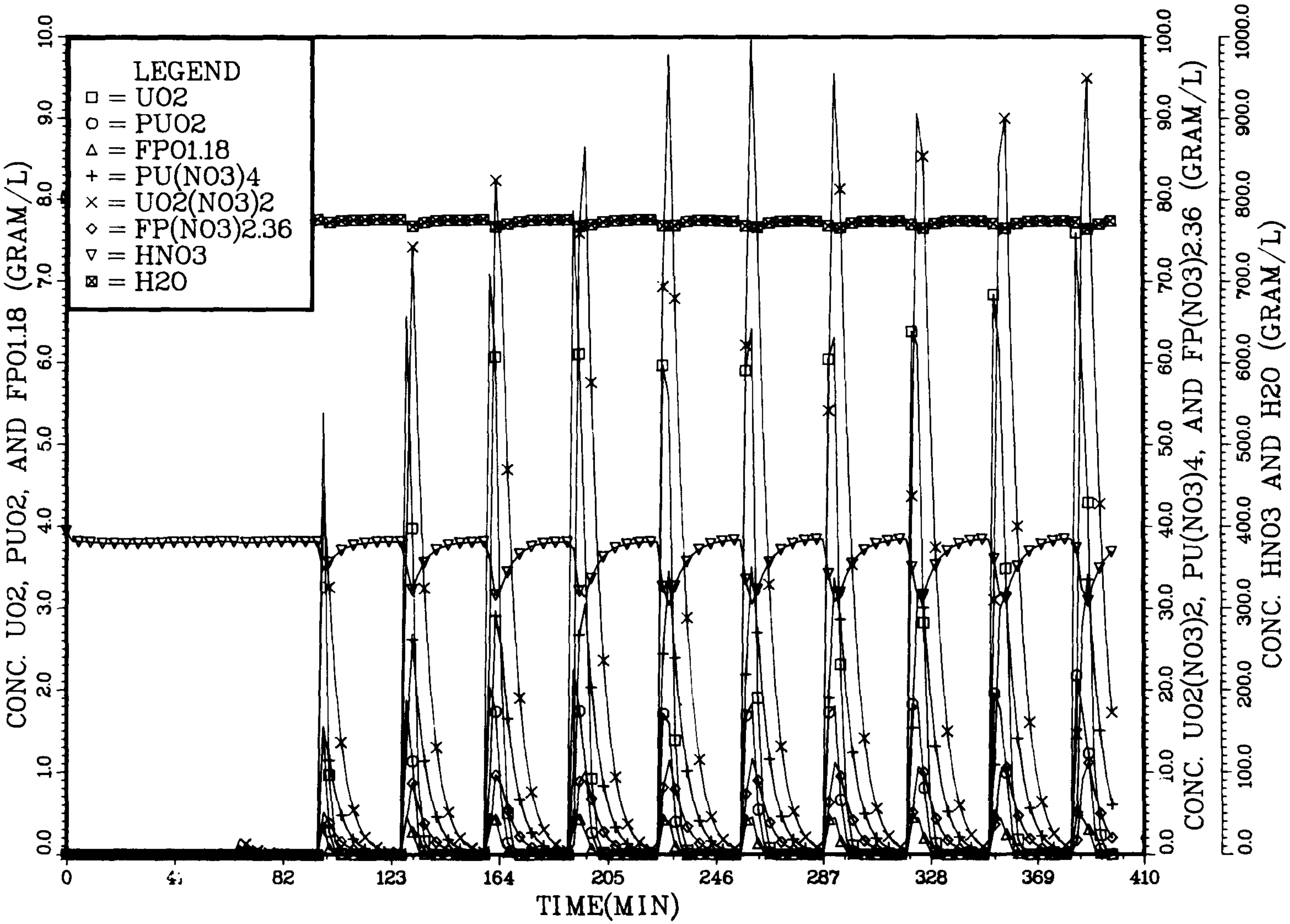


Fig. B.4. Concentration profile for stage 4

ORNL/DWG. 84-12972

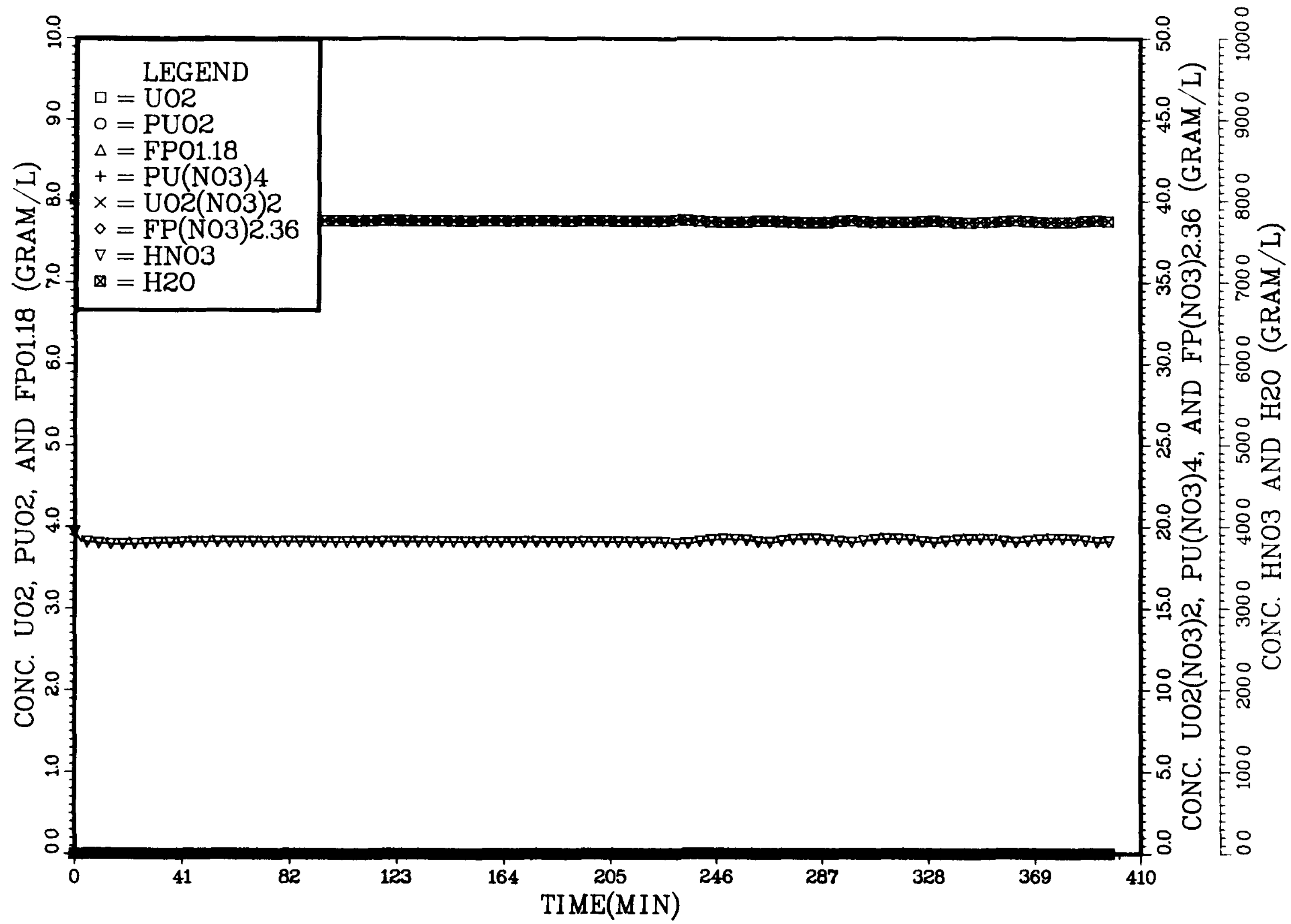


Fig. B.5. Concentration profile for stage 5

ORNL/DWG 84 12973

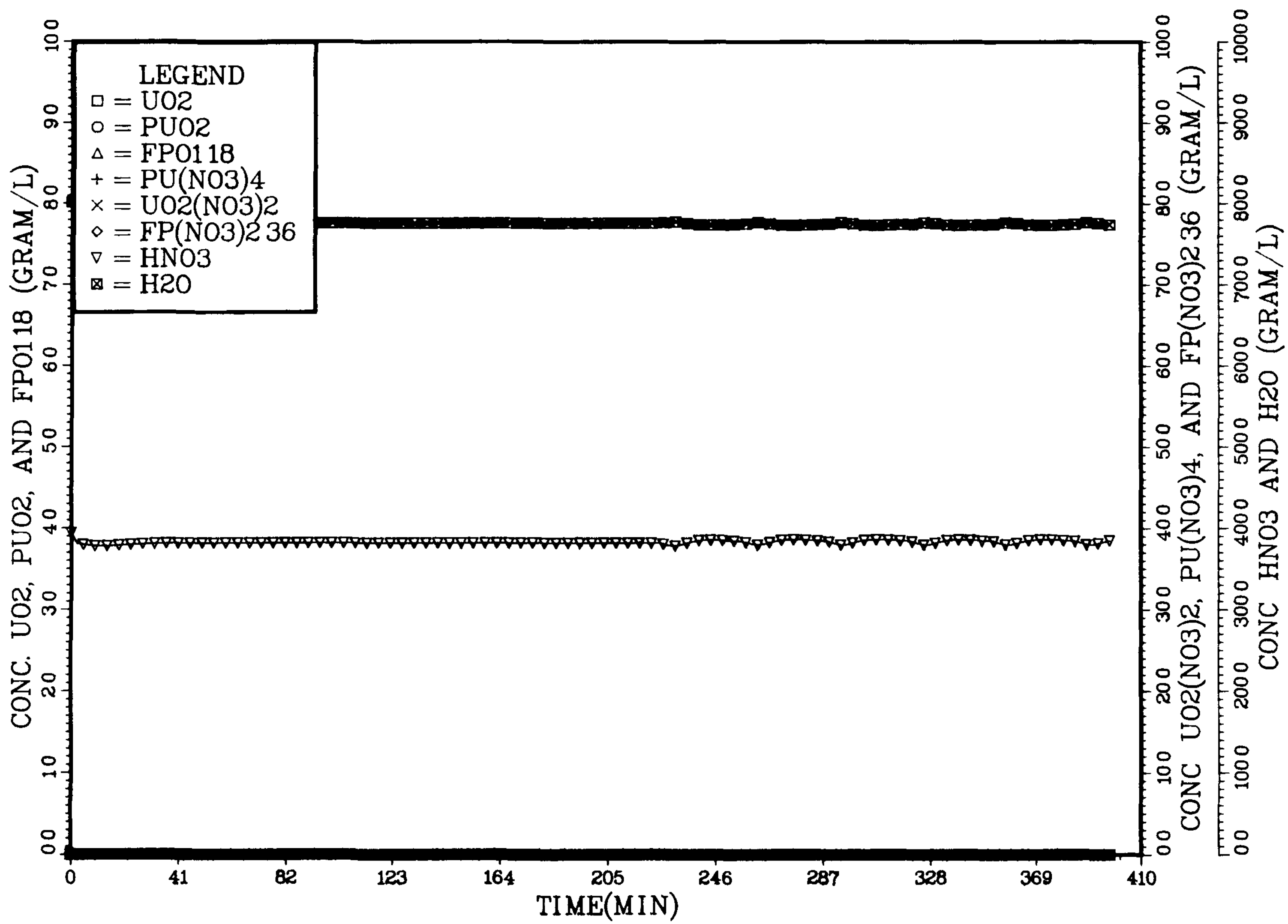


Fig B 6 Concentration profile for stage 6

ORNL/DWG 84 12974

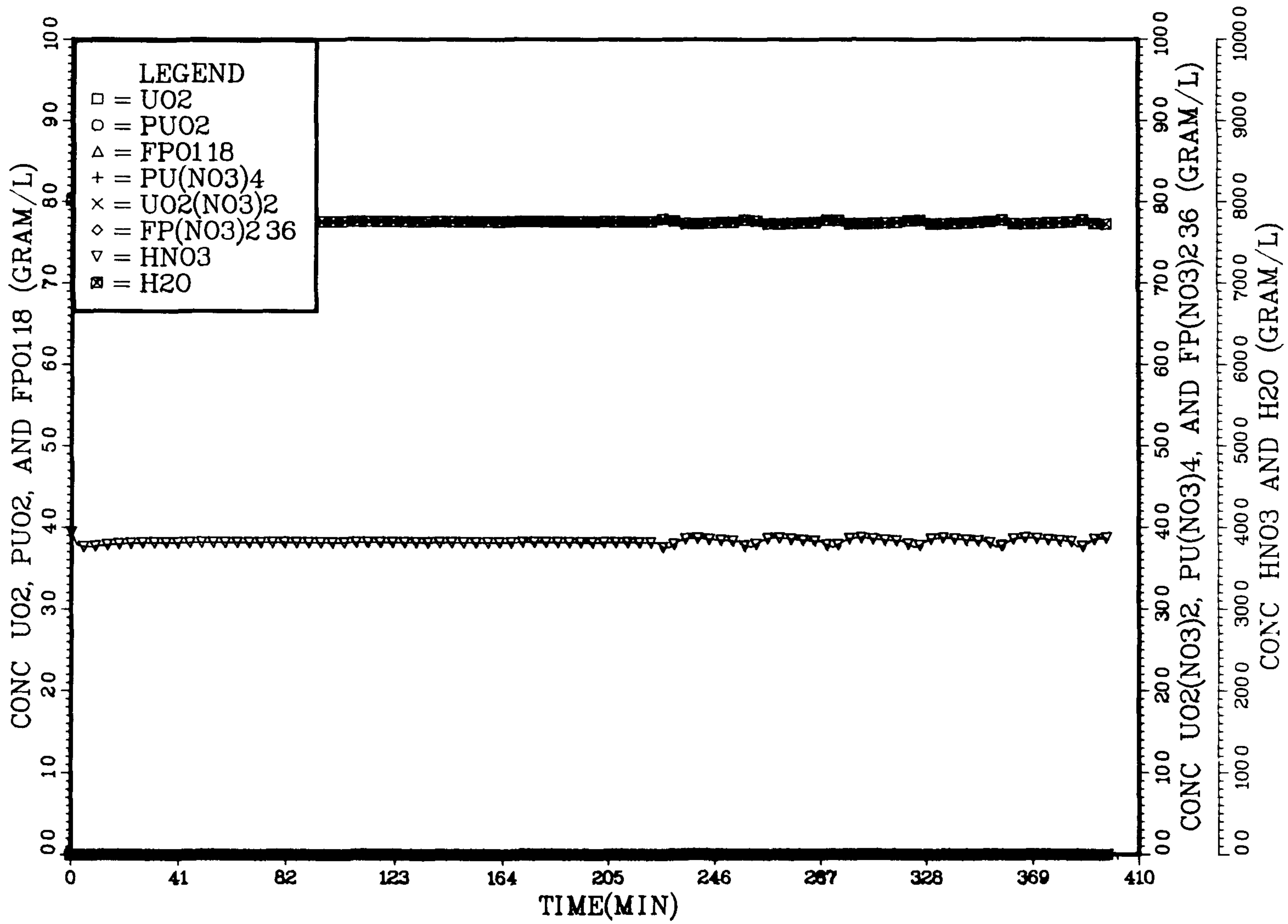


Fig B 7 Concentration profile for stage 7

ORNL/DWG. 84-12975

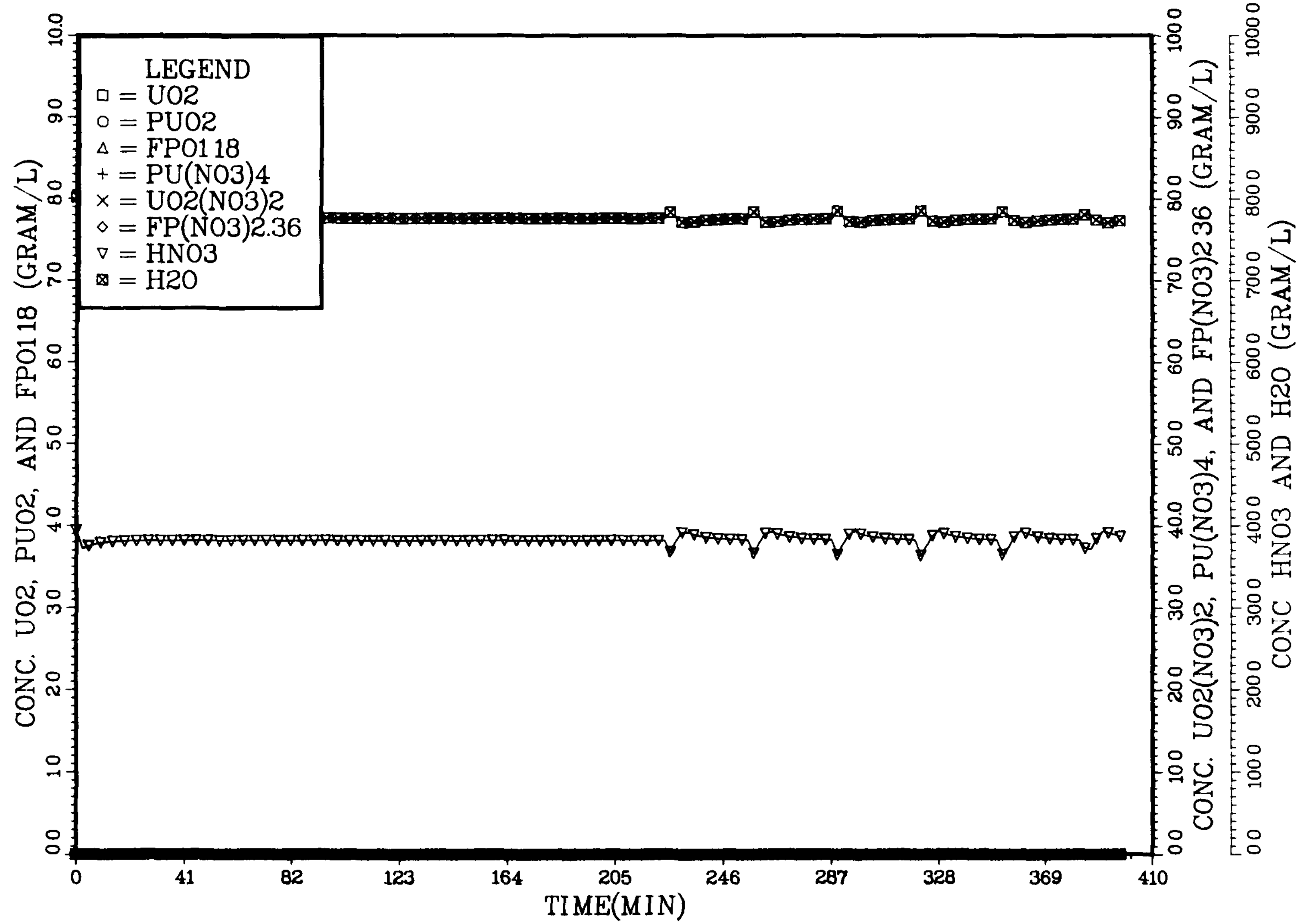


Fig. B.8. Concentration profile for stage 8

ORNL/DWG. 84-12976

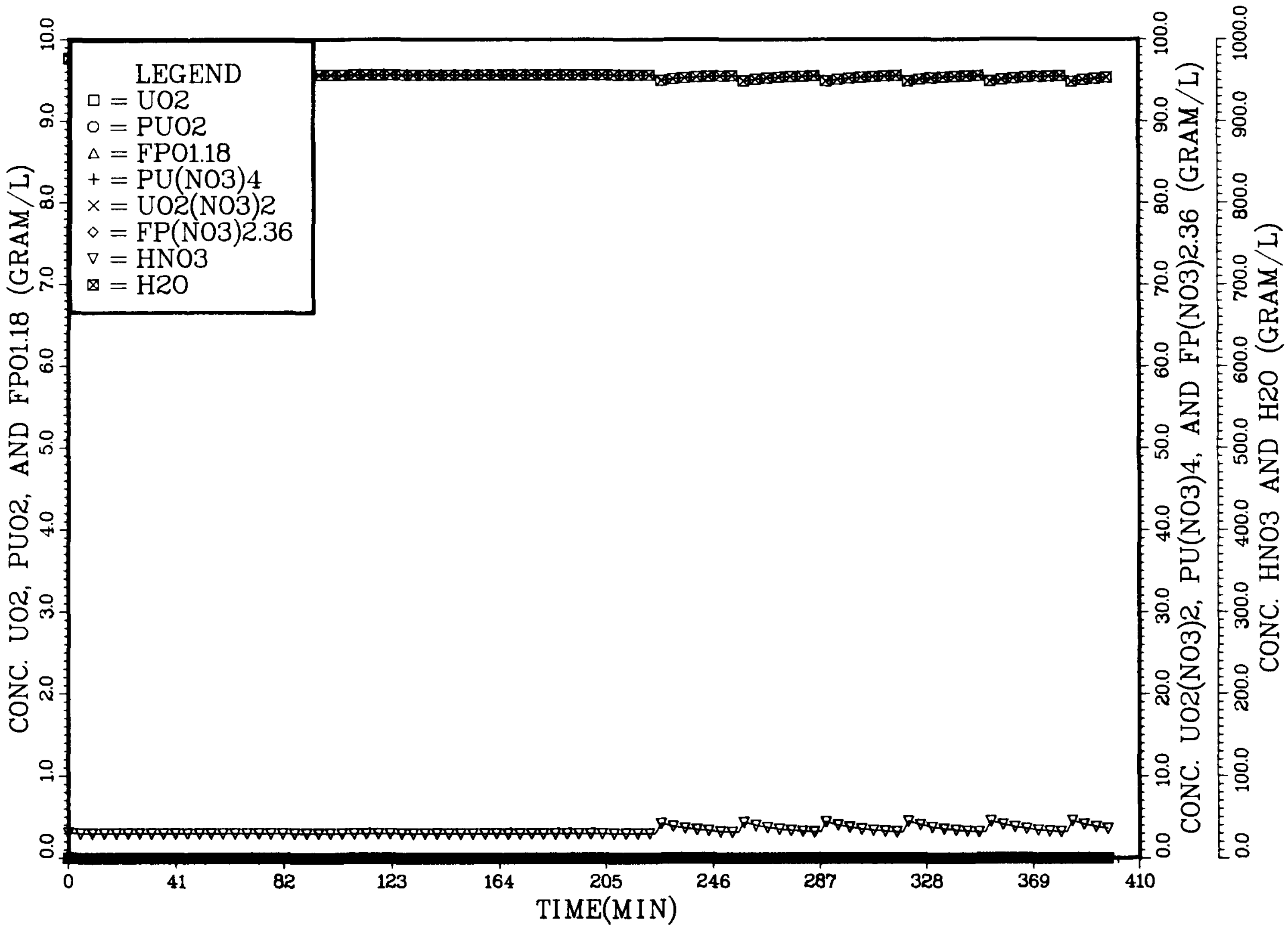


Fig. B.9. Concentration profile for stage 9

ORNL/DWG. 84-12977

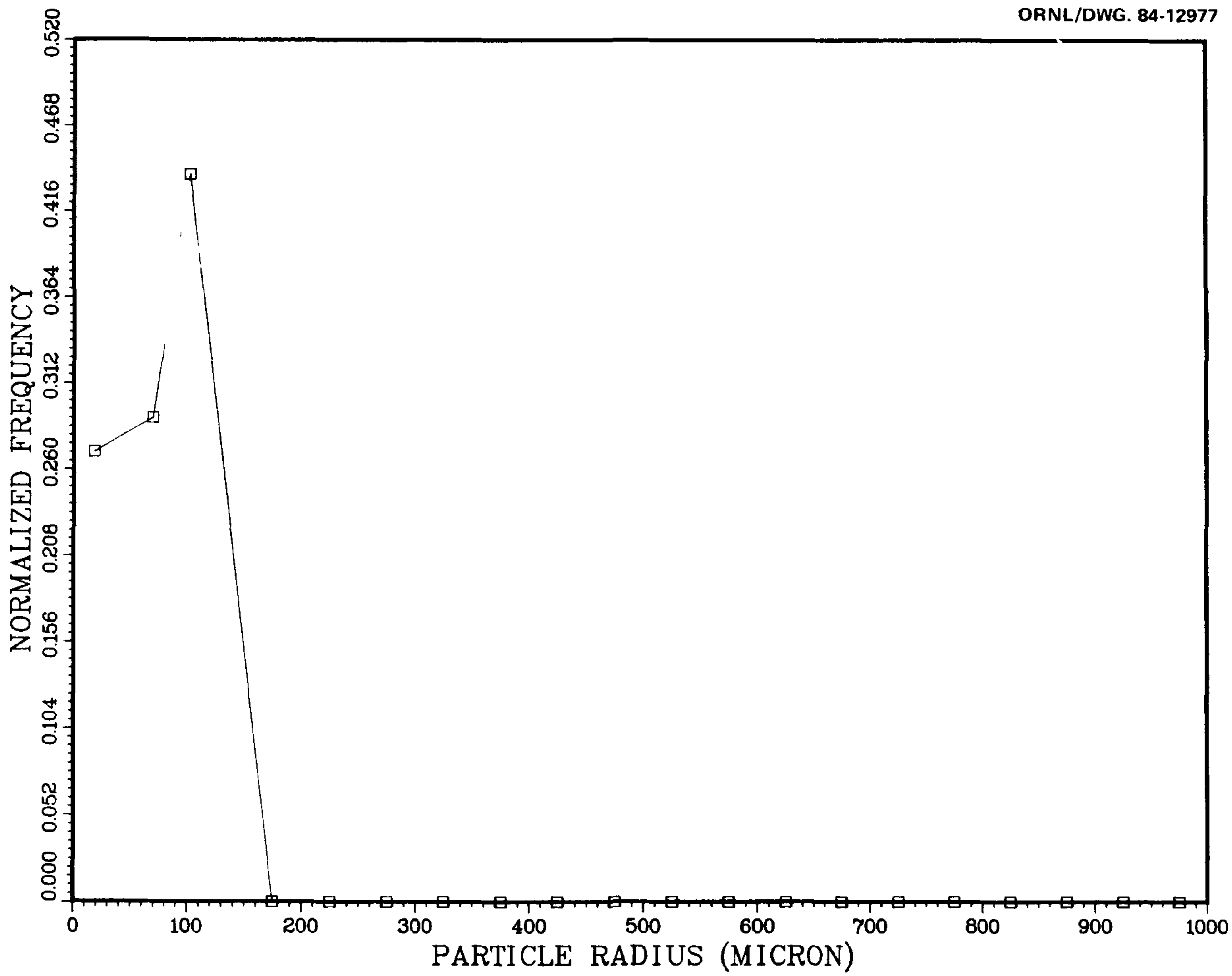


**Fig. B.10. Particle size distribution for stage 1**

ORNL/DWG. 84-12978

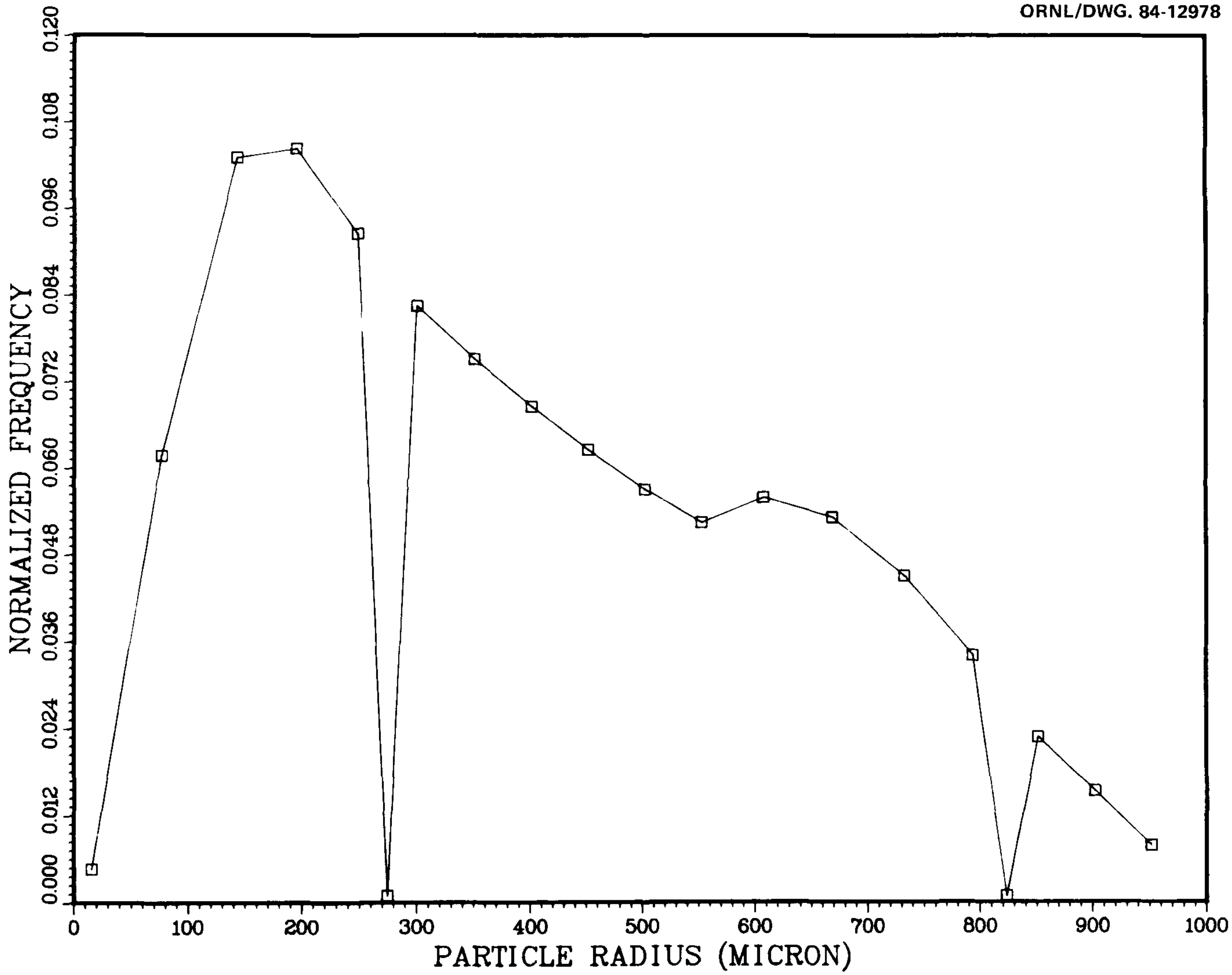


Fig. B.11. Particle size distribution for stage 2

ORNL/DWG. 84-12979

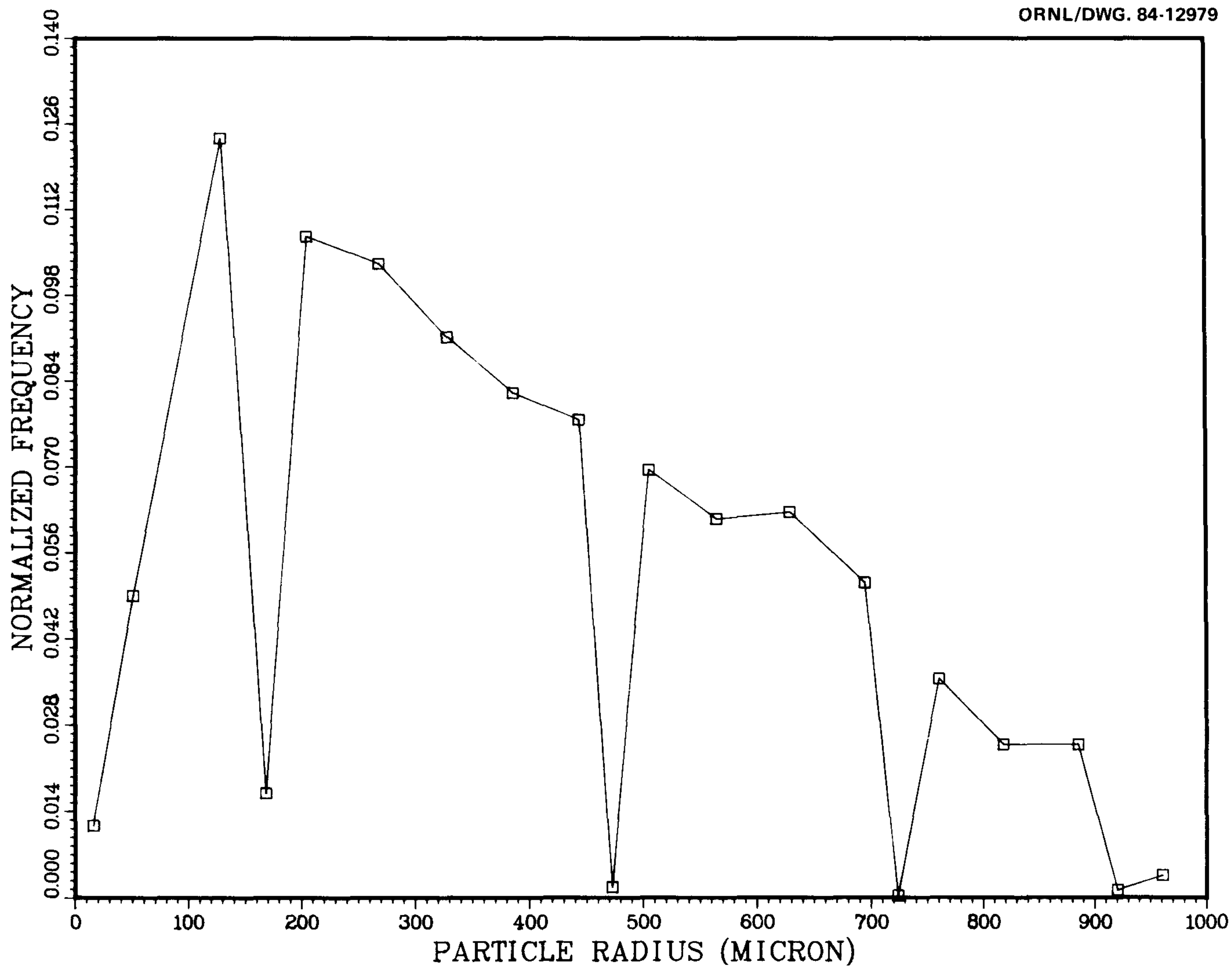


Fig. 8.12. Particle size distribution for stage 3

ORNL/DWG. 84-12980

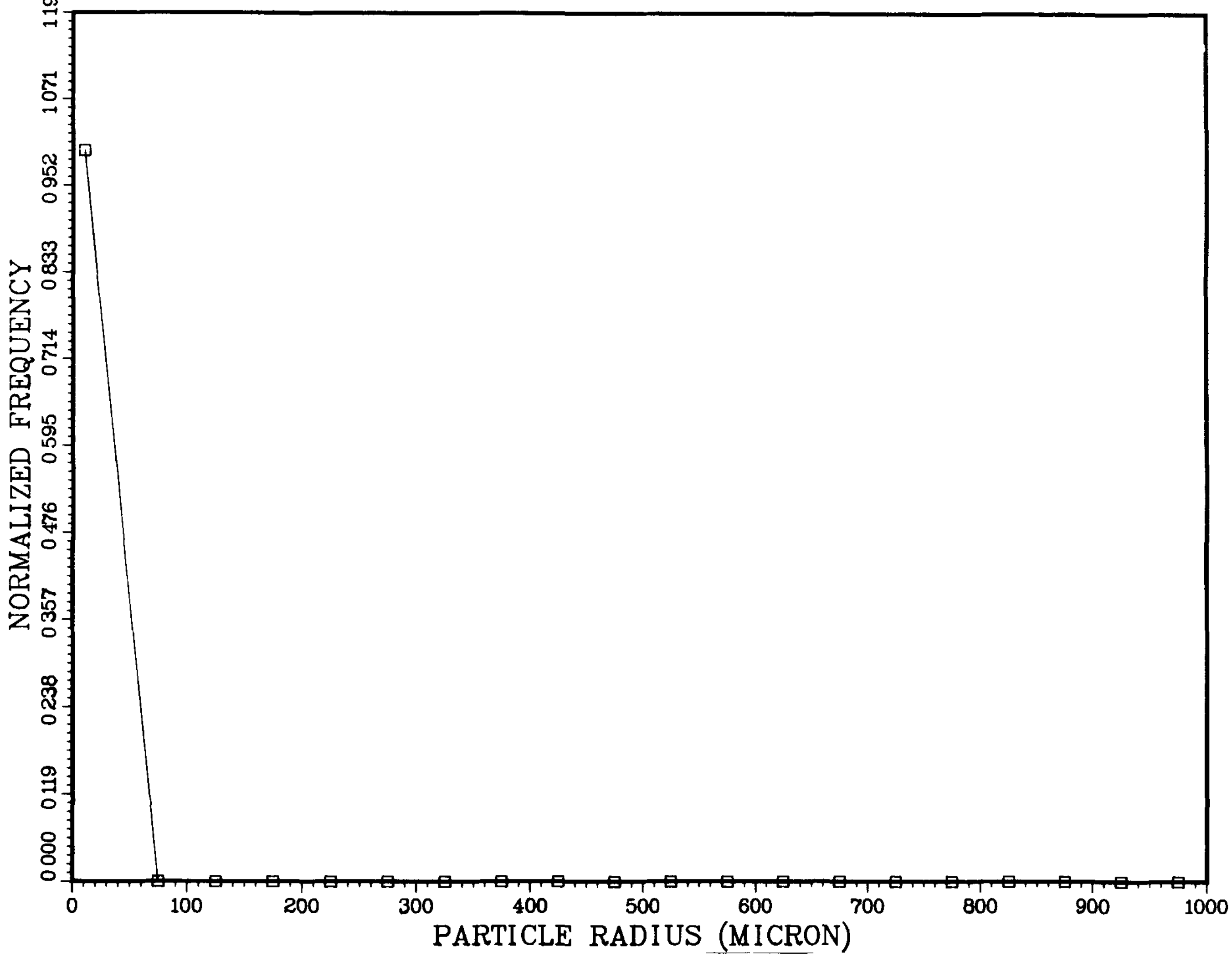


Fig. B.13. Particle size distribution for stage 4

ORNL/DWG. 84 12981

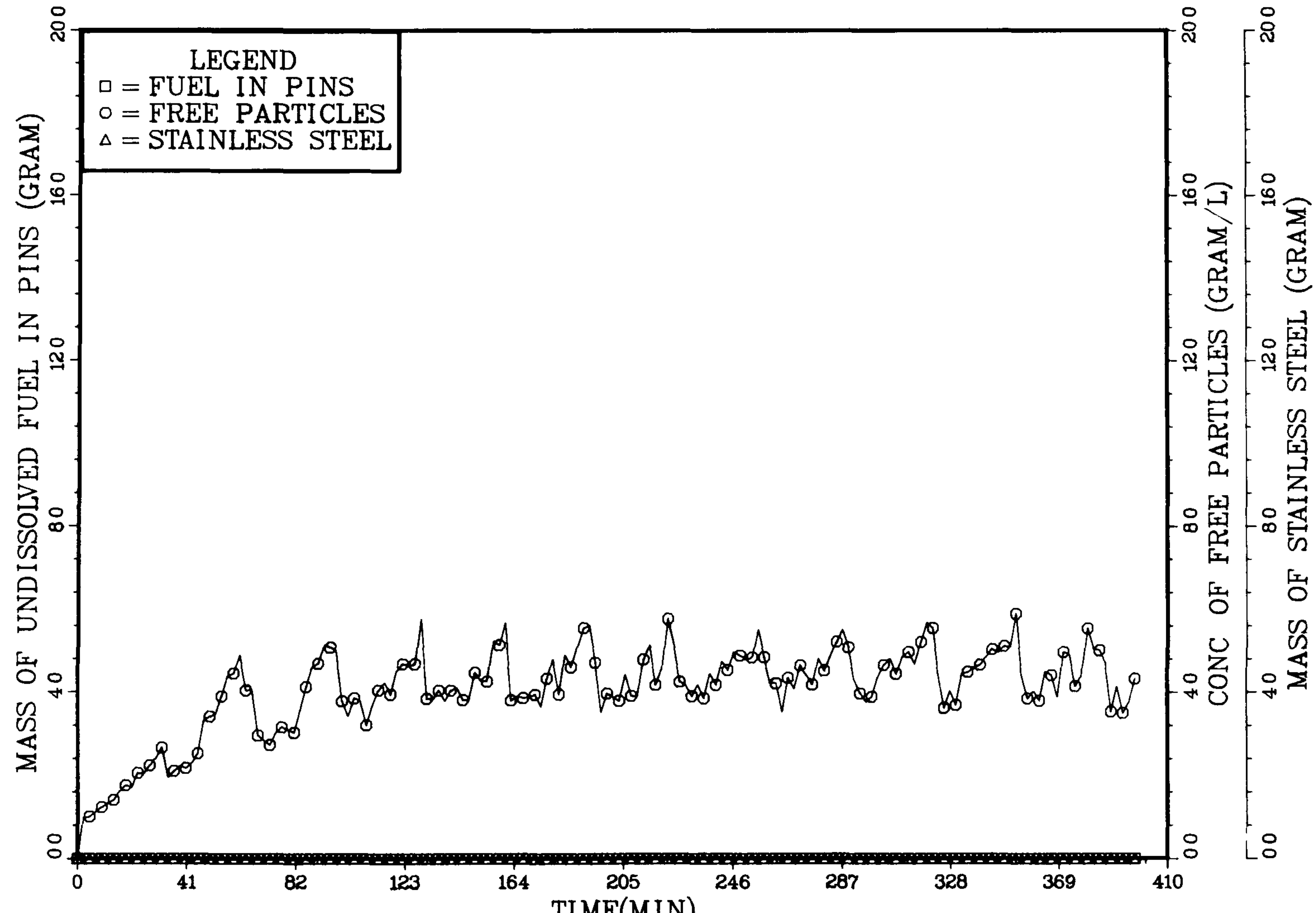


Fig B 14 Concentration history for stage 1

ORNL/DWG. 84-12982

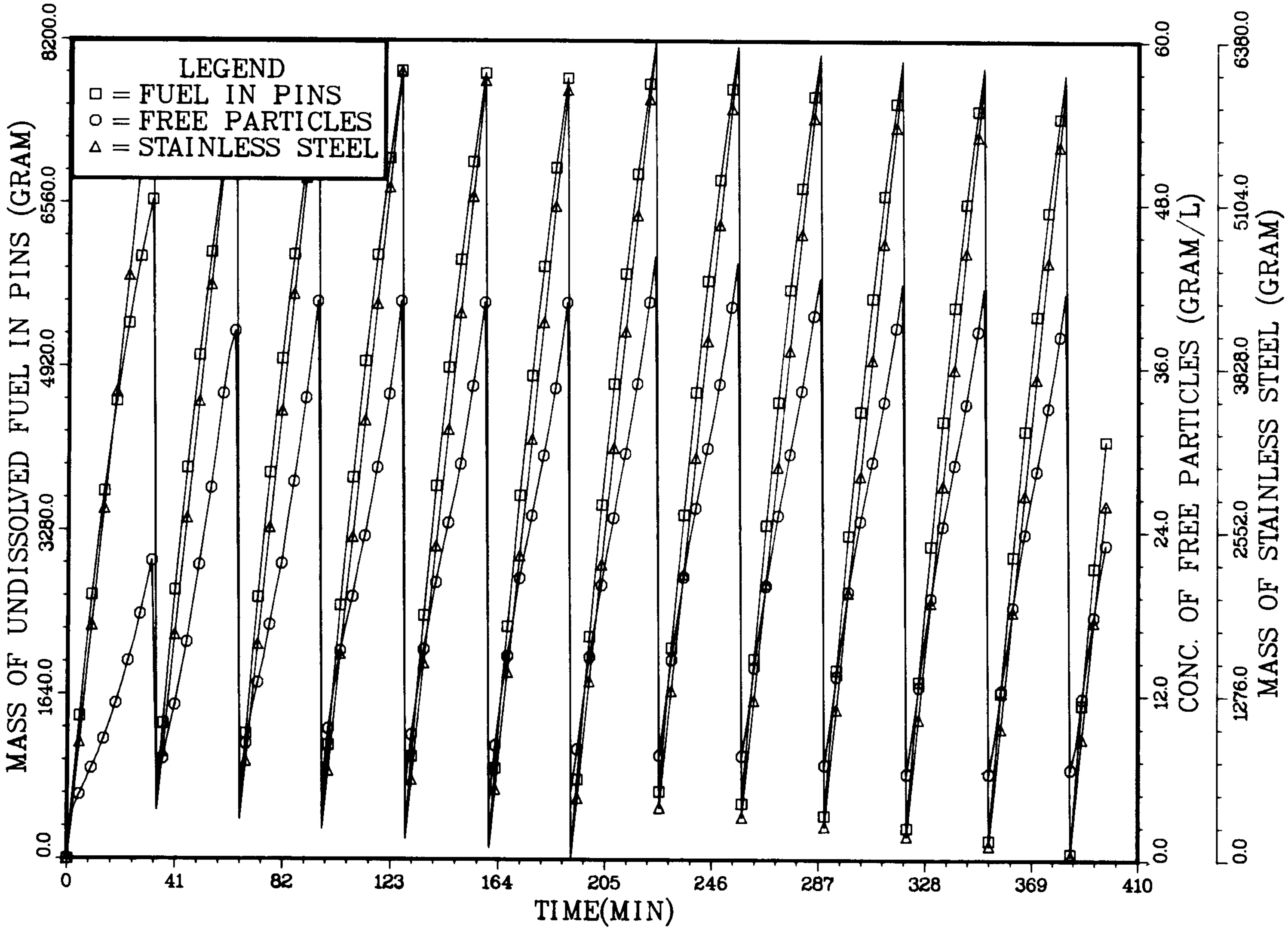


Fig. B.15. Concentration history for stage 2

ORNL/DWG. 84-12983

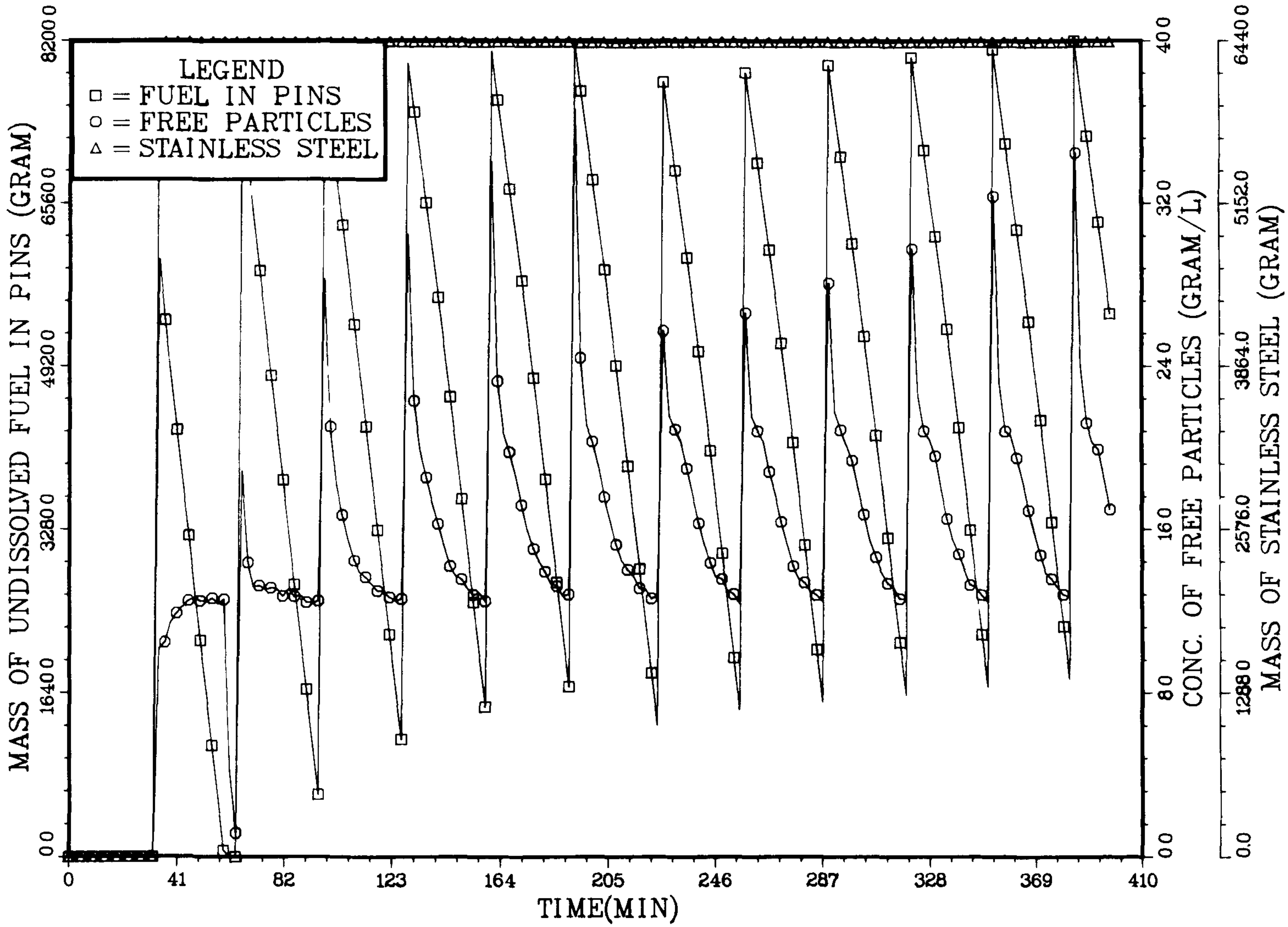


Fig. B.16. Concentration history for stage 3

ORNL/DWG. 84-12984

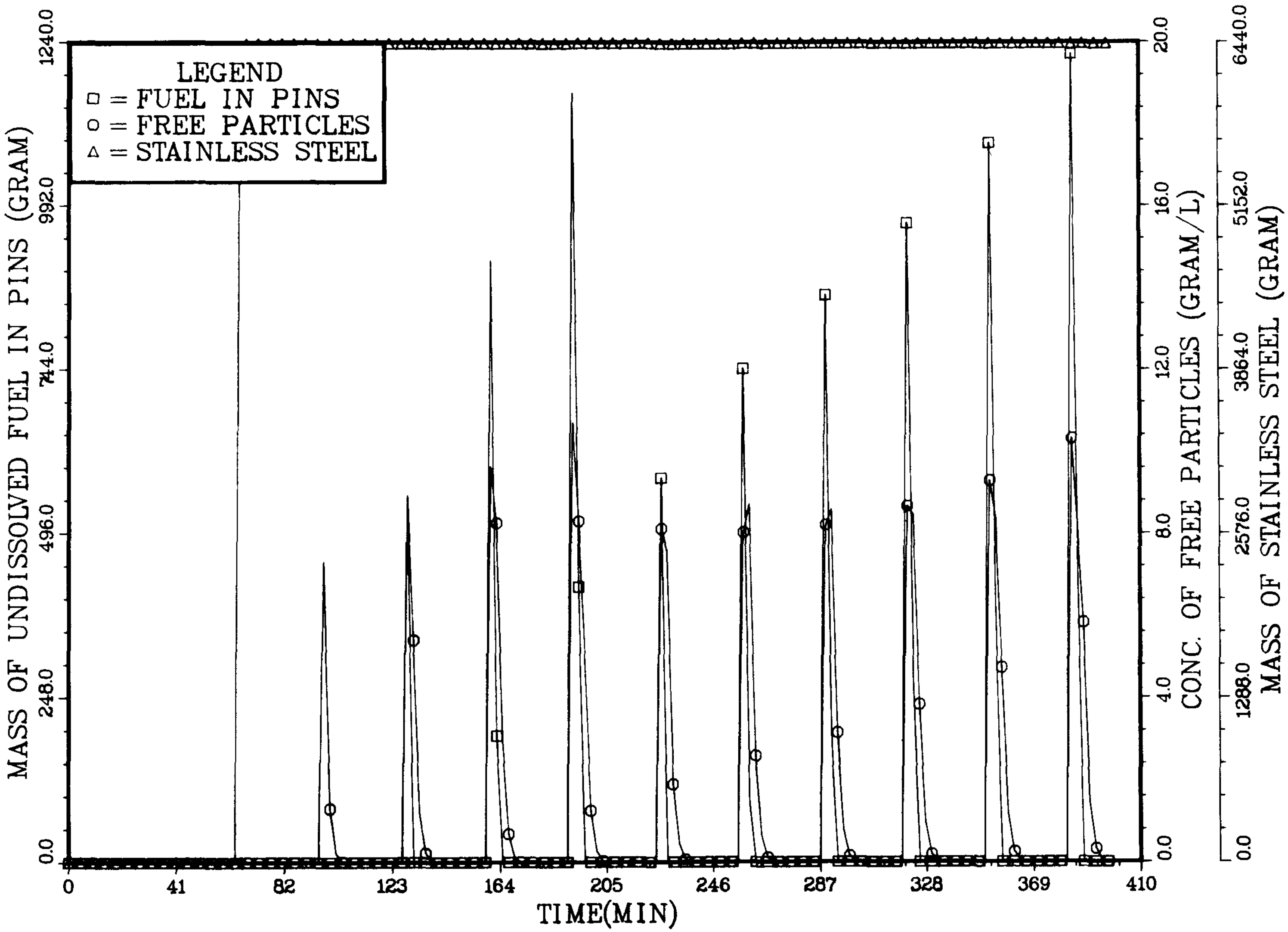


Fig. B.17. Concentration history for stage 4

ORNL/DWG. 84-12985

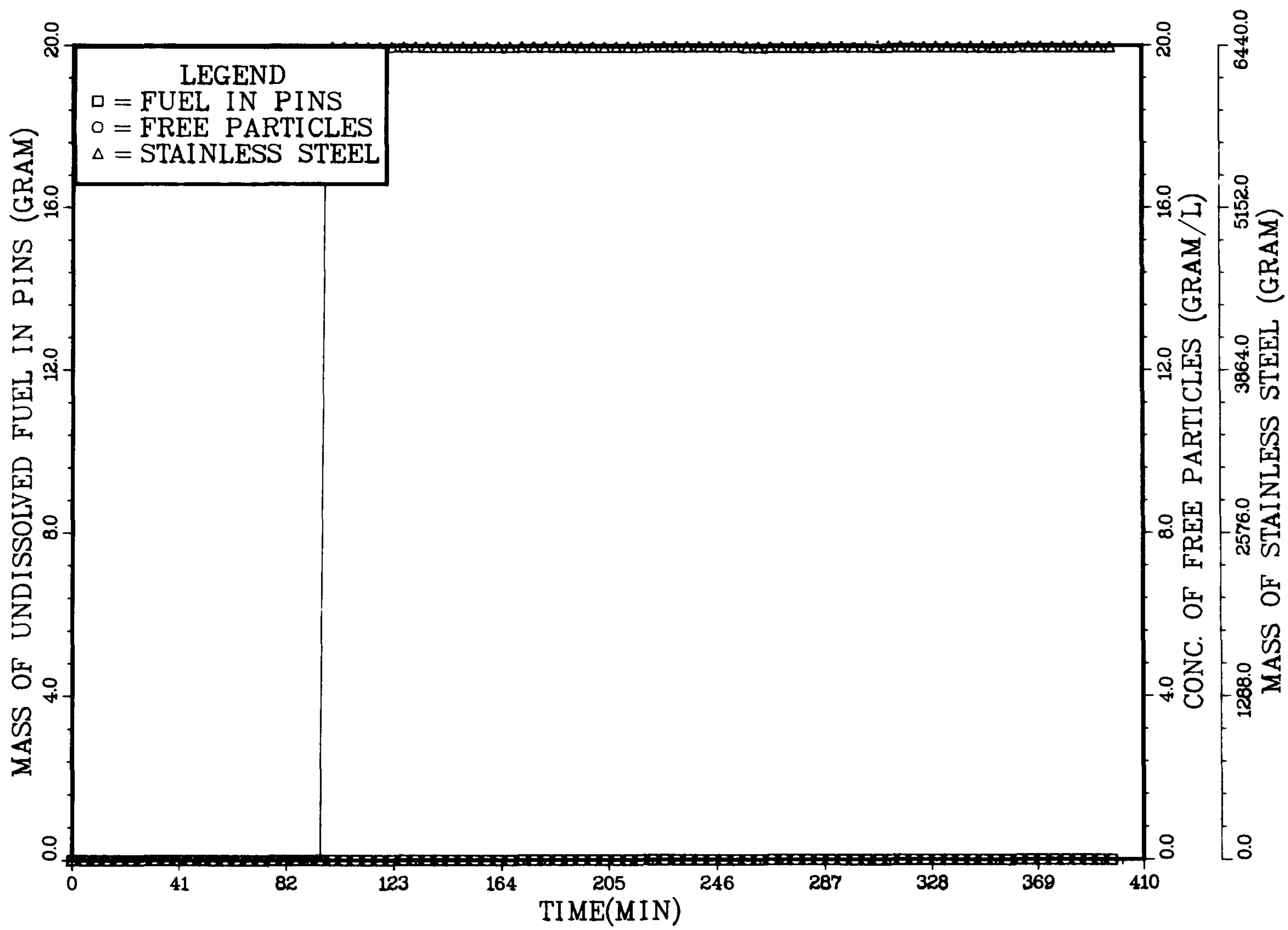


Fig. B.18. Concentration history for stage 5

ORNL/DWG. 84-12986

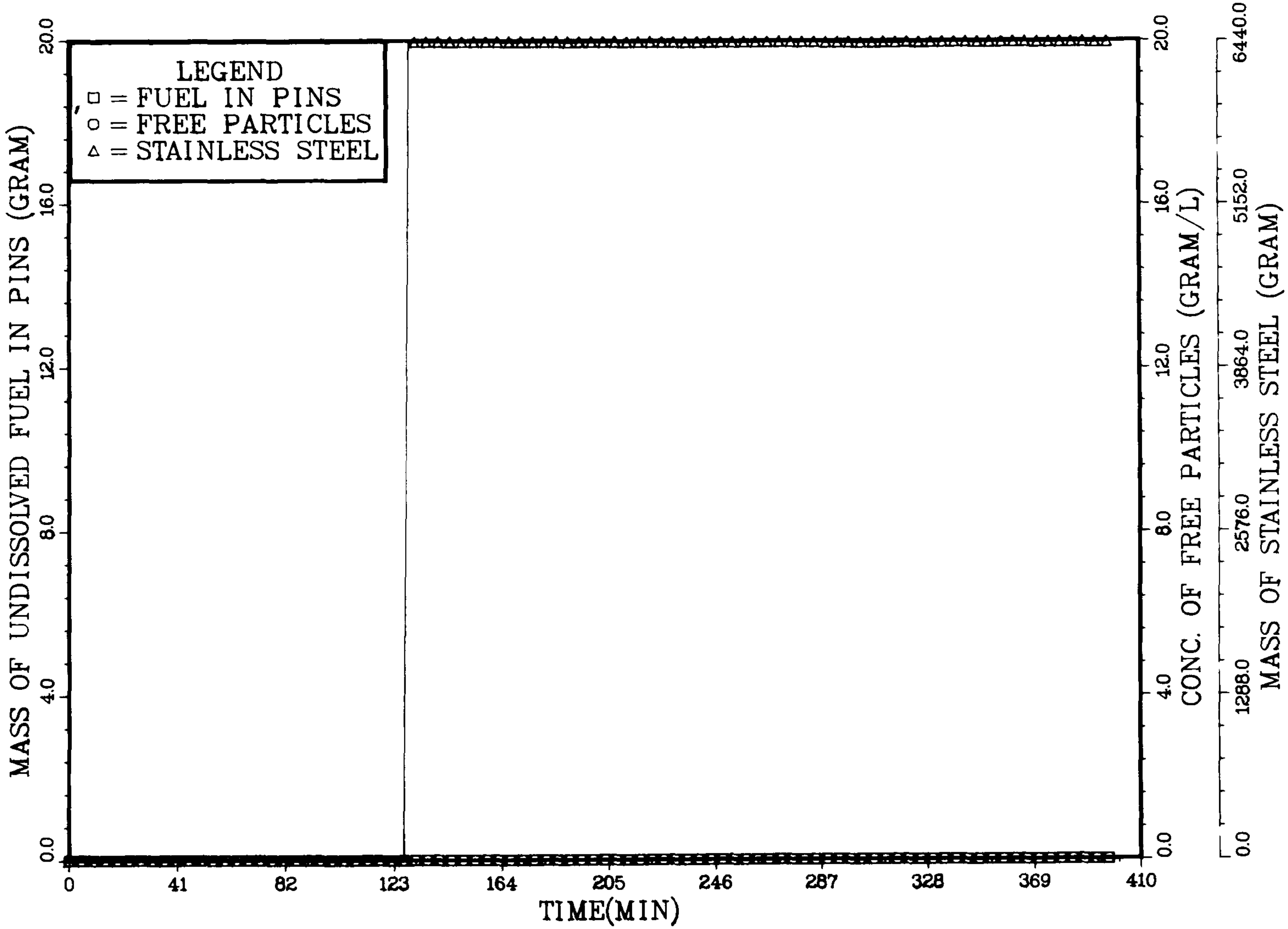


Fig. B.19. Concentration history for stage 6

ORNL/DWG. 84-12987

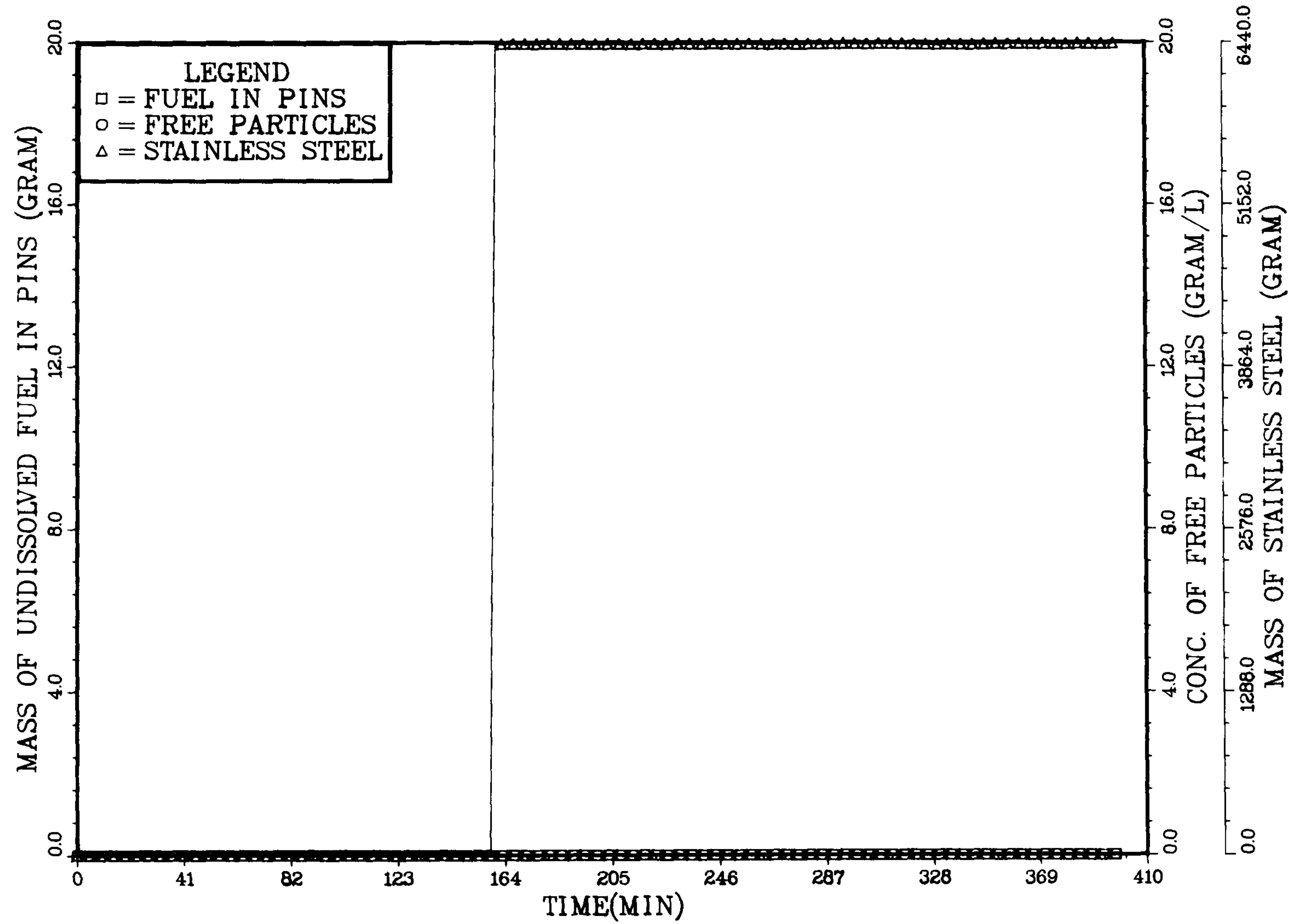


Fig. B.20. Concentration history for stage 7

ORNL/DWG. 84-12988

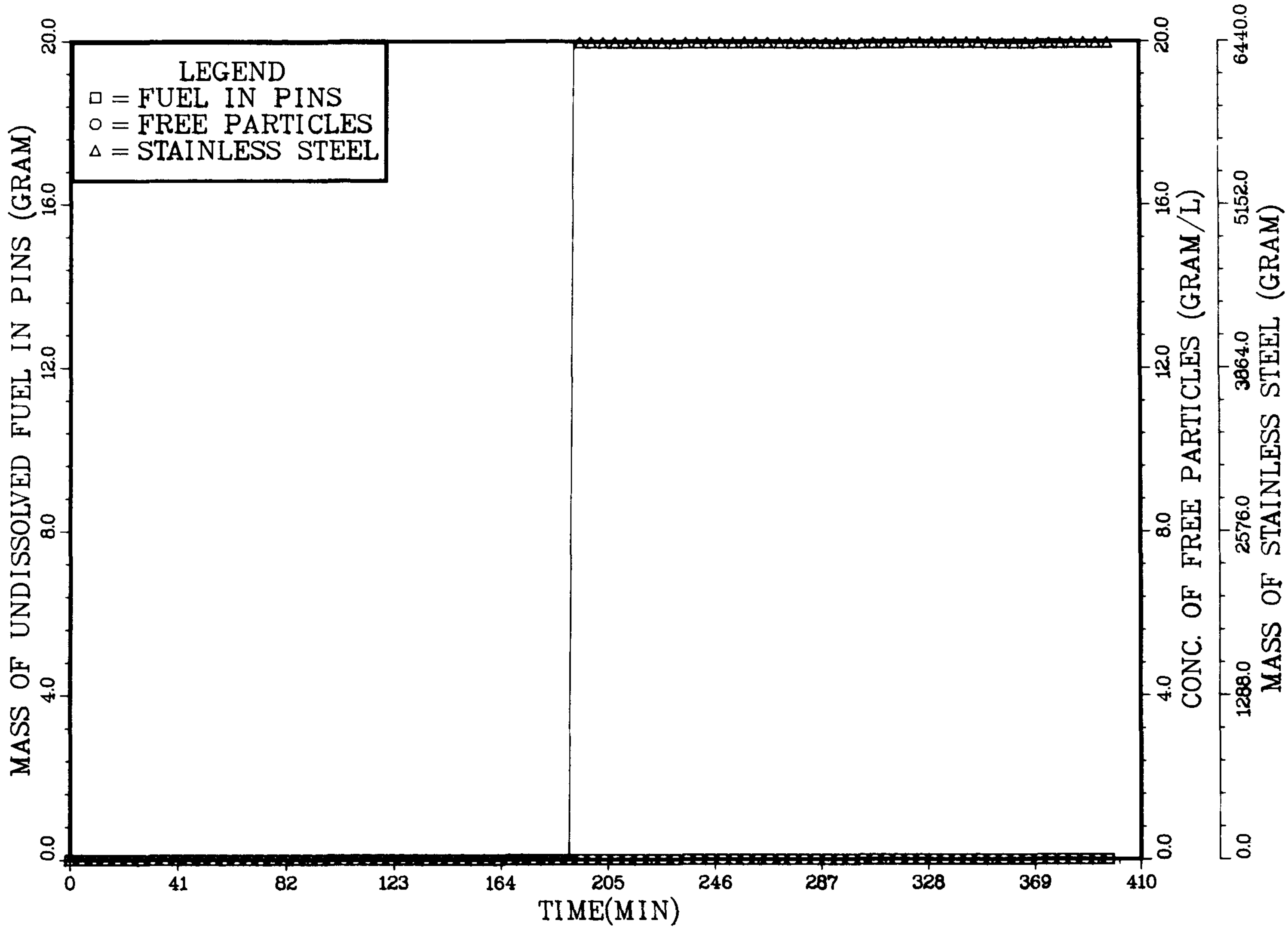


Fig. B.21. Concentration history for stage 8

ORNL/DWG. 84-12989

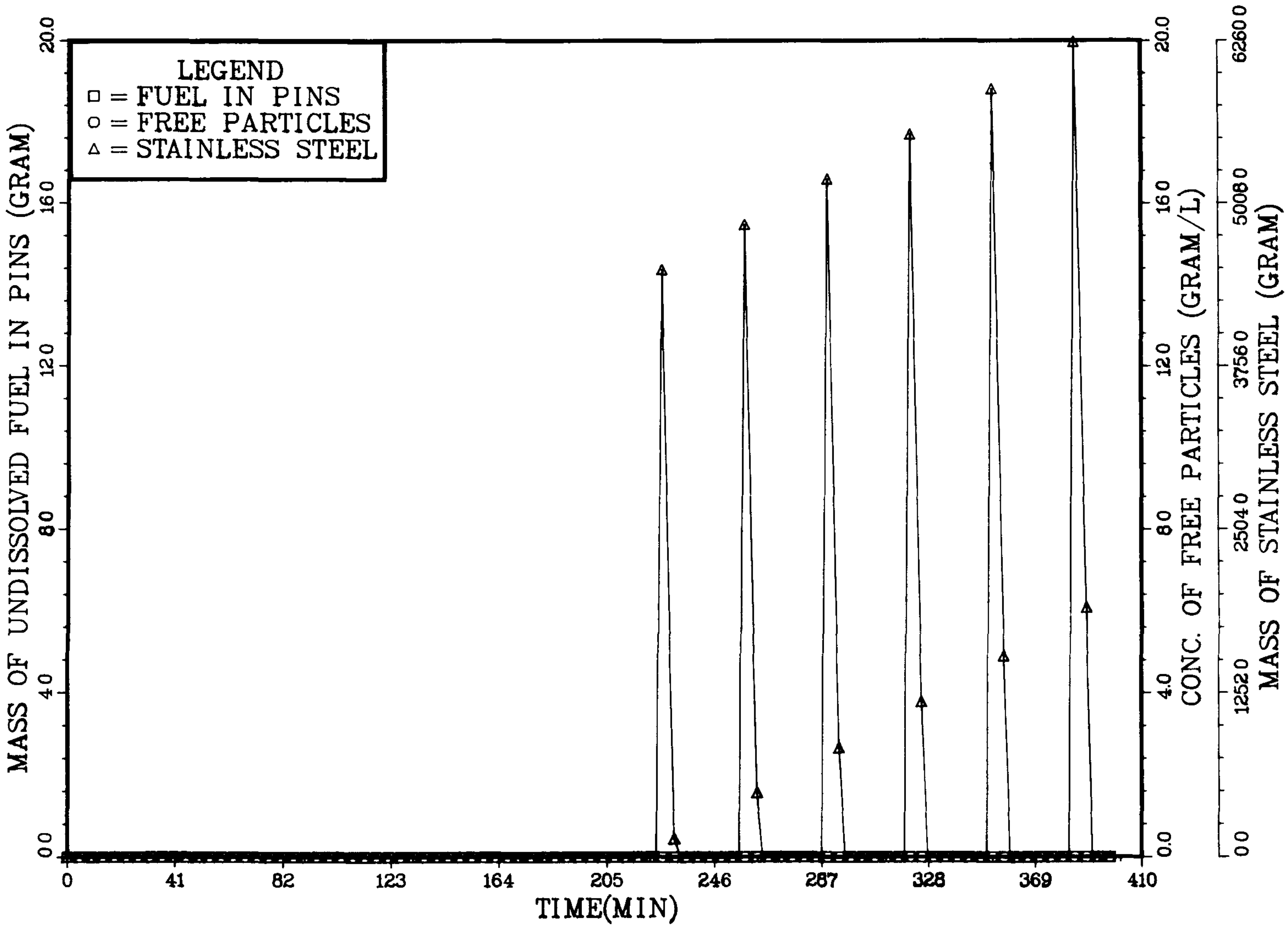


Fig. B.22. Concentration history for stage 9

ORNL/DWG. 84-12990

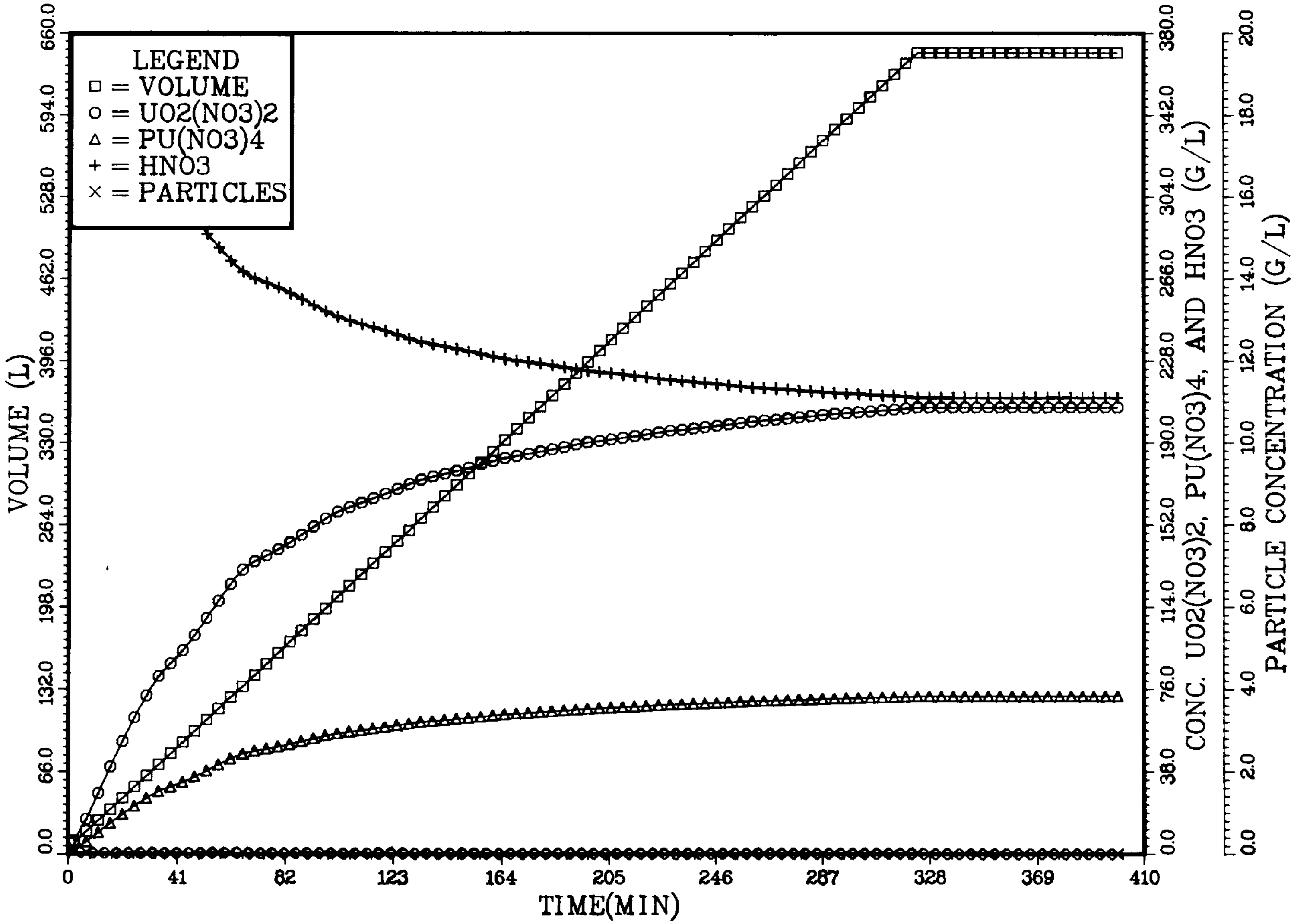


Fig. B.23. Digester tank no. 1 history

ORNL/DWG. 84-12991

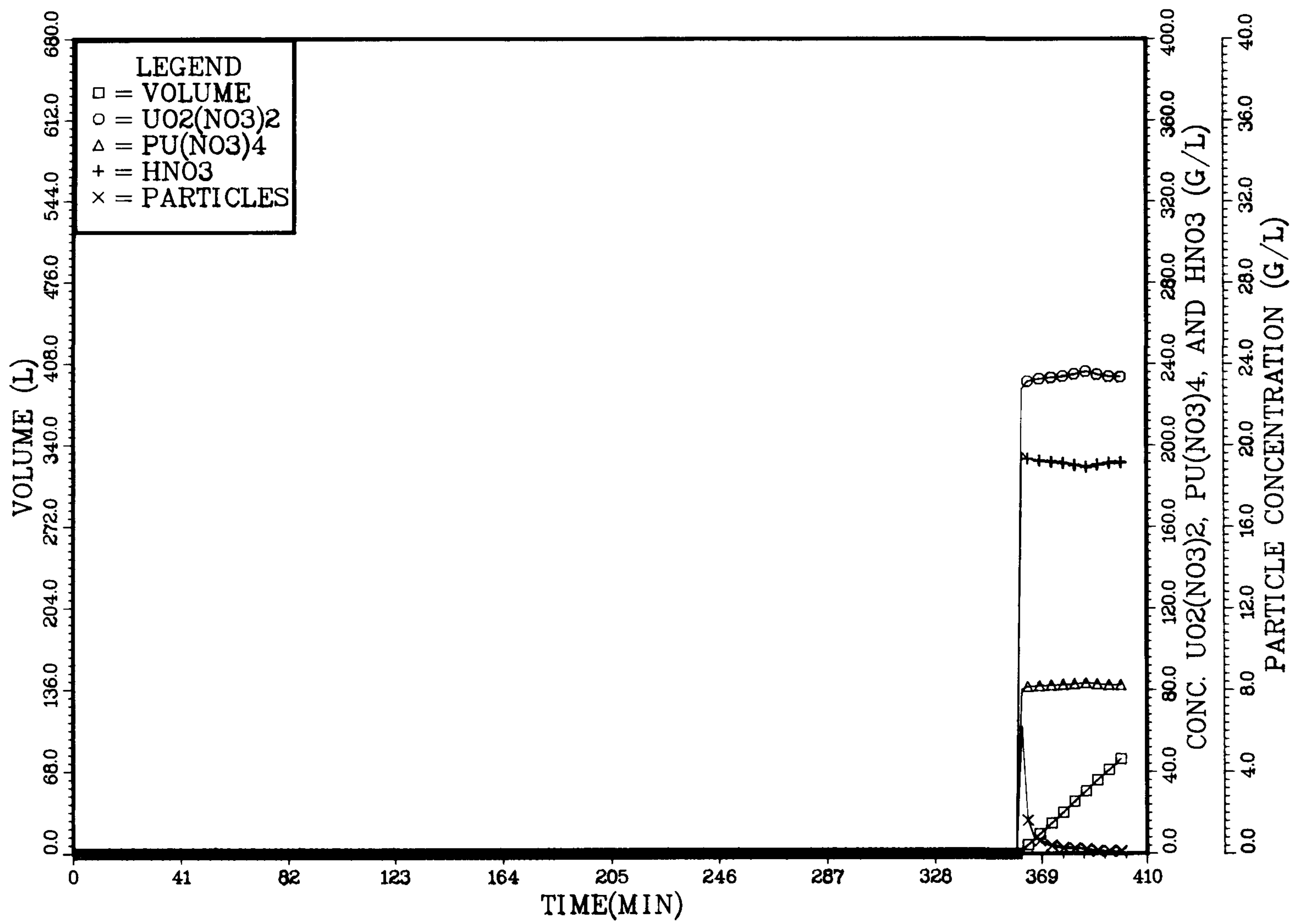


Fig. B.24. Digester tank no. 2 history

# APPENDIX C

## Code Output for Intermittent Solids Feed

The following types of output are the same as those given in Appendix B, however, the intermittent solids feed option was employed. A solids feed cycle of 40 min on and 140 min off was used in this run. All other conditions were at their standard values. An index of the tables and figures containing the intermittent solids feed data output is given in Table C.1.

**Table C.1. Index of tables and figures contained in this appendix**

| Location | Type of output |
|---|---|
| Table C 2 | Summary of input data |
| Table C 3 | Uranium/plutonium material balance closure |
| Table C 4 | Stagewise data for concentrations, volume, density, and flow rates |
| Table C 5 | Stagewise particle size distribution data |
| Table C.6 | Run summary data |
| Figs C 1–C 9 | Stagewise concentration profiles |
| Figs C 10–C 12 | Stagewise particle size distribution |
| Figs. C 13–C 21 | Concentration histories |
| Figs C 22–C 23 | Digester tank concentration profiles |

**Table C.2. Summary of input data**

```
                  SPENT FUEL DATA
COMPONENT      WEIGHT FRACTION     DENSITY      MOLE WEIGHT
                                   (G/CC)       (G/G-MOLE)
  UO2              0.7370          8.300000      270.0500
  PUO2             0.2110         11.460000      271.1700
  F.P.             0.0520         12.100000      135.3400

AVERAGE FUEL DENSITY =     9.903000  G/CC
AVERAGE DIAMETER OF PARTICULATE=    0.001000  CM
TOTAL # FUEL PINS=    12947.21
DIAMETER OF FUEL PELLET=       0.4903  CM
LENGTH OF FUEL PIN=       2.5400  CM
RATIO OF ACTUAL SURFACE AREA TO GEOMETRIC AREA=      1.00000D 00
FRACTION OF FUEL AS FINES=     2.000D-01
FULL STAGE PARTICLE RELEASE RATE=     1.00000D 02  G/MIN
TOTAL MASS FEED RATE OF STAINLESS STEEL=          12.05  KG/HR

    0.5000     TONNE-A-DAY THROUGHPUT
FUEL FEED RATE=   1921.5000  G/MIN

LIQUID FLOW STG 1=       1.7891  L/MIN
LIQUID FEED COMP. STG 1 :
            HNO3     ---       383.98  GRAM/L
            H2O      ---       805.60  GRAM/L
INITIAL DENSITY OF DISSOLVER LIQUID STG 1=      1152.5684  G/L
COEFFICIENT OF WEIR FLOW EQUATION=       9.8880D-01
EXPONENT OF WEIR FLOW EQUATION=       2.8300D 00
LIMITING HEIGHT OVER WEIR (SLOT SIZE)=        3.8100D 00  CM


STAGE 1 INITIAL VOLUME=          6.43  L
STAGES 2- 8 INITIAL VOLUME=          9.95  L
STAGE 9 INITIAL VOLUME=          9.33  L
NUMBER OF STAGES=   9
MAXIMUM TIME INCREMENT=    0.020000  MIN


              INITIAL REACTION RATE CONSTANTS
COMPONENT       PARTICULATE RATE       PIN RATE
  FORMED          (G/MIN-CM**2)     (G/MIN-CM**2)

UO2(NO3)2           7.37934D-02       7.37934D-02
 PU(NO3)4           2.11268D-02       2.11268D-02
F.P. NIT.           5.20659D-03       5.20659D-03

REACTION RATE CONSTANT=    1.83123D-04   (GRAM/(CM**2*MIN*(MOL/L)**(2+2*XPU))
REACTION RATE EXPONENT=    2.59780D 00
PERCENT THEORITICAL DENSITY=   10.7123D 01
INITIAL TEMPERATURE=   108.0000 00  DEG C
MINIMUM PARTICLE DIAMETER TRANSFERING WITH FUEL PINS=      2.0000D 02   MICRON
MINIMUM PARTICLE SIZE IN DISTRIBUTION=       0.0          MICRON
MAXIMUM PARTICLE SIZE IN DISTRIBUTION=       1.0000D 03   MICRON
TOTAL # OF PARTICLE SIZE GROUPS=     20
FLAPPER VALVE CYCLE TIME=  0.0          MIN


TOTAL RUN TIME=       400.00  MIN
CYCLE TIME STG 1=         0.00  MIN
STAGES 2- 9  CYCLE TIME=        32.00  MIN
REVERSE CYCLE TIME         2.00  MIN
RATE OF ROTATION=        3.00  RPM
FEED TIME FROM SHEAR=        4.0000D 01  MIN
ZERO FEED TIME=        1.4000D 02  MIN


ACID DEFICIENT CONCENTRATION FLAG=        3.1500D 01  G-HNO3/L
REACTION RATE MULTIPLICATION FACTOR=        5.0000D 00

ACID FEED RATE INCREASE ANTICIPATION TIME=         0.0          MIN
ACID FEED RATE REDUCTION ANTICIPATION TIME=         0.0          MIN
REDUCED ACID FEED RATE DENSITY=        1.3000D 03  G/L
REDUCED ACID FEED H2O FLOW=        4.7450D 01  KG/HR
REDUCED ACID FEED HNO3 FLOW=        4.0080D 01  KG/HR
```

**Table C.2 (continued)**

EXTERNAL FEED STREAMS MASS FLOW RATES

| COMPONENT | DENSITY (G/L) | FLOW (KG/HR) | CONCENTRATION (G/L) |
|---|---|---|---|
| FEED HNO3 TO STAGE 8 | | 40.08 | 595.27 |
| FEED H2O TO STAGE 8 | | 47.45 | 704.73 |
| TOTAL FEED TO STAGE 8 | 1300.00 | 87.53 | |
| CONDENSATE HNO3 TO STAGE 1 | | 0.0 | 0.0 |
| CONDENSATE H2O TO STAGE 1 | | 2.67 | 951.00 |
| TOTAL CONDENSATE TO STAGE 1 | 951.00 | 2.67 | |
| CONDENSATE HNO3 TO STAGE 9 | | 0.0 | 0.0 |
| CONDENSATE H2O TO STAGE 9 | | 1.33 | 951.00 |
| TOTAL CONDENSATE TO STAGE 9 | 951.00 | 1.33 | |
| RINSE HNO3 TO STAGE 9 | | 1.14 | 0.0 |
| RINSE H2O TO STAGE 9 | | 35.03 | 978.17 |
| TOTAL RINSE LIQUID TO STAGE 9 | 1010.00 | 36.17 | |

*** BACKMIXING DATA ***

| STAGE # | PERIODIC BACKMIXING WITH HULLS TRANSFER (G SOLN / G HULLS) | CONTINUOUS BACKMIXING (L/MIN) | MAXIMUM QUANTITY BACKMIXED (L) | INITIAL STAGE VOLUME (L) |
|---|---|---|---|---|
| 1 | 7.00000D-02 | 0.0 | 1.7564D 00 | 6.4334D 00 |
| 2 | 7.00000D-02 | 0.0 | 1.7494D 00 | 9.9473D 00 |
| 3 | 7.00000D-02 | 0.0 | 1.7494D 00 | 9.9473D 00 |
| 4 | 7.00000D-02 | 0.0 | 1.7494D 00 | 9.9473D 00 |
| 5 | 7.00000D-02 | 0.0 | 1.7494D 00 | 9.9473D 00 |
| 6 | 7.00000D-02 | 0.0 | 1.7494D 00 | 9.9473D 00 |
| 7 | 7.00000D-02 | 0.0 | 1.7494D 00 | 9.9473D 00 |
| 8 | 7.00000D-02 | 0.0 | 1.7494D 00 | 9.9473D 00 |
| 9 | 7.00000D-02 | 0.0 | 2.0526D 00 | 9.3269D 00 |

*** PLOTS REQUESTED ***

DIGESTER CONCENTRATION PROFILES
PARTICLE SIZE DISRTIBUTIONS
CONCENTRATION HISTORIES
CONCENTRATION PROFILES

## Table C.3. Uranium/plutonium material balance closure

| TIME | U(OUT) | PU(OUT) | U(FED) | PU(FED) | U(OUT)-U(FED) | PU(OUT)-PU(FED) |
|---|---|---|---|---|---|---|
| 3.47783D 02 | 9.96192D 04 | 2.85378D 04 | 0.0 | 0.0 | 9.96192D 04 | 2.85378D 04 |

TIME INTO RUN= 348.0032 MIN
DISSOLUTION OF LOOSE FUEL PARTICLES COMPLETED IN STAGE 5 AFTER 28.0032 MINUTES INTO CYCLE.
THIS IS THE 6 FUEL DISSAPPEARANCE CYCLE.

| TIME | U(OUT) | PU(OUT) | U(FED) | PU(FED) | U(OUT)-U(FED) | PU(OUT)-PU(FED) |
|---|---|---|---|---|---|---|
| 3.48803D 02 | 9.96188D 04 | 2.85377D 04 | 0.0 | 0.0 | 9.96188D 04 | 2.85377D 04 |

TIME INTO RUN= 348.8232 MIN
DISSOLUTION OF LOOSE FUEL PARTICLES COMPLETED IN STAGE 3 AFTER 28.8232 MINUTES INTO CYCLE.
THIS IS THE 7 FUEL DISSAPPEARANCE CYCLE.

TIME INTO RUN= 349.2432 MIN
DISSOLUTION OF LOOSE FUEL PARTICLES COMPLETED IN STAGE 2 AFTER 29.2432 MINUTES INTO CYCLE.
THIS IS THE 8 FUEL DISSAPPEARANCE CYCLE.

TIME INTO RUN= 349.5832 MIN
DISSOLUTION OF LOOSE FUEL PARTICLES COMPLETED IN STAGE 1 AFTER 29.5832 MINUTES INTO CYCLE.
THIS IS THE 9 FUEL DISSAPPEARANCE CYCLE.

| TIME | U(OUT) | PU(OUT) | U(FED) | PU(FED) | U(OUT)-U(FED) | PU(OUT)-PU(FED) |
|---|---|---|---|---|---|---|
| 3.49823D 02 | 9.96184D 04 | 2.85376D 04 | 0.0 | 0.0 | 9.96184D 04 | 2.85376D 04 |
| 3.50843D 02 | 9.96180D 04 | 2.85375D 04 | 0.0 | 0.0 | 9.96180D 04 | 2.85375D 04 |
| 3.51863D 02 | 9.96177D 04 | 2.85374D 04 | 0.0 | 0.0 | 9.96177D 04 | 2.85374D 04 |
| 3.52883D 02 | 9.96193D 04 | 2.85379D 04 | 0.0 | 0.0 | 9.96193D 04 | 2.85379D 04 |
| 3.53903D 02 | 9.96189D 04 | 2.85378D 04 | 0.0 | 0.0 | 9.96189D 04 | 2.85378D 04 |
| 3.54923D 02 | 9.96186D 04 | 2.85376D 04 | 0.0 | 0.0 | 9.96186D 04 | 2.85376D 04 |
| 3.55943D 02 | 9.96182D 04 | 2.85375D 04 | 0.0 | 0.0 | 9.96182D 04 | 2.85375D 04 |
| 3.56963D 02 | 9.96179D 04 | 2.85375D 04 | 0.0 | 0.0 | 9.96179D 04 | 2.85375D 04 |
| 3.57983D 02 | 9.96176D 04 | 2.85374D 04 | 0.0 | 0.0 | 9.96176D 04 | 2.85374D 04 |

## Table C.3 (continued)

| TIME | U(OUT) | PU(OUT) | U(FED) | PU(FED) | U(OUT)-U(FED) | PU(OUT)-PU(FED) |
|---|---|---|---|---|---|---|
| 3.59003D 02 | 9.96173D 04 | 2.85373D 04 | 0.0 | 0.0 | 9.96173D 04 | 2.85373D 04 |
| TIME | U(OUT) | PU(OUT) | U(FED) | PU(FED) | U(OUT)-U(FED) | PU(OUT)-PU(FED) |
| 3.60023D 02 | 9.96670D 04 | 2.85515D 04 | 4.49412D 05 | 1.28743D 05 | -3.49744D 05 | -1.00191D 05 |
| TIME | U(OUT) | PU(OUT) | U(FED) | PU(FED) | U(OUT)-U(FED) | PU(OUT)-PU(FED) |
| 3.61043D 02 | 1.00940D 05 | 2.89161D 04 | 4.50685D 05 | 1.29107D 05 | -3.49745D 05 | -1.00191D 05 |
| TIME | U(OUT) | PU(OUT) | U(FED) | PU(FED) | U(OUT)-U(FED) | PU(OUT)-PU(FED) |
| 3.62063D 02 | 1.02211D 05 | 2.92802D 04 | 4.51958D 05 | 1.29472D 05 | -3.49747D 05 | -1.00192D 05 |
| TIME | U(OUT) | PU(OUT) | U(FED) | PU(FED) | U(OUT)-U(FED) | PU(OUT)-PU(FED) |
| 3.63083D 02 | 1.03480D 05 | 2.96440D 04 | 4.53231D 05 | 1.29837D 05 | -3.49751D 05 | -1.00193D 05 |
| TIME | U(OUT) | PU(OUT) | U(FED) | PU(FED) | U(OUT)-U(FED) | PU(OUT)-PU(FED) |
| 3.64103D 02 | 1.04750D 05 | 3.00075D 04 | 4.54505D 05 | 1.30202D 05 | -3.49755D 05 | -1.00194D 05 |
| TIME | U(OUT) | PU(OUT) | U(FED) | PU(FED) | U(OUT)-U(FED) | PU(OUT)-PU(FED) |
| 3.65123D 02 | 1.06018D 05 | 3.03708D 04 | 4.55778D 05 | 1.30566D 05 | -3.49760D 05 | -1.00195D 05 |
| TIME | U(OUT) | PU(OUT) | U(FED) | PU(FED) | U(OUT)-U(FED) | PU(OUT)-PU(FED) |
| 3.66143D 02 | 1.07285D 05 | 3.07340D 04 | 4.57051D 05 | 1.30931D 05 | -3.49766D 05 | -1.00197D 05 |
| TIME | U(OUT) | PU(OUT) | U(FED) | PU(FED) | U(OUT)-U(FED) | PU(OUT)-PU(FED) |
| 3.67163D 02 | 1.08552D 05 | 3.10969D 04 | 4.58324D 05 | 1.31296D 05 | -3.49772D 05 | -1.00199D 05 |
| TIME | U(OUT) | PU(OUT) | U(FED) | PU(FED) | U(OUT)-U(FED) | PU(OUT)-PU(FED) |
| 3.68183D 02 | 1.09819D 05 | 3.14596D 04 | 4.59598D 05 | 1.31661D 05 | -3.49779D 05 | -1.00201D 05 |
| TIME | U(OUT) | PU(OUT) | U(FED) | PU(FED) | U(OUT)-U(FED) | PU(OUT)-PU(FED) |
| 3.69203D 02 | 1.11084D 05 | 3.18221D 04 | 4.60871D 05 | 1.32025D 05 | -3.49787D 05 | -1.00203D 05 |
| TIME | U(OUT) | PU(OUT) | U(FED) | PU(FED) | U(OUT)-U(FED) | PU(OUT)-PU(FED) |
| 3.70223D 02 | 1.12349D 05 | 3.21844D 04 | 4.62144D 05 | 1.32390D 05 | -3.49795D 05 | -1.00206D 05 |
| TIME | U(OUT) | PU(OUT) | U(FED) | PU(FED) | U(OUT)-U(FED) | PU(OUT)-PU(FED) |
| 3.71243D 02 | 1.13612D 05 | 3.25464D 04 | 4.63417D 05 | 1.32755D 05 | -3.49805D 05 | -1.00208D 05 |
| TIME | U(OUT) | PU(OUT) | U(FED) | PU(FED) | U(OUT)-U(FED) | PU(OUT)-PU(FED) |
| 3.72263D 02 | 1.14875D 05 | 3.29082D 04 | 4.64691D 05 | 1.33120D 05 | -3.49815D 05 | -1.00211D 05 |
| TIME | U(OUT) | PU(OUT) | U(FED) | PU(FED) | U(OUT)-U(FED) | PU(OUT)-PU(FED) |
| 3.73283D 02 | 1.16137D 05 | 3.32697D 04 | 4.65964D 05 | 1.33484D 05 | -3.49827D 05 | -1.00215D 05 |
| TIME | U(OUT) | PU(OUT) | U(FED) | PU(FED) | U(OUT)-U(FED) | PU(OUT)-PU(FED) |
| 3.74303D 02 | 1.17398D 05 | 3.36309D 04 | 4.67237D 05 | 1.33849D 05 | -3.49839D 05 | -1.00218D 05 |
| TIME | U(OUT) | PU(OUT) | U(FED) | PU(FED) | U(OUT)-U(FED) | PU(OUT)-PU(FED) |
| 3.75323D 02 | 1.18658D 05 | 3.39918D 04 | 4.68510D 05 | 1.34214D 05 | -3.49852D 05 | -1.00222D 05 |
| TIME | U(OUT) | PU(OUT) | U(FED) | PU(FED) | U(OUT)-U(FED) | PU(OUT)-PU(FED) |
| 3.76343D 02 | 1.19917D 05 | 3.43525D 04 | 4.69784D 05 | 1.34578D 05 | -3.49867D 05 | -1.00226D 05 |

## Table C.3 (continued)

| TIME | U(OUT) | PU(OUT) | U(FED) | PU(FED) | U(OUT)-U(FED) | PU(OUT)-PU(FED) |
|---|---|---|---|---|---|---|
| 3.77363D 02 | 1.21174D 05 | 3.47127D 04 | 4.71057D 05 | 1.34943D 05 | -3.49883D 05 | -1.00231D 05 |
| 3.78383D 02 | 1.22431D 05 | 3.50727D 04 | 4.72330D 05 | 1.35308D 05 | -3.49899D 05 | -1.00235D 05 |
| 3.79403D 02 | 1.23685D 05 | 3.54321D 04 | 4.73603D 05 | 1.35673D 05 | -3.49918D 05 | -1.00241D 05 |
| 3.80423D 02 | 1.24939D 05 | 3.57913D 04 | 4.74877D 05 | 1.36037D 05 | -3.49937D 05 | -1.00246D 05 |
| 3.81443D 02 | 1.26191D 05 | 3.61498D 04 | 4.76150D 05 | 1.36402D 05 | -3.49959D 05 | -1.00252D 05 |
| 3.82463D 02 | 1.27441D 05 | 3.65080D 04 | 4.77423D 05 | 1.36767D 05 | -3.49982D 05 | -1.00259D 05 |
| 3.83483D 02 | 1.28689D 05 | 3.68655D 04 | 4.78696D 05 | 1.37132D 05 | -3.50007D 05 | -1.00266D 05 |
| 3.84503D 02 | 1.29926D 05 | 3.72198D 04 | 4.79970D 05 | 1.37496D 05 | -3.50044D 05 | -1.00277D 05 |
| 3.85523D 02 | 1.31184D 05 | 3.75800D 04 | 4.81243D 05 | 1.37861D 05 | -3.50059D 05 | -1.00281D 05 |
| 3.86543D 02 | 1.32456D 05 | 3.79446D 04 | 4.82516D 05 | 1.38226D 05 | -3.50060D 05 | -1.00281D 05 |
| 3.87563D 02 | 1.33723D 05 | 3.83076D 04 | 4.83789D 05 | 1.38591D 05 | -3.50066D 05 | -1.00283D 05 |
| 3.88583D 02 | 1.34988D 05 | 3.86700D 04 | 4.85063D 05 | 1.38955D 05 | -3.50074D 05 | -1.00285D 05 |
| 3.89603D 02 | 1.36253D 05 | 3.90322D 04 | 4.86336D 05 | 1.39320D 05 | -3.50083D 05 | -1.00288D 05 |
| 3.90623D 02 | 1.37516D 05 | 3.93942D 04 | 4.87609D 05 | 1.39685D 05 | -3.50093D 05 | -1.00291D 05 |
| 3.91643D 02 | 1.38778D 05 | 3.97556D 04 | 4.88882D 05 | 1.40050D 05 | -3.50104D 05 | -1.00294D 05 |
| 3.92663D 02 | 1.40039D 05 | 4.01169D 04 | 4.90156D 05 | 1.40414D 05 | -3.50116D 05 | -1.00298D 05 |
| 3.93683D 02 | 1.41299D 05 | 4.04779D 04 | 4.91429D 05 | 1.40779D 05 | -3.50129D 05 | -1.00301D 05 |

## Table C.3 (continued)

| TIME | U(OUT) | PU(OUT) | U(FED) | PU(FED) | U(OUT)-U(FED) | PU(OUT)-PU(FED) |
|---|---|---|---|---|---|---|
| 3.94703D 02 | 1.42557D 05 | 4.08381D 04 | 4.92702D 05 | 1.41144D 05 | -3.50145D 05 | -1.00306D 05 |
| 3.95723D 02 | 1.43811D 05 | 4.11973D 04 | 4.93975D 05 | 1.41509D 05 | -3.50165D 05 | -1.00311D 05 |
| 3.96743D 02 | 1.45064D 05 | 4.15562D 04 | 4.95249D 05 | 1.41873D 05 | -3.50185D 05 | -1.00317D 05 |
| 3.97763D 02 | 1.46314D 05 | 4.19145D 04 | 4.96522D 05 | 1.42238D 05 | -3.50208D 05 | -1.00324D 05 |
| 3.98783D 02 | 1.47561D 05 | 4.22718D 04 | 4.97795D 05 | 1.42603D 05 | -3.50234D 05 | -1.00331D 05 |
| 3.99803D 02 | 1.48806D 05 | 4.26283D 04 | 4.99068D 05 | 1.42968D 05 | -3.50262D 05 | -1.00339D 05 |

## Table C.4. Stagewise data for concentrations, volume, density, and flow rates

TIME INTO RUN : 400.0032 MIN

*** STAGEWISE PROFILES ***

| COMPONENT | STG 1 | STG 2 | STG 3 | STG 4 | STG 5 | STG 6 | STG 7 | STG 8 | STG 9 |
|---|---|---|---|---|---|---|---|---|---|
| | CONCENTRATION OF COMPONENTS DISSOLVED IN LIQUID (G/L) | | | | | | | | |
| UO2(NO3)2 | 3.270D 02 | 2.831D 02 | 1.908D 02 | 5.161D-02 | 6.192D-03 | 3.288D-04 | 2.367D-06 | 8.831D-08 | 7.974D-16 |
| PU(NO3)4 | 1.153D 02 | 9.980D 01 | 6.727D 01 | 1.820D-02 | 2.183D-03 | 1.159D-04 | 8.345D-07 | 3.113D-08 | 2.811D-16 |
| FP(NO3)3.39 | 3.835D 01 | 3.320D 01 | 2.238D 01 | 6.053D-03 | 7.262D-04 | 3.856D-05 | 2.776D-07 | 1.036D-08 | 9.351D-17 |
| HNO3 | 1.151D 02 | 1.557D 02 | 2.275D 02 | 3.801D 02 | 3.829D 02 | 3.877D 02 | 3.905D 02 | 3.872D 02 | 3.744D 01 |
| H2O | 7.450D 02 | 7.468D 02 | 7.573D 02 | 7.764D 02 | 7.750D 02 | 7.725D 02 | 7.711D 02 | 7.729D 02 | 9.525D 02 |
| | CONCENTRATION OF SUSPENDED FINES (G/L) | | | | | | | | |
| UO2 | 3.177D 01 | 1.345D 02 | 2.442D 01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PUO2 | 9.096D 00 | 3.850D 01 | 6.992D 00 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| F.P. | 2.242D 00 | 9.488D 00 | 1.723D 00 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL | 4.311D 01 | 1.825D 02 | 3.314D 01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | QUANTITY UNDISSOLVED IN FUEL PINS (G) | | | | | | | | |
| UO2 | 0.0 | 1.725D 04 | 1.971D 04 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PUO2 | 0.0 | 4.937D 03 | 5.642D 03 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| F.P. | 0.0 | 1.217D 03 | 1.390D 03 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL | 0.0 | 2.340D 04 | 2.674D 04 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | VOLUME (L) | | | | | | | | |
| TOTAL STAGE | 6.357D 00 | 9.757D 00 | 9.663D 00 | 9.644D 00 | 9.644D 00 | 9.644D 00 | 9.644D 00 | 9.643D 00 | 9.136D 00 |
| LIQUID ONLY | 6.329D 00 | 5.488D 00 | 4.240D 00 | 9.644D 00 | 9.644D 00 | 9.644D 00 | 9.644D 00 | 6.484D 00 | 9.136D 00 |
| STAINLESS | 0.0 | 1.805D 00 | 2.708D 00 | 0.0 | 0.0 | 0.0 | 0.0 | 3.159D 00 | 0.0 |
| | DENSITY (G/L) | | | | | | | | |
| LIQUID | 1.341D 03 | 1.318D 03 | 1.265D 03 | 1.157D 03 | 1.158D 03 | 1.160D 03 | 1.162D 03 | 1.160D 03 | 9.899D 02 |
| | FLOW RATES (L/MIN) | | | | | | | | |
| LIQUID | 2.261D 00 | 2.177D 00 | 1.860D 00 | 1.801D 00 | 1.801D 00 | 1.801D 00 | 1.801D 00 | 1.801D 00 | 6.337D-01 |

## Table C.5. Stagewise particle size distribution data

TIME = 4.000D 02 MIN

*** PARTICLE SIZE DISTRIBUTION PROFILE DATA ***

| GROUP # | STG 1 RADIUS (MICRON) | STG 1 CONC (G/L) | STG 2 RADIUS (MICRON) | STG 2 CONC (G/L) | STG 3 RADIUS (MICRON) | STG 3 CONC (G/L) | STG 4 RADIUS (MICRON) | STG 4 CONC (G/L) | STG 5 RADIUS (MICRON) | STG 5 CONC (G/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.837D 01 | 9.788D 00 | 1.667D 01 | 6.647D-01 | 1.570D 01 | 3.367D-01 | 2.500D 01 | 0.0 | 2.500D 01 | 0.0 |
| 2 | 6.225D 01 | 1.572D 01 | 5.538D 01 | 1.370D 00 | 7.515D 01 | 2.563D 00 | 7.500D 01 | 0.0 | 7.500D 01 | 0.0 |
| 3 | 1.120D 02 | 1.760D 01 | 1.061D 02 | 3.974D 00 | 1.438D 02 | 3.968D 00 | 1.250D 02 | 0.0 | 1.250D 02 | 0.0 |
| 4 | 1.750D 02 | 0.0 | 1.570D 02 | 2.346D 01 | 1.745D 02 | 2.882D-02 | 1.750D 02 | 0.0 | 1.750D 02 | 0.0 |
| 5 | 2.250D 02 | 0.0 | 2.090D 02 | 2.082D 01 | 2.134D 02 | 3.671D 00 | 2.250D 02 | 0.0 | 2.250D 02 | 0.0 |
| 6 | 2.750D 02 | 0.0 | 2.601D 02 | 1.822D 01 | 2.772D 02 | 3.593D 00 | 2.750D 02 | 0.0 | 2.750D 02 | 0.0 |
| 7 | 3.250D 02 | 0.0 | 3.109D 02 | 1.592D 01 | 3.405D 02 | 3.252D 00 | 3.250D 02 | 0.0 | 3.250D 02 | 0.0 |
| 8 | 3.750D 02 | 0.0 | 3.613D 02 | 1.404D 01 | 3.719D 02 | 1.230D-01 | 3.750D 02 | 0.0 | 3.750D 02 | 0.0 |
| 9 | 4.250D 02 | 0.0 | 4.118D 02 | 1.245D 01 | 4.035D 02 | 2.589D 00 | 4.250D 02 | 0.0 | 4.250D 02 | 0.0 |
| 10 | 4.750D 02 | 0.0 | 4.622D 02 | 1.103D 01 | 4.631D 02 | 2.594D 00 | 4.750D 02 | 0.0 | 4.750D 02 | 0.0 |
| 11 | 5.250D 02 | 0.0 | 5.124D 02 | 9.867D 00 | 5.253D 02 | 2.394D 00 | 5.250D 02 | 0.0 | 5.250D 02 | 0.0 |
| 12 | 5.750D 02 | 0.0 | 5.626D 02 | 8.874D 00 | 5.912D 02 | 2.208D 00 | 5.750D 02 | 0.0 | 5.750D 02 | 0.0 |
| 13 | 6.250D 02 | 0.0 | 6.129D 02 | 8.048D 00 | 6.219D 02 | 5.775D-02 | 6.250D 02 | 0.0 | 6.250D 02 | 0.0 |
| 14 | 6.750D 02 | 0.0 | 6.633D 02 | 7.275D 00 | 6.579D 02 | 1.669D 00 | 6.750D 02 | 0.0 | 6.750D 02 | 0.0 |
| 15 | 7.250D 02 | 0.0 | 7.137D 02 | 6.550D 00 | 7.161D 02 | 1.297D 00 | 7.250D 02 | 0.0 | 7.250D 02 | 0.0 |
| 16 | 7.750D 02 | 0.0 | 7.644D 02 | 5.892D 00 | 7.793D 02 | 1.340D 00 | 7.750D 02 | 0.0 | 7.750D 02 | 0.0 |
| 17 | 8.250D 02 | 0.0 | 8.158D 02 | 5.222D 00 | 8.457D 02 | 8.929D-01 | 8.250D 02 | 0.0 | 8.250D 02 | 0.0 |
| 18 | 8.750D 02 | 0.0 | 8.677D 02 | 4.418D 00 | 8.750D 02 | 0.0 | 8.750D 02 | 0.0 | 8.750D 02 | 0.0 |
| 19 | 9.250D 02 | 0.0 | 9.190D 02 | 3.167D 00 | 9.106D 02 | 4.171D-01 | 9.250D 02 | 0.0 | 9.250D 02 | 0.0 |
| 20 | 9.750D 02 | 0.0 | 9.629D 02 | 1.218D 00 | 9.592D 02 | 1.405D-01 | 9.750D 02 | 0.0 | 9.750D 02 | 0.0 |

**Table C.6. Run summary data**

APPROXIMATE FLOWS

```
APPROXIMATE U FEED RATE=        2.7740D 02  G/MIN
APPROXIMATE PU FEED RATE=        7.9466D 01  G/MIN
TOTAL U FLOW OUT LIQUID PHASE=        2.8214D 02  G/MIN
TOTAL PU FLOW OUT LIQUID PHASE=        8.0824D 01  G/MIN
TOTAL U FLOW UNDISSOLVED IN FUEL PINS=        0.0          G/MIN
TOTAL PU FLOW UNDISSOLVED IN FUEL PINS=        0.0          G/MIN
TOTAL U FLOW OUT=        2.8214D 02  G/MIN
TOTAL PU FLOW OUT=        8.0824D 01  G/MIN
```

TOTAL MASS BALANCE

```
TOTAL U FEED=        1.4979D 05  G
TOTAL PU FEED=        4.2911D 04  G
TOTAL U OUT STAGE 1=        1.1286D 05  G
TOTAL PU OUT STAGE 1=        3.2330D 04  G
TOTAL URANIUM FROM RINSE STAGE=        0.0          G
TOTAL PLUTONIUM FROM RINSE STAGE=        0.0          G
TOTAL U UNDISSOLVED IN FUEL PINS=        3.2572D 04  G
TOTAL PU UNDISSOLVED IN FUEL PINS=        9.3308D 03  G
TOTAL U IN PARTICLES UNDISSOLVED=        9.1900D 02  G
TOTAL PU IN PARTICLES UNDISSOLVED=        2.6327D 02  G
TOTAL SUSPENDED PARTICULATE TO DIGESTERS=        6.4025D 03  G
TOTAL U OUT OVER TOTAL RUN=        1.1286D 05  G
TOTAL PU OUT OVER TOTAL RUN=        3.2330D 04  G

TOTAL U DISSOLVED IN LIQUID INVENTORY IN DISSOLVER=        2.6780D 03  (G)
TOTAL PU DISSOLVED IN LIQUID INVENTORY IN DISSOLVER=        7.6715D 02  (G)
CORRECTED SUM OF LIQUID VOLUMES=        0.0          (L)
TOTAL U IN PINS FED TO STAGE 1 FROM FLP=        1.1984D 05  (G)
TOTAL U FINES FED TO STAGE 1 FROM FLP=        2.9959D 04  (G)
TOTAL NUMBER OF PINS REMAINING IN DISSOLVER=        2.7513D 04
TOTAL NUMBER OF PARTICLE SIZE GROUP DEPLETION TRANSFERS=        8.35D 03
```

*** MASS OF PARTICLES DISSOLVED IN EACH STAGE (G) ***

| STG 1 | STG 2 | STG 3 | STG 4 | STG 5 | STG 6 | STG 7 | STG 8 | STG 9 |
|---|---|---|---|---|---|---|---|---|
| 2.170D 04 | 1.887D 04 | 9.337D 03 | 7.699D 03 | 6.334D 03 | 1.879D 03 | 0.0 | 0.0 | 0.0 |

```
PROJECTED URANIUM HOLD-UP IN DISSOLVER=        3.6938D 04  G
PROJECTED PLUTONIUM HOLD-UP IN DISSOLVER=        1.0582D 04  G
PROJECTED TOTAL U OUT PLUS HOLD-UP=        1.4979D 05  G
PROJECTED TOTAL PU OUT PLUS HOLD-UP=        4.2911D 04  G

CORRECTED NEGATIVE SUM OF OVER DISSOLUTION FROM PINS=        -2.0702D 00  G
CORRECTED NEGATIVE SUM OF OVER DISSOLUTION OF PARTICULATE=        -7.4139D 00  G
TOTAL CORRECTED OVER DISSOLUTION=        -9.4841D 00  G
SUM OF HNO3 DEPLETIONS=        0.0          G
```

Table C.6 (continued)

```
TOTAL FUEL IN PINS FED TO STAGE 9=       0.0          G
TOTAL FUEL IN PINS OUT OF STAGE 9=       0.0          G
TOTAL FUEL IN PINS IN STAGE 9=       0.0          G
TOTAL # PINS FED TO STAGE 9=       2.1039D 04
TOTAL # PINS OUT OF STAGE 9=       2.1014D 04
TOTAL # PINS IN STAGE 9=       0.0


ACTUAL U HOLD-UP IN DISSOLVER=       3.6169D 04  G
ACUTAL PU HOLD-UP IN DISSOLVER=       1.0361D 04  G
ACTUAL U OUT PLUS DISSOLVER HOLD-UP=       1.4902D 05  G
ACTUAL PU OUT PLUS DISSOLVER HOLD-UP=       4.2691D 04  G
ACTUAL U HOLD-UP IN FLAPPER VALVES=       0.0          G
% DIFF BETWEEN ACTUAL U FED AND U OUT PLUS HOLD-UP=       5.1377D-01  %
% DIFF BETWEEN ACTUAL PU FED AND PU OUT PLUS HOLD-UP=       5.1377D-01  %


U OUT OVER U FED PLUS HOLD-UP=       9.9486D 01  %
PU OUT OVER PU FED PLUS HOLD-UP=       9.9486D 01  %
% OF TOTAL U FEED IN FLAPPER VALVE HOLD-UP=       0.0          %


TOTAL U FED TO FLAPPER VALVES=       1.4979D 05  G
TOTAL PU FED TO FLAPPER VALVES=       4.2911D 04  G
TOTAL U PLUS PU FED TO FLAPPER VALVES=       1.9271D 05  G
TOTAL U PLUS PU FED TO STAGE 1 FROM FLAPPER VALVES=       1.9271D 05  G
PER CENT TRANSFER THRU FLAPPER VALVES=       1.0000D 02%

NUMBER OF TIME STEPS WITH ACID DEFICIENT COND.=       0
```

*** MAXIMUM PREDICTED CONCENTRATIONS (G/L) ***

| COMPONENT/TIME (MIN) | STG 1 | STG 2 | STG 3 | STG 4 | STG 5 | STG 6 | STG 7 | STG 8 | STG 9 |
|---|---|---|---|---|---|---|---|---|---|
| UO2(NO3)2 | 3.292D 02 | 3.201D 02 | 3.100D 02 | 2.557D 02 | 2.230D 02 | 2.089D 02 | 3.686D-01 | 7.282D-06 | 7.058D-12 |
| TIME | 2.205D 02 | 2.240D 02 | 2.560D 02 | 1.281D 02 | 1.280D 02 | 1.328D 02 | 3.520D 02 | 3.840D 02 | 2.560D 02 |
| PU(NO3)4 | 1.160D 02 | 1.129D 02 | 1.093D 02 | 9.016D 01 | 7.863D 01 | 7.364D 01 | 1.299D-01 | 2.567D-06 | 2.488D-12 |
| TIME | 2.205D 02 | 2.240D 02 | 2.560D 02 | 1.281D 02 | 1.280D 02 | 1.328D 02 | 3.520D 02 | 3.840D 02 | 2.560D 02 |
| FP(NO3)1.18 | 3.860D 01 | 3.754D 01 | 3.636D 01 | 2.999D 01 | 2.615D 01 | 2.450D 01 | 4.322D-02 | 8.540D-07 | 8.277D-13 |
| TIME | 2.205D 02 | 2.240D 02 | 2.560D 02 | 1.281D 02 | 1.280D 02 | 1.328D 02 | 3.520D 02 | 3.840D 02 | 2.560D 02 |
| HNO3 | 3.733D 02 | 3.816D 02 | 3.891D 02 | 3.819D 02 | 3.937D 02 | 4.241D 02 | 4.320D 02 | 4.329D 02 | 9.245D 01 |
| TIME | 2.000D-02 | 2.000D-02 | 1.921D 02 | 2.241D 02 | 2.515D 02 | 1.600D 02 | 1.920D 02 | 2.318D 02 | 2.241D 02 |
| H2O | 7.830D 02 | 1.091D 03 | 9.511D 02 | 8.923D 02 | 8.603D 02 | 8.774D 02 | 8.784D 02 | 8.809D 02 | 9.934D 02 |
| TIME | 2.000D-02 | 3.204D 01 | 6.404D 01 | 9.604D 01 | 1.280D 02 | 1.600D 02 | 1.920D 02 | 2.240D 02 | 2.241D 02 |

## Table C.6 (continued)

```
NUMBER OF TIME STEP REDUCTIONS=        7

MAXIMUM # ITERATIONS IN PARTIC=        1
MAXIMUM # ITERATIONS IN SUBUN=         3
MAXIMUM # ITERATIONS IN SUBPN=         3
MAXIMUM # ITERATIONS IN SUBFP=         3
MAXIMUM # ITERATIONS IN SUBHN=         4
MAXIMUM # ITERATIONS IN SUBH2=         3

NEGATIVE SUM OF OVER DISSOLUTION OF PARTICLES IN DIGESTER # 1 =      -1.9648D-08  G
NEGATIVE SUM OF OVER DISSOLUTION OF PARTICLES IN DIGESTER # 2 =       0.0         G
```

*** STAGEWISE MASS INVENTORY (G) AFTER 400.00 MINUTES ***

| | STG 1 | STG 2 | STG 3 | STG 4 | STG 5 | STG 6 | STG 7 | STG 8 | STG 9 |
|---|---|---|---|---|---|---|---|---|---|
| URANIUM | 1.428D 03 | 1.679D 04 | 1.795D 04 | 3.007D-01 | 3.608D-02 | 1.916D-03 | 1.379D-05 | 3.459D-07 | 4.401D-15 |
| PLUTONIUM | 4.090D 02 | 4.810D 03 | 5.142D 03 | 8.614D-02 | 1.033D-02 | 5.488D-04 | 3.950D-06 | 9.910D-08 | 1.261D-15 |
| U+PU | 1.837D 03 | 2.160D 04 | 2.309D 04 | 3.868D-01 | 4.641D-02 | 2.465D-03 | 1.774D-05 | 4.450D-07 | 5.662D-15 |
| UO2(NO3)2 | 2.070D 03 | 1.553D 03 | 8.090D 02 | 4.977D-01 | 5.971D-02 | 3.171D-03 | 2.283D-05 | 5.726D-07 | 7.285D-15 |
| PU(NO3)4 | 7.297D 02 | 5.477D 02 | 2.852D 02 | 1.755D-01 | 2.105D-02 | 1.118D-03 | 8.047D-06 | 2.019D-07 | 2.568D-15 |
| FP(NO3)2.36 | 2.427D 02 | 1.822D 02 | 9.488D 01 | 5.837D-02 | 7.003D-03 | 3.719D-04 | 2.677D-06 | 6.715D-08 | 8.544D-16 |
| HNO3 | 7.286D 02 | 8.542D 02 | 9.647D 02 | 3.665D 03 | 3.693D 03 | 3.739D 03 | 3.765D 03 | 2.511D 03 | 3.420D 02 |
| H2O | 4.715D 03 | 4.098D 03 | 3.211D 03 | 7.487D 03 | 7.473D 03 | 7.449D 03 | 7.436D 03 | 5.012D 03 | 8.702D 03 |
| UO2 | 2.011D 02 | 7.380D 02 | 1.035D 02 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PUO2 | 5.757D 01 | 2.113D 02 | 2.964D 01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FP(O)1.1776 | 1.419D 01 | 5.207D 01 | 7.305D 00 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

*** ADDITIONAL CONCENTRATION DATA ***

| | STG 1 | STG 2 | STG 3 | STG 4 | STG 5 | STG 6 | STG 7 | STG 8 | STG 9 |
|---|---|---|---|---|---|---|---|---|---|
| U(G/L)LQ | 1.976D 02 | 1.710D 02 | 1.153D 02 | 3.118D-02 | 3.741D-03 | 1.987D-04 | 1.430D-06 | 5.335D-08 | 4.817D-16 |
| U(G/L)PT | 2.801D 01 | 1.185D 02 | 2.153D 01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| U(G/L)PN | 0.0 | 2.770D 03 | 4.097D 03 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PU(G/L)LQ | 5.660D 01 | 4.899D 01 | 3.302D 01 | 8.933D-03 | 1.072D-03 | 5.691D-05 | 4.096D-07 | 1.528D-08 | 1.380D-16 |
| PU(G/L)PT | 8.023D 00 | 3.396D 01 | 6.167D 00 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PU(G/L)PN | 0.0 | 7.936D 02 | 1.174D 03 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| U+PU(G/L)LQ | 2.542D 02 | 2.200D 02 | 1.483D 02 | 4.011D-02 | 4.813D-03 | 2.556D-04 | 1.840D-06 | 6.863D-08 | 6.197D-16 |
| U+PU(G/L)PT | 3.603D 01 | 1.525D 02 | 2.769D 01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| U+PU(G/L)PN | 0.0 | 3.564D 03 | 5.270D 03 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| HNC3(MOL/L) | 1.827D 00 | 2.470D 00 | 3.610D 00 | 6.031D 00 | 6.076D 00 | 6.152D 00 | 6.196D 00 | 6.144D 00 | 5.941D-01 |

ORNL/DWG. 84-12992

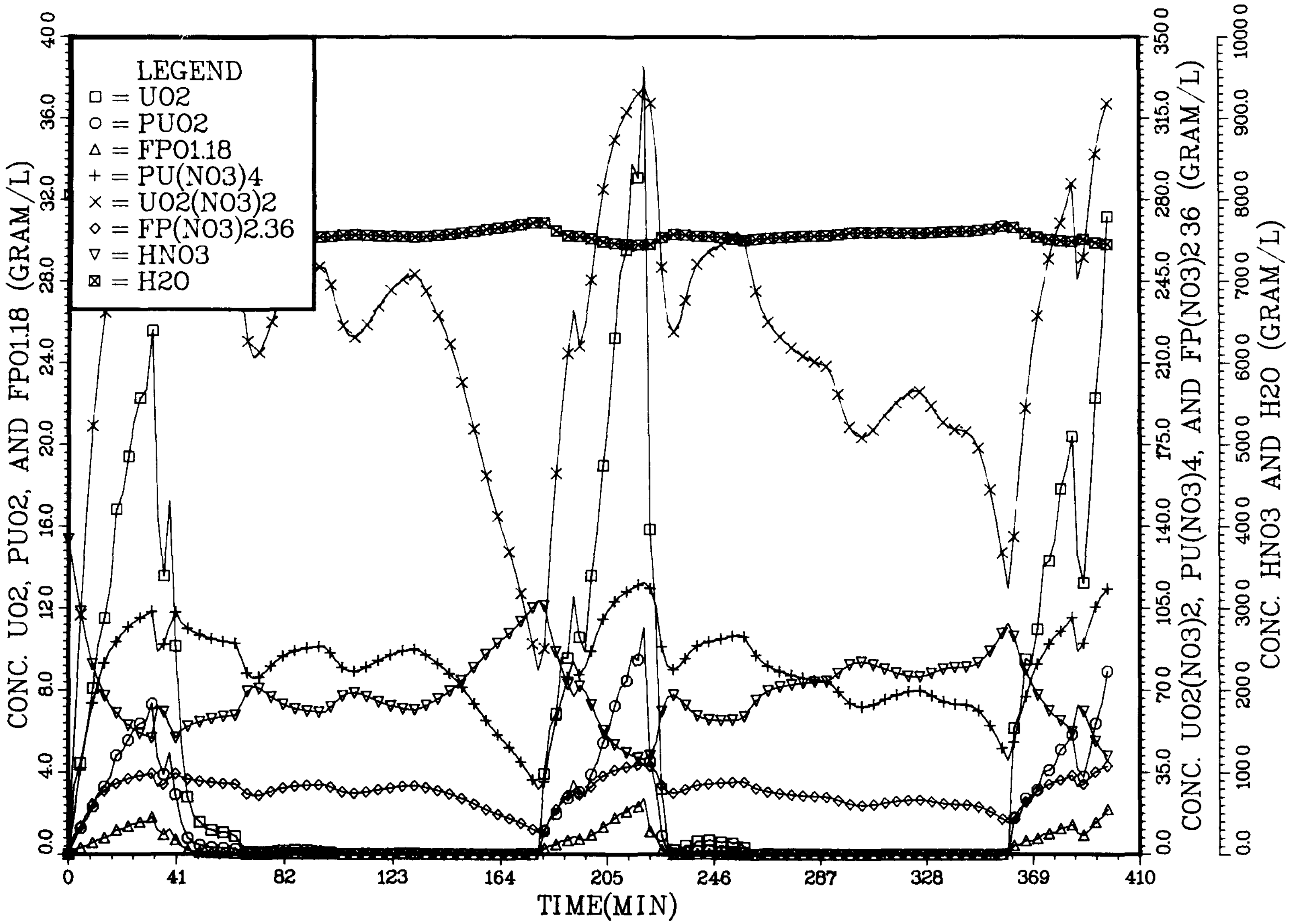


Fig. C.1. Concentration profile for stage 1

ORNL/DWG. 84-12993

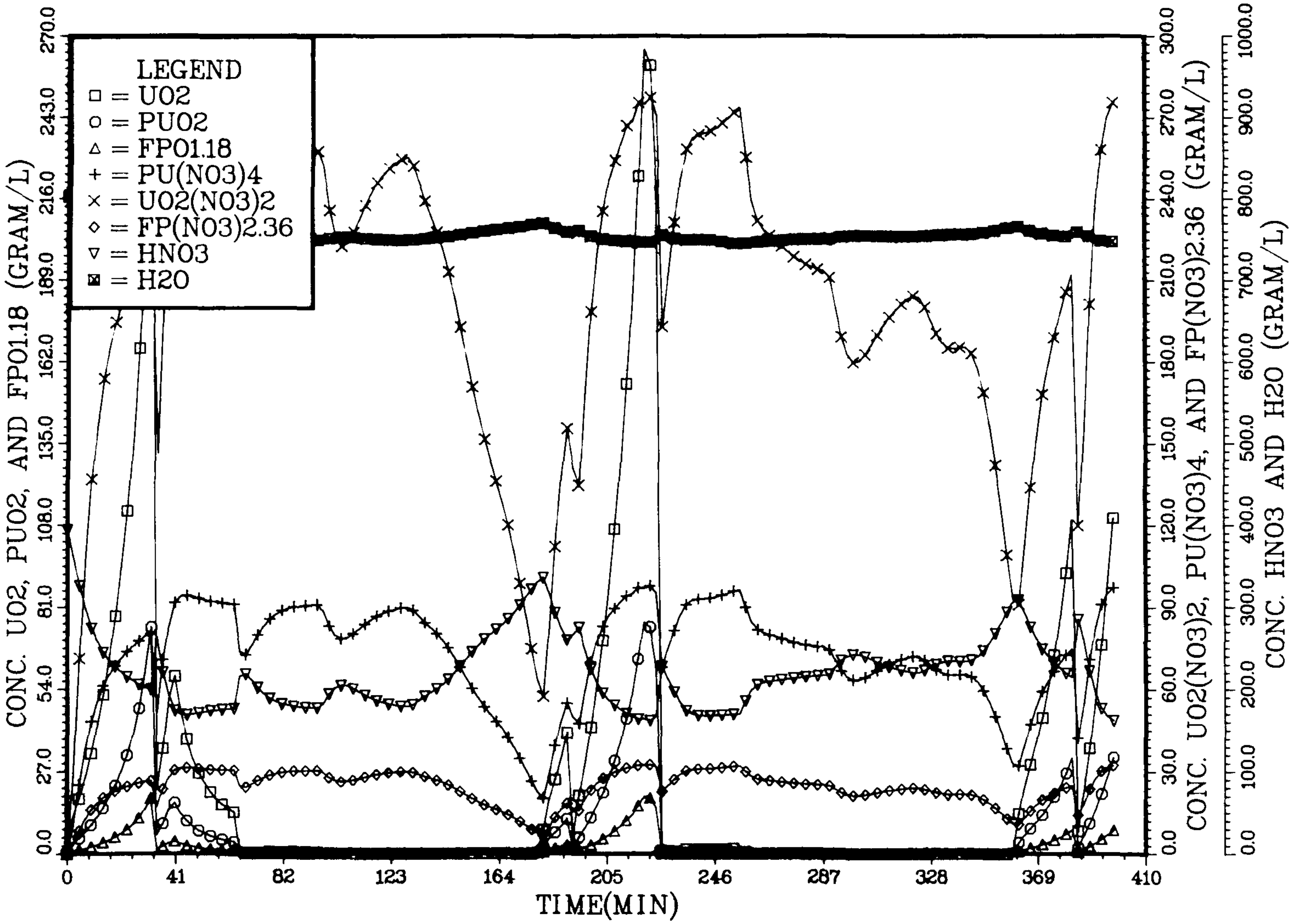


Fig. C.2. Concentration profile for stage 2

ORNL/DWG. 84-12994

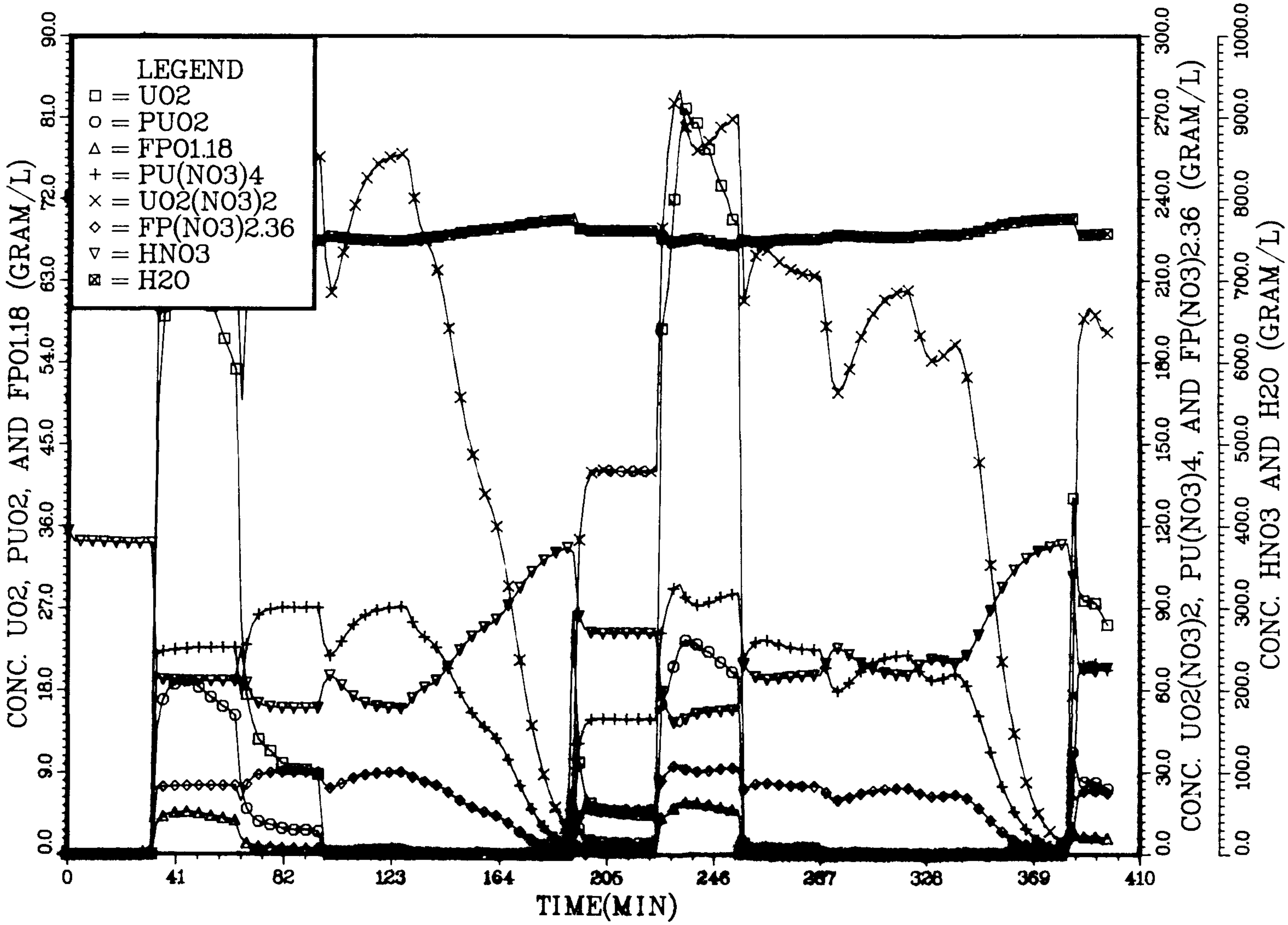


Fig. C.3. Concentration profile for stage 3

ORNL/DWG. 84-12995

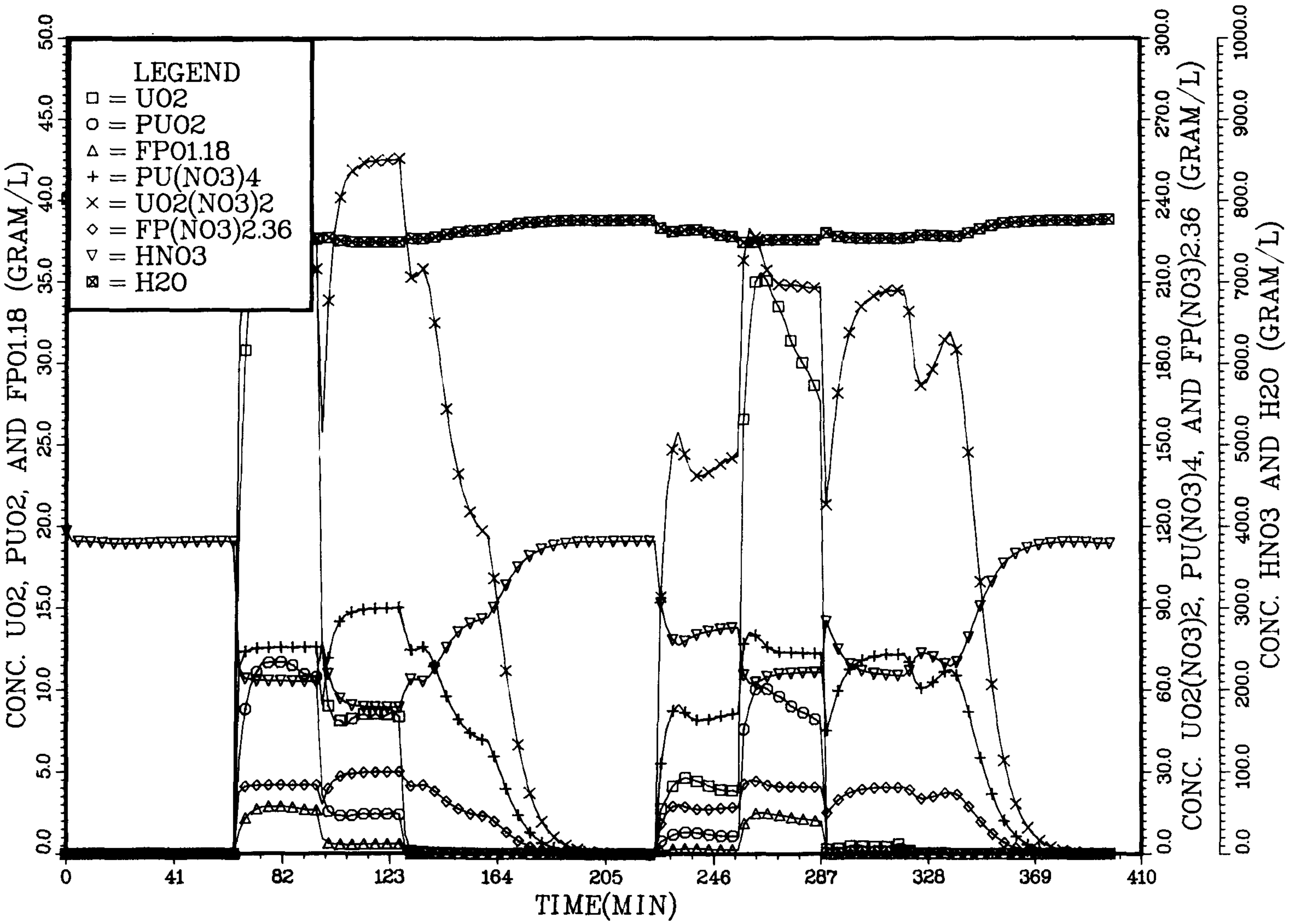


Fig. C.4. Concentration profile for stage 4

ORNL/DWG. 84-12996

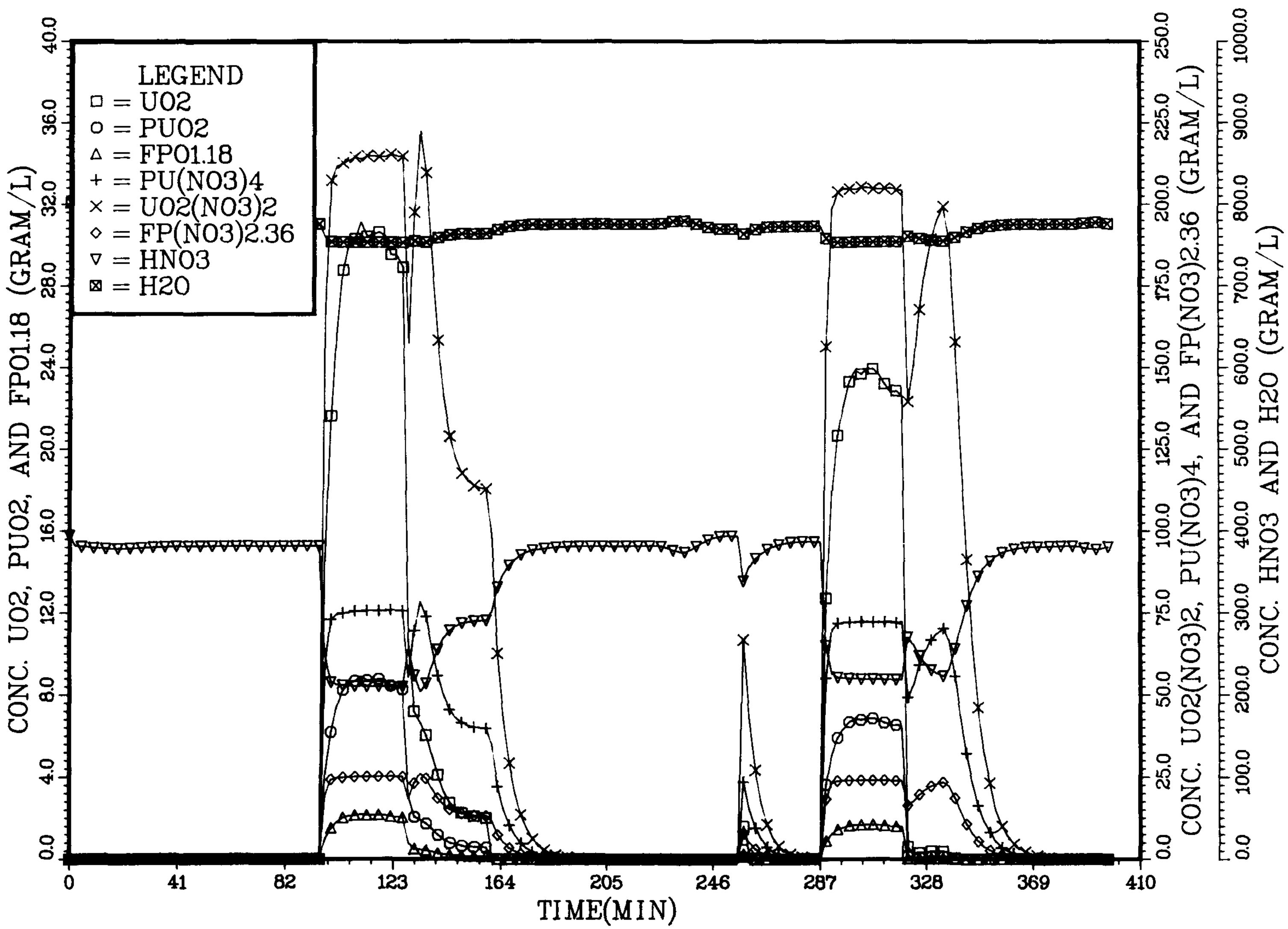


Fig. C.5. Concentration profile for stage 5

ORNL/DWG. 84-12997

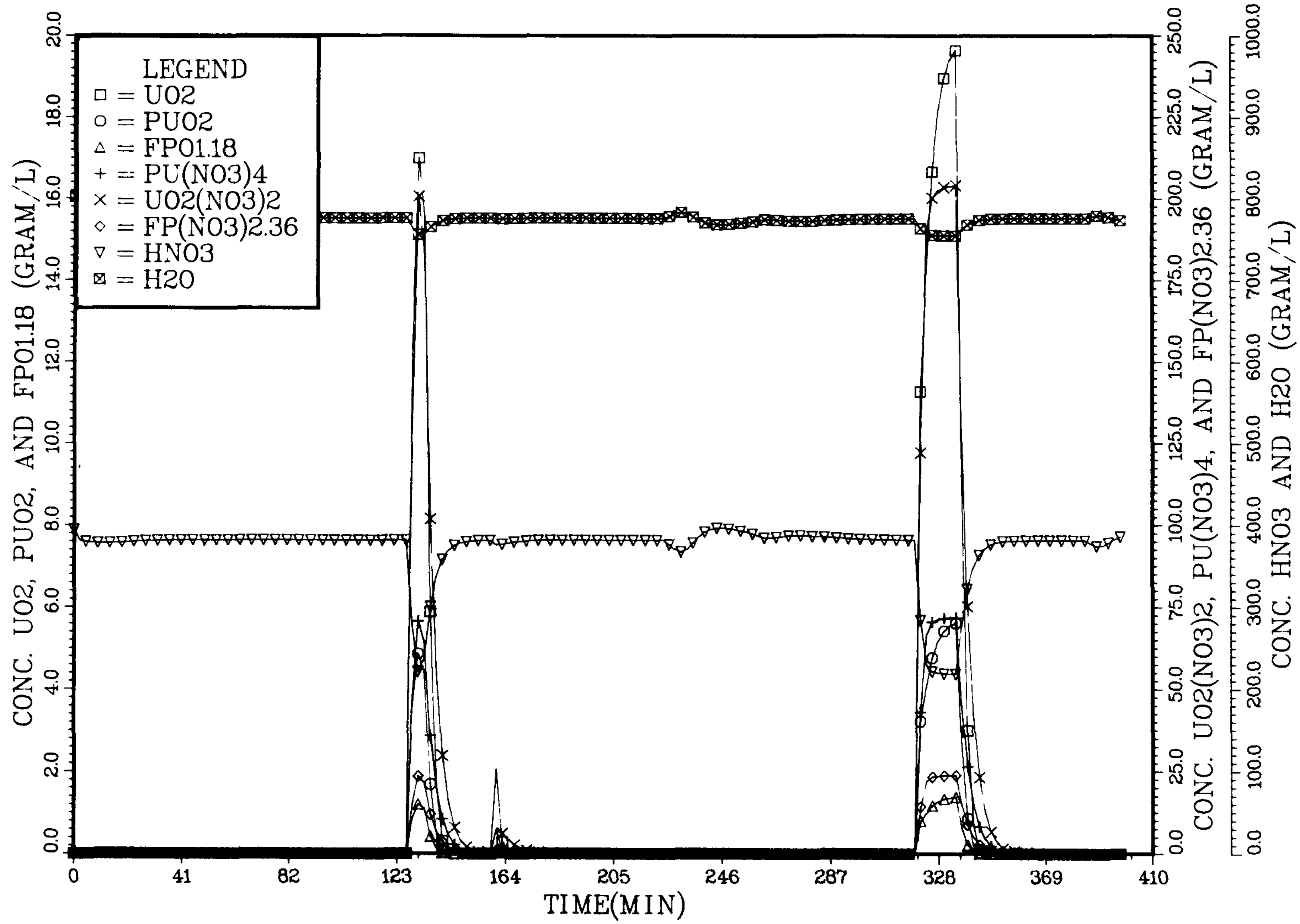


**Fig. C.6. Concentration profile for stage 6**

ORNL/DWG. 84 12998

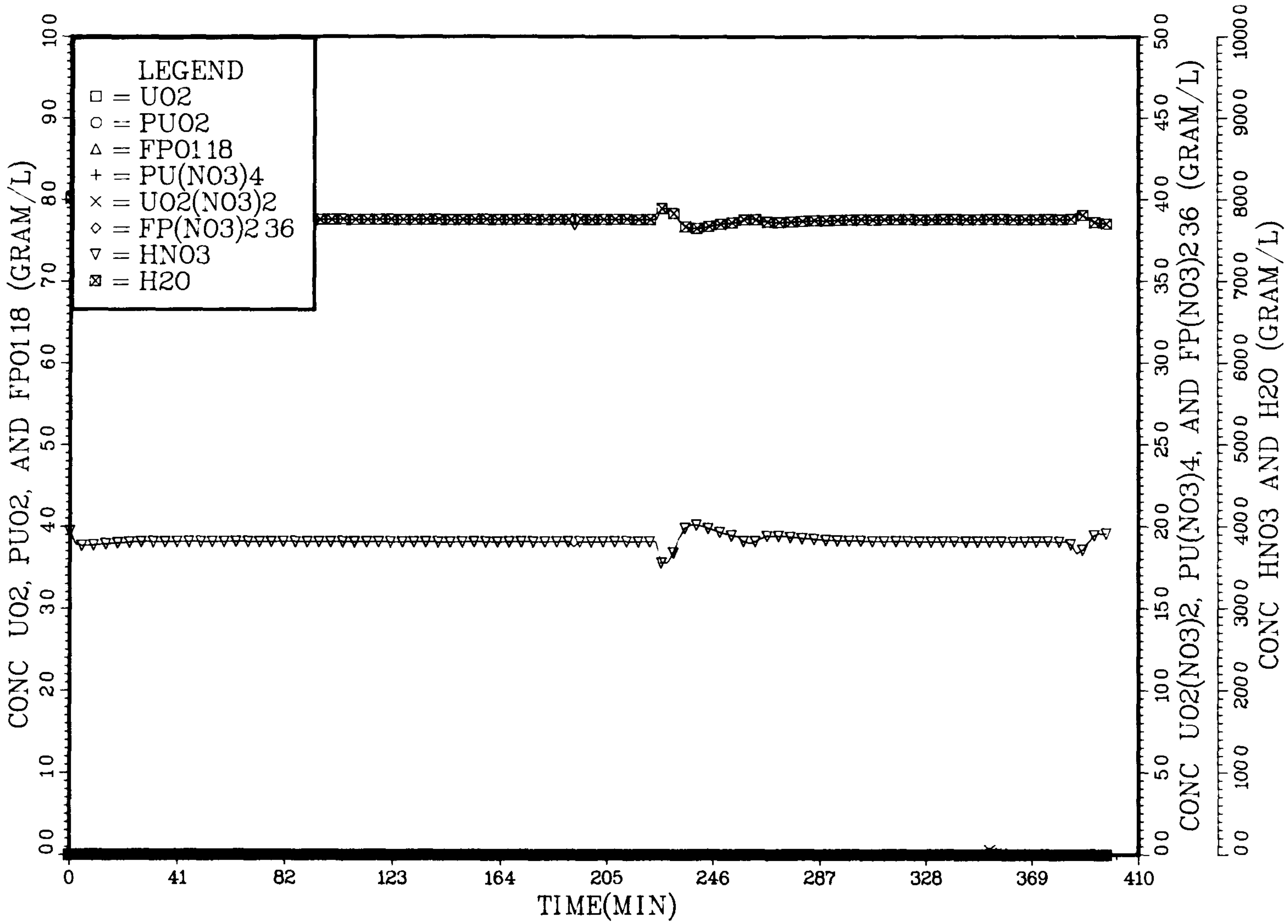


Fig. C 7. Concentration profile for stage 7

ORNL/DWG 84 12999

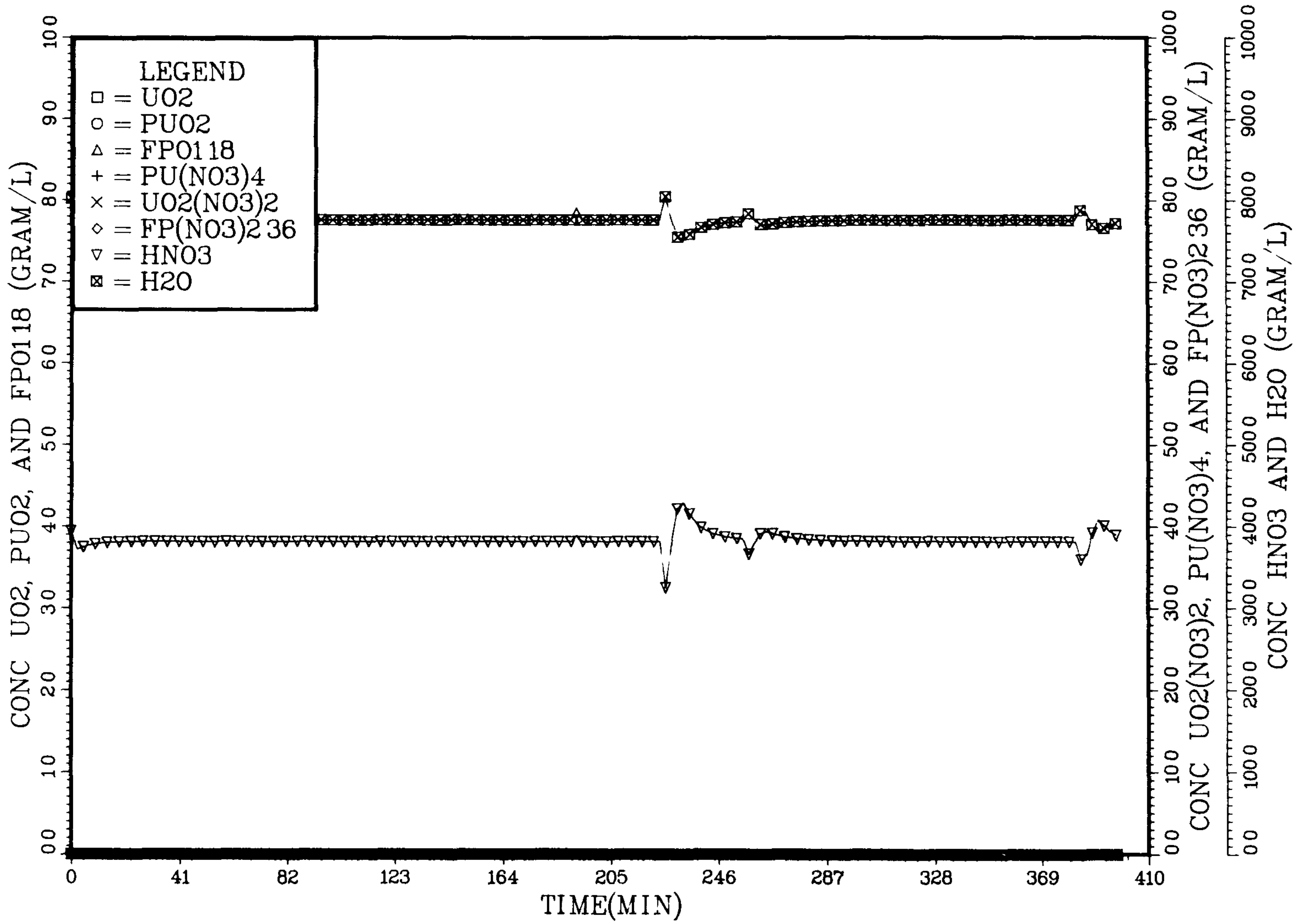


Fig C 8 Concentration profile for stage 8

ORNL/DWG. 84-13000

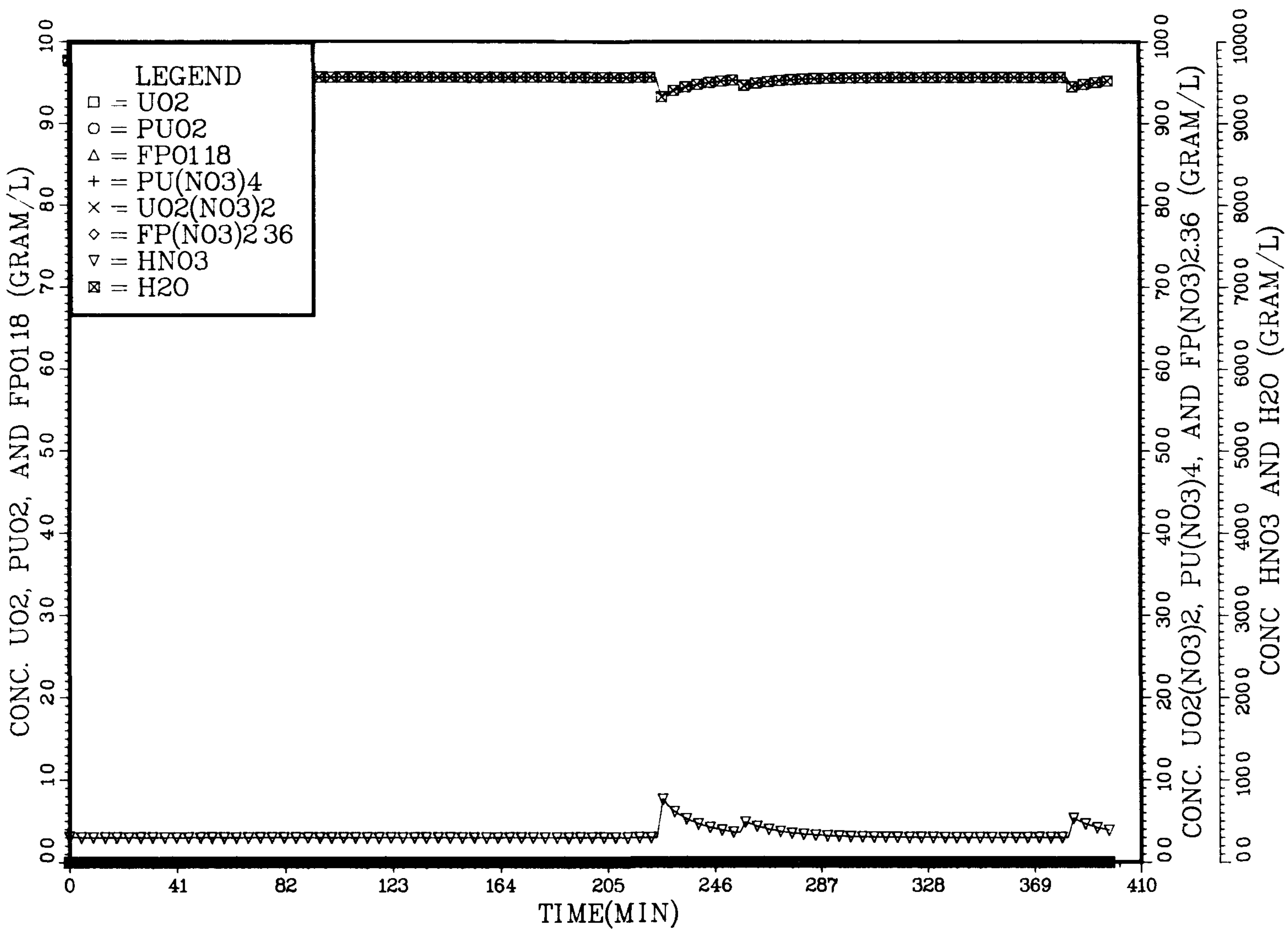


Fig. C.9. Concentration profile for stage 9

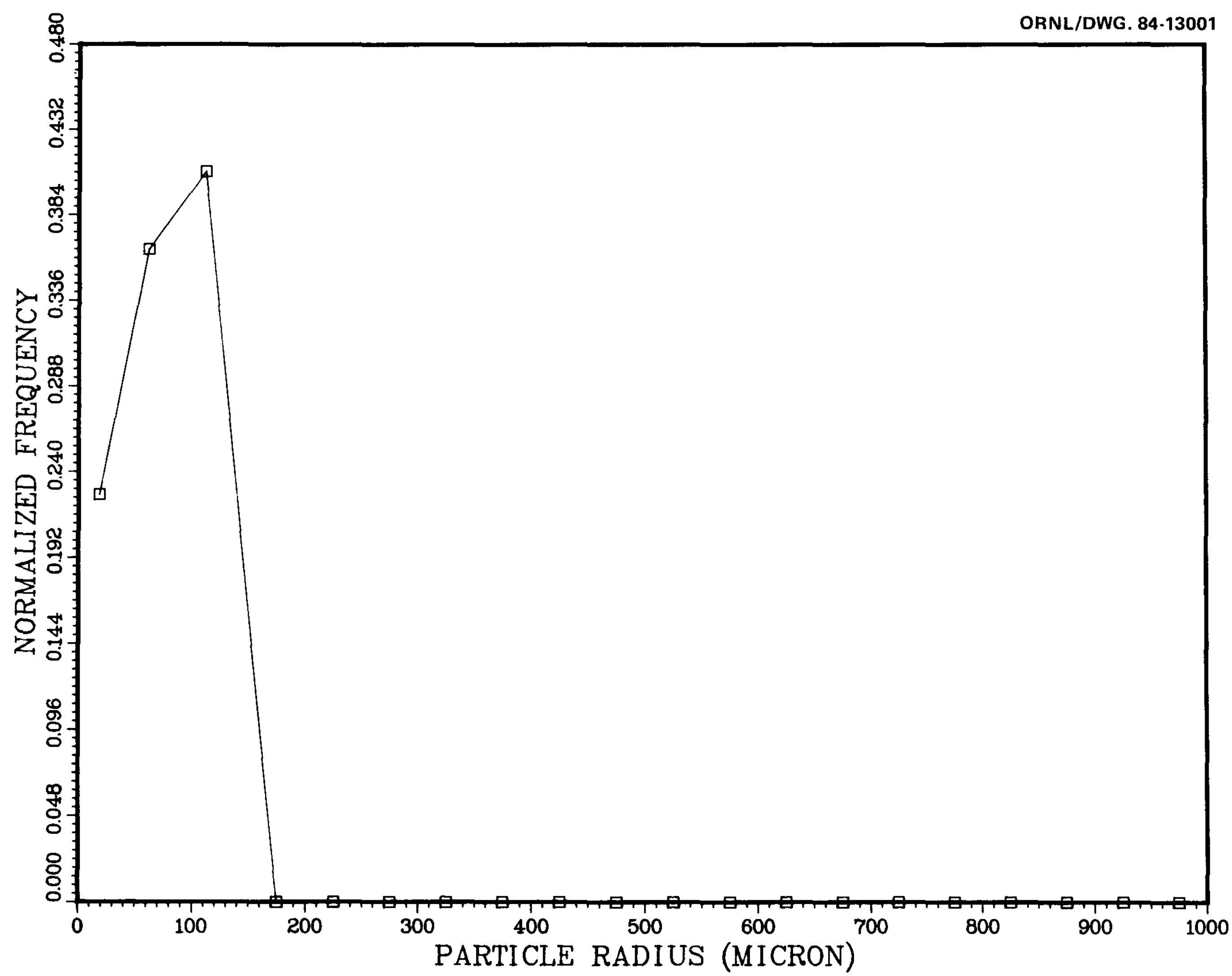


Fig. C.10. Particle size distribution for stage 1

ORNL/DWG. 84-13002

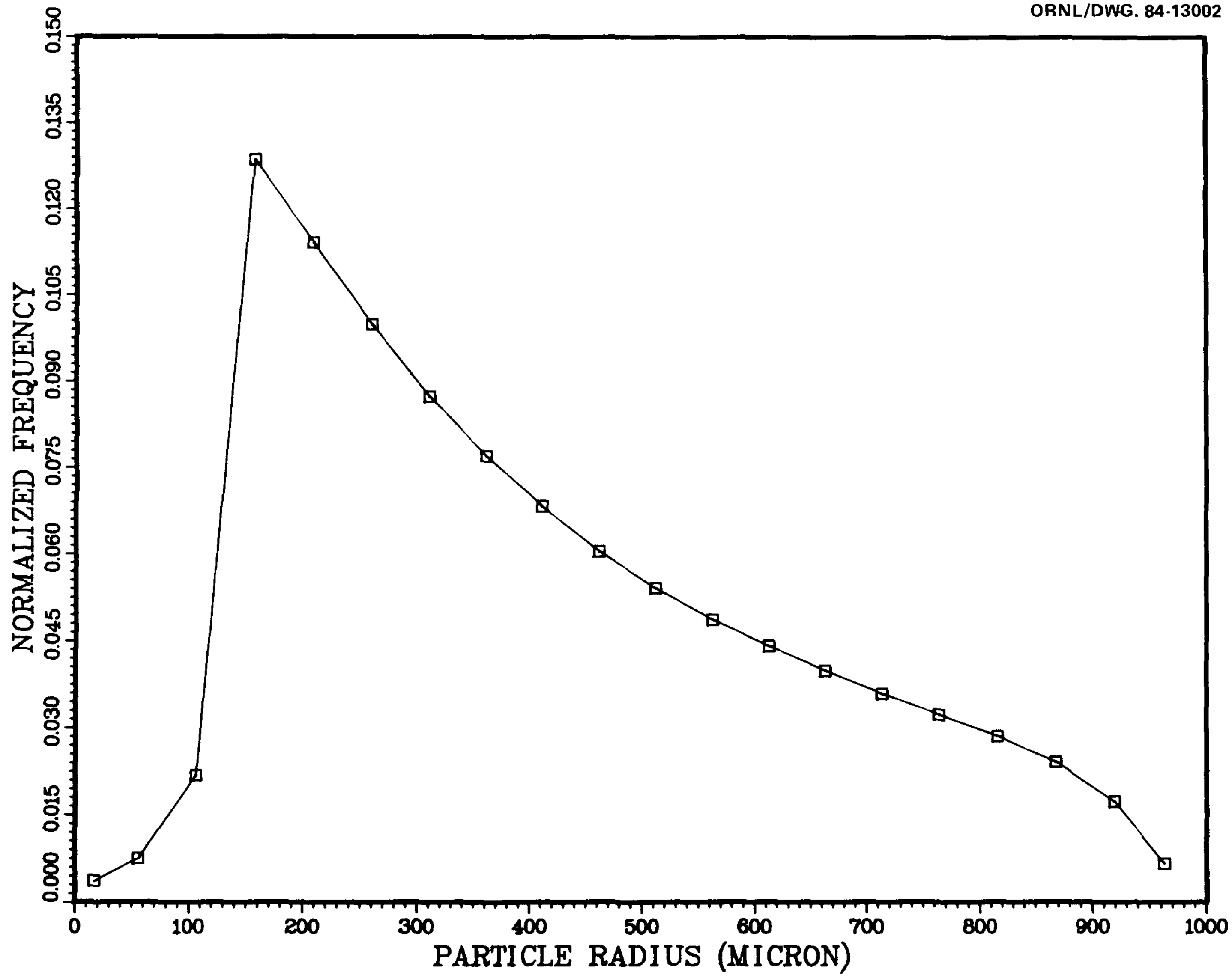


Fig. C.11. Particle size distribution for stage 2

ORNL/DWG. 84-13003

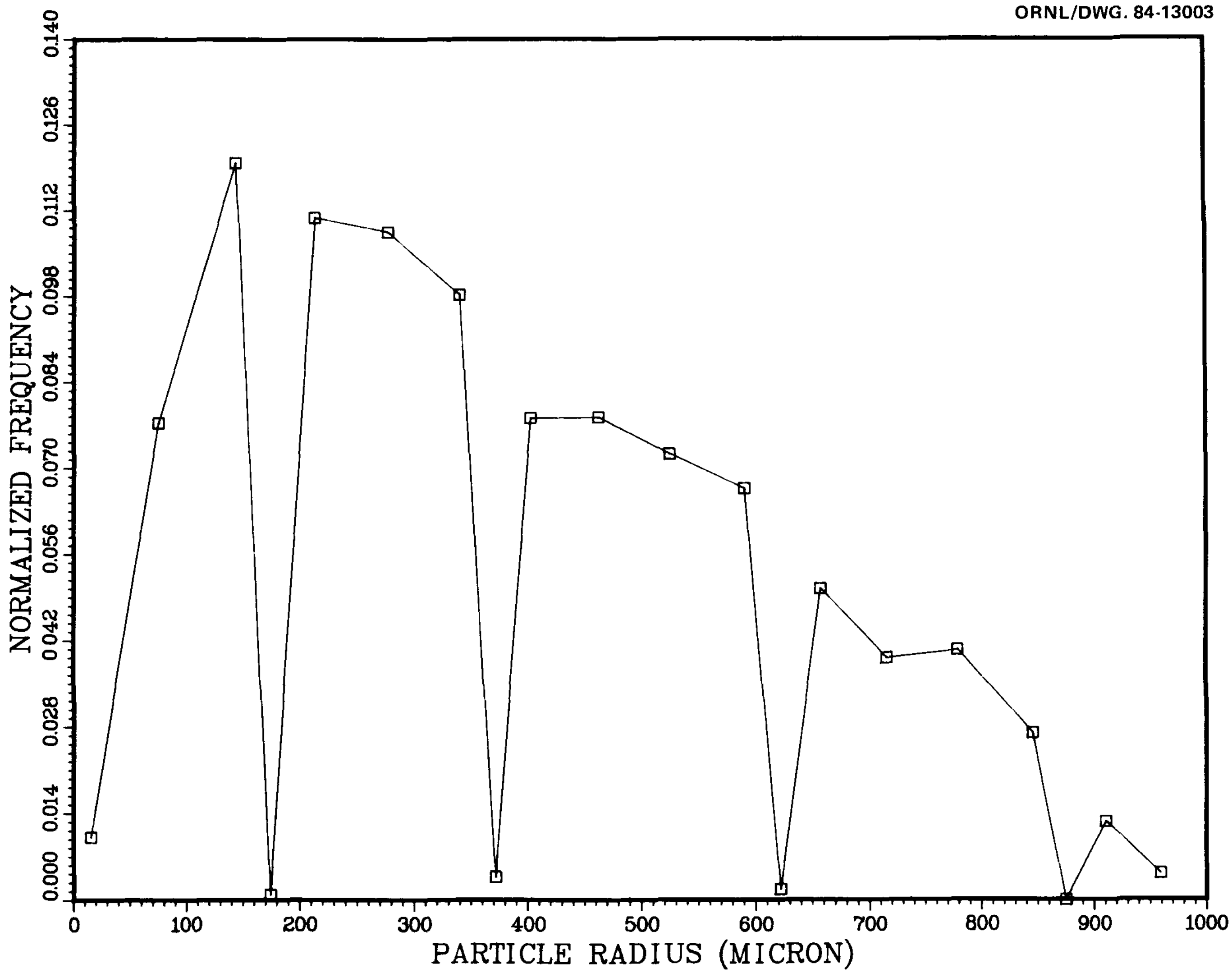


Fig. C.12 Particle size distribution for stage 3

ORNL/DWG. 84-13004

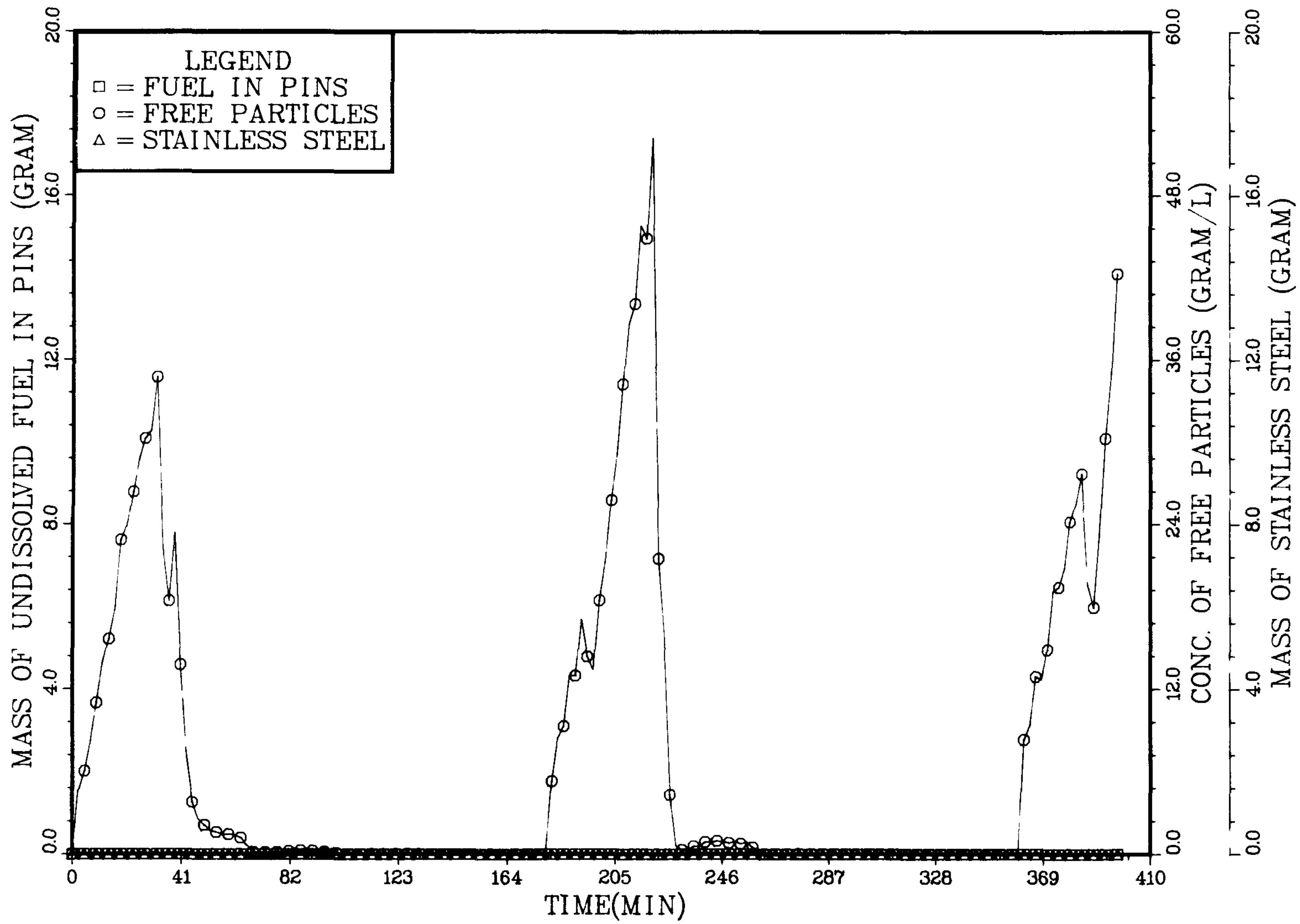


Fig. C.13. Concentration history for stage 1

ORNL/DWG. 84-13005

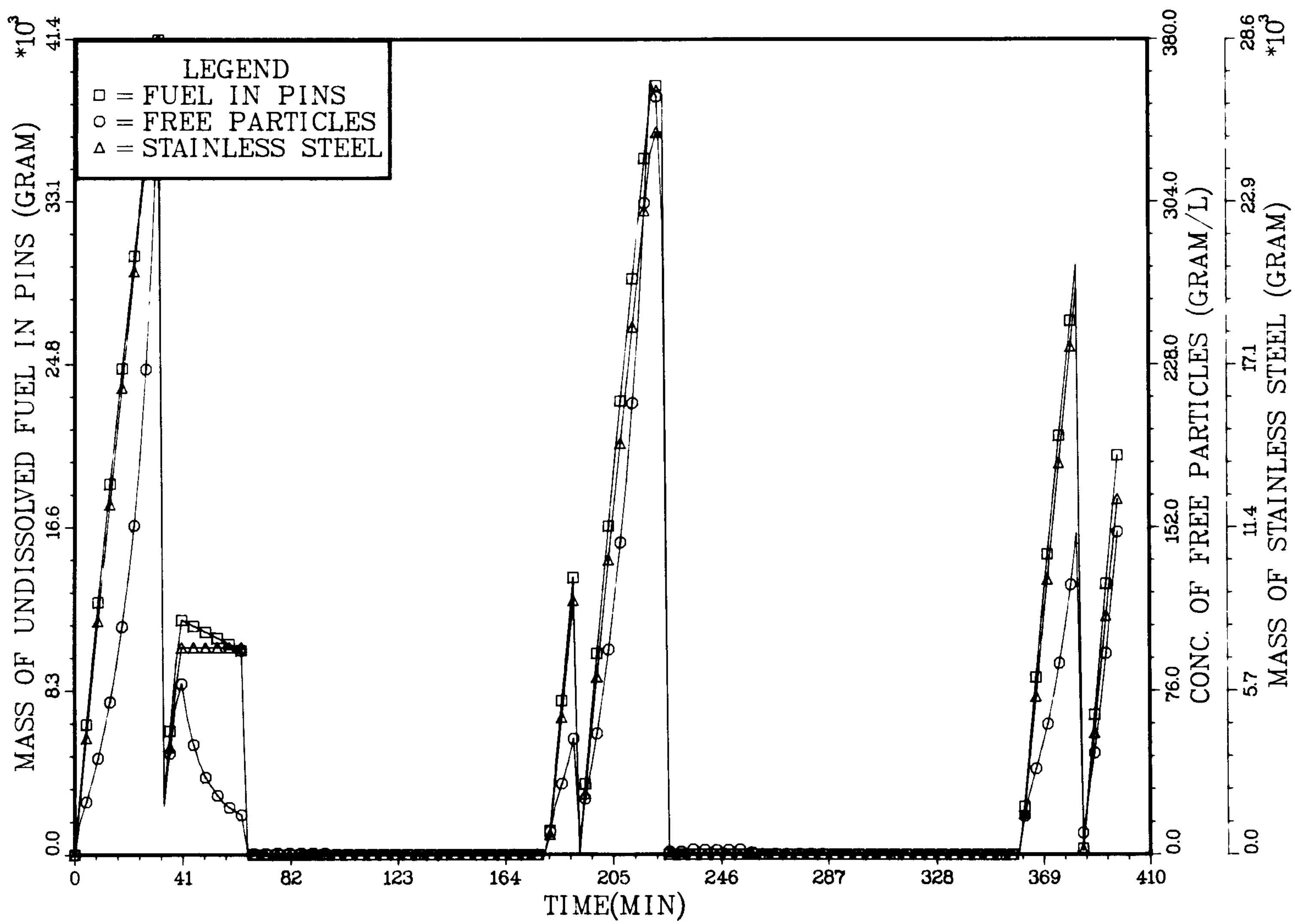


Fig. C.14. Concentration history for stage 2

ORNL/DWG. 84-13006

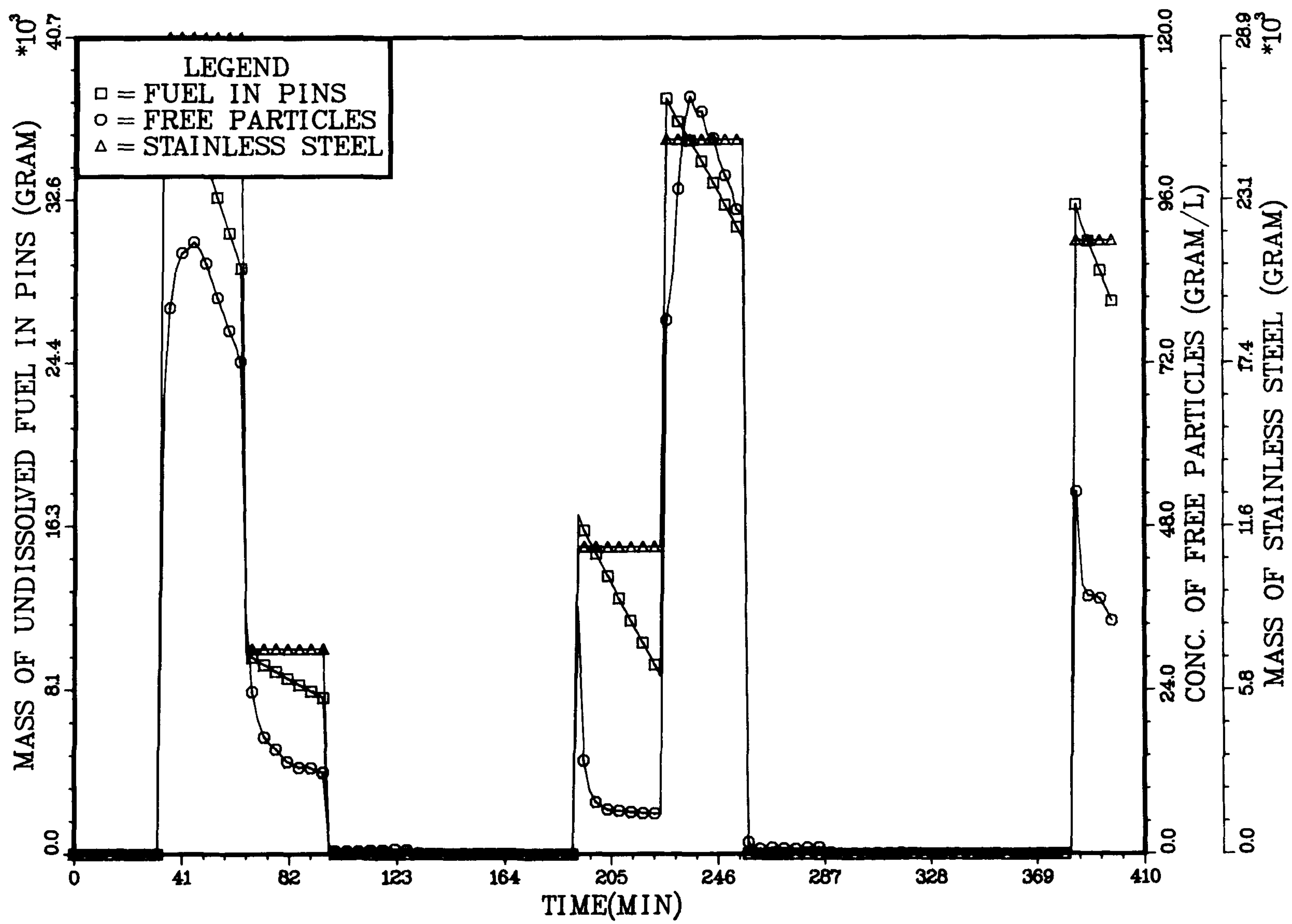


Fig. C.15. Concentration history for stage 3

ORNL/DWG. 84-13007

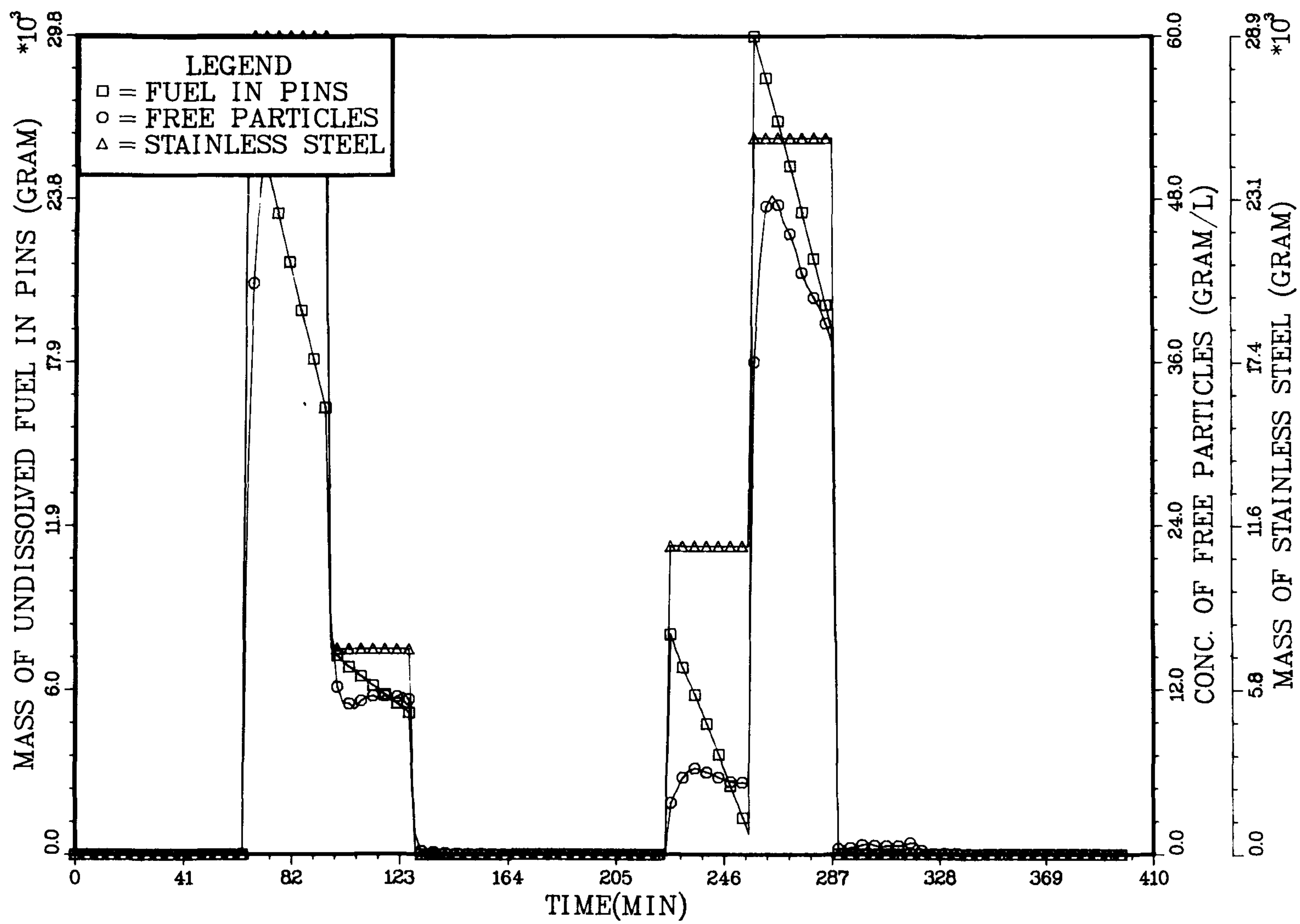


Fig. C.16. Concentration history for stage 4

ORNL/DWG. 84-13008

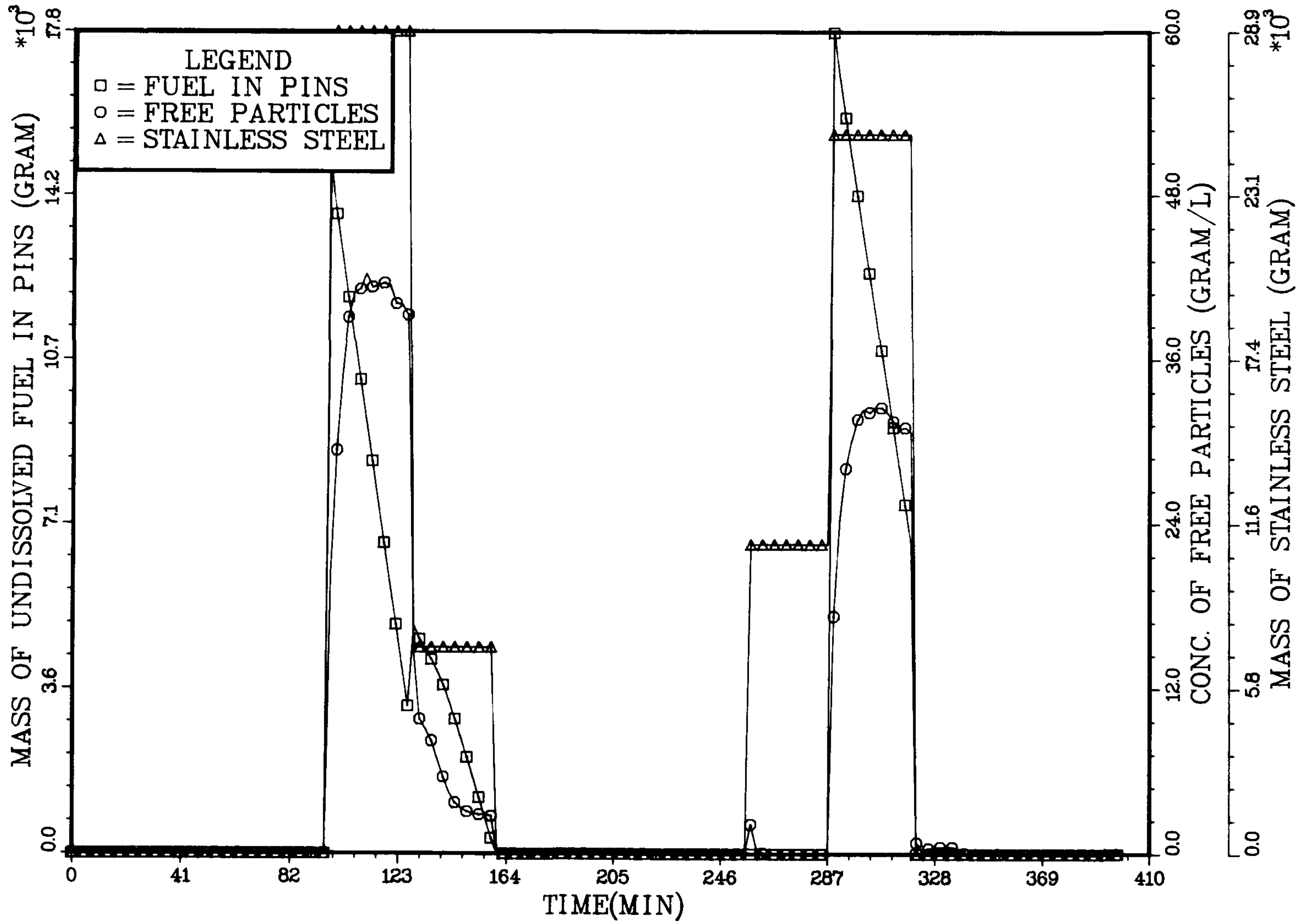


Fig. C.17. Concentration history for stage 5

ORNL/DWG. 84-13009

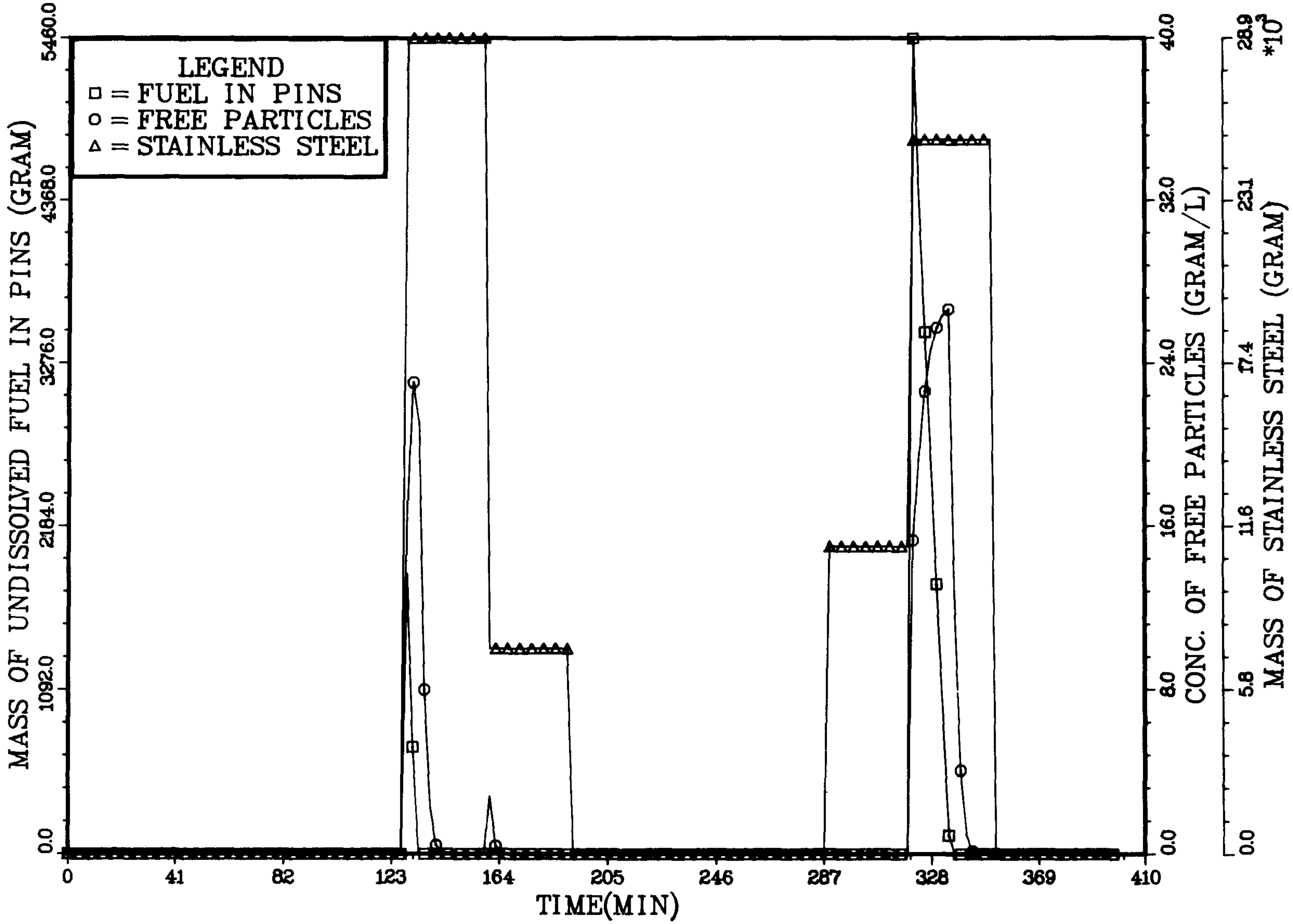


Fig. C.18. Concentration history for stage 6

ORNL/DWG. 84-13010

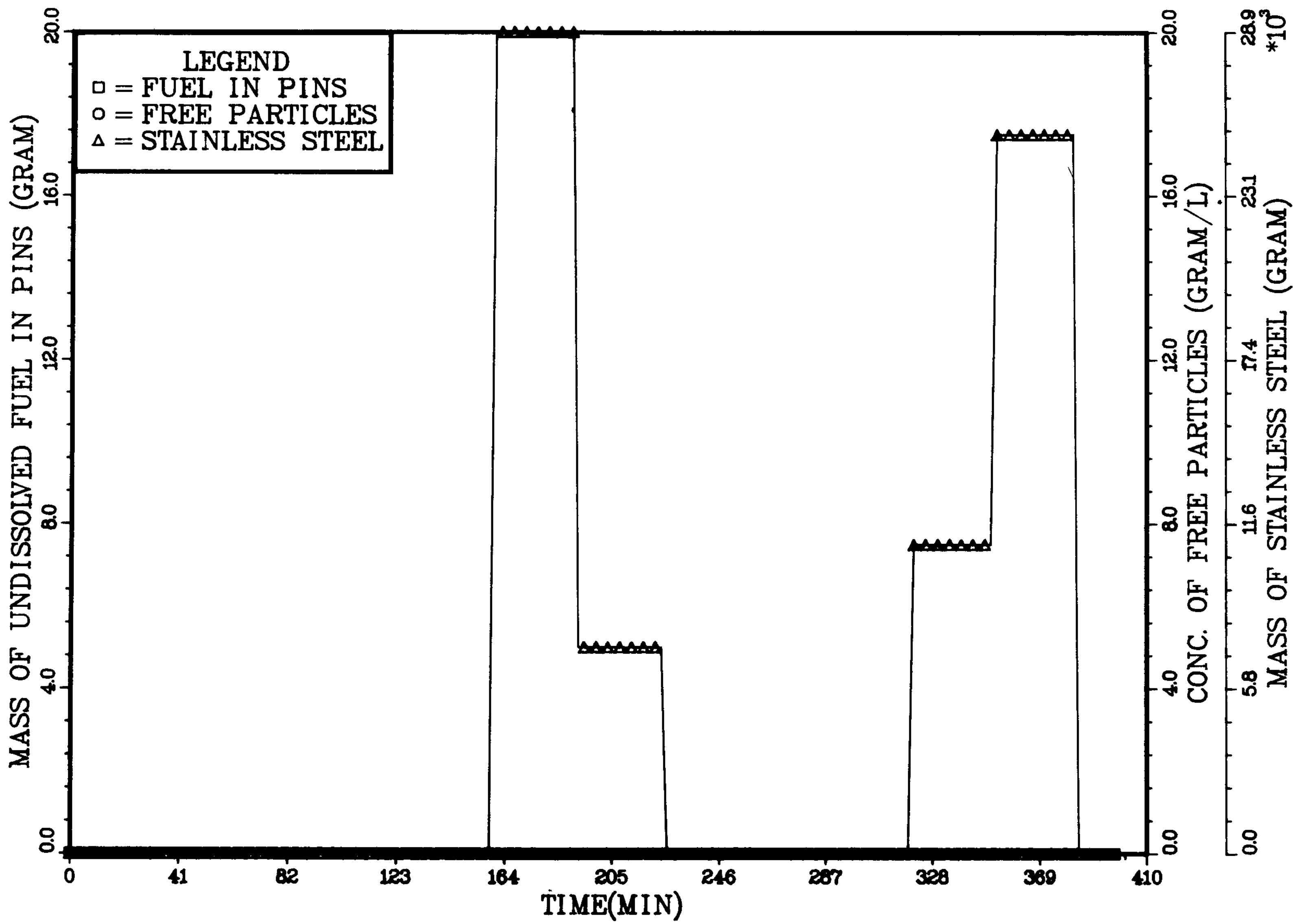


Fig. C.19. Concentration history for stage 7

ORNL/DWG. 84-13011

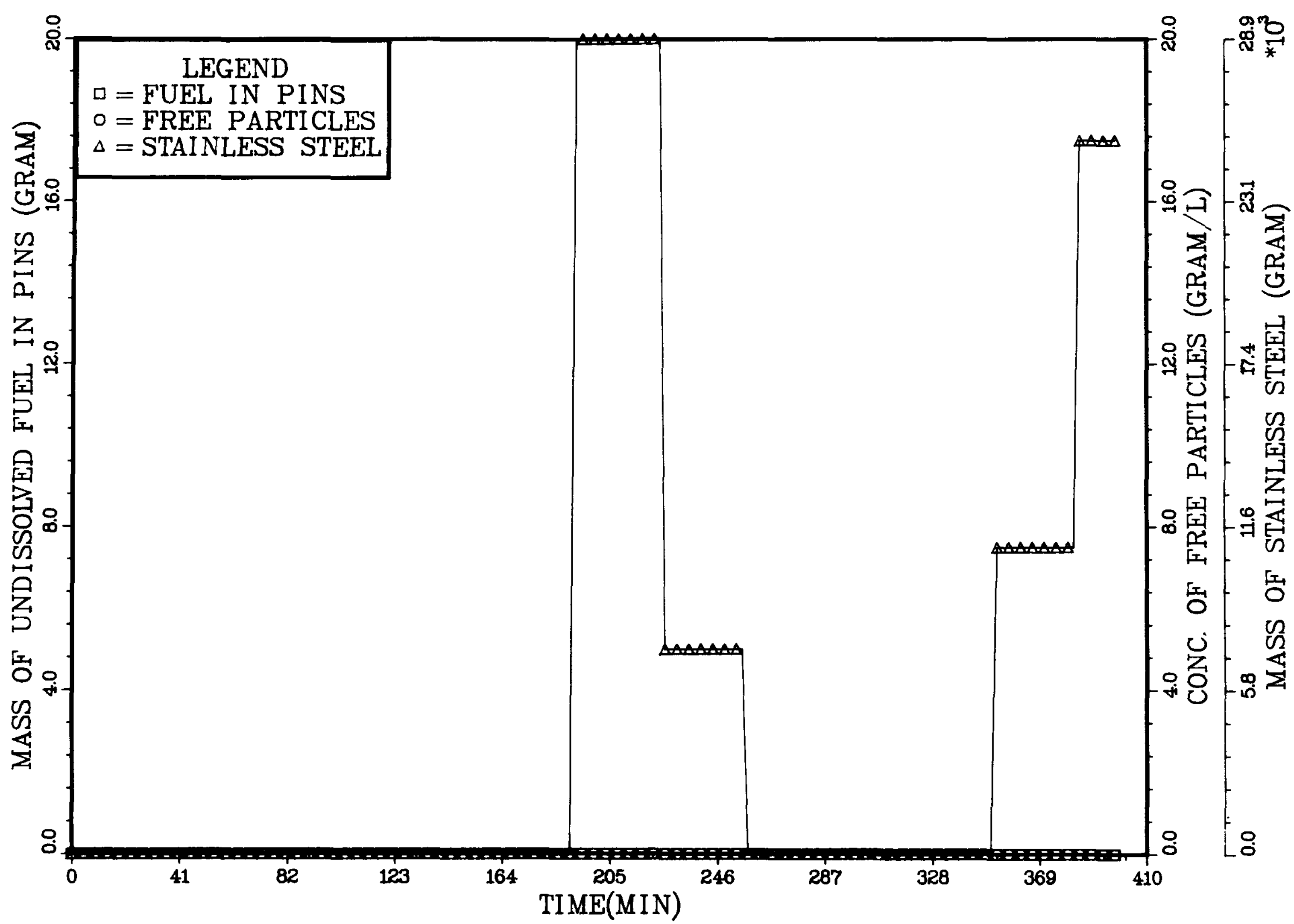


Fig. C.20. Concentration history for stage 8

ORNL/DWG. 84-13012

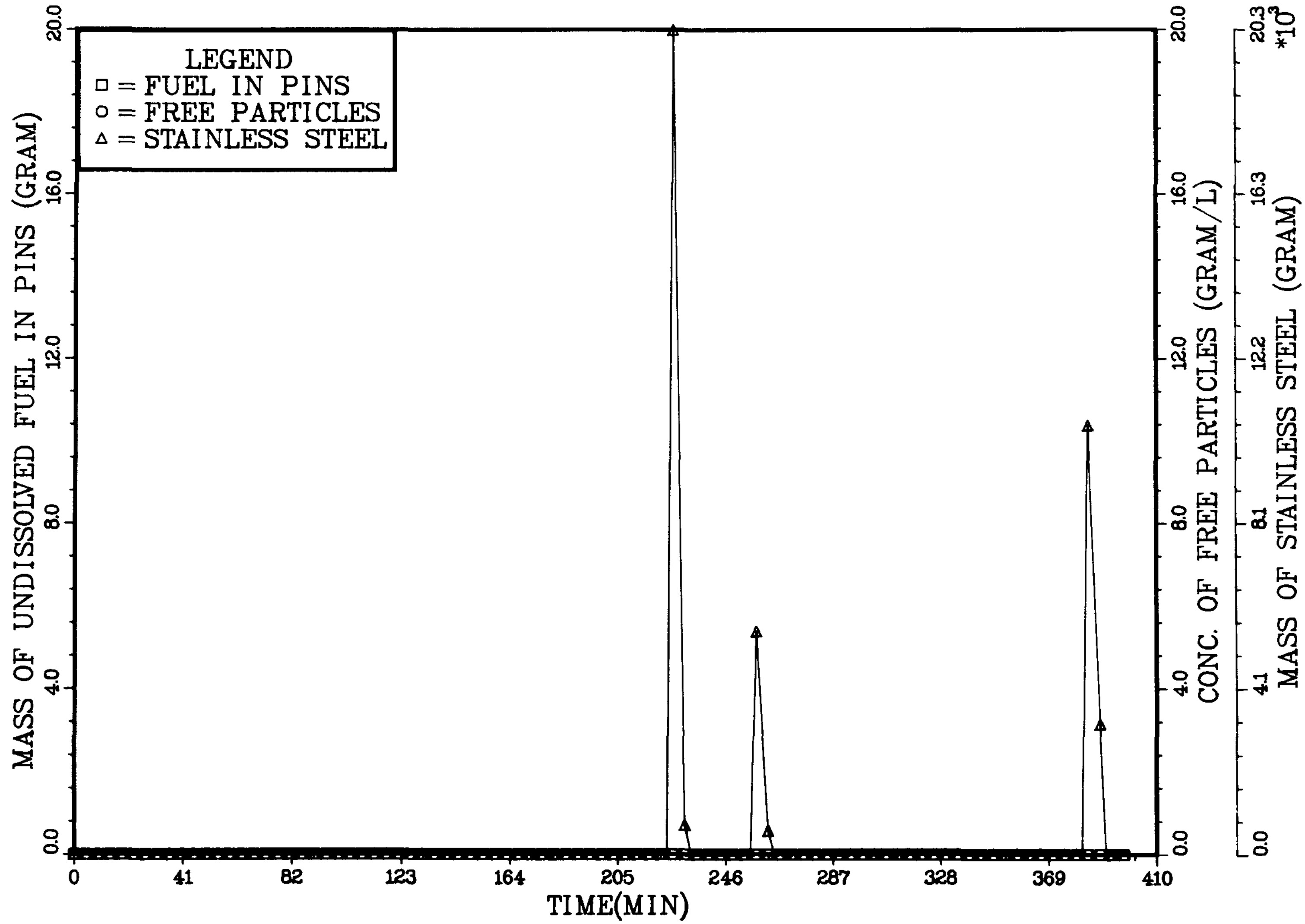


Fig. C.21. Concentration history for stage 9

ORNL/DWG. 84-13013

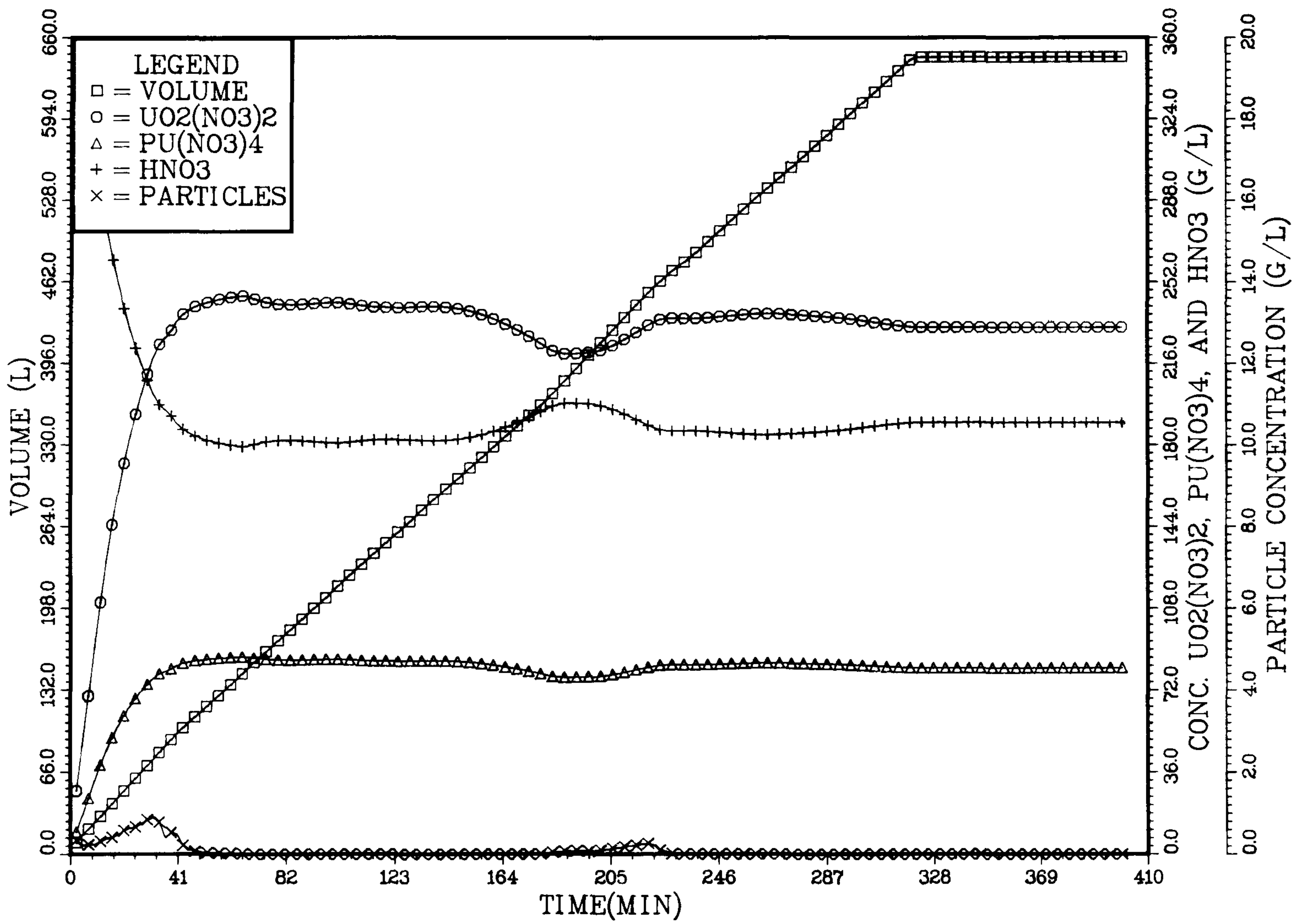


Fig. C.22. Digester tank no. 1 history

ORNL/DWG. 84-13014

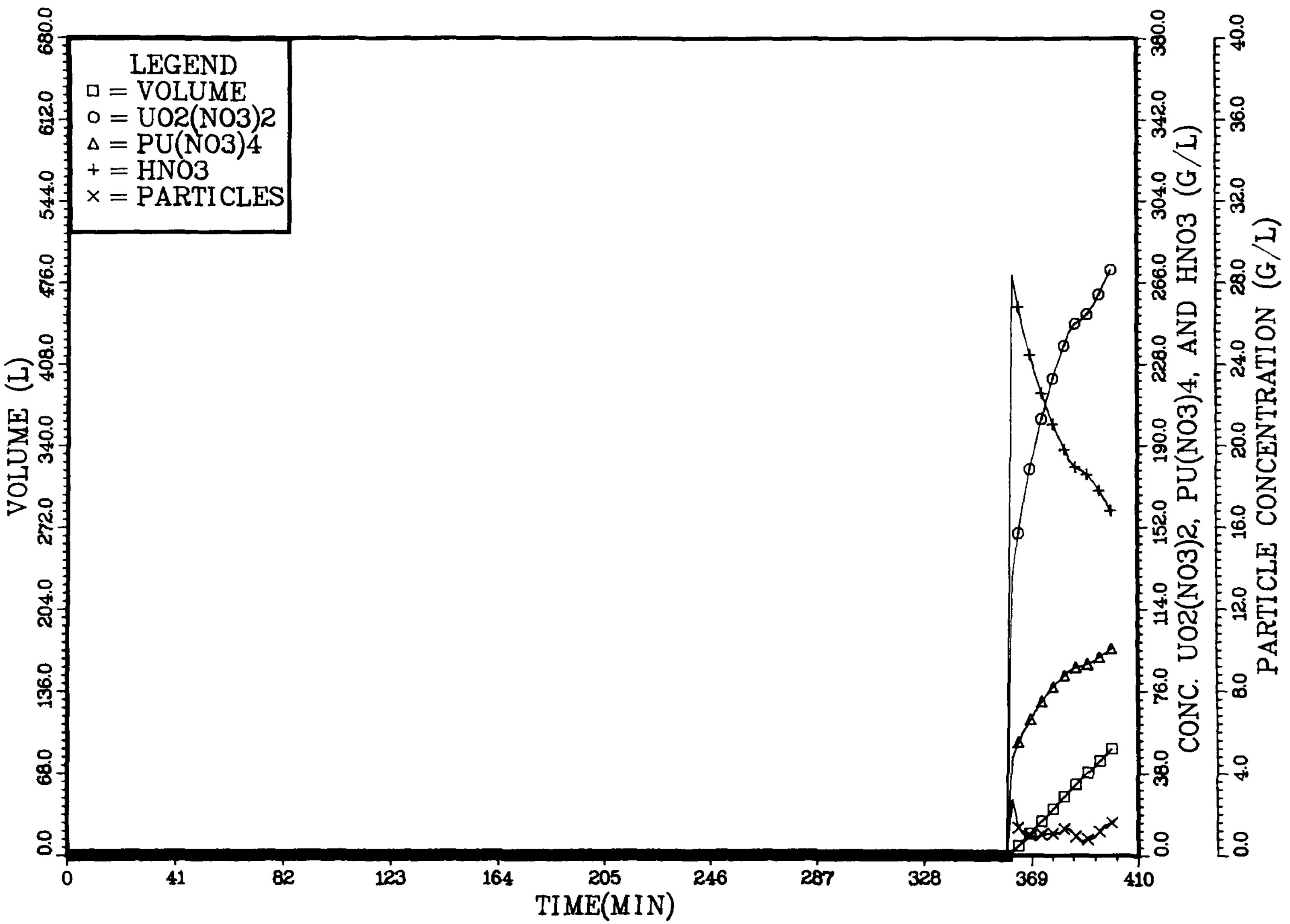


Fig. C.23. Digester tank no. 2 history

## APPENDIX D

### Selected Values for the Student's $t$ Statistic, $t_\nu$

Table D.1 is a collection of commonly used values for the two-sided Student's $t$ statistic. Additional data may be found in any of a number of standard statistical analysis textbooks.

**Table D.1. Two-sided Student's $t$ statistic, $t_\nu$**

| $\nu$ Degrees of freedom | Confidence level | | |
|---|---|---|---|
| | 90% | 95% | 99% |
| 1 | 6.314 | 12.706 | 63.657 |
| 2 | 2.920 | 4.303 | 9.925 |
| 3 | 2.353 | 3.181 | 5.841 |
| 4 | 2.132 | 2.776 | 4.604 |
| 5 | 2.015 | 2.571 | 4.032 |
| 6 | 1.943 | 2.447 | 3.707 |
| 7 | 1.895 | 2.365 | 3.499 |
| 8 | 1.860 | 2.306 | 3.355 |
| 9 | 1.833 | 2.262 | 3.250 |
| 10 | 1.812 | 2.228 | 3.169 |
| 11 | 1.796 | 2.201 | 3.106 |
| 12 | 1.782 | 2.179 | 3.055 |
| 13 | 1.771 | 2.160 | 3.012 |
| 14 | 1.761 | 2.145 | 2.977 |
| 15 | 1.753 | 2.131 | 2.947 |
| 16 | 1.746 | 2.120 | 2.921 |
| 17 | 1.740 | 2.110 | 2.898 |
| 18 | 1.734 | 2.101 | 2.878 |
| 19 | 1.729 | 2.093 | 2.861 |
| 20 | 1.725 | 2.083 | 2.845 |
| 21 | 1.721 | 2.080 | 2.831 |
| 22 | 1.717 | 2.074 | 2.819 |
| 23 | 1.714 | 2.069 | 2.807 |
| 24 | 1.711 | 2.064 | 2.797 |
| 25 | 1.708 | 2.060 | 2.787 |
| 26 | 1.706 | 2.056 | 2.779 |
| 27 | 1.703 | 2.052 | 2.771 |
| 28 | 1.701 | 2.048 | 2.763 |
| 29 | 1.699 | 2.045 | 2.756 |
| 30 | 1.697 | 2.042 | 2.750 |
| 40 | 1.684 | 2.021 | 2.704 |
| 60 | 1.671 | 2.000 | 2.660 |
| 100 | 1.658 | 1.980 | 2.617 |
| ∞ | 1.645 | 1.960 | 2.576 |

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