DATE ISSUED: APR 26 1972

ORNL-4746

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Calculation of the Transient Behavior of a Dilute-Purex Solvent Extraction Process having Application to the Reprocessing of LMFBR Fuels

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

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ORNL-4746
UC-10 – Chemical Separations Processes
for Plutonium and Uranium

Contract No. W-7405-eng-26

CHEMICAL TECHNOLOGY DIVISION

CALCULATION OF THE TRANSIENT BEHAVIOR OF A DILUTE-PUREX SOLVENT EXTRACTION PROCESS HAVING APPLICATION TO THE REPROCESSING OF LMFBR FUELS

W. S. Groenier

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CALCULATION OF THE TRANSIENT BEHAVIOR OF A DILUTE-PUREX SOLVENT EXTRACTION PROCESS HAVING APPLICATION TO THE REPROCESSING OF LMFBR FUELS

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ABSTRACT

A method for calculating the time-dependent behavior of countercurrent solvent extraction processes has been applied to a dilute-Purex flowsheet proposed for use in the recovery of spent Liquid-Metal-Cooled Fast Breeder Reactor (LMFBR) fuels. This effort led to the development of a computer program, SEPHIS, which employs a combination of approximate mathematical equilibrium expressions and the transient, stagewise process calculational method to allow the prediction of stage and product stream concentrations with accuracy and reliability. The applications of SEPHIS to process analysis and control, criticality analysis, and inventory control for nuclear safeguards purposes are particularly intriguing.

1. INTRODUCTION

The comparatively high plutonium content (i.e., ~20%) of LMFBR fuels presents criticality problems during reprocessing operations. To circumvent such problems in solvent extraction equipment, a "dilute-Purex" flowsheet utilizing 15 vol % tri-*n*-butyl phosphate (TBP) in a hydrocarbon diluent was suggested. [The reprocessing of light-water-moderated power reactor (LWR) fuels normally involves the use of 30 vol % TBP.] However, at the temperatures (25–30°C) usually specified in the flowsheet, solvent loadings <80% of those attained with 30 vol % TBP must be accepted in order to prevent excessive reflux of plutonium and/or formation of a third phase. Decontamination from fission products can be less effective at these lower loadings. In addition, the use of a reductant in the stripping stream in the last plutonium purification cycle may be undesirable from the standpoint of purity of the final product solution. These and other factors, plus increased emphasis toward complete recovery of the plutonium because of its high intrinsic value, prompted us to take a new look at Purex reprocessing conditions. It is possible that this effort may result in the development of a flowsheet that is somewhat different from the one that has become classical for the reprocessing of LWR fuels.

SEPHIS, a computer program for *S*olvent *E*xtraction *P*rocesses *H*aving *I*nteracting *S*olutes, was developed to provide answers to many of the questions regarding the application of the Purex process to LMFBR fuels. The use of this program has already reduced the number of experimental runs required to establish optimum flowsheet conditions by simulating the extraction process with sufficient accuracy to allow many of the interrelated effects of varying the process parameters to be explored rapidly and inexpensively. Experimentation has been required only to verify a small fraction of the computer-predicted results.

The following sections describe the solvent extraction flowsheet, mathematical model, and computer program, and provide instructions for use of the program.

2. LIST OF SYMBOLS

A Aqueous-phase flow rate

D Distribution coefficient — Eq. (7)

FR Flow ratio — Eq. (3)

K′ Pseudo-mass-action equilibrium constant — Eqs. (11)–(13)

NF Net flow rate – Eq. (1)
O Organic-phase flow rate
PR Phase ratio – Eq. (4)
t Time
T Absolute temperature
T_0 Absolute reference temperature
TF Total flow rate – Eq. (2)
V Volume of stage
x Solute concentration in aqueous phase
y Solute concentration in organic phase
μ Total ionic strength – Eq. (14)

Subscripts:

H Acid
j Stage number
P Plutonium
R_1 Recycle of type 1
R_2 Recycle of type 2
t Time
T Absolute temperature
T_0 Absolute reference temperature
U Uranium

Superscripts:

f Feed stream
p Product stream

3. DESCRIPTION OF THE FLOWSHEET

The dilute-Purex flowsheet employs 15 vol % TBP in a hydrocarbon diluent as the extractant. As shown in Fig. 1, the flowsheet consists of a partition cycle and two plutonium purification cycles.

In the partition cycle, uranium and plutonium are coextracted to achieve separation from fission products and then scrubbed with nitric acid. The metal-rich organic phase is next contacted with a reductant to convert the plutonium to a less extractable species in the partition column, where it transfers to the aqueous phase. Finally, the uranium-rich organic phase is stripped with dilute nitric acid.

The two plutonium purification cycles are nearly identical. Aqueous plutonium solutions from the previous cycle are contacted with an extractant after feed adjustment. The extractant is then stripped of plutonium using fresh nitric acid, possibly containing a reductant.

A further description of the process can be found in refs. 1–7.

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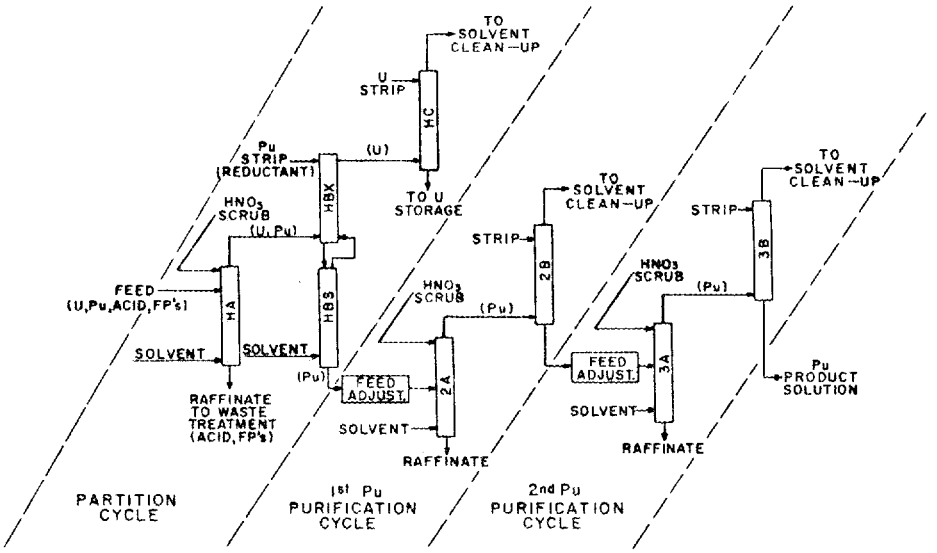

Fig. 1. Dilute-Purex Flowsheet for LMFBR Fuels.

4. DESCRIPTION OF THE MODEL

The computations made in this study were based on a solvent extraction contactor model consisting of a finite series of discrete stages, each containing a zone of intense ("perfect") mixing and a settling zone where phases separate completely. All mass transfer between phases occurs in the mixers. These mixers have essentially zero volume. The settlers serve to provide holdup between mixers, and "plug" flow is assumed to occur here. As shown in Fig. 2, each stage may accept streams from an adjacent stage or from outside the contactor, may provide streams to supply an adjacent stage or a product stream that leaves the contactor, and may have internal recycle streams.

The recycle streams can be of two types. Type 1 recycle involves only one phase flowing from the settler back to the mixer in order to satisfy the condition where the phase ratio is not the same as the flow ratio imposed on the contactor. This condition exists in pulsed columns, some forms of mixer-settlers, and stacked-clone contactors. Type 2 recycle involves both phases and applies to stages having disproportionately large volumes.

The net stage flow does not include recycle streams since these are internal. Net stage flow is defined as:

$$NF_j = A_{j-1} + O_{j+1} + A_j^f + O_j^f \,. \tag{1}$$

Total stage flow includes recycle and is defined as:

$$TF_j = A_{j-1} + O_{j+1} + A_j^f + O_j^f + A_{R_1} + A_{R_2} + O_{R_1} + O_{R_2} \,. \tag{2}$$

The flow ratio is:

$$FR_j = \frac{A_{j-1} + A_j^f}{O_{j+1} + O_j^f} \,, \tag{3}$$

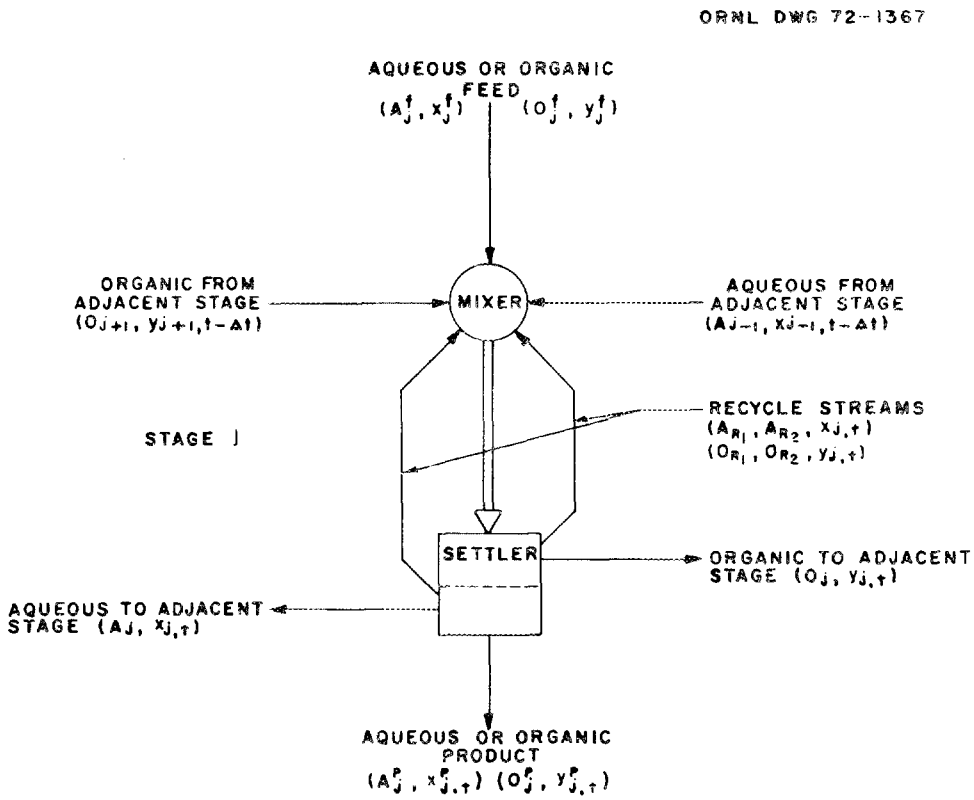

Fig. 2. Stage Model.

but the phase ratio of the stage is:

$$PR_j = \frac{A_{j-1} + A_j^f + A_{R_1} + A_{R_2}}{O_{j+1} + O_j^f + O_{R_1} + O_{R_2}} . \tag{4}$$

In type 2 recycle, the ratio of stage volume to total stage flow is the same for each stage in the contactor because of the large intrastage flow. The solution residence time represented by this ratio is the time interval at which transient calculations are performed. It can be expressed in real time by using actual stage volumes and flow rates rather than relative values, as follows:

$$\Delta t = \frac{V_j}{TF_j} . \tag{5}$$

Pulsed columns and most other process-sized contactors will exhibit recycle of the second type. No recycle of either type would occur in laboratory-scale batch countercurrent devices, since the stage volumes are proportional to the net stage flow, and the phase and flow ratios are equal, in these devices. The recycle flow concept enables any existing type of solvent extraction contactor to be simulated.

5. CALCULATIONAL PROCEDURE

Transient calculations are begun by assuming that all stages are full of liquid to the proper volume and in the proper phase ratio. An initial concentration profile in the contactor (for each phase) is used as a starting point, which may be zero. Consider a normal extraction-scrub contactor having n stages and one organic and two aqueous feed streams. The aqueous feed streams enter at stages 1 and j and the organic enters at n, as shown in Fig. 3. In the first time interval, calculations are made at the feed stage (j) and at the scrub and solvent stages (1 and n) if the initial concentration values are different from those of the entering stream. In the second time interval (t), calculations are made at the adjacent stages as well as at the stages described above. Thus, stage j is recalculated, and stages j − 1 and j + 1 are calculated using the results from stage j in the previous interval (t − Δt). This procedure continues for as many time intervals as necessary to reach a steady-state operation.

Individual stage calculations are made by solving the stage mass balance equation,

$$A_{j-1}x_{j-1,t-\Delta t} + O_{j+1}y_{j+1,t-\Delta t} + A_j^f x_j^f + O_j^f y_j^f = (A_j + A_j^p)x_{j,t} + (O_j + O_j^p)y_{j,t} \ , \tag{6}$$

and the usual mass-transfer equation involving a distribution coefficient (D),

$$x_{j,t} = \frac{y_{j,t}}{D} \ . \tag{7}$$

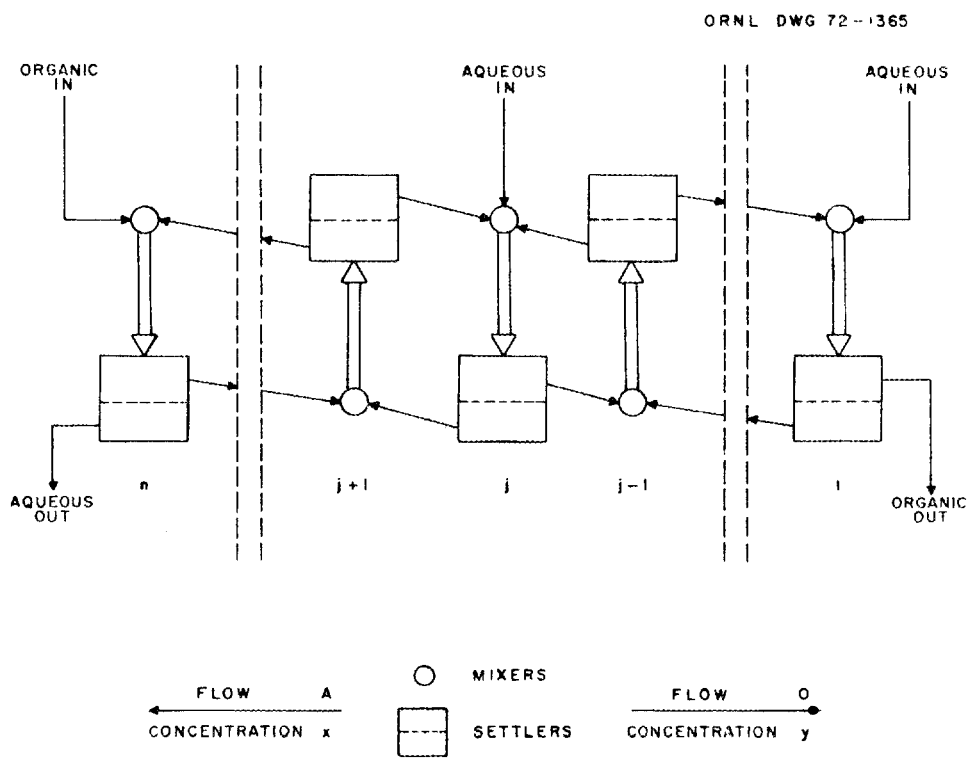

Fig. 3. Cascade Model.

The above computational method was adapted from that used by Lowe,[8] and produces concentrations throughout the contactor as a function of time. This allows one to study the transient behavior of the system resulting from a start-up, shutdown, process variable perturbation, or other non-steady-state situation. Of course, if allowed to make computations for a large number of time intervals, the method also produces the steady-state results.

Distribution coefficients in the dilute-Purex system have been correlated by Horner,[9] who showed the interrelationships among the various solutes. For example, he found that the distribution coefficient for uranium is a function of the *equilibrium* concentrations of *all* solutes as well as the total ionic content of the aqueous phase. To obtain a distribution coefficient for Eq. (7), one must assume values for $x_{j,t}$ for each solute, then use an iterative procedure in which the assumed and calculated values of $x_{j,t}$ are compared and a test is made to determine the degree of fit.

The following reactions are assumed to apply to Purex extractions:

$$UO_2^{2+} + 2NO_3^- + 2TBP = UO_2(NO_3)_2 \cdot 2TBP \,, \tag{8}$$

$$Pu^{4+} + 4NO_3^- + 2TBP = Pu(NO_3)_4 \cdot 2TBP \,, \tag{9}$$

$$H^+ + NO_3^- + TBP = HNO_3 \cdot TBP \,. \tag{10}$$

Equations (8)–(10) define the pseudo-mass-action equilibrium expressions (having embedded activity coefficient ratios):

$$K'_U = \frac{[UO_2(NO_3)_2 \cdot 2TBP]}{[UO_2^{2+}]\ [NO_3^-]^2\ [TBP]^2} \,, \tag{11}$$

$$K'_P = \frac{[Pu(NO_3)_4 \cdot 2TBP]}{[Pu^{4+}]\ [NO_3^-]^4\ [TBP]^2} \,, \tag{12}$$

$$K'_H = \frac{[HNO_3 \cdot TBP]}{[H^+]\ [NO_3^-]\ [TBP]} \,, \tag{13}$$

where the brackets represent molar concentrations. Since the K′ values are not true constants (i.e., they reflect changes in the activity coefficient ratio), they were correlated as a function of the total ionic strength, defined as:

$$\mu = [H^+] + 3\ [UO_2^{2+}] + 10\ [Pu^{4+}] \,. \tag{14}$$

In this correlation, the C values are empirical constants.

$$K'_U = C_1 + C_2\mu + C_3\mu^2 + C_4\mu^3 \tag{15}$$

$$K'_P = C_5 + C_6\mu + C_7\mu^2 + C_8\mu^3 \tag{16}$$

$$K'_H = C_9 + C_{10}\mu + C_{11}\mu^2 + C_{12}\mu^3 \tag{17}$$

Distribution coefficients are defined as:

$$D_U = \frac{[UO_2(NO_3)_2 \cdot 2TBP]}{[UO_2{}^{2+}]} = K'_U [NO_3{}^-]^2 \, [TBP]^2 \tag{18}$$

$$D_P = \frac{[Pu(NO_3)_4 \cdot 2TBP]}{[Pu^{4+}]} = K'_P [NO_3{}^-]^4 \, [TBP]^2 \ , \tag{19}$$

$$D_H = \frac{[HNO_3 \cdot TBP]}{[H^+]} = K'_H [NO_3{}^-] \, [TBP] \ . \tag{20}$$

The quantity [TBP] is the concentration of uncomplexed or free TBP, defined as:

$$[TBP] = T - 2[UO_2(NO_3)_2 \cdot 2TBP] - 2\,[Pu(NO_3)_4 \cdot 2TBP] - [HNO_3 \cdot TBP] \ , \tag{21}$$

where T is the original TBP concentration in the organic phase before extraction, corrected for volume changes. Substitution of Eqs. (18), (19), and (20) into Eq. (21) produces:

$$[TBP] = T - 2K'_U [UO_2{}^{2+}] \, [NO_3{}^-]^2 \, [TBP]^2 - 2K'_P [Pu^{4+}] \, [NO_3{}^-]^4 \, [TBP]^2 - K'_H [H^+] \, [NO_3{}^-] \, [TBP] \ . \tag{22}$$

Rearranging gives:

$$2[NO_3{}^-]^2 \left\{ K'_U [UO_2{}^{2+}] + K'_P [Pu^{4+}] \, [NO_3{}^-]^2 \right\} [TBP]^2 + \left\{ 1 + K'_H [H^+] \, [NO_3{}^-] \right\} [TBP] = T \ . \tag{23}$$

The solution of Eq. (23) is:

$$[TBP] = \frac{-\left\{ 1 + K'_H [H^+] \, [NO_3{}^-] \right\}}{4[NO_3{}^-]^2 \left\{ K'_U [UO_2{}^{2+}] + K'_P [Pu^{4+}] \, [NO_3{}^-]^2 \right\}} + \frac{\sqrt{\left\{ 1 + K'_H [H^+] \, [NO_3{}^-] \right\}^2 + 8T[NO_3{}^-]^2 \left\{ K'_U [UO_2{}^{2+}] + K'_P [Pu^{4+}] \, [NO_3{}^-]^2 \right\}}}{4[NO_3{}^-]^2 \left\{ K'_U [UO_2{}^{2+}] + K'_P [Pu^{4+}] \, [NO_3{}^-]^2 \right\}} \ . \tag{24}$$

The following method is used for calculating distribution coefficients: (1) assume equilibrium values for $[UO_2{}^{2+}]$, $[Pu^{4+}]$, and $[H^+]$; (2) calculate μ using Eq. (14); (3) determine K′ values from Eqs. (15)–(17); (4) solve Eq. (24); and (5) substitute [TBP] into Eqs. (18)–(20). Then the calculated equilibrium values are determined for each solute, using Eqs. (6) and (7), as:

$$(x_{j,t})_{calc} = \frac{A_{j-1}\, x_{j-1,t-\Delta t} + O_{j+1}\, y_{j+1,t-\Delta t} + A_j{}^f x_j{}^f + O_j{}^f y_j{}^f - (O_j + O_j{}^p)\, Dx_{j,t}}{A_j + A_j{}^p} . \tag{25}$$

These values are compared with the assumed values for goodness of fit. Use of the calculated value as the next assumption usually provides agreement within a few iterations.

A simple correction may be made for a distribution coefficient if the isothermal contactor temperature is different from that at which the equilibrium data were obtained. This correction is made according to the following equation:

$$D_T = D_{T_0} \exp\left(\frac{1}{T} - \frac{1}{T_0}\right) C , \tag{26}$$

where temperatures are given in degrees Kelvin and C is a constant peculiar to each solute. In the existing SEPHIS program, C = 2220 for uranium and is 0 for other solutes. When a means of correcting for the temperature dependence for the other solutes is known, it can easily be included. According to Horner,[10] the correction for uranium should vary in some manner, depending on the organic loading, and become zero at saturation. However, it is not yet clear how this effect can be expressed mathematically.

In the course of correlating existing equilibrium data, it was possible to develop more than one set of coefficients for Eqs. (15)–(17) by optimizing for the best fit for each solute separately.[9] Thus, in program SEPHIS, 36 coefficients are provided.

6. DESCRIPTION OF THE PROGRAM

Computer program SEPHIS is written in FORTRAN IV for use with the IBM System 360. Input data are read in according to an input format described in Appendix A (Sect. 10). The listing of the program is given in Appendix B (Sect. 11).

SEPHIS consists of a MAIN program, into which most of the input data are read, and seven subroutines described as follows:

STOU handles the printout of results and analyzes the approach to steady-state operation.

STGS performs the stagewise calculations in each time interval set by STOU.

DOFX provides the distribution coefficients required by STGS.

FLWS defines feed and product streams and calculates phase ratios, flow ratios, recycle flows, and interstage flows for each stage.

PROF defines the initial concentration profile in the contactor, providing it is not zero.

COEF provides the empirical constants necessary in the calculation of distribution coefficients and temperature corrections.

PORD, if called for by STOU, provides the necessary orders to prepare a magnetic tape or disk for the Calcomp plotter. These orders are given to additional subroutines of the Intrigue package.[11]

Note that, if an improved correlation for equilibrium data is developed, one merely needs to replace the subroutine DOFX; no other program change is required.

Included in the input are the number of stages, the initial TBP concentration, the relative flow rates of all feed streams and of product streams other than the normal end streams, the feed stream concentrations, the initial concentration profile in the contactor, the phase ratios of the stages (if different from flow ratios), and the relative stage volumes (if unequal and not proportional to total stage flow). Other input information concerns the program user's desire to obtain graphs of stage concentrations vs time and/or position, adjust for the case in which the contactor temperature is different from that of the equilibrium data correlation, or to alter the built-in empirical constants for equilibrium or temperature calculations. Options are included to allow either a complete printout of results at every time interval or simply a final result at steady-state operation.

The program is organized to perform the stage calculations (as described in the previous section) using an iterative procedure in each stage at each interval of time. If a convergence precision (comparison of assumed and calculated values) of 0.1% is attained within 25 iterations, the computation is considered to be complete. If a precision less than this is attained, an additional 25 iterations are allowed to attain a 0.5% precision. In the case of failure to converge, the results of all 50 iterations are printed out, the last values are accepted, and the program is permitted to continue. The idea here is that failure to converge during the transient period does not necessarily mean steady-state values cannot be attained.

The program ends all computations when a steady-state value has been established for each solute. (Steady state is defined as the point at which the absolute overall contactor material balance for each solute is greater than 99.9%.) The printout includes the time intervals at which absolute material balances of 90, 95, 99, 99.5, and 99.9% are achieved. For a shutdown transient, steady state is considered to be reached when the heavy-metal concentrations become less than 10^{-6} *M*. The computation proceeds in blocks of 500 time intervals. In a slow approach to steady-state operation, exhibited under conditions of reflux for example, several time blocks may be required. To prevent long computing times, the number of time blocks is limited to five in the present program.

Graphs of stage composition vs time and/or position may be prepared from a computer-written magnetic tape or disk using the Calcomp plotter. Additional subroutines must be added to those listed in Appendix B to prepare the tape or disk. These are described by Emmett.[11] If the user does not wish to obtain graphs, these subroutines may be omitted.

The final concentration profile, at steady-state operation, is punched on cards suitable for use as input data for an initial concentration profile in a new calculation.

The program requires 270K memory bits and consumes about $\frac{1}{8}$ sec of computing time for each time interval when calculating 10 stages using the IBM System 360.

7. APPLICATION AND USES OF THE PROGRAM

In the application of computer program SEPHIS to predict the transient and steady-state behavior of solvent extraction contactors operating as specified by a dilute-Purex flowsheet, several facts must be considered:

(1) The correlation of the equilibrium data is only approximate and was developed from a single set of experimental data which did not include the very dilute or the most extensively loaded regions of the concentration spectrum. Therefore, flowsheet predictions made at high reflux operation near saturation (about 85% of saturation) may be unreliable. However, it appears that the predicted plutonium concentrations tend to be high in these regions, thus leading to a conservative conclusion.

(2) The calculational procedure does not take into account changes in solution volume with varying solute concentrations or the extraction of water. Nevertheless, in the dilute-Purex system, these corrections are probably less than the uncertainty in equilibrium values.

(3) Temperatures of feed streams are assumed to be the same as the temperature within the contactor, and no provisions are made for heat losses or for heat generation by chemical reaction or nuclear decay.

The program applies to extraction and stripping contactors. As yet, no attempt has been made to extend it to the treatment of a partition contactor and the associated change of plutonium species from extractable to nonextractable. Also, the common addition of a reductant to the solution for stripping plutonium is not accounted for in the program.

The program can be improved by obtaining more accurate Purex equilibrium values since the precision of much of the available data is not adequate. In doing this, care should be taken to obtain solution densities and water contents of the organic phase. Additional knowledge is also needed concerning the formation of a $HNO_3 \cdot 2TBP$ complex species, the degree of ionization of $Pu(NO_3)_4$, the disproportionation of Pu(IV) to Pu(III) and Pu(VI), the temperature dependence of distribution coefficients, and the effects of organic-phase loading on this temperature dependence.

In its present form, computer program SEPHIS can be used to:

1. Guide flowsheet optimization studies and thus minimize the amount of experimentation required to establish a particular set of operating conditions.
2. Aid in a criticality analysis of the solvent extraction plant.
3. Analyze the transient response to start up or shut down operations and optimize methods of control.
4. Study the effects of a process upset caused by component failure, process solution error, or change in feed characteristics, and the return of the process to normal operation upon correction of the problem.
5. Aid in maintaining an exact inventory of security-sensitive materials for nuclear safeguards purposes.
6. Help maintain process control in an automated solvent extraction plant.

Tables 1 and 2 provide a direct comparison of computer-predicted steady-state stage concentrations and those obtained experimentally. The data given in these tables are for the dilute-Purex partition cycle coextraction contactor and the plutonium cycle extraction contactor. The experimental values were obtained from laboratory-scale batch countercurrent runs. The agreement is considered to be good. The computer results for these problems are given in Appendix C (Sect. 12). Not all time intervals are shown in order to conserve space. Sample graphs of the transient concentrations in the feed stage and the concentration profiles are provided. Note that the graphs are of reduced concentrations (i.e., concentrations divided by the maximum concentration as shown in the printout).

In the course of establishing flowsheet conditions for a variety of conceptual LMFBR fuels,[5] experimental runs were made to substantiate the predicted conditions for certain cases. Direct comparisons could not be obtained, however, because of differences between the values specified for flow ratio, feed makeup, and TBP concentration in the conceptual flowsheet and those actually used in the laboratory. Other experimental runs were made to study problems of high priority such as effectiveness of the reductant, formation of a third plutonium phase, temperature effects, etc., as reported by Horner.[10] It is notable that the predicted values of stage concentrations were *substantially* verified by experimentation. Additional runs, to be made as funds become available, should provide increased assurance of the accuracy of the predicted data.

Table 1. Comparison of Experimental and Predicted Data for First-Cycle Coextraction of Uranium and Plutonium

Aqueous feed: 3.2 *M* HNO_3, 67.7 g of U and 4.43 g of Pu(IV) per liter
Organic: 15.3% TBP–84.7% *n*-dodecane
Scrub solution: 2 *M* HNO_3
Relative volumes, feed/organic/scrub: 1.0/1.8/0.3

Stage	Organic Phase[a]						Aqueous Phase[a]					
	U (g/liter)		Pu (g/liter)		HNO_3 (*M*)		U (g/liter)		Pu (g/liter)		HNO_3 (*M*)	
	A	B	A	B	A	B	A	B	A	B	A	B
Scrub-3	38.8	37.6	2.53	2.46	0.21	0.12	18.5	21.0	4.1	5.2	2.07	1.85
-2	42.1	41.1	2.91	3.33	0.21	0.10	23.0	28.2	5.8	9.1	2.10	1.82
-1	43.6	42.3	3.05	3.98	0.24	0.09	18.5	30.6	4.2	11.2	2.90	1.96
Feed							67.7		4.43		3.20	
Extraction-1	43.7	42.7	3.21	4.33	0.26	0.12	18.2	24.5	3.75	7.23	3.00	3.13
-2	13.9	17.7	2.65	5.22	0.29	0.27	2.72	2.57	0.91	1.91	2.90	3.33
-3	1.28	1.85	0.50	1.36	0.34	0.41	0.11	0.127	0.092	0.227	3.10	3.36
-4	0.07	0.092	0.074	0.164	0.34	0.44	<0.01	0.006	0.015	0.024	3.10	3.36
-5	<0.02	0.004	0.009	0.018	0.34	0.44	<0.01	<0.001	0.003	0.003	3.10	3.36
-6	<0.02	<0.001	0.002	0.002	0.35	0.44	<0.01	<0.001	0.001	<0.001	3.07	3.36
-7	<0.02	<0.001	<0.001	<0.001	0.34	0.44	<0.01	<0.001	0.001	<0.001	3.01	3.31
-8	<0.02	<0.001	0.004	<0.001	0.30	0.40	<0.01	<0.001	0.010	<0.001	2.64	2.75

[a]A = Experimental value; B = predicted value.

Table 2. Comparison of Experimental and Predicted Data for Second-Cycle Extraction of Plutonium

Aqueous feed: 4.1 *M* HNO_3, 19.2 g of Pu(IV) per liter
Organic: 15.0% TBP–85.0% *n*-dodecane
Scrub solution: 2 *M* HNO_3
Relative volumes, feed/organic/scrub: 1.0/0.9/0.11

Stage	Organic Phase[a]				Aqueous Phase[a]			
	Pu (g/liter)		HNO_3 (*M*)		Pu (g/liter)		HNO_3 (*M*)	
	A	B	A	B	A	B	A	B
Scrub-3	20.7	21.3	0.24	0.20	14.1	12.9	2.2	2.0
-2	20.9	22.9	0.24	0.21	13.9	12.7	2.5	2.2
-1	19.9	22.9	0.22	0.23	11.4	10.2	2.8	2.6
Feed					19.2		4.1	
Extraction-1	22.0	22.6	0.35	0.28	6.60	6.33	3.9	4.0
-2	7.2	7.82	0.33	0.39	1.52	1.26	3.9	4.1
-3	1.8	1.55	0.34	0.45	0.307	0.204	4.0	4.1
-4	0.351	0.252	0.36	0.46	0.080	0.032	4.0	4.1
-5	0.075	0.039	0.36	0.46	0.034	0.005	4.0	4.1
-6	0.015	0.006	0.38	0.46	0.044	<0.001	4.0	4.1
-7	0.005	<0.001	0.37	0.45	0.029	<0.001	3.9	3.7

[a]A = Experimental value; B = predicted value.

8. CONCLUSIONS

The computer program SEPHIS has been shown to be a valuable aid in determining optimum solvent extraction conditions for the reprocessing of potential LMFBR fuels by the dilute-Purex method. Certain improvements in the method are desirable and, if made, would result in a significant contribution and advancement to the technology of LMFBR fuel reprocessing. The possible applications to inventory control for nuclear safeguards, criticality analysis, and process analysis and control are of special interest.

9. REFERENCES

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11. M. B. Emmett, *Intrigue-II: An IBM-360 Subroutine Package for Making Linear, Logarithmic and Semilogarithmic Graphs Using the Calcomp Plotter,* ORNL-4664 (March 1971).

10. Appendix A: INPUT DATA CARD FORMATS

The data cards must be arranged in the order shown. An "I" prefix in the format column refers to an integer number which must be punched at the right side of the format field without a decimal point. An "F" prefix refers to a "real" number that must contain a decimal point and may be placed anywhere within the format field. The variable names are those used in the FORTRAN coding.

Variable Name	Column Field	Description	Field Format
		Problem Card	
TAT1-TAT4	1–16	Problem title.	4A4
NTS	17–20	Total number of stages (25 maximum).	I4
CTBP	21–24	Volume fraction TBP in solvent.	F4.0
ICO	25–28	1 to alter built-in equilibrium coefficients. 0 for no change.	I4
IPO	29–32	1 if the initial concentration profile is nonzero. 0 for a zero initial condition.	I4
IRT	33–36	1 if phase ratios do not equal flow ratios. 0 if phase and flow ratios are equal.	I4
ICC	37–40	1 for startup or interruptive transient calculation. 0 for shutdown transient.	I4
IGO	41–44	1 if there are product streams in addition to end streams. 0 for no extra product streams.	I4
IVL	45–48	0 if all stage volumes are equal. 1 if stage volumes are unequal, but proportional to total stage flow. 2 if stage volumes are unequal and not flow-related.	I4
IPL	49–52	0 if no Calcomp graphs are desired. 1 to obtain profile graphs of logarithm of concentration vs stage number at "steady state" (or at each 100th time interval) and at one-half, one-fourth, and one-eighth of this time; total of six graphs for each time block. 2 to obtain two transient graphs of concentration vs time for specified stages for each time block. 3 to obtain both 1 and 2 above.	I4
IPR	53–56	0 to print results of every time interval. 1 to print steady-state (or each 100th time interval) results only. Use 0 if IPL >0.	I4
DDU	57–60	Adjustment factor for uranium distribution coefficient (if none, use 1.0).	F4.0
DDP	61–64	Adjustment factor for plutonium distribution coefficient.	F4.0
DDH	65–68	Adjustment factor for acid distribution coefficient.	F4.0
DELT	69–72	Inverse absolute difference between process temperature (T) and equilibrium data (T_0), calculated as $1/T - 1/T_0$ (use °K).	F4.0
ITP	73–76	1 to alter built-in temperature coefficients. 0 for no change.	I4
ICON	77–80	1 if this problem uses the result from the previous problem as an initial profile. 0 for a zero profile or for a profile on data cards.	I4
		Feed Stream Cards (one card for each feed stream)	
J	1–4	Stage number that feed enters (numbered from organic product end).	I4
JPH	5–8	1 if an aqueous feed; −1 if an organic feed.	I4
FR	9–16	Actual or relative flow rate (volume units).	F8.0
CON (1)	17–24	Uranium concentration (g/liter).	F8.0
CON (2)	25–32	Plutonium concentration (g/liter).	F8.0
CON (3)	33–40	Nitric acid concentration (*M*).	F8.0
K	41–44	1 if more cards of this type follow. 0 for last card.	I4
		Product Stream Cards (one card for each product stream in addition to usual end streams.)	
J	1–4	Stage number from which product leaves.	I4
JPH	5–8	1 if an aqueous stream; −1 if an organic stream.	I4
FR	9–16	Actual or relative flow rate (volume units).	F8.0
K	17–20	1 if more cards of this type follow. 0 for last card.	I4

Variable Name	Column Field	Description	Field Format
Phase Ratio Cards (one card for each region of constant phase ratio, used only if phase ratios do not equal flow ratios.)			
I	1–8	Number of stages having phase ratio shown.	I8
RATIO	9–16	Aqueous/organic phase ratio.	F8.0
Stage Volume Cards (Used if stage volumes are unequal and not flow-related. Define volumes of ten stages on each card. Can be actual or relative.)			
(Card 1) SVO (1)	1–8	Volume of stage No. 1.	F8.0
SVO (2)	9–16	Volume of stage No. 2.	F8.0
DO	DO	DO	DO
SVO (10)	72–80	Volume of stage No. 10.	F8.0
(Card 2) SVO (11)	1–8	Volume of stage No. 11.	F8.0
DO	DO	DO	DO
Initial Profile Cards (one card for each stage, required only for a nonzero initial profile.)			
ASP (J,1)	1–12	Aqueous-phase uranium concentration in stage J (g/liter).	F12.0
ASP (J,2)	13–24	Aqueous-phase plutonium concentration (g/liter).	F12.0
ASP (J,3)	25–36	Aqueous-phase nitric acid concentration (*M*).	F12.0
OSP (J,1)	37–48	Organic-phase uranium concentration (g/liter).	F12.0
OSP (J,2)	49–60	Organic-phase plutonium concentration (g/liter).	F12.0
OSP (J,3)	61–72	Organic-phase nitric acid concentration (*M*).	F12.0
Equilibrium Coefficient Alteration Cards (Used only if built-in equilibrium coefficients are to be altered.)			
I	1–4	Number of coefficient to be altered [see Eqs. (15)–(17)].	I4
C	5–20	New value of coefficient.	F16.0
J	21–24	1 if more cards of this type follow. 0 for last card.	I4
Temperature Coefficient Alteration Card (Used only if built-in temperature coefficients are to be altered.)			
SLU	1–8	New coefficient for uranium [see Eq. (26)].	F8.0
SLP	9–16	New plutonium coefficient.	F8.0
SLH	17–24	New nitric acid coefficient.	F8.0
Graph Cards (Used only if graphs are desired.)			
(Card 1)	1–5	Number of characters in profile graph title.	I5
(Card 2)	1–72	Profile graph title.	18A4
(Card 3)	1–4	Stage number for first set of transient graphs	I4
	5–8	Stage number for second set of transient graphs	I4
	DO	DO	DO
	76–80	Stage number for 20th set of transient graphs	I4
(Card 4)	1–5	Number of characters in transient graph title.	I5
(Card 5)	1–72	Transient graph title.	18A4

Note: Use cards 1 and 2 if a "1" appears in column 52 of Problem Card. Use cards 3, 4, and 5 if a "2" appears. If a "3" appears, use cards 1 through 5. Supply a complete set of these cards, except for card 3, for each succeeding time block. To know how many time blocks are needed, run problem without requesting plots the first time.

Problem Card for succeeding problem, if desired.

11. Appendix B: FORTRAN LISTING OF PROGRAM SEPHIS

```
**FTN,L,M,P.
CCC                                                                     CCC
C                          OAK RIDGE NATIONAL LABORATORY                  C
C                 CHEMICAL TECHNOLOGY DIVISION  -  UNIT OPERATIONS SECTION  C
C                                                                         C
C                                PROGRAM SEPHIS                           C
C                                                                         C
C  TRANSIENT CALCULATIONS FOR SOLVENT EXTRACTION PROCESSES HAVING INTERACTING  C
C  SOLUTES  -  FOR USE IN TBP SYSTEMS  -  VALID FOR 3 SOLUTES  -  INTENDED TO  C
C  BE USED FOR RATHER DILUTE SYSTEMS WHERE VOLUME CHANGES DUE TO SOLUTE TRANS  C
C  FER ARE NOT SIGNIFICANT  -  ASSUMES ISOTHERMAL OPERATION  -  ALLOWS SYSTEM  C
C  CALCULATIONS AT TEMPERATURES OTHER THAN THAT ASSIGNED TO EQUILIBRIUM DATA.  C
C                              SOLUTE 1 - URANYL NITRATE                  C
C                              SOLUTE 2 - PLUTONIUM NITRATE               C
C                              SOLUTE 3 - NITRIC ACID                     C
CCC                                                                     CCC
      DIMENSION X(3,25,101),Y(3,25,101),XFD(3,25),YFD(3,25),ASP(3,25),
     1OSP(3,25),ASC(3),OSC(3),DTRY(3),A(25),O(25),AFD(25),OFD(25),APR(25
     2),OPR(25),RA(25),RO(25),R(25),REC(25),CIT(25,101),CO(35)
      COMMON/RES/X,Y
      COMMON/ITR/CIT
      COMMON/ALL/XFD,YFD,A,O,AFD,OFD,APR,OPR,RA,RO,R,REC,ASC,OSC,DTRY,CO
     1,DFA,DFB,DFC,DFD,DFE,NTA,NTB,NTC,NTD,NTE,DDU,DDP,DDH,DELT,CTBP,ASP
     2,OSP,IXO,SLU,SLP,SLH
      REAL*8 X,Y,ASC,OSC,DTRY,CO,CTBP,ASP,OSP
    2 READ 100,TAT1,TAT2,TAT3,TAT4,NTS,CTBP,ICO,IPO,IRT,ICC,IGO,IVL,IPL,
     1IPR,DDU,DDP,DDH,DELT,ITP,ICON
C
C  TAT1-TAT4 IS THE PROBLEM TITLE        CTBP = VOLUME FRACTION OF TBP
C  NTS = TOTAL NUMBER OF STAGES           IGO = 1 IF THERE ARE PRODUCT STREAMS IN
C  ICO = 1 TO ALTER CORRELATION             ADDITION TO END STREAMS, 0 IF NOT
C    COEFFICIENTS, 0 FOR NO CHANGE        IVL = 0 FOR EQUAL STAGE VOLUMES, 1 IF
C  IPO = 1 FOR A NON-ZERO INITIAL           UNEQUAL BUT PROPORTIONAL TO TOTAL
C    PROFILE, 0 FOR A ZERO PROFILE          STAGE FLOW, 2 IF INDEPENDENTLY UNEQUAL
C  IRT = 1 TO READ IN PHASE RATIOS       IPL = 0 FOR NO GRAPHS, 1 FOR PLOT OF
C    FOR EACH STAGE, 0 IF PHASE             SOLUTE CONCENTRATION VS. STAGE NO.,
C    RATIO = FLOW RATIO                     2 FOR CONC. VS. TIME, 3 FOR BOTH 1 + 2
C  ICC = 1 FOR START-UP OR INTERUP-      IPR = 1 TO PRINT RESULTS FROM LAST TIME
C    TIVE TRANSIENT, 0 FOR SHUT-DOWN        INTERVAL ONLY, 0 FOR ALL RESULTS
C  DDU,DDP,DDH = BIAS CORRECTIONS FOR U, PU, AND ACID DISTRIBUTION COEFFICIENTS
C    (DC). FOR NO BIAS USE 1.0.          ITP = 1 TO READ IN CONSTANT FOR TEMP.
C  DELT = INVERSE ABSOLUTE TEMPERATURE DIFFERENCE BETWEEN EQUILIBRIUM DATA,TO
C    AND SYSTEM,T   (DELT = 1/T - 1/TO)   USE DEGREES K.
C  ICON = 1 IF THIS IS A NEW CASE, BUT STARTING WITH A PROFILE ESTABLISHED
C    BY THE PREVIOUS CASE.
C
C  INDEX VARIABLES
C
      NSO = 3
      DFA = 90.0
      DFB = 95.0
      DFC = 99.0
      DFD = 99.5
      DFE = 99.9
      DO 3 I=1,3
      ASC(I) = 0.0D0
      OSC(I) = 0.0D0
```

```
      DTRY(I) = 0.0D0
      DO 3 J=1,25
      XFD(I,J) = 0.0
      YFD(I,J) = 0.0
      DO 3 K=1,101
      X(I,J,K) = 0.0D0
      Y(I,J,K) = 0.0D0
    3 CONTINUE
      DO 4 I=1,25
      A(I) = 0.0
      O(I) = 0.0
      AFD(I) = 0.0
      OFD(I) = 0.0
      APR(I) = 0.0
      OPR(I) = 0.0
      RA(I) = 0.0
      RO(I) = 0.0
      R(I) = 0.0
      REC(I) = 0.0
      DO 4 J=1,101
      CIT(I,J) = 0.0
    4 CONTINUE
      NTA = 0
      NTB = 0
      NTC = 0
      NTD = 0
      NTE = 0
      PRINT 200,TAT1,TAT2,TAT3,TAT4,NTS
      PRINT 210
      CALL FLWS(IGO,IRT,IVL,NTS)
      CALL PROF(IPO,NTS,ICON)
      CALL COEF(ICO,ITP)
C
C   PRINT-OUT OF INPUT DATA
C
      DO 6 I=1,NTS
      IF(AFD(I)) 6,6,5
    5 X1 = XFD(1,I)*238.0
      X2 = XFD(2,I)*239.0
      PRINT 220,I,X1,X2,XFD(3,I),AFD(I)
    6 CONTINUE
      PRINT 230,CTBP
      DO 8 I=1,NTS
      IF(OFD(I)) 8,8,7
    7 Y1 = YFD(1,I)*238.0
      Y2 = YFD(2,I)*239.0
      PRINT 220,I,Y1,Y2,YFD(3,I),OFD(I)
    8 CONTINUE
      IF(IGO) 14,14,9
    9 PRINT 240
      DO 11 I=1,NTS
      IF(APR(I)) 11,11,10
   10 PRINT 250,I,APR(I)
   11 CONTINUE
      PRINT 260
      DO 13 I=1,NTS
      IF(OPR(I)) 13,13,12
   12 PRINT 250,I,OPR(I)
   13 CONTINUE
   14 IF(IPO) 17,17,15
   15 PRINT 270
      DO 16 I=1,NTS
      X(1,I,1) = ASP(1,I)
      X(2,I,1) = ASP(2,I)
      X(3,I,1) = ASP(3,I)
```

```
      Y(1,I,1) = OSP(1,I)
      Y(2,I,1) = OSP(2,I)
      Y(3,I,1) = OSP(3,I)
      X1 = X(1,I,1)*238.0
      X2 = X(2,I,1)*239.0
      Y1 = Y(1,I,1)*238.0
      Y2 = Y(2,I,1)*239.0
      PRINT 280,I,X1,X2,X(3,I,1),Y1,Y2,Y(3,I,1)
   16 CONTINUE
   17 PRINT 290
      PRINT 300
      PRINT 310,(CO(I),I=1,4)
      PRINT 320,(CO(I),I=5,8)
      PRINT 330,(CO(I),I=9,12)
      PRINT 340
      PRINT 300
      PRINT 310,(CO(I),I=13,16)
      PRINT 320,(CO(I),I=17,20)
      PRINT 330,(CO(I),I=21,24)
      PRINT 350
      PRINT 300
      PRINT 310,(CO(I),I=25,28)
      PRINT 320,(CO(I),I=29,32)
      PRINT 330,(CO(I),I=33,36)
      IF(IRT) 18,18,19
   18 PRINT 370
      GO TO 20
   19 PRINT 360
   20 DO 26 I=1,NTS
      IF(I-1) 21,21,22
   21 RATIO = R(I)
      NST = I
      IF(I-NTS) 26,25,25
   22 IF(RATIO-R(I)) 23,24,23
   23 IK = I - 1
      PRINT 380,NST,IK,RATIO
      GO TO 21
   24 IF(I-NTS) 26,25,25
   25 PRINT 380,NST,I,RATIO
   26 CONTINUE
      PRINT 390
      DO 27 I=1,NTS
      AA = APR(I) + A(I)
      OO = OPR(I) + O(I)
      RATIO = AA/OO
      AR = REC(I)*R(I)/(1.0+R(I))
      OR = REC(I)/(1.0+R(I))
      AT = AA + AR + RA(I)
      OT = OO + OR + RO(I)
      TT = AT + OT
      PRINT 400,I,RATIO,AA,AR,RA(I),AT,OO,OR,RO(I),OT,TT
   27 CONTINUE
      CALL STOU(ICC,IPR,IPL,NTS)
      GO TO 2
  100 FORMAT (4A4,I4,F4.0,8I4,4F4.0,2I4)
  200 FORMAT (30H1OAK RIDGE NATIONAL LABORATORY//67H SEPHIS  -  A SOLVEN
     1T EXTRACTION PROCESS HAVING INTERACTING SOLUTES//10X,4A4,6X,I4,2X,
     212HTOTAL STAGES)
  210 FORMAT (27H0FEED STREAM DATA - AQUEOUS,6X,5HSTAGE,3X,7HURANIUM,5X,
     19HPLUTONIUM,6X,4HACID,6X,9HFLOW RATE/34X,3HNO.,5X,5H(G/L),8X,5H(G/
     2L),9X,3H(M),5X,11H(VOL.UNITS)/)
  220 FORMAT (32X,I4,3(3X,1PE10.4),3X,1PE9.2)
  230 FORMAT (7X,F6.3,14H T8P - ORGANIC)
  240 FORMAT (27H0EXIT STREAM DATA - AQUEOUS/)
```

```
  250 FORMAT (32X,I4,42X,1PE9.2)
  260 FORMAT (18X,9H- ORGANIC)
  270 FORMAT (25HONON-ZERO INITIAL PROFILE,8X,5HSTAGE,13X,13HAQUEOUS PHA
     1SE,25X,13HORGANIC PHASE/34X,3HNO.,4X,7HURANIUM,5X,9HPLUTONIUM,6X,4
     2HACID,7X,7HURANIUM,5X,9HPLUTONIUM,6X,4HACID/31X,9H(OUTFLOW),2X,5H(
     3G/L),8X,5H(G/L),9X,3H(M),8X,5H(G/L),8X,5H(G/L),9X,3H(M)/)
  280 FORMAT (32X,I4,6(3X,1PE10.4))
  290 FORMAT (85HOEQUILIBRIUM EXPRESSIONS - CORRELATION COEFFICIENTS OPT
     1IMIZED WITH RESPECT TO URANIUM)
  300 FORMAT (1H0,44X,2HA0,18X,2HA1,18X,2HA2,18X,2HA3/)
  310 FORMAT (19X,13HFOR URANIUM  ,4F20.8)
  320 FORMAT (17X,15HFOR PLUTONIUM  ,4F20.8)
  330 FORMAT (22X,10HFOR ACID  ,4F20.8)
  340 FORMAT (1H0,24X,62H- CORRELATION COEFFICIENTS OPTIMIZED WITH RESPE
     1CT TO PLUTONIUM)
  350 FORMAT (1H0,24X,57H- CORRELATION COEFFICIENTS OPTIMIZED WITH RESPE
     1CT TO ACID)
  360 FORMAT (54HOPHASE RATIOS DO NOT EQUAL FLOW RATIOS - THEY ARE --- ,
     13X,9HSTAGE NO.,3X,11HPHASE RATIO/)
  370 FORMAT (36HOPHASE RATIOS EQUAL FLOW RATIOS --- ,21X,9HSTAGE NO.,3X
     1,11HPHASE RATIO/)
  380 FORMAT (54X,I4,3H  -,I4,4X,1PE10.2)
  390 FORMAT (36HOFLOWS IN EACH STAGE (VOL.UNITS) ---/34X,13HAQUEOUS PHA
     1SE,32X,13HORGANIC PHASE,18X,7HOVERALL/22X,4HFLOW,4X,20HRECYCLE 2
     2RECYCLE 1,4X,5HTOTAL,8X,4HFLOW,4X,20HRECYCLE 2  RECYCLE 1,4X,5HTOT
     3AL,7X,5HTOTAL/13H  STAGE  FLOW,8X,6HOUT OF,4X,7HTO FILL,3X,9HFOR P
     4HASE,3X,7HAQUEOUS,6X,6HOUT OF,4X,7HTO FILL,3X,9HFOR PHASE,3X,7HORG
     5ANIC,6X,5HSTAGE/3X,3HNO.,3X,5HRATIO,7X,5HSTAGE,6X,5HSTAGE,6X,5HRAT
     6IC,6X,4HFLOW,8X,5HSTAGE,6X,5HSTAGE,6X,5HRATIO,6X,4HFLOW,8X,4HFLOW/
     7)
  400 FORMAT (I5,2X,1PE9.2,1X,4(2X,1PE9.2),1X,4(2X,1PE9.2),3X,1PE9.2)
      END

      SUBROUTINE STOU(ICC,IPR,IPL,NTS)
      DIMENSION X(3,25,101),Y(3,25,101),XFD(3,25),YFD(3,25),ASP(3,25),
     1OSP(3,25),ASC(3),OSC(3),DTRY(3),A(25),O(25),AFD(25),OFD(25),APR(25
     2),OPR(25),RA(25),RO(25),R(25),REC(25),CIT(25,101),CO(36),SIN(3),
     3SOT(3,101),CF(6),DF(3)
      COMMON/RES/X,Y
      COMMON/ITR/CIT
      COMMON/ALL/XFC,YFD,A,O,AFD,OFD,APR,OPR,RA,RO,R,REC,ASC,OSC,DTRY,CO
     1,DFA,DFB,DFC,DFD,DFE,NTA,NTB,NTC,NTD,NTE,DDU,DDP,DDH,DELT,CTBP,ASP
     2,OSP,IXO,SLU,SLP,SLH
      REAL*8 X,Y,ASC,OSC,DTRY,CO,CTBP,ASP,OSP,DDF,SIN,SOT,CF,DF
C
C
C  STOU CALLS FOR STAGE CALCULATIONS IN EACH TIME INTERVAL, CHECKS TO SEE
C  IF STEADY-STATE HAS BEEN ATTAINED, AND PRINTS OUT RESULTS.
C
      PRINT 200
      M = 101
      NTI = 0
      NT = 0
      IXO = 0
      DDF = 0.10D0
      DO 2 I=1,3
      SIN(I) = 0.0D0
      DO 2 J=1,101
      SOT(I,J) = 0.0D0
    2 CONTINUE
      DO 3 I=1,3
      DO 3 J=1,NTS
      SIN(I) = SIN(I) + AFD(J)*XFD(I,J) + OFD(J)*YFD(I,J)
    3 CONTINUE
```

```
C
C   TRY THE FIRST HUNDRED TIME INTERVALS  (THE INTERVAL = THE RESIDENCE
C   TIME OF THE SMALLEST STAGE)
C
    4 DO 23 K=2,M
      CALL STGS(K,NTS)
      IF(NT) 5,5,6
    5 IF(K-NTS) 23,6,6
    6 IF(ICC) 7,7,12
C
C   CHECK FOR NEAR ZERO CONCENTRATION AT SHUT-DOWN (ICC=0)
C
    7 DO 11 J=1,NTS
      IF(X(1,J,K)-1.0D-6) 8,8,23
    8 IF(Y(1,J,K)-1.0D-6) 9,9,23
    9 IF(X(2,J,K)-1.0D-6) 10,10,23
   10 IF(Y(2,J,K)-1.0D-6) 11,11,23
   11 CONTINUE
      M = K
      GO TO 25
C
C   CHECK FOR STEADY-STATE OPERATION
C
   12 DO 15 I=1,3
      SOT(I,K) = A(NTS)*X(I,NTS,K) + O(1)*Y(I,1,K)
      DO 13 J=1,NTS
      SOT(I,K) = SOT(I,K) + APR(J)*X(I,J,K) + OPR(J)*Y(I,J,K)
   13 CONTINUE
      IF(SIN(I).LE.0.0D0) GO TO 15
      DF(I) = DABS((SIN(I)-SOT(I,K))/SIN(I))
   14 IF(DF(I)-DDF) 15,15,23
   15 CONTINUE
      IF(DDF-0.1D0) 17,16,16
   16 NTA = K + 99 + 100*(NTI-1)
      DDF = 0.05D0
      GO TO 23
   17 IF(DDF-0.05D0) 19,18,18
   18 NTB = K + 99 + 100*(NTI-1)
      DDF = 0.01D0
      GO TO 23
   19 IF(DDF-0.01D0) 21,20,20
   20 NTC = K + 99 + 100*(NTI-1)
      DDF = 0.005D0
      GO TO 23
   21 IF(DDF-0.005D0) 24,22,22
   22 NTD = K + 99 + 100*(NTI-1)
      DDF = 0.001D0
   23 CONTINUE
      GO TO 25
   24 M = K
      NTE = K + 99 + 100*(NTI-1)
   25 DO 33 K=1,M
      IF(IPR) 27,27,26
   26 IF(K-M) 33,27,27
   27 DO 33 J=1,NTS
      DO 30 I=1,2
      IF(I-2) 28,29,30
   28 X(I,J,K) = X(I,J,K)*238.D0
      Y(I,J,K) = Y(I,J,K)*238.D0
      GO TO 30
   29 X(I,J,K) = X(I,J,K)*239.D0
      Y(I,J,K) = Y(I,J,K)*239.D0
   30 CONTINUE
      IF(J-1) 31,31,32
   31 L = K + 99 + 100*(NTI-1)
```

```
C
C   PRINT OUT RESULTS FOR EACH TIME INTERVAL IF IPR=0, ONLY LAST TIME
C   INTERVAL IF IPR=1.
C
      PRINT 210,L,J,(X(I,J,K),I=1,3),(Y(I,J,K),I=1,3),CIT(J,K)
      GO TO 33
   32 PRINT 220,J,(X(I,J,K),I=1,3),(Y(I,J,K),I=1,3),CIT(J,K)
   33 CONTINUE
      PRINT 230,DFE,NTE
      PRINT 240,DFD,NTD
      PRINT 240,DFC,NTC
      PRINT 240,DFB,NTB
      PRINT 240,DFA,NTA
      IF(M-101) 34,36,36
   34 DO 35 J=1,NTS
C
C   PUNCH CARDS OF FINAL VALUES FOR POSSIBLE INITIAL STARTING POINT IN A
C   SUCCEEDING PROBLEM.
C
      PUNCH 250,(X(I,J,M),I=1,3),(Y(I,J,M),I=1,3)
      DO 35 I=1,3
      ASP(I,J) = X(I,J,M)
      OSP(I,J) = Y(I,J,M)
   35 CONTINUE
      NT = 0
      GO TO 41
C
C   RESET CONCENTRATION MATRIX FOR THE NEXT HUNDRED TIME INTERVALS
C
   36 DO 40 J=1,NTS
      DO 40 I=1,3
      IF(I-2) 37,38,39
   37 X(I,J,1) = X(I,J,101)/238.D0
      Y(I,J,1) = Y(I,J,101)/238.D0
      GO TO 40
   38 X(I,J,1) = X(I,J,101)/239.D0
      Y(I,J,1) = Y(I,J,101)/239.D0
      GO TO 40
   39 X(I,J,1) = X(I,J,101)
      Y(I,J,1) = Y(I,J,101)
   40 CONTINUE
      NT = NT + 1
C
C   CALCULATE MAXIMUM CONCENTRATIONS
C
   41 DO 42 I=1,6
      CF(I) = 0.0D0
   42 CONTINUE
      DO 44 I=1,3
      II = I + 3
      DO 43 J=1,NTS
      DO 43 K=2,M
      CF(I) = DMAX1(X(I,J,K),CF(I))
      CF(II) = DMAX1(Y(I,J,K),CF(II))
   43 CONTINUE
      PRINT 260,I,CF(I),CF(II)
   44 CONTINUE
      IF(IPL) 52,52,45
C
C   CALCULATE REDUCED CONCENTRATIONS FOR PLOTS
C
   45 DO 51 I=1,3
      II = I + 3
      DO 51 J=1,NTS
      DO 51 K=2,M
      IF(CF(I)) 47,46,47
```

```
   46 X(I,J,K) = 0.0D0
      GO TO 48
   47 X(I,J,K) = X(I,J,K)*1.0D2/CF(I)
   48 IF(CF(II)) 50,49,50
   49 Y(I,J,K) = 0.0D0
      GO TO 51
   50 Y(I,J,K) = Y(I,J,K)*1.0D2/CF(II)
   51 CONTINUE
      CALL PORD(IPL,NTS,M,NTI)
   52 IF (NT) 54,54,53
   53 IF(NT -5) 4,54,54
   54 IF(IXO) 56,56,55
   55 PRINT 270,IXO
   56 RETURN
  200 FORMAT (27H1TRANSIENT BEHAVIOR RESULTS,10X,49HSOLUTE CONCENTRATION
     1S IN EFFLUENT FROM EACH STAGE//5X,4HTIME,6X,5HSTAGE,10X,20HAQUEOUS
     2 PHASE VALUES,16X,20HORGANIC PHASE VALUES/3X,8HINTERVAL,13X,7HURAN
     3IUM,5X,9HPLUTONIUM,5X,4HACID,6X,7HURANIUM,5X,9HPLUTONIUM,5X,4HACID
     4/25X,5H(G/L),8X,5H(G/L),7X,3H(M),8X,5H(G/L),8X,5H(G/L),7X,3H(M),15
     5X,10HITERATIONS)
  210 FORMAT (1H0,3X,I4,7X,I4,2X,6(2X,1PD10.2),7X,0PF10.0)
  220 FORMAT (15X,I4,2X,6(2X,1PD10.2),7X,0PF10.0)
  230 FORMAT (1H0,F6.1,2X,72HPER CENT OF STEADY STATE BY OVERALL MATERIA
     1L BALANCE AFTER TIME INTERVAL,I6)
  240 FORMAT (F7.1,2X,14HPER CENT AFTER,I6)
  250 FORMAT (6(1PD12.5))
  260 FORMAT (32H0MAXIMUM CONCENTRATION OF SOLUTE,I4,12H  IN AQUEOUS,2X,
     11PD10.4,5X,10HIN ORGANIC,2X,1PD10.4)
  270 FORMAT (29H1TOTAL NUMBER OF OVERFLOWS IS,I4)
      END
      SUBROUTINE STGS(K,NTS)
      DIMENSION X(3,25,101),Y(3,25,101),XFD(3,25),YFD(3,25),ASP(3,25),
     1OSP(3,25),ASC(3),OSC(3),DTRY(3),A(25),O(25),AFD(25),OFD(25),APR(25
     2),OPR(25),RA(25),RO(25),R(25),REC(25),CIT(25,101),CO(36),DPR(3),
     3XPR(3),XXPR(3),AIN(3),OIN(3)
      COMMON/RES/X,Y
      COMMON/ITR/CIT
      COMMON/ALL/XFD,YFD,A,O,AFD,OFD,APR,OPR,RA,RO,R,REC,ASC,OSC,DTRY,CO
     1,DFA,DFB,DFC,DFD,DFE,NTA,NTB,NTC,NTD,NTE,DDU,DDP,DDH,DELT,CTBP,ASP
     2,OSP,IXO,SLU,SLP,SLH
      REAL*8 X,Y,ASC,OSC,DTRY,CO,CTBP,ASP,OSP,DPR,XPR,XXPR,AIN,OIN,CCD,
     1DI,DIF
C
C
C  STGS PERFORMS STAGE CALCULATIONS FOR EACH TIME INTERVAL
C
      DO 26 J=1,NTS
      MPR = 0
    2 R1 = 1.0 + R(J)
      R2 = REC(J)/R1
      R3 = R(J)*REC(J)/R1
      DO 9 I=1,3
      DPR(I) = 0.0D0
      XPR(I) = 0.0D0
      KK = K - 1
      IF(J-1) 3,3,4
    3 AIN(I) = AFD(J)*XFD(I,J) + (R3+RA(J))*X(I,J,KK)
      GO TO 5
    4 JJ = J - 1
      AIN(I) = AFD(J)*XFD(I,J) + (R3+RA(J))*X(I,J,KK) + A(JJ)*X(I,JJ,KK)
    5 IF(J-NTS) 6,7,7
    6 JJ = J + 1
      OIN(I) = OFD(J)*YFD(I,J) + (R2+RO(J))*Y(I,J,KK) + O(JJ)*Y(I,JJ,KK)
      GO TO 8
```

```
    7 CIN(I) = OFD(J)*YFD(I,J) + (R2+RO(J))*Y(I,J,KK)
    8 AIN(I) = AIN(I)/(A(J)+APR(J)+R3+RA(J))
      OIN(I) = OIN(I)/(O(J)+OPR(J)+R2+RO(J))
      ASC(I) = AIN(I)
      OSC(I) = OIN(I)
    9 CONTINUE
      CCD = 1.0D-3
      MCK = 0
   10 MDEX = 0
C
C  MPR IS NON-ZERO ONLY IF STAGE CALCULATION ITERATION WILL NOT CLOSE
C  AND CONSEQUENTLY IT IS DESIRED THAT EACH TRIAL AND RESULT BE PRINTED.
C  MCK COUNTS THE ITERATIONS
C  MDEX IS THE FIT INDEX - IT IS NON-ZERO WHEN TRIAL AND RESULT DO NOT
C  AGREE THUS SIGNALING FOR A NEW TRIAL.
C
      CALL DOFX
      DTRY(1) = DTRY(1)* EXP(SLU*DELT)*DDU
      DTRY(2) = DTRY(2)* EXP(SLP*DELT)*DDP
      DTRY(3) = DTRY(3)* EXP(SLH*DELT)*DDH
      DO 14 I=1,3
      XPR(I) = ASC(I)
      X(I,J,K) = (AIN(I)*R(J) + OIN(I))/(R(J)+DTRY(I))
      IF(X(I,J,K)-1.0D-10) 13,13,11
   11 DI = (X(I,J,K)-ASC(I))/((X(I,J,K)+ASC(I))/2.0D0)
      DIF = DABS(DI)
      DPR(I) = DIF
      IF(DIF-CCD) 13,13,12
   12 ASC(I) = X(I,J,K)
      MDEX = MDEX + 1
   13 XXPR(I) = X(I,J,K)
   14 CONTINUE
      MCK = MCK + 1
      IF(MPR) 16,16,15
   15 PRINT 200,(XPR(I),DTRY(I),XXPR(I),DPR(I),I=1,3)
   16 IF(MCK-25) 20,17,18
   17 CCD = 5.0D-3
      GO TO 20
   18 IF(MCK-50) 20,19,23
   19 CCD = 1.0D-2
   20 IF(MDEX) 21,21,10
   21 DO 22 I=1,3
      Y(I,J,K) = X(I,J,K)*DTRY(I)
   22 CONTINUE
      CIT(J,K) = MCK
      GO TO 26
   23 IF(MPR) 24,24,25
   24 MPR = MPR + 1
      CIT(J,K) = MCK
      PRINT 210,KK,J
      GO TO 2
   25 IXO = IXO + 1
      GO TO 21
   26 CONTINUE
      RETURN
  200 FORMAT (12(1PD10.3))
  210 FORMAT (37H1   ITERATION OVERFLOW, TIME INTERVAL,I4,6H STAGE,I4//
     116X,11HURANIUM (M),28X,13HPLUTONIUM (M),29X,8HACID (M)/3(7H  TRIAL
     2,7X,1HD,7X,18HRESULT  DIFFERENCE)/)
      END
```

```
      SUBROUTINE DOFX
      DIMENSION XFD(3,25),YFD(3,25),ASP(3,25),OSP(3,25),ASC(3),OSC(3),
     1DTRY(3),A(25),O(25),AFD(25),OFD(25),APR(25),OPR(25),RA(25),RO(25),
     2R(25),REC(25),CO(36),GU(3),GP(3),GA(3),C(12),Y(3),Z(3),TBPF(3)
      COMMON/ALL/XFD,YFD,A,O,AFD,OFD,APR,OPR,RA,RO,R,REC,ASC,OSC,DTRY,CO
     1,DFA,DFB,DFC,DFD,DFE,NTA,NTB,NTC,NTD,NTE,DDU,DDP,DDH,DELT,CTBP,ASP
     2,OSP,IXO,SLU,SLP,SLH
      REAL*8 ASC,OSC,DTRY,CO,CTBP,ASP,OSP,TNT,STN,GU,GP,GA,T,C,Y,Z,TBPF
C
C
C  DOFX PROVIDES A MASS DISTRIBUTION COEFFICIENT (DTRY) FOR GIVEN VALUES
C  OF AQUEOUS PHASE SOLUTE CONCENTRATION (ASC) USING METHODS REPORTED BY
C  D.E. HORNER IN ORNL-TM-2711.    TNT = TOTAL NITRATE CONCENTRATION
C                                  STN = IONIC STRENGTH
C                                C,CO = CORRELATION COEFFICIENTS
C                                CTBP = VOLUME FRACTION TBP
C                            GU,GP,GA = MASS ACTION EQUILIBRIUM CONSTANT
C                                       FOR U, PU, ACID
C                                TBPF = UNCOMPLEXED TBP
C
C  CHECK FOR NEG. VALUES OF INPUT.
C
      DO 3 I=1,3
      IF(ASC(I)) 2,2,3
    2 ASC(I) = 0.0D0
    3 CONTINUE
C
C  CHECK FOR ZERO U AND PU, IF YES CALC. GA ONLY.
C
      IF(ASC(1)-1.0D-10) 4,4,9
    4 IF(ASC(2)-1.0D-10) 5,5,9
    5 IF(OSC(1)) 8,6,8
    6 IF(OSC(2)) 8,7,8
    7 DTRY(1) = 0.0D0
      DTRY(2) = 0.0D0
      TNT = ASC(3)
      STN = ASC(3)
      GA(3) = CO(33) + CO(34)*STN + CO(35)*STN**2 + CO(36)*STN**3
      T = 3.65377394*CTBP
      DTRY(3) = T*GA(3)*TNT/(1.0D0+ASC(3)*GA(3)*TNT)
      GO TO 12
    8 ASC(1) = 1.0D-10
C
C  CALC. GU, GP, AND GA.
C
    9 TNT = 2.0*ASC(1) + 4.0*ASC(2) + ASC(3)
      STN = 3.0*ASC(1) + 10.*ASC(2) + ASC(3)
      T = 29.2301915*CTBP
      DO 11 I=1,3
      DO 10 J=1,12
      JJ = (I-1)*12 + J
      C(J) = CO(JJ)
   10 CONTINUE
      GU(I) = C(1) + C( 2)*STN + C( 3)*STN**2 + C( 4)*STN**3
      GP(I) = C(5) + C( 6)*STN + C( 7)*STN**2 + C( 8)*STN**3
      GA(I) = C(9) + C(10)*STN + C(11)*STN**2 + C(12)*STN**3
      Z(I) = 1.0D0/(GP(I)*ASC(2)*TNT**2+GU(I)*ASC(1))
      Y(I) = (1.0D0+GA(I)*ASC(3)*TNT)*Z(I)/TNT
      TBPF(I) = (-Y(I)/(4.0D0*TNT))*(1.0D0-DSQRT(1.0D0+T*Z(I)/Y(I)**2))
   11 CONTINUE
      DTRY(1) = GU(1)*TNT**2*TBPF(1)**2
      DTRY(2) = GP(2)*TNT**4*TBPF(2)**2
      DTRY(3) = GA(3)*TNT*TBPF(3)
   12 RETURN
      END
```

```
      SUBROUTINE FLWS(IGO,IRT,IVL,NTS)
      DIMENSION XFD(3,25),YFD(3,25),ASP(3,25),OSP(3,25),ASC(3),OSC(3),
     1DTRY(3),A(25),O(25),AFD(25),OFD(25),APR(25),OPR(25),RA(25),RO(25),
     2R(25),REC(25),CC(26),CCN(3),SVO(25)
      COMMON/ALL/XFD,YFD,A,O,AFD,OFD,APR,OPR,RA,RO,R,REC,ASC,OSC,DTRY,CO
     1,DFA,DFB,DFC,DFD,DFE,NTA,NTB,NTC,NTD,NTE,DDU,DDP,DDH,DELT,CTBP,ASP
     2,OSP,IXO,SLU,SLP,SLH
      REAL*8 ASC,OSC,DTRY,CO,CTBP,ASP,OSP
C
C
C   FLWS DEFINES ALL FEED AND PRODUCT STREAMS, SETS INTERSTAGE FLOWS
C   INCLUDING RECYCLE FLOWS AND CALCULATES ALL PHASE AND FLOW RATIOS.
C
C   FEED STREAMS ARE NOW DEFINED WHERE AFD OR OFD IS THE FLOW RATE AND
C   XFD OR YFD ARE THE SOLUTE CONCENTRATIONS.
C
    2 READ 100,J,JPH,FR,(CCN(I),I=1,3),K
C
C   J = STAGE NO. THAT FEED ENTERS      FR = FLOW RATE
C   JPH =  1 FOR AQUEOUS PHASE         CON = SOLUTE CONCENTRATIONS
C   JPH =  0 FOR ORGANIC PHASE           K = 1 IF MORE CARDS FOLLOW
C                                        K = 0 FOR LAST CARD
C
      IF(JPH) 3,3,4
    3 OFD(J) = FR
      YFD(1,J) = CON(1)/238.
      YFD(2,J) = CON(2)/239.
      YFD(3,J) = CON(3)
      GO TO 5
    4 AFD(J) = FR
      XFD(1,J) = CON(1)/238.
      XFD(2,J) = CON(2)/239.
      XFD(3,J) = CON(3)
    5 IF(K) 6,6,2
C
C   NEXT DEFINE PRODUCT STREAMS OTHER THAN NORMAL END STREAMS.  THESE
C   RATES TO BE APR OR OPR.  NONE EXIST IF IGO IS ZERO, NONE CAN RETURN.
C
    6 IF(IGO) 11,11,7
    7 READ 110,J,JPH,FR,K
      IF(JPH) 8,8,9
    8 OPR(J) = FR
      GO TO 10
    9 APR(J) = FR
   10 IF(K) 11,11,7
C
C   SET NET INTERSTAGE FLOWS.
C
   11 DO 14 I=1,NTS
      IF(I-1)12,12,13
   12 A(1) = AFD(1) - APR(1)
      O(NTS) = OFD(NTS) - OPR(NTS)
      GO TO 14
   13 A(I) = A(I-1) + AFD(I) - APR(I)
      NST = NTS + 1 - I
      O(NST) = O(NST+1) + OFD(NST) - OPR(NST)

   14 CONTINUE
C
C   INDEX VARIABLES.
C
      DO 15 I=1,NTS
      RA(I) = 0.0
      RO(I) = 0.0
   15 CONTINUE
```

```
      FLOMAX = 0.0
      K = 1
      IF(IRT) 16,16,27
C
C  IRT = 0 IF PHASE RATIO = FLOW RATIO, 1 IF PHASE RATIOS ARE READ IN.
C  R IS THE PHASE RATIO OF AQUEOUS TO ORGANIC.
C
   16 DO 17 I=1,NTS
      R(I) = (APR(I)+A(I))/(OPR(I)+O(I))
   17 CONTINUE
      IF(IVL-1) 18,25,18
C
C  IVL = 0 IF STAGE VOLUMES ARE ALL EQUAL, 1 IF VOLUMES VARY WITH TOTAL
C  FLOW, 2 IF THEY ARE INDEPENDENTLY UNEQUAL.  FOR IVL=2 VOLUMES ARE TO
C  BE READ IN (SVO).  CALCULATE MAXIMUM FLOW FOR IVL = 0 OR 2.
C
   18 DO 19 I=1,NTS
      FLOTOT = APR(I) + A(I) + OPR(I) + O(I)
      REC(I) = FLOTOT
      FLOMAX = AMAX1(FLOTOT,FLOMAX)
   19 CONTINUE
C
C  FLOMAX IS THE LARGEST TOTAL FLOW WITHIN A SINGLE STAGE.
C
   20 IF(IVL-1) 23,25,21
C
C  READ IN STAGE VOLUMES.
C
   21 READ 120,(SVO(I),I=1,NTS)
      TIMIN = 0.0
C
C  COMPUTE INTRASTAGE RECYCLE FLOW TYPE 2 (REC) NECESSARY TO CAUSE TOTAL
C  STAGE FLOW TO EQUAL FLOMAX.
C
      DO 22 I=1,NTS
      REC(I) = REC(I)/SVO(I)
      TIMIN = AMAX1(REC(I),TIMIN)
   22 CONTINUE
      FLOMAX = TIMIN
   23 DO 24 I=1,NTS
      REC(I) = FLOMAX - REC(I)
   24 CONTINUE
      RETURN
   25 DO 26 I=1,NTS
      REC(I) = 0.0
   26 CONTINUE
      RETURN
   27 READ 130,I,RATIO
C
C  I IS THE NUMBER OF STAGES ALL HAVING THE RATIO SHOWN.
C  COMPUTE INTRASTAGE RECYCLE FLOWS. TYPE 1 IS RECYCLE OF ONLY ONE PHASE
C  TO SATISFY SPECIFIED PHASE RATIO. TYPE 2 IS RECYCLE OF BOTH PHASES IN
C  THE RATIO R TO EACH OTHER TO CAUSE TOTAL STAGE FLOW TO EQUAL FLOMAX.
C  TYPE 1 USED WHEN IRT = 1, THIS FLOW IS RA OR RO.
C  TYPE 2 USED WHEN IVL = 0 OR 2, TOTAL TYPE 2 FLOW IS REC.
C
      I = K + I - 1
      DO 28 J=K,I
      R(J) = RATIO
   28 CONTINUE
      IF(I-NTS) 29,30,30
   29 K = I + 1
      GO TO 27
```

```
   30 DO 34 I=1,NTS
      AFL = APR(I) + A(I)
      OFL = OPR(I) + O(I)
      FLOTOT = AFL + OFL
      RFL = AFL/OFL
      IF(RFL-R(I)) 31,33,32
   31 FLOTOT = FLOTOT*(R(I)+1.0)/(RFL+1.0)
      RA(I) = FLOTOT - AFL - OFL
      GO TO 33
   32 FLOTOT = FLOTOT*RFL*(R(I)+1.0)/(R(I)*(RFL+1.0))
      RO(I) = FLOTOT - AFL - OFL
   33 REC(I) = FLOTOT
C
C  CALCULATE MAXIMUM FLOW
C
      FLOMAX = AMAX1(FLOTOT,FLOMAX)
C
C  FLOMAX IS THE LARGEST TOTAL FLOW WITHIN A SINGLE STAGE.
C
   34 CONTINUE
      GO TO 20
  100 FORMAT (2I4,4F8.0,I4)
  110 FORMAT (2I4,F8.0,I4)
  120 FORMAT (10F8.0)
  130 FORMAT (I8,F8.0)
      END

      SUBROUTINE PROF(IPO,NTS,ICON)
      DIMENSION XFD(3,25),YFD(3,25),ASP(3,25),OSP(3,25),ASC(3),OSC(3),
     1DTRY(3),A(25),O(25),AFD(25),OFD(25),APR(25),OPR(25),RA(25),RO(25),
     2R(25),REC(25),CO(36)
      COMMON/ALL/XFD,YFD,A,O,AFD,OFD,APR,OPR,RA,RO,R,REC,ASC,OSC,DTRY,CO
     1,DFA,DFB,DFC,DFD,DFE,NTA,NTB,NTC,NTD,NTE,DDU,DDP,DDH,DELT,CTBP,ASP
     2,OSP,IXO,SLU,SLP,SLH
      REAL*8 ASC,OSC,DTRY,CO,CTBP,ASP,OSP
C
C
C  PROF DEFINES ANY NON-ZERO INITIAL SOLUTE CONCENTRATION PROFILE WHERE
C  ASP = AQUEOUS SOLUTE PROFILE                    IPO = 1 TO ESTABLISH A
C  OSP = ORGANIC SOLUTE PROFILE                 PROFILE FROM EXTERNAL DATA
C
      IF(IPO) 6,6,2
    2 DO 5  I=1,NTS
      IF(ICON) 3,3,4
    3 READ 100,(ASP(J,I),J=1,3),(OSP(J,I),J=1,3)
    4 ASP(1,I) = ASP(1,I)/238.D0
      ASP(2,I) = ASP(2,I)/239.D0
      OSP(1,I) = OSP(1,I)/238.D0
      OSP(2,I) = OSP(2,I)/239.D0
    5 CONTINUE
    6 RETURN
  100 FORMAT (6D12.0)
      END


      SUBROUTINE COEF(ICO,ITP)
      DIMENSION XFD(3,25),YFD(3,25),ASP(3,25),OSP(3,25),ASC(3),OSC(3),
     1DTRY(3),A(25),O(25),AFD(25),OFD(25),APR(25),OPR(25),RA(25),RO(25),
     2R(25),REC(25),CO(36)
      COMMON/ALL/XFD,YFD,A,O,AFD,OFD,APR,OPR,RA,RO,R,REC,ASC,OSC,DTRY,CO
     1,DFA,DFB,DFC,DFD,DFE,NTA,NTB,NTC,NTD,NTE,DDU,DDP,DDH,DELT,CTBP,ASP
     2,OSP,IXO,SLU,SLP,SLH
      REAL*8 ASC,OSC,DTRY,CO,CTBP,ASP,OSP,C
C
```

```
C
C   COEF SETS VALUES OF CORRELATION COEFFICIENTS USED BY DOFX IN EQUILIB-
C   RIUM CALCULATIONS.  THE VALUES ARE REPLACED BY EXTERNAL DATA IF ICO = 1.
C   COEF ALSO DEFINES THE TEMPERATURE DEPENDENCE OF DISTRIBUTION DATA.
C
      CO( 1) =  22.795242
      CO( 2) =   7.2565203
      CO( 3) = - 2.7138472
      CO( 4) =   2.1633701
      CO( 5) =   5.4904842
      CO( 6) = - 0.39458656
      CO( 7) =   0.043830797
      CO( 8) =   0.0055821687
      CO( 9) =   0.56466365
      CO(10) = - 0.12194633
      CO(11) =   0.014745042
      CO(12) =   0.0
      CO(13) =   7.6288233
      CO(14) =   8.7138548
      CO(15) = - 2.9776511
      CO(16) =   2.1414728
      CO(17) =   2.7832937
      CO(18) = - 0.51696092
      CO(19) =   0.046492174
      CO(20) =   0.029787377
      CO(21) =   0.49267280
      CO(22) = - 0.16650909
      CO(23) =   0.029404197
      CO(24) =   0.0
      CO(25) =  22.795242
      CO(26) =   7.2565203
      CO(27) = - 2.7138472
      CO(28) =   2.1633701
      CO(29) =   5.4904842
      CO(30) = - 0.39458656
      CO(31) =   0.043830797
      CO(32) =   0.0055821687
      CO(33) =   0.56466365
      CO(34) = - 0.12194633
      CO(35) =   0.014745042
      CO(36) =   0.0
C
C   MASS ACTION EQUIL. CONST. = C1 + C2X + C3Y + C4Z WHERE X,Y,AND Z ARE
C   1ST, 2ND, AND 3RD POWERS OF IONIC STRENGTH.
C   C1 IS CO  1,  5, OR  9 FOR U,PU,ACID OPTIMIZED FOR U ACCURACY.
C   C2 IS CO  2,  6, OR 10 FOR U,PU,ACID OPTIMIZED FOR U ACCURACY.
C   C3 IS CO  3,  7, OR 11 FOR U,PU,ACID OPTIMIZED FOR U ACCURACY.
C   C4 IS CO  4,  8, OR 12 FOR U,PU,ACID OPTIMIZED FOR U ACCURACY.
C   C1 IS CO 13, 17, OR 21 FOR U,PU,ACID OPTIMIZED FOR PU ACCURACY.
C   C2 IS CO 14, 18, OR 22 FOR U,PU,ACID OPTIMIZED FOR PU ACCURACY.
C   C3 IS CO 15, 19, OR 23 FOR U,PU,ACID OPTIMIZED FOR PU ACCURACY.
C   C4 IS CO 16, 20, OR 24 FOR U,PU,ACID OPTIMIZED FOR PU ACCURACY.
C   C1 IS CO 25, 29, OR 33 FOR U,PU,ACID OPTIMIZED FOR ACID ACCURACY.
C   C2 IS CO 26, 30, OR 34 FOR U,PU,ACID OPTIMIZED FOR ACID ACCURACY.
C   C3 IS CO 27, 31, OR 35 FOR U,PU,ACID OPTIMIZED FOR ACID ACCURACY.
C   C4 IS CO 28, 32, OR 36 FOR U,PU,ACID OPTIMIZED FOR ACID ACCURACY.
C
      IF(ICO) 3,3,2
    2 READ 100,I,C,J
C
C   I = COEFFICIENT NO. TO BE REPLACED
C   C = NEW VALUE
C   J = 1 IF MORE CARDS FOLLOW, 0 FOR LAST CARD
C
      CO(I) = C
      IF(J) 3,3,2
```

```
    3 IF(ITP) 5,5,4
    4 READ 110,SLU,SLP,SLH
      RETURN
    5 SLU = 2220.
      SLP = 0.0
      SLH = 0.0
      RETURN
  100 FORMAT (I4,F16.0,I4)
  110 FORMAT (3F8.0)
      END
      SUBROUTINE PORD(IPL,NTS,M,NTI)
      DIMENSION X(3,25,101),Y(3,25,101),AAA(7),TITLE(18),NSTA(20)
      COMMON/RES/X,Y
      REAL*8 X,Y
C
C
C   PORD PROVIDES THE APPROPRIATE ORDERS FOR PLOTTING SUBROUTINES
C
      AAA(7) = 10.0
      IF(IPL-2) 2,8,2
    2 CALL HOLLER(NL,TITLE,50)
      NOINT = NTS - 1
      DO 7 I=1,3
      MM = M
      CALL SEMLOG(5,2,1.0,1.0,NOINT,7.0,0,AAA)
      DO 4 K=1,4
      DO 3 J=1,NTS
      XP = J
      CALL POINT(J,XP,X(I,J,MM),K,0.08,0.0,2,AAA)
    3 CONTINUE
      MM = MM/2
    4 CONTINUE
      CALL LETTER(0,NL,TITLE,AAA)
      CALL LETTER(1,12,12HSTAGE NUMBER,AAA)
      CALL LETTER(2,21,21HREDUCED CONCENTRATION,AAA)
      CALL ADVANC(AAA)
      CALL SEMLOG(5,2,1.0,1.0,NOINT,7.0,0,AAA)
      MM = M
      DO 6 K=1,4
      DO 5 J=1,NTS
      XP = J
      CALL POINT(J,XP,Y(I,J,MM),K,0.08,0.0,2,AAA)
    5 CONTINUE
      MM = MM/2
    6 CONTINUE
      CALL LETTER(0,NL,TITLE,AAA)
      CALL LETTER(1,12,12HSTAGE NUMBER,AAA)
      CALL LETTER(2,21,21HREDUCED CONCENTRATION,AAA)
      CALL ADVANC(AAA)
    7 CONTINUE
      IF(IPL-2) 17,17,8
    8 IF(NTI) 9,9,10
    9 READ 100,(NSTA(I),I=1,20)
      NTI = NTI + 1
   10 CALL HOLLER(NL,TITLE,50)
      NOINTX = M/5 + 1
      DO 16 JJ=1,20
      IF(NSTA(JJ)) 17,17,11
   11 NS = NSTA(JJ)
      CALL LINEAR(0.0,10.0,10,0.0,5.0,NOINTX,15.5,0,AAA)
      DO 13 I=1,3
      DO 12 K=3,M,2
      XP = K-1
      KM = K-2
      CALL POINT(KM,XP,X(I,NS,K),I,0.08,0.0,2,AAA)
   12 CONTINUE
```

```
      DO 13 K=2,M,2
      XP = K
      KM = K - 1
      CALL POINT(KM,XP,X(I,NS,K),I,0.08,0.0,2,AAA)
   13 CONTINUE
      CALL LETTER(0,NL,TITLE,AAA)
      CALL LETTER(1,13,13HTIME INTERVAL,AAA)
      CALL LETTER(2,21,21HREDUCED CONCENTRATION,AAA)
      CALL ADVANC(AAA)
      CALL LINEAR(0.0,10.0,10,0.0,5.0,NOINTX,15.5,0,AAA)
      DO 15 I=1,3
      DO 14 K=3,M,2
      XP = K-1
      KM = K-2
      CALL POINT(KM,XP,Y(I,NS,K),I,0.08,0.0,2,AAA)
   14 CONTINUE
      DO 15 K=2,M,2
      XP = K
      KM = K - 1
      CALL POINT(KM,XP,Y(I,NS,K),I,0.08,0.0,2,AAA)
   15 CONTINUE
      CALL LETTER(0,NL,TITLE,AAA)
      CALL LETTER(1,13,13HTIME INTERVAL,AAA)
      CALL LETTER(2,21,21HREDUCED CONCENTRATION,AAA)
      CALL ADVANC(AAA)
   16 CONTINUE
   17 RETURN
  100 FORMAT (20I4)
      END
```

SAMPLE PRINT-OUT COEXTRACTION RUN

OAK RIDGE NATIONAL LABORATORY

SEPHIS - A SOLVENT EXTRACTION PROCESS HAVING INTERACTING SOLUTES

COEXTRACTION RUN 11 TOTAL STAGES

FEED STREAM DATA - AQUEOUS	STAGE NO.	URANIUM (G/L)	PLUTONIUM (G/L)	ACID (M)	FLOW RATE (VOL.UNITS)
	1	0.0	0.0	2.0000E 00	3.00E-01
	4	6.7700E 01	4.4300E 00	3.2000E 00	1.00E 00
0.153 TBP - ORGANIC	11	0.0	0.0	0.0	1.80E 00

EQUILIBRIUM EXPRESSIONS - CORRELATION COEFFICIENTS OPTIMIZED WITH RESPECT TO URANIUM

	A0	A1	A2	A3
FOR URANIUM	22.79524200	7.25652030	-2.71384716	2.16337010
FOR PLUTONIUM	5.49048420	-0.39458650	0.04383080	0.00558217
FOR ACID	0.56466365	-0.12194628	0.01474504	0.0

- CORRELATION COEFFICIENTS OPTIMIZED WITH RESPECT TO PLUTONIUM

	A0	A1	A2	A3
FOR URANIUM	7.62882030	3.71385480	-2.97765064	2.14147280
FOR PLUTONIUM	2.78329370	-0.51696092	0.04649217	0.02978738
FOR ACID	0.49267280	-0.16650903	0.02940420	0.0

- CORRELATION COEFFICIENTS OPTIMIZED WITH RESPECT TO ACID

	A0	A1	A2	A3
FOR URANIUM	22.79524200	7.25652030	-2.71384716	2.16337010
FOR PLUTONIUM	5.49048420	-0.39458650	0.04383080	0.00558217
FOR ACID	0.56466365	-0.12194628	0.01474504	0.0

PHASE RATIOS EQUAL FLOW RATIOS ---

STAGE NO.	PHASE RATIO
1 - 3	1.67E-01
4 - 11	7.22E-01

FLOWS IN EACH STAGE (VOL.UNITS) ---

		AQUEOUS PHASE				ORGANIC PHASE				OVERALL
STAGE NO.	FLOW RATIO	FLOW OUT OF STAGE	RECYCLE 2 TO FILL STAGE	RECYCLE 1 FOR PHASE RATIO	TOTAL AQUEOUS FLOW	FLOW OUT OF STAGE	RECYCLE 2 TO FILL STAGE	RECYCLE 1 FOR PHASE RATIO	TOTAL ORGANIC FLOW	TOTAL STAGE FLOW
1	1.67E-01	3.00E-01	0.0	0.0	3.00E-01	1.80E 00	0.0	0.0	1.80E 00	2.10E 00
2	1.67E-01	3.00E-01	0.0	0.0	3.00E-01	1.80E 00	0.0	0.0	1.80E 00	2.10E 00
3	1.67E-01	3.00E-01	0.0	0.0	3.00E-01	1.80E 00	0.0	0.0	1.80E 00	2.10E 00

4	7.22E-01	1.30E 00	0.0	0.0	1.30E 00	1.80E 00	0.0	0.0	1.80E 00	3.10E 00
5	7.22E-01	1.30E 00	0.0	0.0	1.30E 00	1.80E 00	0.0	0.0	1.80E 00	3.10E 00
6	7.22E-01	1.30E 00	0.0	0.0	1.30E 00	1.80E 00	0.0	0.0	1.80E 00	3.10E 00
7	7.22E-01	1.30E 00	0.0	0.0	1.30E 00	1.80E 00	0.0	0.0	1.80E 00	3.10E 00
8	7.22E-01	1.30E 00	0.0	0.0	1.30E 00	1.80E 00	0.0	0.0	1.80E 00	3.10E 00
9	7.22E-01	1.30E 00	0.0	0.0	1.30E 00	1.80E 00	0.0	0.0	1.80E 00	3.10E 00
10	7.22E-01	1.30E 00	0.0	0.0	1.30E 00	1.80E 00	0.0	0.0	1.80E 00	3.10E 00
11	7.22E-01	1.30E 00	0.0	0.0	1.30E 00	1.80E 00	0.0	0.0	1.80E 00	3.10E 00

TRANSIENT BEHAVIOR RESULTS — SOLUTE CONCENTRATIONS IN EFFLUENT FROM EACH STAGE

TIME INTERVAL	STAGE	AQUEOUS PHASE VALUES URANIUM (G/L)	PLUTONIUM (G/L)	ACID (M)	ORGANIC PHASE VALUES URANIUM (G/L)	PLUTONIUM (G/L)	ACID (M)	ITERATIONS
0	1	0.0	0.0	0.0	0.0	0.0	0.0	0.
	2	0.0	0.0	0.0	0.0	0.0	0.0	0.
	3	0.0	0.0	0.0	0.0	0.0	0.0	0.
	4	0.0	0.0	0.0	0.0	0.0	0.0	0.
	5	0.0	0.0	0.0	0.0	0.0	0.0	0.
	6	0.0	0.0	0.0	0.0	0.0	0.0	0.
	7	0.0	0.0	0.0	0.0	0.0	0.0	0.
	8	0.0	0.0	0.0	0.0	0.0	0.0	0.
	9	0.0	0.0	0.0	0.0	0.0	0.0	0.
	10	0.0	0.0	0.0	0.0	0.0	0.0	0.
	11	0.0	0.0	0.0	0.0	0.0	0.0	0.
1	1	0.0	0.0	9.77D-01	0.0	0.0	1.70D-01	4.
	2	0.0	0.0	0.0	0.0	0.0	0.0	1.
	3	0.0	0.0	0.0	0.0	0.0	0.0	1.
	4	1.01D 01	1.50D 00	2.21D 00	3.03D 01	1.38D 00	1.85D-01	11.
	5	0.0	0.0	0.0	0.0	0.0	0.0	1.
	6	0.0	0.0	0.0	0.0	0.0	0.0	1.
	7	0.0	0.0	0.0	0.0	0.0	0.0	1.
	8	0.0	0.0	0.0	0.0	0.0	0.0	1.
	9	0.0	0.0	0.0	0.0	0.0	0.0	1.
	10	0.0	0.0	0.0	0.0	0.0	0.0	1.
	11	0.0	0.0	0.0	0.0	0.0	0.0	1.
2	1	0.0	0.0	9.77D-01	0.0	0.0	1.70D-01	4.
	2	0.0	0.0	5.43D-01	0.0	0.0	7.23D-02	7.
	3	1.75D 01	4.40D 00	6.87D-01	2.74D 01	6.42D-01	7.02D-02	10.
	4	1.01D 01	1.50D 00	2.21D 00	3.03D 01	1.38D 00	1.85D-01	11.
	5	1.04D 00	4.63D-01	1.82D 00	6.56D 00	7.51D-01	2.79D-01	6.
	6	0.0	0.0	0.0	0.0	0.0	0.0	1.
	7	0.0	0.0	0.0	0.0	0.0	0.0	1.
	8	0.0	0.0	0.0	0.0	0.0	0.0	1.
	9	0.0	0.0	0.0	0.0	0.0	0.0	1.
	10	0.0	0.0	0.0	0.0	0.0	0.0	1.
	11	0.0	0.0	0.0	0.0	0.0	0.0	1.

3	1	0.0	0.0	1.17D 00	0.0	0.0	2.11D-01	4.
	2	1.37D 01	1.76D 00	8.40D-01	2.51D 01	3.49D-01	9.31D-02	7.
	3	1.43D 01	3.07D 00	1.01D 00	2.79D 01	8.64D-01	1.07D-01	6.
	4	1.43D 01	2.48D 00	2.78D 00	3.68D 01	2.15D 00	1.62D-01	11.
	5	1.04D 00	4.63D-01	1.82D 00	6.56D 00	7.51D-01	2.79D-01	6.
	6	1.08D-01	1.81D-01	1.46D 00	6.72D-01	2.04D-01	2.59D-01	4.
	7	0.0	0.0	0.0	0.0	0.0	0.0	1.
	8	0.0	0.0	0.0	0.0	0.0	0.0	1.
	9	0.0	0.0	0.0	0.0	0.0	0.0	1.
	10	0.0	0.0	0.0	0.0	0.0	0.0	1.
	11	0.0	0.0	0.0	0.0	0.0	0.0	1.
4	1	7.93D 00	4.26D-01	1.51D 00	2.38D 01	2.73D-01	1.75D-01	8.
	2	1.19D 01	1.75D 00	1.08D 00	2.59D 01	5.72D-01	1.21D-01	7.
	3	2.16D 01	5.17D 00	1.21D 00	3.54D 01	1.58D 00	1.01D-01	8.
	4	1.37D 01	2.28D 00	2.85D 00	3.66D 01	2.08D 00	1.66D-01	11.
	5	1.22D 00	5.29D-01	2.69D 00	1.01D 01	1.61D 00	3.24D-01	6.
	6	1.08D-01	1.81D-01	1.46D 00	6.72D-01	2.04D-01	2.59D-01	4.
	7	1.33D-02	9.70D-02	1.17D 00	6.81D-02	6.08D-02	2.10D-01	4.
	8	0.0	0.0	0.0	0.0	0.0	0.0	1.
	9	0.0	0.0	0.0	0.0	0.0	0.0	1.
	10	0.0	0.0	0.0	0.0	0.0	0.0	1.
	11	0.0	0.0	0.0	0.0	0.0	0.0	1.
5	1	7.99D 00	6.37D-01	1.63D 00	2.46D 01	4.66D-01	1.82D-01	8.
	2	1.80D 01	2.95D 00	1.38D 00	3.37D 01	1.16D 00	1.21D-01	10.
	3	2.01D 01	4.39D 00	1.39D 00	3.53D 01	1.64D 00	1.14D-01	9.
	4	1.63D 01	3.24D 00	2.98D 00	3.92D 01	2.60D 00	1.49D-01	11.
	5	1.13D 00	4.67D-01	2.75D 00	9.78D 00	1.51D 00	3.31D-01	6.
	6	8.54D-02	9.95D-02	2.47D 00	8.91D-01	3.71D-01	3.73D-01	5.
	7	1.33D-02	9.70D-02	1.17D 00	6.81D-02	6.08D-02	2.10D-01	4.
	8	2.00D-03	6.62D-02	9.43D-01	8.13D-03	2.23D-02	1.63D-01	4.
	9	0.0	0.0	0.0	0.0	0.0	0.0	1.
	10	0.0	0.0	0.0	0.0	0.0	0.0	1.
	11	0.0	0.0	0.0	0.0	0.0	0.0	1.
6	1	1.30D 01	1.46D 00	1.78D 00	3.16D 01	9.21D-01	1.59D-01	10.
	2	1.71D 01	2.80D 00	1.53D 00	3.38D 01	1.28D 00	1.31D-01	10.
	3	2.35D 01	5.56D 00	1.61D 00	3.83D 01	2.16D 00	1.11D-01	9.
	4	1.63D 01	3.02D 00	3.03D 00	3.90D 01	2.52D 00	1.52D-01	13.
	5	1.37D 00	6.52D-01	3.05D 00	1.21D 01	2.24D 00	3.25D-01	8.
	6	7.73D-02	8.61D-02	2.52D 00	8.31D-01	3.36D-01	3.78D-01	5.
	7	6.84D-03	2.52D-02	2.20D 00	6.49D-02	7.59D-02	3.57D-01	4.
	8	2.00D-03	6.62D-02	9.43D-01	8.13D-03	2.23D-02	1.63D-01	4.
	9	3.75D-04	5.31D-02	7.71D-01	1.18D-03	9.50D-03	1.24D-01	5.
	10	0.0	0.0	0.0	0.0	0.0	0.0	1.
	11	0.0	0.0	0.0	0.0	0.0	0.0	1.
7	1	1.29D 01	1.56D 00	1.82D 00	3.16D 01	1.02D 00	1.61D-01	10.
	2	2.06D 01	3.91D 00	1.70D 00	3.70D 01	1.75D 00	1.24D-01	10.
	3	2.24D 01	5.02D 00	1.73D 00	3.81D 01	2.15D 00	1.18D-01	10.
	4	1.84D 01	3.78D 00	3.09D 00	4.03D 01	2.90D 00	1.41D-01	11.
	5	1.27D 00	5.82D-01	3.10D 00	[illegible] 01	2.10D 00	3.31D-01	8.

	6	7.59D-02	9.06D-02	2.98D 00	1.00D 00	4.82D-01	4.07D-01	5.
	7	6.13D-03	2.17D-02	2.25D 00	5.95D-02	6.87D-02	3.61D-01	4.
	8	6.81D-04	9.42D-03	1.92D 00	5.62D-03	2.09D-02	3.27D-01	4.
	9	3.75D-04	5.31D-02	7.71D-01	1.18D-03	9.50D-03	1.24D-01	5.
	10	8.69D-05	4.68D-02	6.41D-01	2.08D-04	4.54D-03	9.42D-02	5.
	11	0.0	0.0	0.0	0.0	0.0	0.0	1.
8	1	1.58D 01	2.33D 00	1.86D 00	3.44D 01	1.37D 00	1.47D-01	10.
	2	2.01D 01	3.77D 00	1.77D 00	3.69D 01	1.78D 00	1.28D-01	10.
	3	2.45D 01	6.01D 00	1.87D 00	3.97D 01	2.55D 00	1.13D-01	9.
	4	1.78D 01	3.56D 00	3.12D 00	4.01D 01	2.82D 00	1.44D-01	11.
	5	1.49D 00	7.61D-01	3.21D 00	1.32D 01	2.66D 00	3.21D-01	8.
	6	6.86D-02	7.88D-02	3.03D 00	9.27D-01	4.32D-01	4.11D-01	5.
	7	4.39D-03	1.46D-02	2.87D 00	5.73D-02	7.57D-02	4.09D-01	4.
	8	6.12D-04	8.25D-03	1.96D 00	5.15D-03	1.92D-02	3.32D-01	4.
	9	8.90D-05	5.03D-03	1.64D 00	6.36D-04	7.71D-03	2.92D-01	4.
	10	8.69D-05	4.68D-02	6.41D-01	2.08D-04	4.54D-03	9.42D-02	5.
	11	2.46D-05	4.35D-02	5.42D-01	4.50D-05	2.36D-03	7.19D-02	5.
9	1	1.57D 01	2.35D 00	1.88D 00	3.43D 01	1.39D 00	1.48D-01	10.
	2	2.25D 01	4.79D 00	1.82D 00	3.85D 01	2.14D 00	1.20D-01	11.
	3	2.38D 01	5.64D 00	1.93D 00	3.95D 01	2.51D 00	1.17D-01	9.
	4	1.93D 01	4.18D 00	3.15D 00	4.09D 01	3.11D 00	1.37D-01	12.
	5	1.39D 00	6.89D-01	3.24D 00	1.28D 01	2.51D 00	3.27D-01	8.
	6	7.50D-02	9.39D-02	3.19D 00	1.08D 00	5.58D-01	4.18D-01	5.
	7	3.88D-03	1.25D-02	2.92D 00	5.19D-02	6.71D-02	4.13D-01	4.
	8	2.94D-04	3.37D-03	2.72D 00	3.59D-03	1.58D-02	4.00D-01	4.
	9	8.12D-05	4.50D-03	1.68D 00	5.91D-04	7.25D-03	2.97D-01	4.
	10	1.60D-05	3.47D-03	1.39D 00	9.78D-05	3.49D-03	2.52D-01	4.
	11	2.46D-05	4.35D-02	5.42D-01	4.50D-05	2.36D-03	7.19D-02	5.

(Intervening time intervals have been deleted to conserve space)

99	1	2.10D 01	5.19D 00	1.85D 00	3.76D 01	2.45D 00	1.24D-01	13.
	2	2.82D 01	9.08D 00	1.82D 00	4.11D 01	3.32D 00	9.93D-02	11.
	3	3.06D 01	1.12D 01	1.96D 00	4.23D 01	3.97D 00	9.33D-02	9.
	4	2.45D 01	7.20D 00	3.13D 00	4.27D 01	4.32D 00	1.16D-01	10.
	5	2.55D 00	1.89D 00	3.33D 00	1.76D 01	5.19D 00	2.75D-01	11.
	6	1.26D-01	2.25D-01	3.36D 00	1.84D 00	1.37D 00	4.14D-01	6.
	7	5.64D-03	2.42D-02	3.36D 00	9.09D-02	1.62D-01	4.36D-01	4.
	8	2.51D-04	2.60D-03	3.36D 00	4.08D-03	1.75D-02	4.38D-01	3.
	9	1.12D-05	2.78D-04	3.36D 00	1.81D-04	1.87D-03	4.38D-01	2.
	10	5.06D-07	2.99D-05	3.31D 00	8.05D-06	1.98D-04	4.36D-01	4.
	11	2.78D-08	3.90D-06	2.75D 00	3.45D-07	1.88D-05	4.03D-01	5.
100	1	2.10D 01	5.19D 00	1.85D 00	3.76D 01	2.46D 00	1.24D-01	13.
	2	2.82D 01	9.08D 00	1.82D 00	4.11D 01	3.32D 00	9.93D-02	11.
	3	3.06D 01	1.12D 01	1.96D 00	4.23D 01	3.97D 00	9.33D-02	9.
	4	2.44D 01	7.19D 00	3.13D 00	4.27D 01	4.32D 00	1.16D-01	12.

	5	2.55D 00	1.90D 00	3.33D 00	1.77D 01	5.19D 00	2.75D-01	11.
	6	1.26D-01	2.25D-01	3.36D 00	1.84D 00	1.37D 00	4.14D-01	6.
	7	5.65D-03	2.43D-02	3.36D 00	9.10D-02	1.63D-01	4.36D-01	4.
	8	2.51D-04	2.60D-03	3.36D 00	4.03D-03	1.75D-02	4.38D-01	3.
	9	1.12D-05	2.78D-04	3.36D 00	1.82D-04	1.87D-03	4.38D-01	2.
	10	5.06D-07	2.99D-05	3.31D 00	8.05D-06	1.98D-04	4.36D-01	4.
	11	2.78D-08	3.90D-06	2.75D 00	3.45D-07	1.88D-05	4.03D-01	5.

99.9 PER CENT OF STEADY STATE BY OVERALL MATERIAL BALANCE AFTER TIME INTERVAL 0
99.5 PER CENT AFTER 86
99.0 PER CENT AFTER 72
95.0 PER CENT AFTER 40
90.0 PER CENT AFTER 26

MAXIMUM CONCENTRATION OF SOLUTE 1 IN AQUEOUS 3.0597D 01 IN ORGANIC 4.2706D 01

MAXIMUM CONCENTRATION OF SOLUTE 2 IN AQUEOUS 1.1161D 01 IN ORGANIC 5.1945D 00

MAXIMUM CONCENTRATION OF SOLUTE 3 IN AQUEOUS 3.3599D 00 IN ORGANIC 4.3309D-01

100	1	2.10D 01	5.19D 00	1.85D 00	3.76D 01	2.46D 00	1.24D-01	0.
	2	2.82D 01	9.08D 00	1.82D 00	4.11D 01	3.32D 00	9.93D-02	0.
	3	3.06D 01	1.12D 01	1.96D 00	4.23D 01	3.97D 00	9.33D-02	0.
	4	2.44D 01	7.19D 00	3.13D 00	4.27D 01	4.32D 00	1.16D-01	0.
	5	2.55D 00	1.90D 00	3.33D 00	1.77D 01	5.19D 00	2.75D-01	0.
	6	1.26D-01	2.25D-01	3.36D 00	1.84D 00	1.37D 00	4.14D-01	0.
	7	5.65D-03	2.43D-02	3.36D 00	9.10D-02	1.63D-01	4.36D-01	0.
	8	2.51D-04	2.60D-03	3.36D 00	4.03D-03	1.75D-02	4.38D-01	0.
	9	1.12D-05	2.78D-04	3.36D 00	1.82D-04	1.87D-03	4.38D-01	0.
	10	5.06D-07	2.99D-05	3.31D 00	8.05D-06	1.98D-04	4.36D-01	0.
	11	2.78D-08	3.90D-06	2.75D 00	3.45D-07	1.88D-05	4.03D-01	0.

(Intervening time intervals have been deleted to conserve space)

124	1	2.10D 01	5.20D 00	1.85D 00	3.76D 01	2.46D 00	1.23D-01	13.
	2	2.82D 01	9.10D 00	1.82D 00	4.11D 01	3.33D 00	9.93D-02	11.
	3	3.06D 01	1.12D 01	1.96D 00	4.23D 01	3.98D 00	9.32D-02	8.
	4	2.45D 01	7.23D 00	3.13D 00	4.27D 01	4.32D 00	1.16D-01	10.
	5	2.57D 00	1.91D 00	3.33D 00	1.77D 01	5.22D 00	2.74D-01	11.
	6	1.27D-01	2.27D-01	3.36D 00	1.85D 00	1.38D 00	4.14D-01	6.
	7	5.69D-03	2.45D-02	3.36D 00	9.17D-02	1.64D-01	4.36D-01	4.
	8	2.53D-04	2.63D-03	3.36D 00	4.11D-03	1.77D-02	4.38D-01	3.
	9	1.13D-05	2.81D-04	3.36D 00	1.83D-04	1.89D-03	4.38D-01	2.
	10	5.10D-07	3.03D-05	3.31D 00	8.12D-06	2.00D-04	4.36D-01	4.
	11	2.80D-08	3.95D-06	2.75D 00	3.48D-07	1.90D-05	4.03D-01	5.
125	1	2.10D 01	5.20D 00	1.85D 00	3.76D 01	2.46D 00	1.24D-01	13.
	2	2.82D 01	9.10D 00	1.82D 00	4.11D 01	3.33D 00	9.92D-02	11.
	3	3.06D 01	1.12D 01	1.96D 00	4.23D 01	3.98D 00	9.32D-02	8.

	4	2.45D 01	7.23D 00	3.13D 00	4.27D 01	4.33D 00	1.16D-01	10.
	5	2.56D 00	1.91D 00	3.33D 00	1.77D 01	5.22D 00	2.74D-01	11.
	6	1.27D-01	2.27D-01	3.36D 00	1.85D 00	1.38D 00	4.14D-01	6.
	7	5.69D-03	2.45D-02	3.36D 00	9.16D-02	1.64D-01	4.36D-01	4.
	8	2.53D-04	2.63D-03	3.36D 00	4.11D-03	1.77D-02	4.38D-01	3.
	9	1.13D-05	2.81D-04	3.36D 00	1.83D-04	1.89D-03	4.38D-01	2.
	10	5.10D-07	3.03D-05	3.31D 00	8.12D-06	2.00D-04	4.36D-01	4.
	11	2.80D-08	3.95D-06	2.75D 00	3.48D-07	1.90D-05	4.03D-01	5.
126	1	2.10D 01	5.20D 00	1.85D 00	3.76D 01	2.46D 00	1.23D-01	13.
	2	2.82D 01	9.10D 00	1.82D 00	4.11D 01	3.33D 00	9.92D-02	11.
	3	3.06D 01	1.12D 01	1.96D 00	4.23D 01	3.98D 00	9.32D-02	8.
	4	2.45D 01	7.23D 00	3.13D 00	4.27D 01	4.33D 00	1.16D-01	10.
	5	2.57D 00	1.91D 00	3.33D 00	1.77D 01	5.22D 00	2.74D-01	11.
	6	1.27D-01	2.27D-01	3.36D 00	1.85D 00	1.38D 00	4.14D-01	6.
	7	5.69D-03	2.45D-02	3.36D 00	9.17D-02	1.64D-01	4.36D-01	4.
	8	2.53D-04	2.63D-03	3.36D 00	4.11D-03	1.77D-02	4.38D-01	3.
	9	1.13D-05	2.81D-04	3.36D 00	1.83D-04	1.89D-03	4.38D-01	2.
	10	5.10D-07	3.03D-05	3.31D 00	8.12D-06	2.00D-04	4.36D-01	4.
	11	2.80D-08	3.95D-06	2.75D 00	3.48D-07	1.90D-05	4.03D-01	5.

99.9 PER CENT OF STEADY STATE BY OVERALL MATERIAL BALANCE AFTER TIME INTERVAL 126
99.5 PER CENT AFTER 86
99.0 PER CENT AFTER 72
95.0 PER CENT AFTER 40
90.0 PER CENT AFTER 26

MAXIMUM CONCENTRATION OF SOLUTE 1 IN AQUEOUS 3.0625D 01 IN ORGANIC 4.2713D 01

MAXIMUM CONCENTRATION OF SOLUTE 2 IN AQUEOUS 1.1198D 01 IN ORGANIC 5.2198D 00

MAXIMUM CONCENTRATION OF SOLUTE 3 IN AQUEOUS 3.3587D 00 IN ORGANIC 4.3796D-01

SAMPLE PRINT-OUT Pu EXTRACTION RUN

OAK RIDGE NATIONAL LABORATORY

SEPHIS - A SOLVENT EXTRACTION PROCESS HAVING INTERACTING SOLUTES

PU EXTRACTION 10 TOTAL STAGES

FEED STREAM DATA - AQUEOUS	STAGE NO.	URANIUM (G/L)	PLUTONIUM (G/L)	ACID (M)	FLOW RATE (VOL.UNITS)
	1	0.0	0.0	2.0000E 00	1.10E-01
	4	0.0	1.9200E 01	4.1000E 00	1.00E 00
0.150 TBP - ORGANIC	10	0.0	0.0	0.0	9.00E-01

EQUILIBRIUM EXPRESSIONS - CORRELATION COEFFICIENTS OPTIMIZED WITH RESPECT TO URANIUM

	A0	A1	A2	A3
FOR URANIUM	22.79524200	7.25652030	-2.71384716	2.16337010
FOR PLUTONIUM	5.49048420	-0.39458650	0.04383080	0.00558217
FOR ACID	0.56466365	-0.12194628	0.01474504	0.0

- CORRELATION COEFFICIENTS OPTIMIZED WITH RESPECT TO PLUTONIUM

	A0	A1	A2	A3
FOR URANIUM	7.62382330	8.71385480	-2.97765064	2.14147280
FOR PLUTONIUM	2.78329370	-0.51696092	0.04649217	0.02978738
FOR ACID	0.49267280	-0.16650303	0.02940420	0.0

- CORRELATION COEFFICIENTS OPTIMIZED WITH RESPECT TO ACID

	A0	A1	A2	A3
FOR URANIUM	22.79524200	7.25652030	-2.71384716	2.16337010
FOR PLUTONIUM	5.49048420	-0.39458650	0.04383080	0.00558217
FOR ACID	0.56466365	-0.12194628	0.01474504	0.0

PHASE RATIOS EQUAL FLOW RATIOS ---

STAGE NO.	PHASE RATIO
1 - 3	1.22E-01
4 - 10	1.23E 00

FLOWS IN EACH STAGE (VOL.UNITS) ---

		AQUEOUS PHASE				ORGANIC PHASE				OVERALL
STAGE NO.	FLOW RATIO	FLOW OUT OF STAGE	RECYCLE 2 TO FILL STAGE	RECYCLE 1 FOR PHASE RATIO	TOTAL AQUEOUS FLOW	FLOW OUT OF STAGE	RECYCLE 2 TO FILL STAGE	RECYCLE 1 FOR PHASE RATIO	TOTAL ORGANIC FLOW	TOTAL STAGE FLOW
1	1.22E-01	1.10E-01	0.0	0.0	1.10E-01	9.00E-01	0.0	0.0	9.00E-01	1.01E 00
2	1.22E-01	1.10E-01	0.0	0.0	1.10E-01	9.00E-01	0.0	0.0	9.00E-01	1.01E 00
3	1.22E-01	1.10E-01	0.0	0.0	1.10E-01	9.00E-01	0.0	0.0	9.00E-01	1.01E 00
4	1.23E 00	1.11E 00	0.0	0.0	1.11E 00	9.00E-01	0.0	0.0	9.00E-01	2.01E 00
5	1.23E 00	1.11E 00	0.0	0.0	1.11E 00	9.00E-01	0.0	0.0	9.00E-01	2.01E 00
6	1.23E 00	1.11E 00	0.0	0.0	1.11E 00	9.00E-01	0.0	0.0	9.00E-01	2.01E 00
7	1.23E 00	1.11E 00	0.0	0.0	1.11E 00	9.00E-01	0.0	0.0	9.00E-01	2.01E 00
8	1.23E 00	1.11E 00	0.0	0.0	1.11E 00	9.00E-01	0.0	0.0	9.00E-01	2.01E 00
9	1.23E 00	1.11E 00	0.0	0.0	1.11E 00	9.00E-01	0.0	0.0	9.00E-01	2.01E 00
10	1.23E 00	1.11E 00	0.0	0.0	1.11E 00	9.00E-01	0.0	0.0	9.00E-01	2.01E 00

TRANSIENT BEHAVIOR RESULTS SOLUTE CONCENTRATIONS IN EFFLUENT FROM EACH STAGE

TIME INTERVAL	STAGE	AQUEOUS PHASE VALUES URANIUM (G/L)	PLUTONIUM (G/L)	ACID (M)	ORGANIC PHASE VALUES URANIUM (G/L)	PLUTONIUM (G/L)	ACID (M)	ITERATIONS
0	1	0.0	0.0	0.0	0.0	0.0	0.0	0.
	2	0.0	0.0	0.0	0.0	0.0	0.0	0.
	3	0.0	0.0	0.0	0.0	0.0	0.0	0.
	4	0.0	0.0	0.0	0.0	0.0	0.0	0.
	5	0.0	0.0	0.0	0.0	0.0	0.0	0.
	6	0.0	0.0	0.0	0.0	0.0	0.0	0.
	7	0.0	0.0	0.0	0.0	0.0	0.0	0.
	8	0.0	0.0	0.0	0.0	0.0	0.0	0.
	9	0.0	0.0	0.0	0.0	0.0	0.0	0.
	10	0.0	0.0	0.0	0.0	0.0	0.0	0.
1	1	0.0	0.0	8.54D-01	0.0	0.0	1.40D-01	3.
	2	0.0	0.0	0.0	0.0	0.0	0.0	1.
	3	0.0	0.0	0.0	0.0	0.0	0.0	1.
	4	0.0	4.05D 00	3.45D 00	0.0	1.63D 01	3.06D-01	7.
	5	0.0	0.0	0.0	0.0	0.0	0.0	1.
	6	0.0	0.0	0.0	0.0	0.0	0.0	1.
	7	0.0	0.0	0.0	0.0	0.0	0.0	1.
	8	0.0	0.0	0.0	0.0	0.0	0.0	1.
	9	0.0	0.0	0.0	0.0	0.0	0.0	1.
	10	0.0	0.0	0.0	0.0	0.0	0.0	1.
2	1	0.0	0.0	8.54D-01	0.0	0.0	1.40D-01	3.
	2	0.0	0.0	4.43D-01	0.0	0.0	5.02D-02	8.
	3	0.0	1.65D 01	1.22D 00	0.0	1.43D 01	1.57D-01	11.
	4	0.0	4.05D 00	3.45D 00	0.0	1.63D 01	3.06D-01	7.
	5	0.0	7.75D-01	3.13D 00	0.0	4.04D 00	3.84D-01	5.
	6	0.0	0.0	0.0	0.0	0.0	0.0	1.
	7	0.0	0.0	0.0	0.0	0.0	0.0	1.
	8	0.0	0.0	0.0	0.0	0.0	0.0	1.
	9	0.0	0.0	0.0	0.0	0.0	0.0	1.
	10	0.0	0.0	0.0	0.0	0.0	0.0	1.
3	1	0.0	0.0	1.00D 00	0.0	0.0	1.72D-01	4.
	2	0.0	1.80D 01	1.01D 00	0.0	1.21D 01	1.37D-01	9.
	3	0.0	1.33D 01	1.45D 00	0.0	1.47D 01	1.82D-01	12.
	4	0.0	5.45D 00	3.89D 00	0.0	2.07D 01	2.87D-01	8.
	5	0.0	7.75D-01	3.13D 00	0.0	4.04D 00	3.84D-01	5.
	6	0.0	1.60D-01	2.82D 00	0.0	7.58D-01	3.93D-01	4.
	7	0.0	0.0	0.0	0.0	0.0	0.0	1.
	8	0.0	0.0	0.0	0.0	0.0	0.0	1.
	9	0.0	0.0	0.0	0.0	0.0	0.0	1.
	10	0.0	0.0	0.0	0.0	0.0	0.0	1.
4	1	0.0	9.60D 00	1.47D 00	0.0	1.10D 01	2.01D-01	10.
	2	0.0	1.53D 01	1.19D 00	0.0	1.28D 01	1.59D-01	10.
	3	0.0	1.47D 01	1.82D 00	0.0	2.11D 01	1.89D-01	11.
	4	0.0	5.32D 00	3.92D 00	0.0	2.04D 01	2.89D-0_	8.

	5	0.0	9.89D-01	3.89D 00	0.0	6.26D 00	3.97D-01	5.
	6	0.0	1.60D-01	2.82D 00	0.0	7.58D-01	3.93D-01	4.
	7	0.0	3.88D-02	2.51D 00	0.0	1.49D-01	3.76D-01	4.
	8	0.0	0.0	0.0	0.0	0.0	0.0	1.
	9	0.0	0.0	0.0	0.0	0.0	0.0	1.
	10	0.0	0.0	0.0	0.0	0.0	0.0	1.
5	1	0.0	9.17D 00	1.58D 00	0.0	1.17D 01	2.10D-01	9.
	2	0.0	1.66D 01	1.60D 00	0.0	2.02D 01	1.74D-01	9.
	3	0.0	1.32D 01	1.93D 00	0.0	2.07D 01	1.99D-01	11.
	4	0.0	6.04D 00	3.97D 00	0.0	2.19D 01	2.79D-01	9.
	5	0.0	9.62D-01	3.91D 00	0.0	6.14D 00	3.99D-01	5.
	6	0.0	1.60D-01	3.84D 00	0.0	1.17D 00	4.40D-01	4.
	7	0.0	3.88D-02	2.51D 00	0.0	1.49D-01	3.76D-01	4.
	8	0.0	1.14D-02	2.22D 00	0.0	3.39D-02	3.53D-01	4.
	9	0.0	0.0	0.0	0.0	0.0	0.0	1.
	10	0.0	0.0	0.0	0.0	0.0	0.0	1.
6	1	0.0	1.28D 01	1.80D 00	0.0	1.86D 01	1.98D-01	12.
	2	0.0	1.51D 01	1.70D 00	0.0	2.00D 01	1.84D-01	9.
	3	0.0	1.25D 01	2.18D 00	0.0	2.24D 01	2.08D-01	11.
	4	0.0	5.94D 00	3.98D 00	0.0	2.18D 01	2.81D-01	9.
	5	0.0	1.15D 00	4.01D 00	0.0	7.21D 00	3.93D-01	6.
	6	0.0	1.56D-01	3.86D 00	0.0	1.14D 00	4.41D-01	4.
	7	0.0	2.68D-02	3.76D 00	0.0	1.98D-01	4.46D-01	4.
	8	0.0	1.14D-02	2.22D 00	0.0	3.39D-02	3.53D-01	4.
	9	0.0	4.03D-03	1.96D 00	0.0	9.04D-03	3.26D-01	4.
	10	0.0	0.0	0.0	0.0	0.0	0.0	1.
7	1	0.0	1.22D 01	1.85D 00	0.0	1.85D 01	2.03D-01	12.
	2	0.0	1.46D 01	1.93D 00	0.0	2.22D 01	1.92D-01	8.
	3	0.0	1.18D 01	2.25D 00	0.0	2.22D 01	2.14D-01	9.
	4	0.0	6.25D 00	4.00D 00	0.0	2.24D 01	2.77D-01	9.
	5	0.0	1.12D 00	4.02D 00	0.0	7.09D 00	3.94D-01	6.
	6	0.0	1.85D-01	4.01D 00	0.0	1.39D 00	4.44D-01	4.
	7	0.0	2.61D-02	3.78D 00	0.0	1.94D-01	4.47D-01	4.
	8	0.0	4.98D-03	3.67D 00	0.0	3.60D-02	4.43D-01	4.
	9	0.0	4.03D-03	1.96D 00	0.0	9.04D-03	3.26D-01	4.
	10	0.0	1.73D-03	1.72D 00	0.0	2.84D-03	2.96D-01	4.
8	1	0.0	1.32D 01	1.93D 00	0.0	2.06D 01	2.00D-01	10.
	2	0.0	1.39D 01	1.98D 00	0.0	2.20D 01	1.97D-01	8.
	3	0.0	1.12D 01	2.40D 00	0.0	2.28D 01	2.19D-01	10.
	4	0.0	6.18D 00	4.01D 00	0.0	2.22D 01	2.78D-01	9.
	5	0.0	1.22D 00	4.05D 00	0.0	7.59D 00	3.91D-01	6.
	6	0.0	1.80D-01	4.02D 00	0.0	1.36D 00	4.45D-01	4.
	7	0.0	2.93D-02	4.00D 00	0.0	2.27D-01	4.55D-01	4.
	8	0.0	4.85D-03	3.69D 00	0.0	3.52D-02	4.44D-01	4.
	9	0.0	1.09D-03	3.55D 00	0.0	7.63D-03	4.39D-01	4.
	10	0.0	1.73D-03	1.72D 00	0.0	2.84D-03	2.96D-01	4.
9	1	0.0	1.28D 01	1.96D 00	0.0	2.04D 01	2.02D-01	10.
	2	0.0	1.36D 01	2.09D 00	0.0	2.27D 01	2.00D-01	8.

	3	0.0	1.08D 01	2.44D 00	0.0	2.26D 01	2.22D-01	9.
	4	0.0	6.31D 00	4.03D 00	0.0	2.25D 01	2.76D-01	8.
	5	0.0	1.20D 00	4.05D 00	0.0	7.49D 00	3.92D-01	7.
	6	0.0	1.97D-01	4.06D 00	0.0	1.49D 00	4.45D-01	4.
	7	0.0	2.85D-02	4.01D 00	0.0	2.22D-01	4.55D-01	4.
	8	0.0	4.85D-03	3.99D 00	0.0	3.78D-02	4.56D-01	3.
	9	0.0	1.07D-03	3.57D 00	0.0	7.50D-03	4.39D-01	4.
	10	0.0	1.85D-04	3.21D 00	0.0	1.12D-03	4.22D-01	4.
10	1	0.0	1.31D 01	1.99D 00	0.0	2.11D 01	2.01D-01	11.
	2	0.0	1.32D 01	2.11D 00	0.0	2.26D 01	2.03D-01	8.
	3	0.0	1.06D 01	2.51D 00	0.0	2.29D 01	2.24D-01	9.
	4	0.0	6.26D 00	4.03D 00	0.0	2.24D 01	2.77D-01	8.
	5	0.0	1.24D 00	4.07D 00	0.0	7.74D 00	3.91D-01	6.
	6	0.0	1.93D-01	4.06D 00	0.0	1.46D 00	4.45D-01	4.
	7	0.0	3.10D-02	4.05D 00	0.0	2.43D-01	4.56D-01	3.
	8	0.0	4.72D-03	4.00D 00	0.0	3.69D-02	4.56D-01	3.
	9	0.0	7.89D-04	3.96D 00	0.0	6.13D-03	4.55D-01	3.
	10	0.0	1.80D-04	3.23D 00	0.0	1.10D-03	4.23D-01	4.
11	1	0.0	1.29D 01	2.00D 00	0.0	2.10D 01	2.03D-01	11.
	2	0.0	1.31D 01	2.16D 00	0.0	2.29D 01	2.04D-01	8.
	3	0.0	1.04D 01	2.53D 00	0.0	2.28D 01	2.26D-01	9.
	4	0.0	6.33D 00	4.04D 00	0.0	2.26D 01	2.76D-01	8.
	5	0.0	1.23D 00	4.07D 00	0.0	7.67D 00	3.91D-01	6.
	6	0.0	2.02D-01	4.08D 00	0.0	1.53D 00	4.45D-01	4.
	7	0.0	3.03D-02	4.06D 00	0.0	2.38D-01	4.57D-01	3.
	8	0.0	4.86D-03	4.05D 00	0.0	3.83D-02	4.58D-01	3.
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	10	0.0	1.17D-04	3.60D 00	0.0	8.29D-04	4.41D-01	4.
12	1	0.0	1.30D 01	2.01D 00	0.0	2.13D 01	2.02D-01	11.
	2	0.0	1.29D 01	2.17D 00	0.0	2.28D 01	2.05D-01	8.
	3	0.0	1.04D 01	2.56D 00	0.0	2.29D 01	2.27D-01	9.
	4	0.0	6.30D 00	4.04D 00	0.0	2.25D 01	2.76D-01	8.
	5	0.0	1.25D 00	4.08D 00	0.0	7.79D 00	3.91D-01	6.
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	10	0.0	1.13D-04	3.61D 00	0.0	8.07D-04	4.41D-01	4.
13	1	0.0	1.29D 01	2.02D 00	0.0	2.12D 01	2.03D-01	11.
	2	0.0	1.29D 01	2.19D 00	0.0	2.29D 01	2.06D-01	8.
	3	0.0	1.03D 01	2.57D 00	0.0	2.28D 01	2.28D-01	9.
	4	0.0	6.34D 00	4.04D 00	0.0	2.26D 01	2.76D-01	8.
	5	0.0	1.24D 00	4.08D 00	0.0	7.75D 00	3.91D-01	6.
	6	0.0	2.04D-01	4.09D 00	0.0	1.54D 00	4.45D-01	4.
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	8	0.0	4.91D-03	4.08D 00	0.0	3.88D-02	4.59D-01	3.
	9	0.0	7.32D-04	4.05D 00	0.0	5.77D-03	4.58D-01	2.
	10	0.0	1.09D-04	3.68D 00	0.0	7.91D-04	4.44D-01	4.

14	1	0.0	1.29D 01	2.02D 00	0.0	2.13D 01	2.03D-01	11.
	2	0.0	1.28D 01	2.19D 00	0.0	2.28D 01	2.06D-01	8.
	3	0.0	1.02D 01	2.58D 00	0.0	2.29D 01	2.28D-01	9.
	4	0.0	6.32D 00	4.04D 00	0.0	2.25D 01	2.76D-01	8.
	5	0.0	1.26D 00	4.08D 00	0.0	7.81D 00	3.91D-01	6.
	6	0.0	2.02D-01	4.09D 00	0.0	1.53D 00	4.45D-01	4.
	7	0.0	3.19D-02	4.09D 00	0.0	2.51D-01	4.58D-01	3.
	8	0.0	4.83D-03	4.08D 00	0.0	3.82D-02	4.59D-01	3.
	9	0.0	7.49D-04	4.07D 00	0.0	5.92D-03	4.59D-01	2.
	10	0.0	1.06D-04	3.69D 00	0.0	7.72D-04	4.44D-01	4.
15	1	0.0	1.29D 01	2.03D 00	0.0	2.13D 01	2.03D-01	11.
	2	0.0	1.28D 01	2.20D 00	0.0	2.29D 01	2.06D-01	8.
	3	0.0	1.02D 01	2.58D 00	0.0	2.29D 01	2.28D-01	9.
	4	0.0	6.34D 00	4.04D 00	0.0	2.26D 01	2.76D-01	8.
	5	0.0	1.25D 00	4.09D 00	0.0	7.78D 00	3.91D-01	6.
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	10	0.0	1.08D-04	3.71D 00	0.0	7.91D-04	4.45D-01	4.
16	1	0.0	1.29D 01	2.03D 00	0.0	2.13D 01	2.03D-01	11.
	2	0.0	1.27D 01	2.20D 00	0.0	2.29D 01	2.07D-01	8.
	3	0.0	1.02D 01	2.59D 00	0.0	2.29D 01	2.28D-01	9.
	4	0.0	6.33D 00	4.04D 00	0.0	2.26D 01	2.76D-01	8.
	5	0.0	1.26D 00	4.09D 00	0.0	7.82D 00	3.91D-01	6.
	6	0.0	2.03D-01	4.10D 00	0.0	1.54D 00	4.45D-01	4.
	7	0.0	3.19D-02	4.10D 00	0.0	2.52D-01	4.58D-01	3.
	8	0.0	4.88D-03	4.09D 00	0.0	3.87D-02	4.60D-01	3.
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	10	0.0	1.06D-04	3.71D 00	0.0	7.77D-04	4.45D-01	4.
17	1	0.0	1.29D 01	2.03D 00	0.0	2.13D 01	2.03D-01	11.
	2	0.0	1.27D 01	2.21D 00	0.0	2.29D 01	2.07D-01	8.
	3	0.0	1.02D 01	2.59D 00	0.0	2.29D 01	2.29D-01	9.
	4	0.0	6.34D 00	4.04D 00	0.0	2.26D 01	2.76D-01	8.
	5	0.0	1.25D 00	4.09D 00	0.0	7.80D 00	3.91D-01	6.
	6	0.0	2.04D-01	4.10D 00	0.0	1.55D 00	4.45D-01	4.
	7	0.0	3.17D-02	4.10D 00	0.0	2.50D-01	4.58D-01	3.
	8	0.0	4.95D-03	4.10D 00	0.0	3.92D-02	4.60D-01	3.
	9	0.0	7.43D-04	4.08D 00	0.0	5.88D-03	4.60D-01	2.
	10	0.0	1.08D-04	3.72D 00	0.0	7.94D-04	4.46D-01	4.
18	1	0.0	1.29D 01	2.03D 00	0.0	2.13D 01	2.03D-01	12.
	2	0.0	1.27D 01	2.21D 00	0.0	2.29D 01	2.07D-01	8.
	3	0.0	1.02D 01	2.59D 00	0.0	2.29D 01	2.28D-01	9.
	4	0.0	6.33D 00	4.04D 00	0.0	2.26D 01	2.76D-01	8.
	5	0.0	1.26D 00	4.09D 00	0.0	7.82D 00	3.91D-01	6.
	6	0.0	2.04D-01	4.10D 00	0.0	1.55D 00	4.46D-01	4.
	7	0.0	3.20D-02	4.10D 00	0.0	2.52D-01	4.58D-01	3.
	8	0.0	4.91D-03	4.10D 00	0.0	3.90D-02	4.60D-01	3.
	9	0.0	7.53D-04	4.08D 00	0.0	5.97D-03	4.60D-01	2.
	10	0.0	1.07D-04	3.72D 00	0.0	7.84D-04	4.46D-01	4.

19	1	0.0	1.29D 01	2.03D 00	0.0	2.13D 01	2.03D-01	11.
	2	0.0	1.27D 01	2.21D 00	0.0	2.29D 01	2.07D-01	8.
	3	0.0	1.02D 01	2.59D 00	0.0	2.29D 01	2.29D-01	9.
	4	0.0	6.34D 00	4.04D 00	0.0	2.26D 01	2.76D-01	8.
	5	0.0	1.26D 00	4.09D 00	0.0	7.81D 00	3.91D-01	6.
	6	0.0	2.04D-01	4.10D 00	0.0	1.55D 00	4.45D-01	4.
	7	0.0	3.18D-02	4.10D 00	0.0	2.51D-01	4.58D-01	3.
	8	0.0	4.95D-03	4.10D 00	0.0	3.93D-02	4.60D-01	3.
	9	0.0	7.47D-04	4.09D 00	0.0	5.92D-03	4.60D-01	2.
	10	0.0	1.08D-04	3.72D 00	0.0	7.96D-04	4.46D-01	4.
20	1	0.0	1.29D 01	2.03D 00	0.0	2.13D 01	2.03D-01	12.
	2	0.0	1.27D 01	2.21D 00	0.0	2.29D 01	2.07D-01	8.
	3	0.0	1.02D 01	2.59D 00	0.0	2.29D 01	2.29D-01	9.
	4	0.0	6.33D 00	4.04D 00	0.0	2.26D 01	2.76D-01	8.
	5	0.0	1.26D 00	4.09D 00	0.0	7.82D 00	3.91D-01	6.
	6	0.0	2.04D-01	4.10D 00	0.0	1.55D 00	4.46D-01	4.
	7	0.0	3.20D-02	4.10D 00	0.0	2.52D-01	4.58D-01	3.
	8	0.0	4.93D-03	4.10D 00	0.0	3.91D-02	4.60D-01	3.
	9	0.0	7.54D-04	4.09D 00	0.0	5.98D-03	4.60D-01	2.
	10	0.0	1.07D-04	3.72D 00	0.0	7.89D-04	4.46D-01	4.

99.9 PER CENT OF STEADY STATE BY OVERALL MATERIAL BALANCE AFTER TIME INTERVAL 20
99.5 PER CENT AFTER 16
99.0 PER CENT AFTER 15
95.0 PER CENT AFTER 12
90.0 PER CENT AFTER 11

MAXIMUM CONCENTRATION OF SOLUTE 1 IN AQUEOUS 0.0 IN ORGANIC 0.0

MAXIMUM CONCENTRATION OF SOLUTE 2 IN AQUEOUS 1.7980D 01 IN ORGANIC 2.2914D 01

MAXIMUM CONCENTRATION OF SOLUTE 3 IN AQUEOUS 4.0995D 00 IN ORGANIC 4.6000D-01

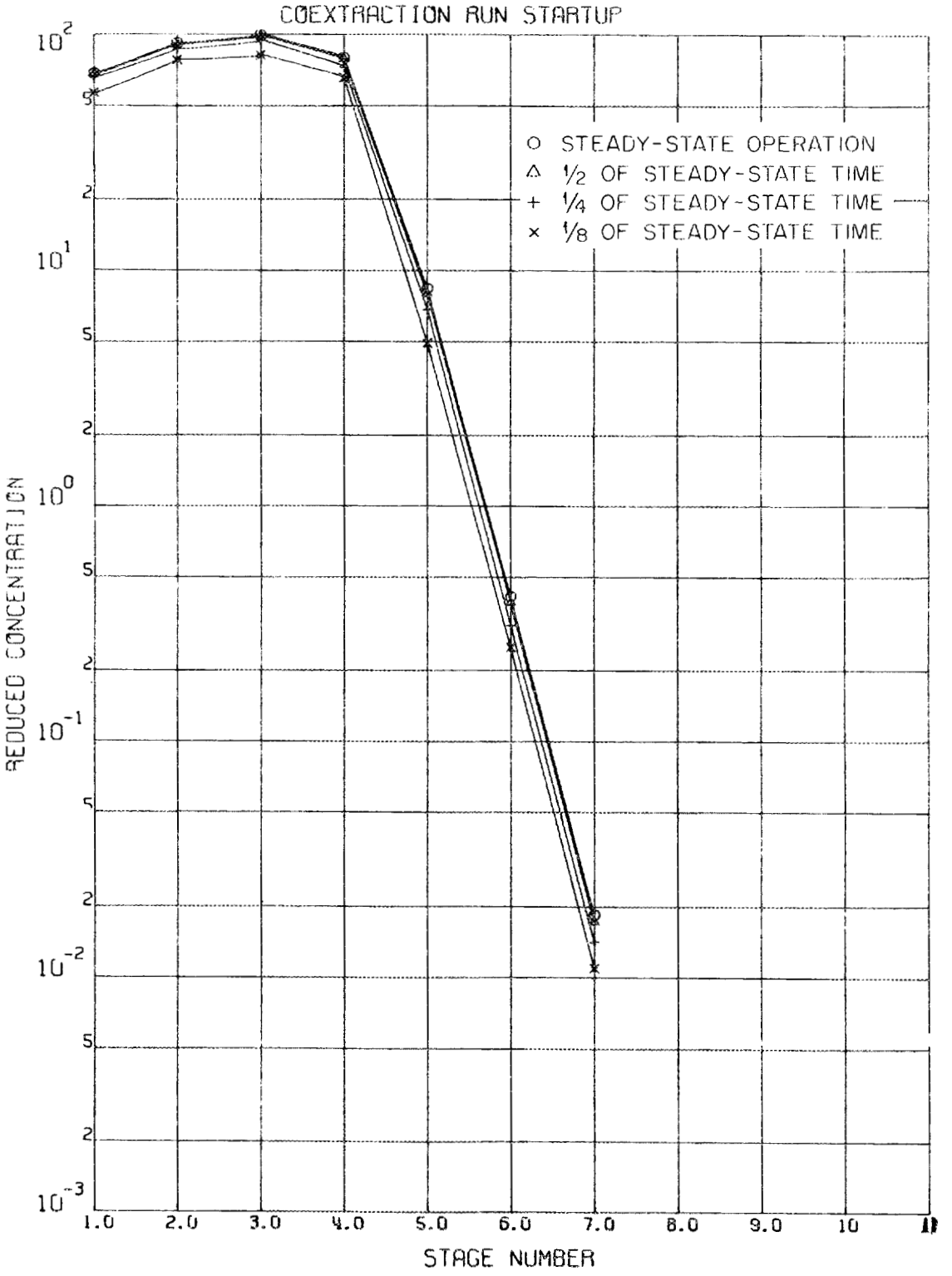

Fig. 4. Aqueous-Phase Uranium Concentration Profile for Coextraction Run.

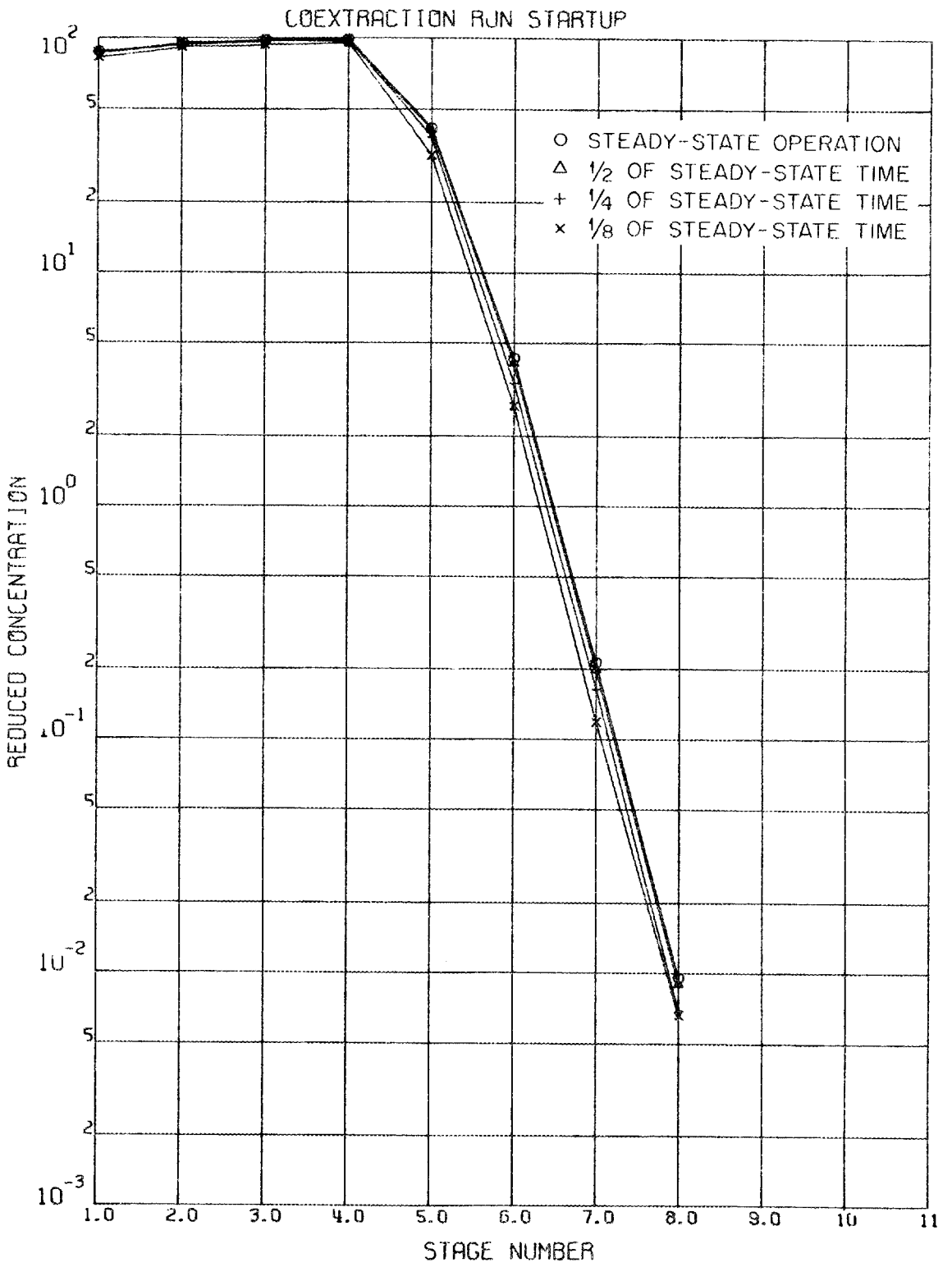

Fig. 5. Organic-Phase Uranium Concentration Profile for Coextraction Run.

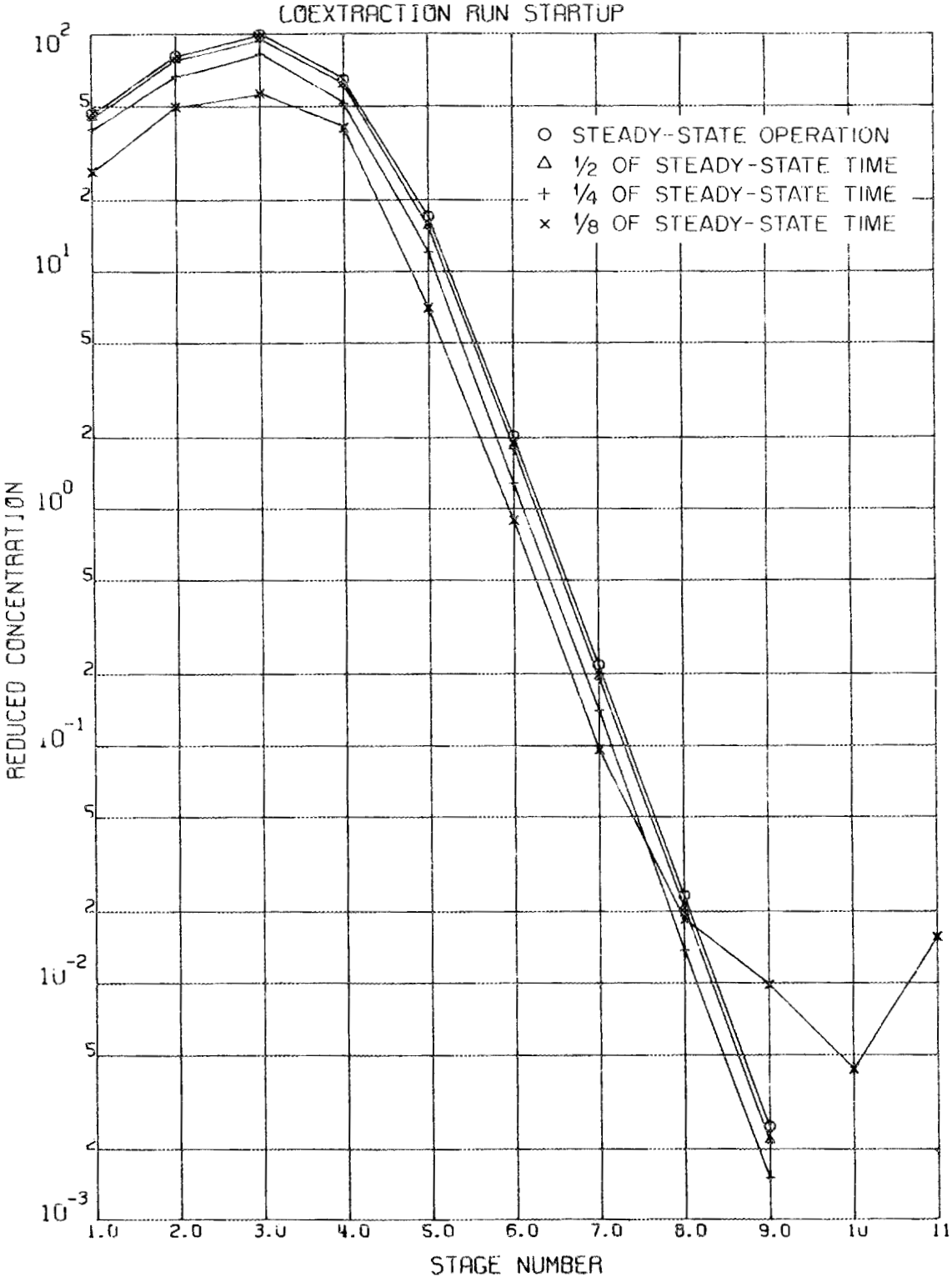

Fig. 6. Aqueous-Phase Plutonium Concentration Profile for Coextraction Run.

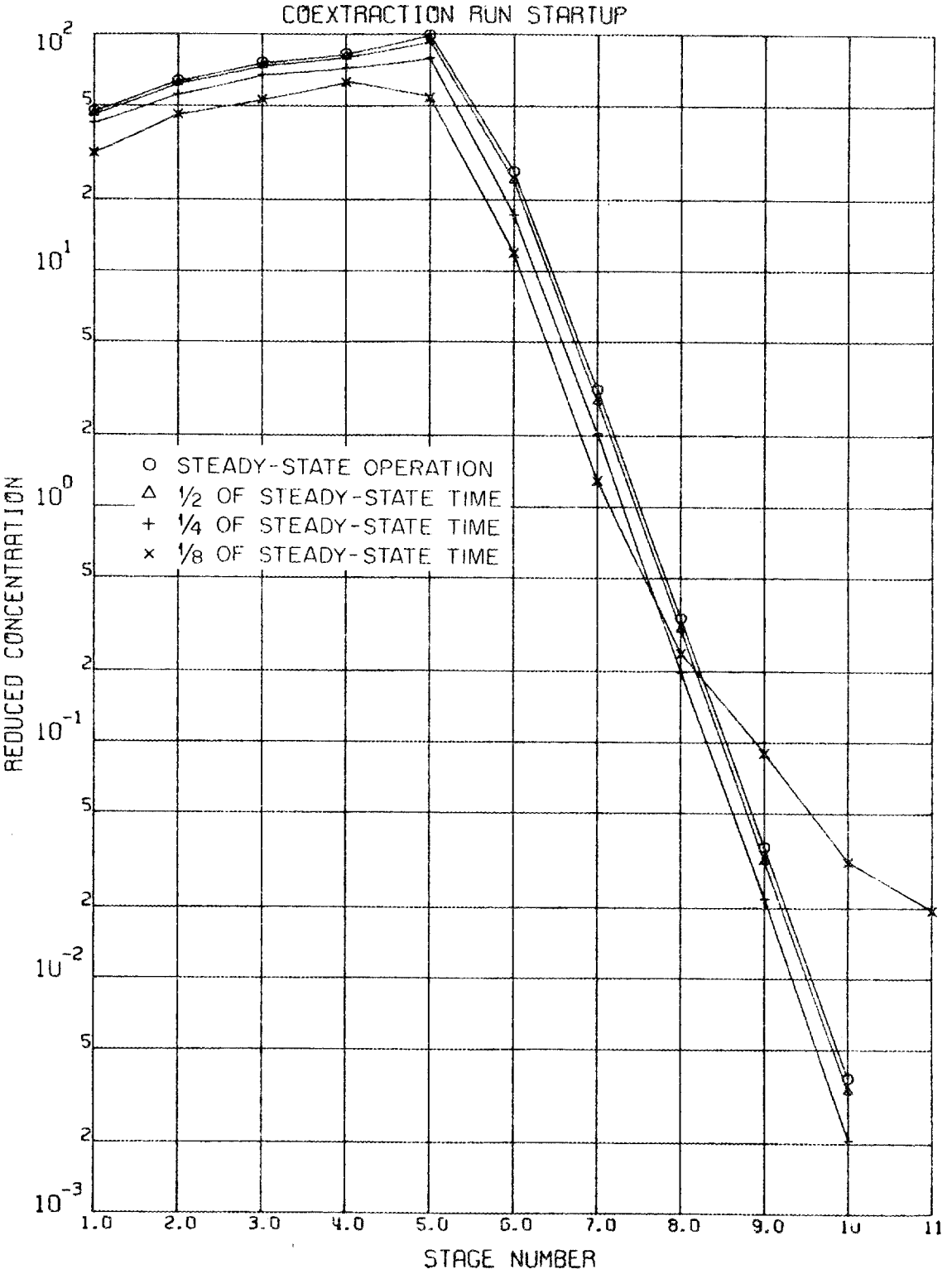

Fig. 7. Organic-Phase Plutonium Concentration Profile for Coextraction Run.

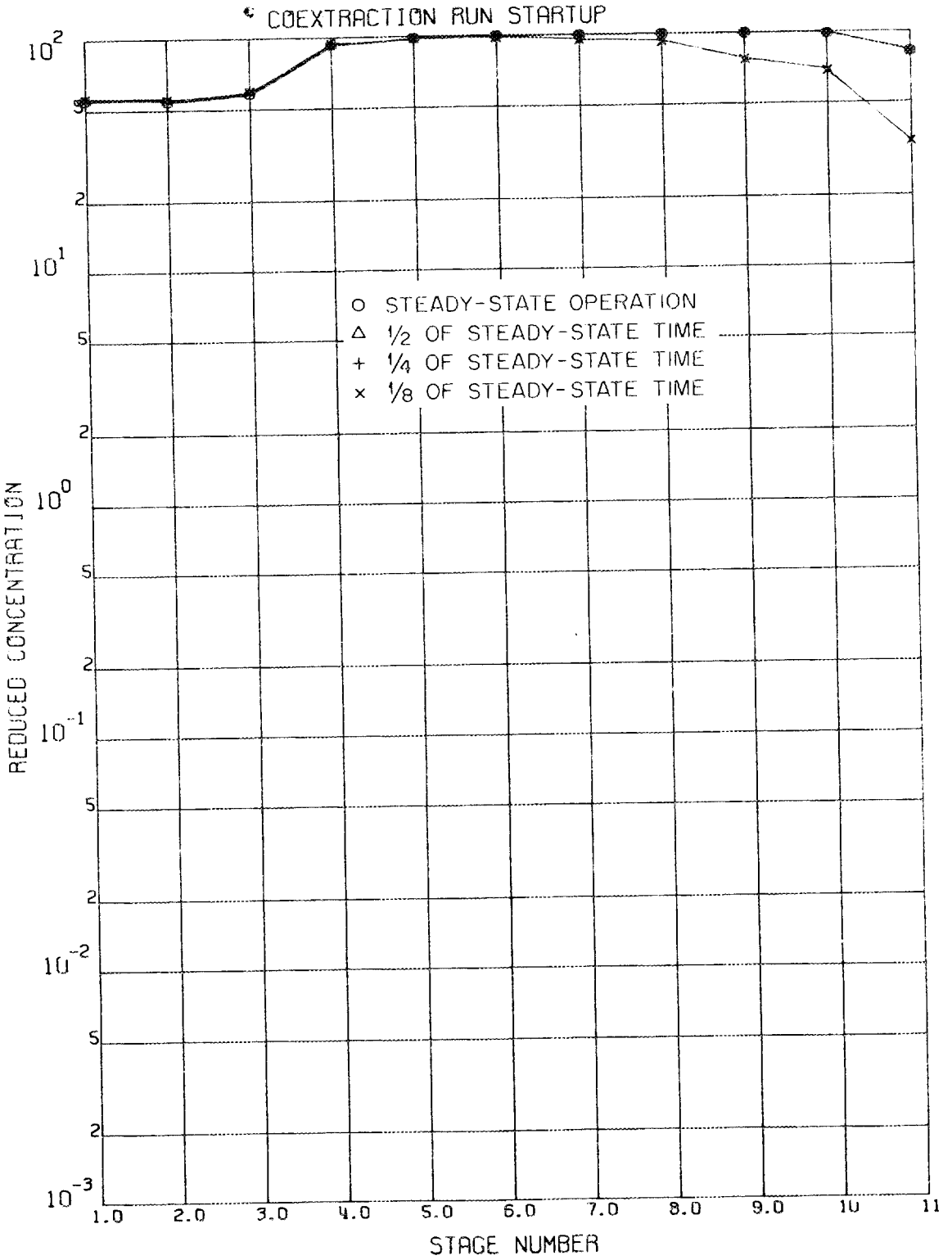

Fig. 8. Aqueous-Phase Nitric Acid Concentration Profile for Coextraction Run.

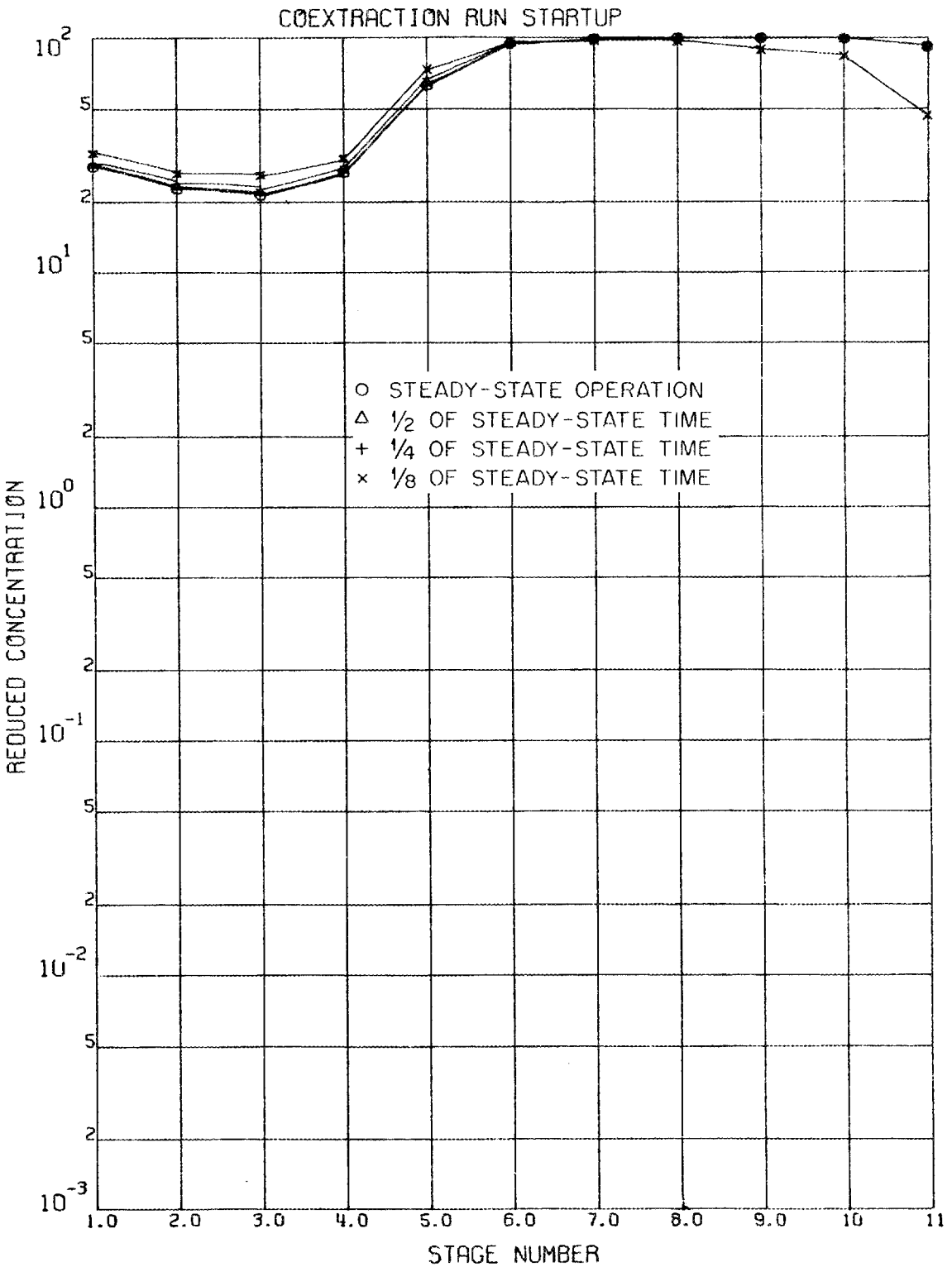

Fig. 9. Organic-Phase Nitric Acid Concentration Profile for Coextraction Run.

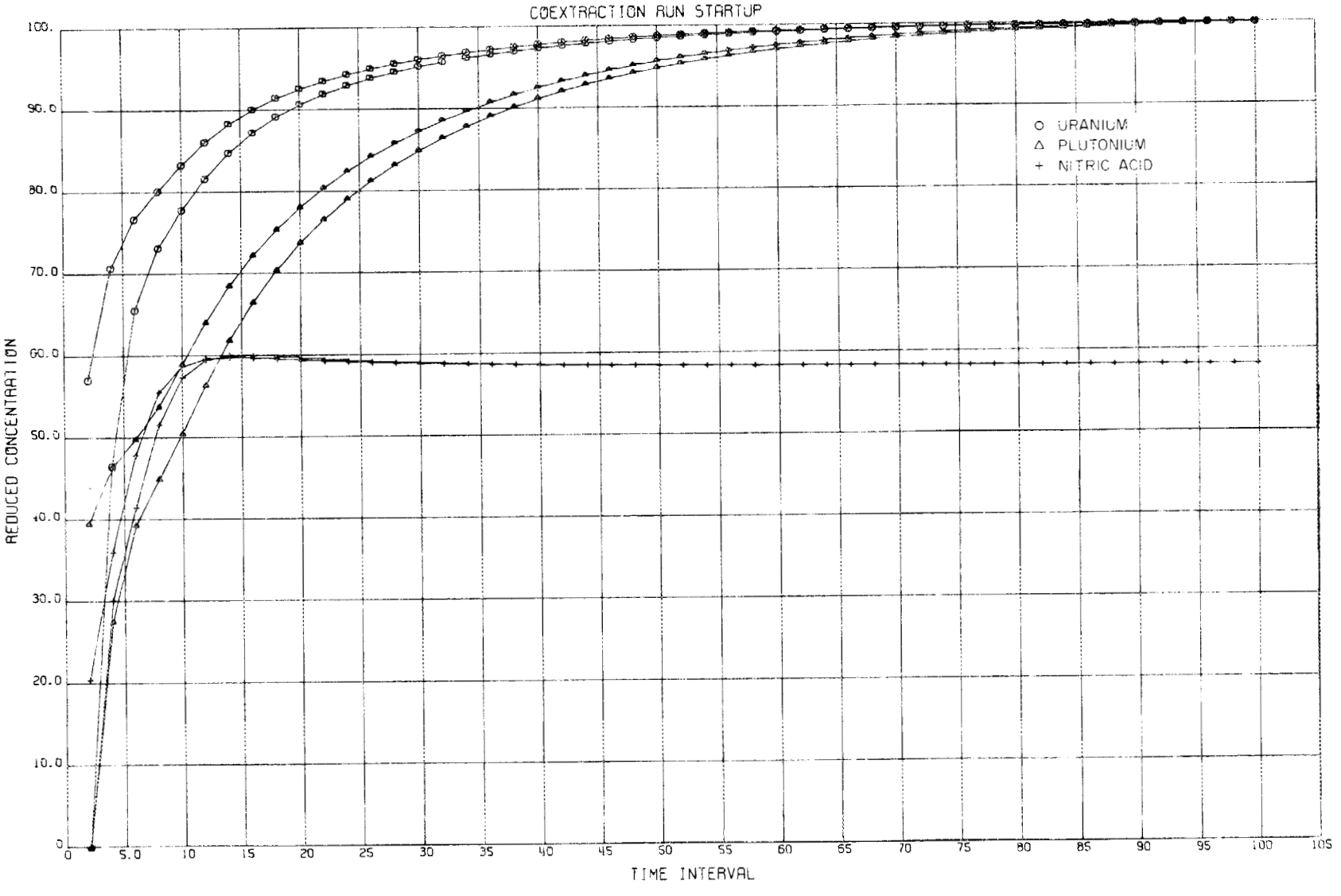

Fig. 10. **Feed Stage Approach to Steady State.** Aqueous phase; coextraction run.

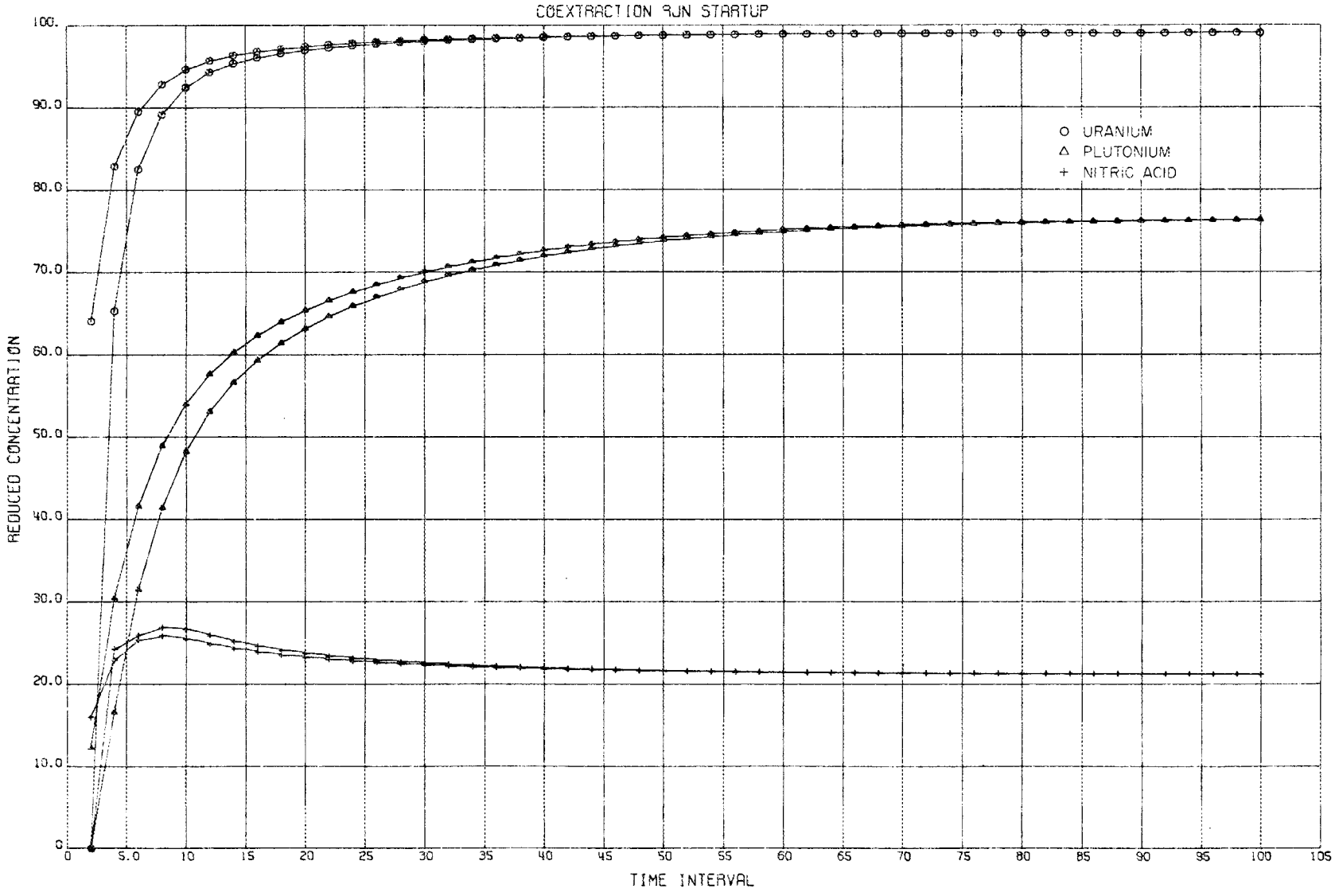

Fig. 11. Feed Stage Approach to Steady State. Organic phase; coextraction run.

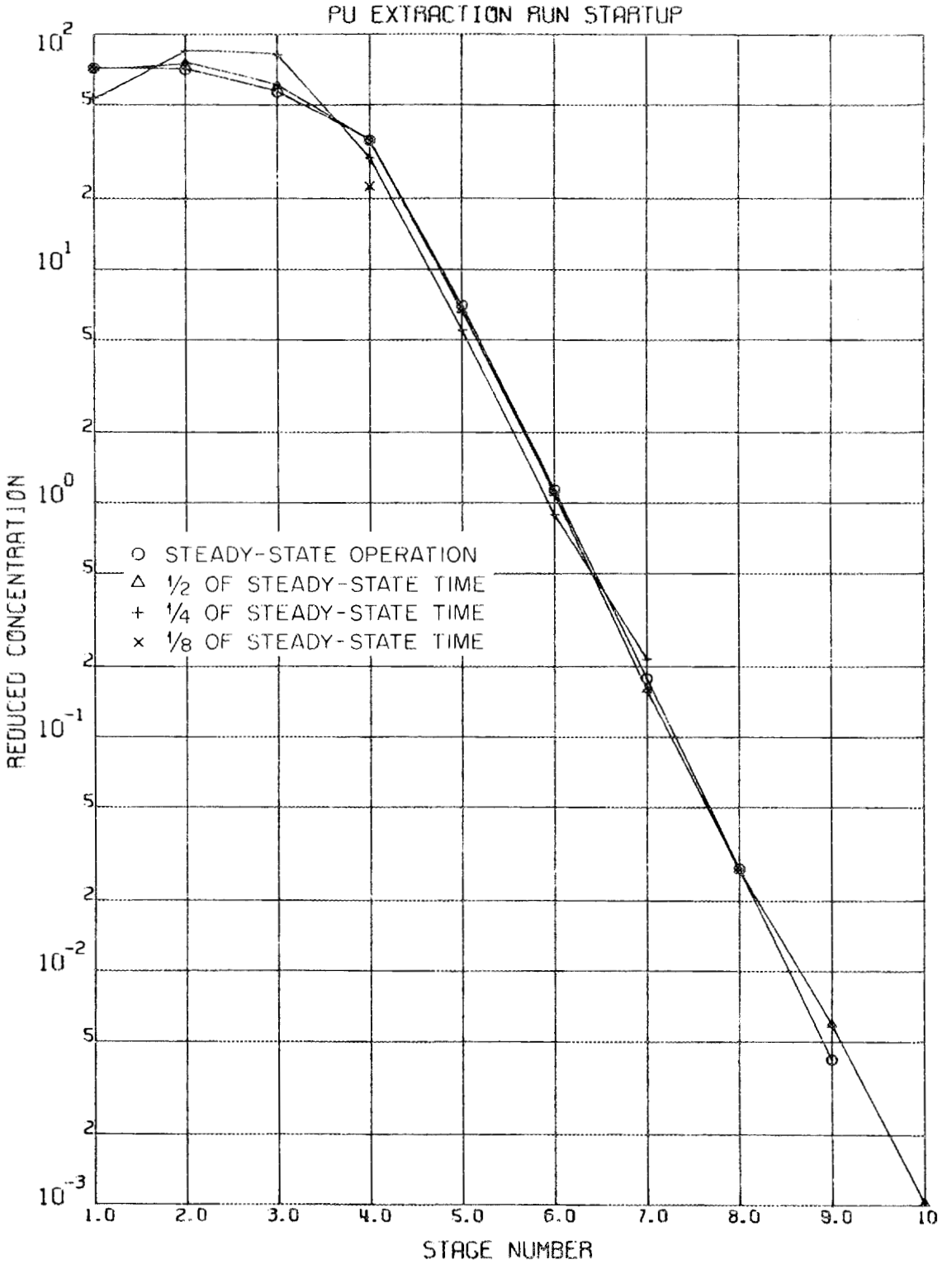

Fig. 12. Aqueous-Phase Plutonium Concentration Profile for Plutonium Extraction Run.

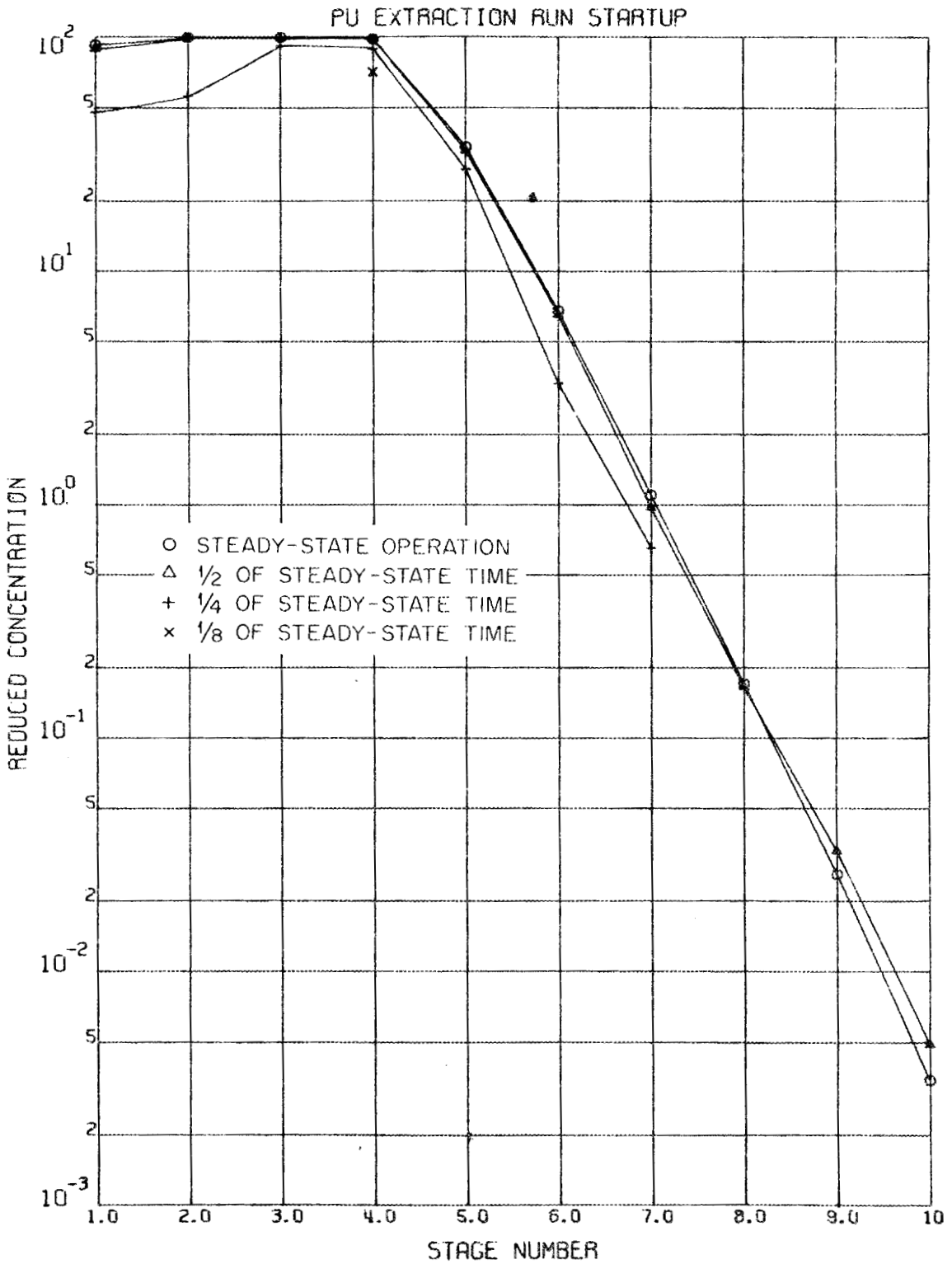

Fig. 13. Organic-Phase Plutonium Concentration Profile for Plutonium Extraction Run.

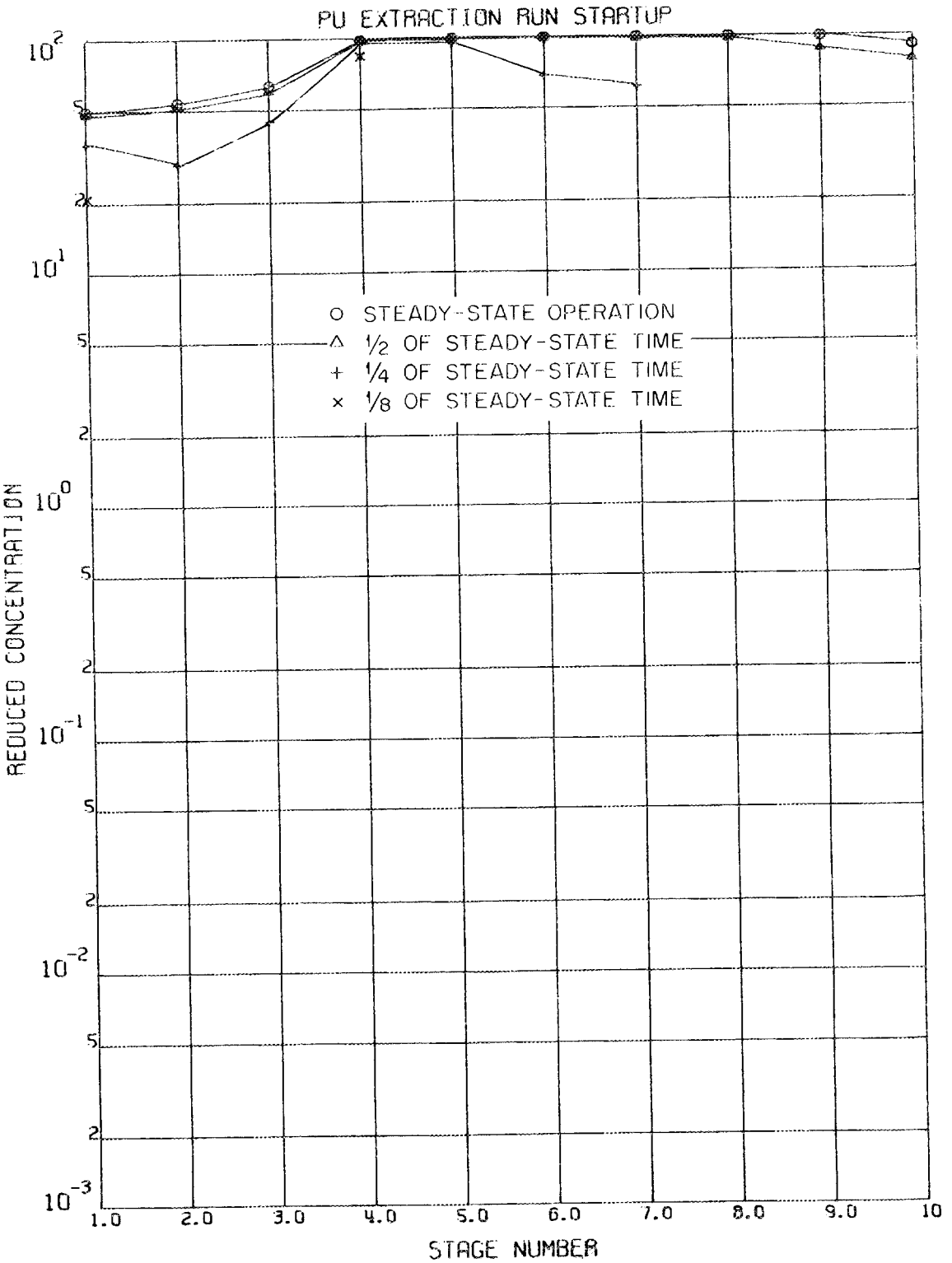

Fig. 14. Aqueous-Phase Nitric Acid Concentration Profile for Plutonium Extraction Run.

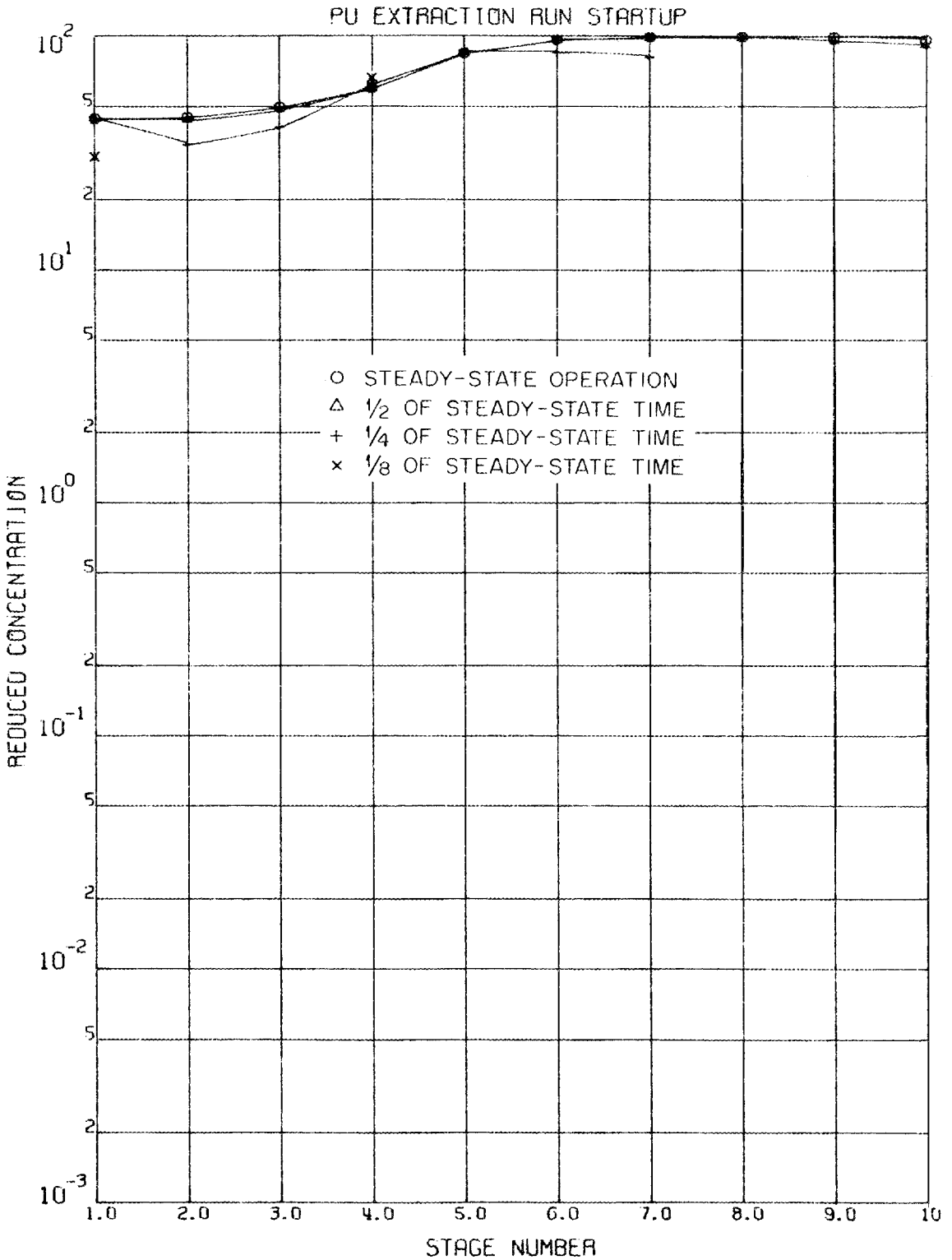

Fig. 15. Organic-Phase Nitric Acid Concentration Profile for Plutonium Extraction Run.

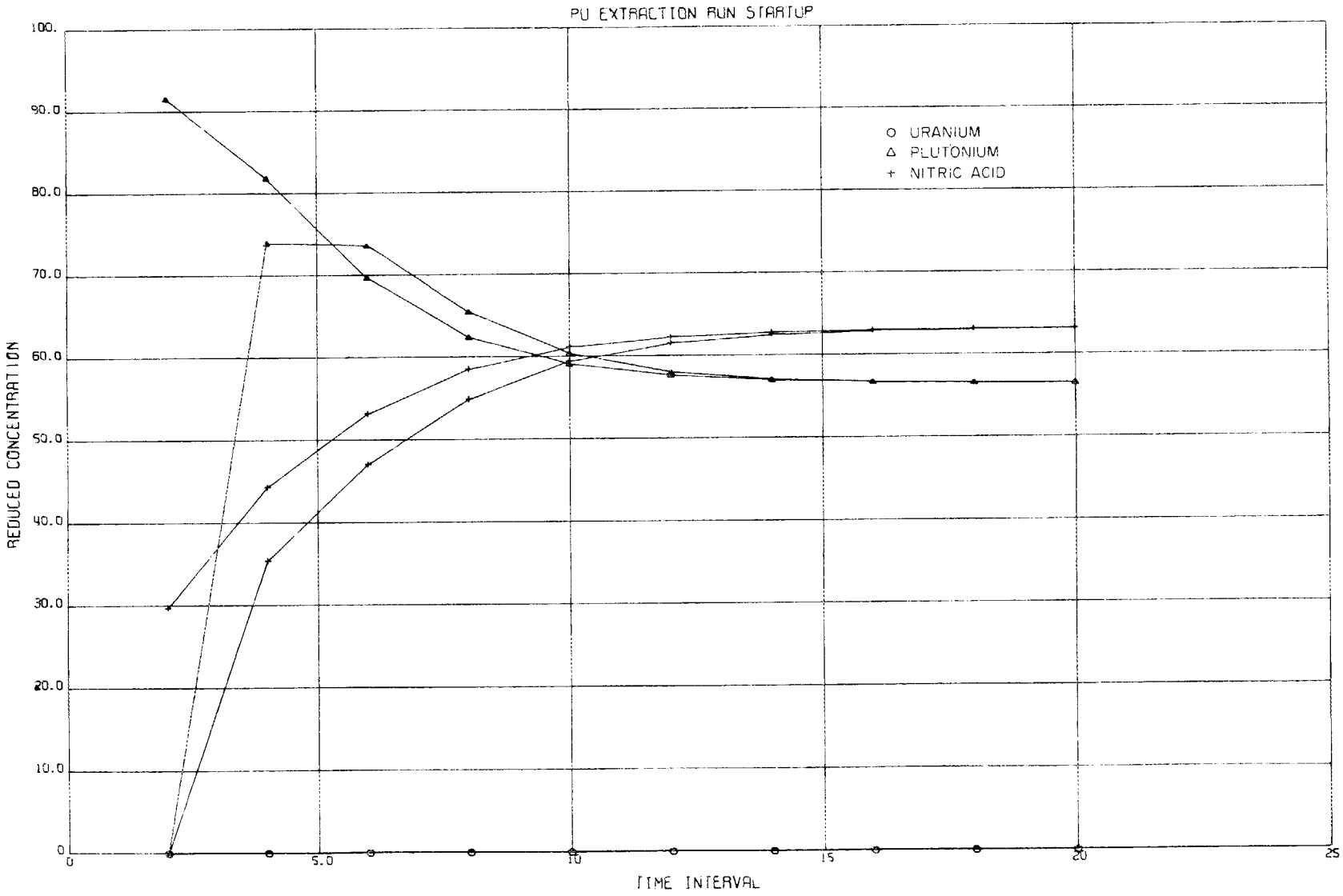

Fig. 16. Feed Stage Approach to Steady State. Aqueous phase; plutonium extraction run.

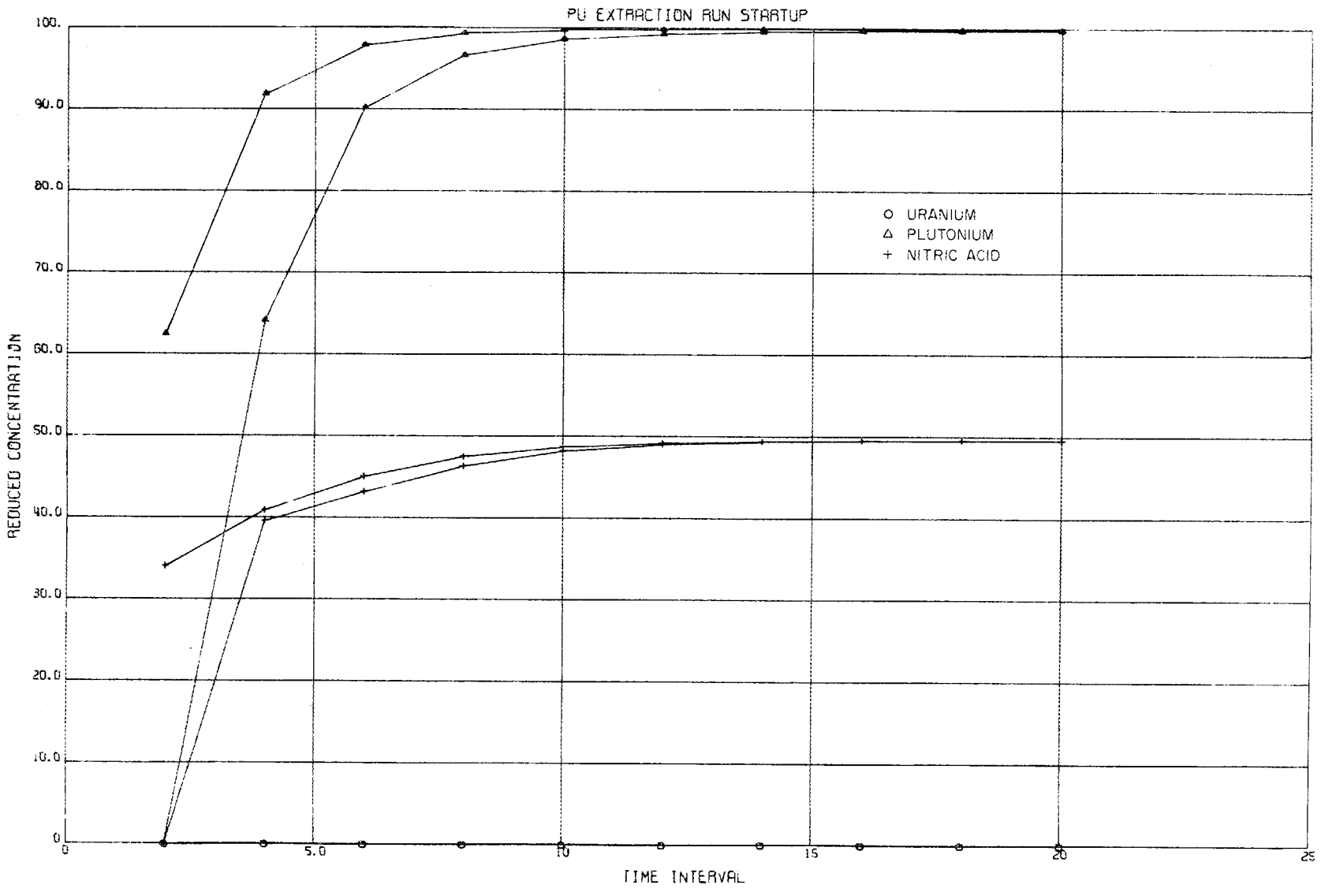

Fig. 17. Feed Stage Approach to Steady State. Organic phase; plutonium extraction run.

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