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Modifications of the SEPHIS Computer Code for Calculating the Purex Solvent Extraction System

S. B. Watson R. H. Rainey

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DECEMBER 1975

NOTICE

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MODIFICATIONS OF THE SEPHIS COMPUTER CODE FOR CALCULATING THE PUREX SOLVENT EXTRACTION SYSTEM

S. B. Watson and R. H. Rainey

ABSTRACT

The SEPHIS computer program was developed to simulate the countercurrent solvent extraction. This report gives modifications in the program which result in improved fit to experimental data, a decrease in computer storage requirements, and a decrease in execution time. Methods for applying the computer program to practical solvent extraction problems are explained.

I. INTRODUCTION

SEPHIS, a computer program for Solvent Extraction Processes Having Interacting Solutes, was developed by W. S. Groenier[1] for the purpose of studying the application of a 15% TBP solvent extraction system for recovering irradiated LMFBR fuel. Due to the success of the program in helping to establish optimum flowsheet conditions by simulation of the extraction process, the program has been widely used. In particular, G. L. Richardson of HEDL adapted the SEPHIS program to the conventional Purex process and also has made valuable changes in program structure.[2,3] The Richardson version of SEPHIS has undergone additional modifications at ORNL. The purposes of this report are to describe additional program modifications, to give instructions for use of the program, and to indicate some of its various applications.

A modification of the SEPHIS program is being made for the simulation of the Acid Thorex flowsheet.[4]

The changes in the Purex solvent extraction version of SEPHIS would not have been possible without the generous assistance of G. L. Richardson, who provided a copy of his computer program, and of W. S. Groenier, who gave valuable guidance in the operation of the program. This work is funded by the HTGR program.

II. NOTATION AND TERMINOLOGY

The symbols used in Section III are defined as follows:

U - molar uranium concentration,

Pu - molar plutonium concentration,

H - molar acid concentration,

S - molar unextractable salt nitrate concentration,

u - molal uranium concentration,

pu - molal plutonium concentration,

h - molal acid concentration,

s - molal salt nitrate concentration,

M - total molarity of the solution,

m - total molality of the solution,

W - molar water concentration in the TBP phase - Eq. (3),

w - molal water concentration in the TBP phase - Eq. (4),

F - volume fraction of TBP in dry, solute-free solvent,

T - molarity of TBP in dry, solute-free solvent,

t - temperature, °C,

K - pseudo-mass equilibrium constant - Eqs. (8)-(11),

n - total nitrate salting strength in the aqueous phase (molal) - Eq. (15),

r - reductant concentration (molal),

D - distribution coefficient, (i.e., $D_u = \frac{U_o}{U_a}$),

Subscripts:

a - aqueous phase,

o - organic phase,

os - solute molarity in solute-saturated solvent,

u - uranium,

pu - plutonium,

h1 - acid associated with 1 molecule of TBP,

h2 - acid associated with 2 molecules of TBP.

III. PROGRAM MODIFICATIONS

The details of the original SEPHIS program are available in Ref. 1; therefore, they will not be repeated in this report. At the time of the preparation of this report, the modifications by Richardson[2] have not been published. This program started with the Richardson version of the program; consequently, portions of his program are described in this report for completeness. The changes have been both in the program structure and in the mathematical modeling of the system. The complete modified program listing is given in Appendix A.

Programming changes

The following programming changes are present in the current version of SEPHIS:

1. Many of the variable names have been altered to enhance program readability. A listing of these changes is unnecessary since comment cards within the program specify the meanings of the majority of variables.
2. Common blocks have been reorganized for more efficient use of computer storage.
3. The multidimensional variables which contain the calculated concentrations for each stage have been reduced in size. Previously, these variables retained concentrations for each stage for 100 time intervals. Now only those concentrations for the previous and the current time intervals are stored. This modification resulted in a reduction of about 100 K of computer core storage.

4. The subroutines have been renamed, and computational capability of certain subroutines has been altered. SEPHIS presently consists of the following routines:

   MAIN reads program description cards, initializes arrays, performs molarity and molality conversions, prints results, and analyzes the approach to steady-state operation.

   PRØFIL defines feed streams and initial profile, if not zero.

   FLØWS defines outgoing streams, calculates phase ratios, flow ratios, recycle flows, interstage flows, and stage volumes for each stage.

   STAGES performs stage calculations for the current time interval.

   UCØR calculates the distribution coefficients required by STAGES.

   PLØTR and PPL generate Calcomp plots (profile graphs and transient graphs). PLØTR and PPL invoke the ORGRAPH[5] plotting package which is available at ORNL, and the subroutines in the package are not printed in Appendix A.

Modeling changes

Modifications to the modeling of the extraction system for the uranium, plutonium, and nitric acid are summarized as follows:

1. As before, calculations are valid for three transferring components; however, the current version also includes the salting effect from nonextractable nitrate salts.

2. Provisions have been made for estimating the partitioning of plutonium from uranium by entering the reductant normality as a negative plutonium concentration. The code does not, however, include the effects of kinetics, which is an important consideration in actual processing facilities.

3. Stage calculations are performed on a solute-free basis. The relationship between solute-free concentrations (small letters) and molarities (capital letters) for aqueous and organic solutions is given below (taken from Ref. 2 with slight modifications):

$$\frac{m_a}{M_a} = \frac{1.0}{1.0 - 0.0724U_a - 0.13Pu_a - 0.0309H_a - 0.031S_a} \tag{1}$$

$$= 1.0 + 0.0724u_a + 0.13pu_a + 0.0309h_a + 0.031s_a$$

$$\frac{m_o}{M_o} = \frac{1.0}{1.0 - 0.097U_o - 0.139Pu_o - 0.043H_o - 0.0174W_o} \tag{2}$$

$$= 1.0 + 0.097u_o + 0.139pu_o + 0.043h_o + 0.0174w_o$$

where W_o and w_o are calculated water concentrations in the TBP phase defined by

$$W_o = (3.95 - 0.0144t)\left(1.0 - \frac{U_o}{U_{os}} - \frac{Pu_o}{Pu_{os}} - \frac{0.65H_o}{H_{os}}\right)F^{1.65} \tag{3}$$

$$w_o = (4.2 - 0.015t)\left(1.0 - \frac{2u_o}{T} - \frac{2pu_o}{T} - \frac{0.6h_o}{T}\right)F^{1.69} \tag{4}$$

U_{os}, Pu_{os}, and H_{os} are molarities of uranium, plutonium, and acid, respectively, required to saturate the TBP. They are defined by:

$$U_{os} = \frac{0.5T}{1.0 + 0.046T} \tag{5}$$

$$Pu_{os} = \frac{0.5T}{1.0 + 0.09T} \tag{6}$$

$$H_{os} = \frac{T(1.0 - 0.00609(3.95 - 0.0144t)F^{1.65})}{(1.0 + 0.043T)} . \tag{7}$$

4. Profile temperature may vary with the time interval.
5. The program accounts for the amount of water the TBP extracts.
6. The criterion for convergence of stage calculations has been somewhat modified. As in the original SEPHIS stage, calculations are performed using an iterative procedure in each stage for each time interval. If convergence ((observed-calculated)/calculated <.001) is achieved within 20 iterations, the computation is considered to be complete in the current version of SEPHIS. If the computation fails to converge, the last calculated values are accepted. This is based on the assumption that steady-state values may be obtained even though there was failure to converge in a transient period. (It should be emphasized that, when the 20th iteration is reported in the printout, it may have no physical significance.)

7. The definition of steady state as given by Groenier is also used in the current version of SEPHIS with additional complexities. Additional convergence criteria have been added to the program to obtain less precise answers where convenience required over 100 iterations.

8. Richardson developed a new method for calculating distribution coefficients in an attempt to extend the code to higher temperatures and TBP concentrations than the restrictions of 25°C and 15% TBP imposed by the earlier code. The following is taken in part from his work and includes some additional details.

The equilibrium correlation was based on deriving empirical equations for the following pseudo-mass-action equilibrium constants:

$$K_u = \frac{(UO_2(NO_3)_2 \cdot 2TBP)_o}{(UO_2^{2+})_a (TBP)_o^2} = K_u'(NO_3^-)_a^2 \tag{8}$$

$$K_{pu} = \frac{(Pu(NO_3)_4 \cdot 2TBP)_o}{(Pu^{4+})_a (TBP)_o^2} = K_{Pu}'(NO_3^-)_a^4 \tag{9}$$

$$K_{h1} = \frac{(HNO_3 \cdot TBP)_o}{(H^+)_a (TBP)_o} = K_{h1}'(NO_3^-)_a \tag{10}$$

$$K_{h2} = \frac{(HNO_3 \cdot 2TBP)_o}{(H^+)_a (TBP)_o^2} = K_{h2}'(NO_3^-)_a \tag{11}$$

This program and Richardson's program are based on a fitting of the K values above. Groenier's program was based on a fitting of the K′ values. The basic empirical equilibrium expressions were derived at 100% TBP equilibrated at 25°C, giving the following equations[2]:

$$K_u^* = 3.7n_a^{1.57} + 1.4n_a^{3.9} + 0.011n_a^{7.3} \tag{12}$$

$$K_{h1}^* = 0.135n_a^{0.82} + 0.0052n_a^{3.44} \tag{13}$$

$$K_{h2}^* \simeq K_{h2}^* \tag{14}$$

where

$$n_a = h_a + 2u_a + 4pu_a + s_a \ . \tag{15}$$

The plutonium constant was determined as a function of the uranium constant at 25°C.

$$K_{pu}^* = K_u^*(0.20 + 0.55F^{1.25} + 0.0074n_a^2) \ . \tag{16}$$

The code provides correction factors for other TBP concentrations and temperatures:

$$K_u = K_u^*(4F^{-0.17} - 3)e^{(2500\tau)} \tag{17}$$

$$K_{pu} = K_{pu}^*(4F^{-0.17} - 3)e^{(-200\tau)} \tag{18}$$

$$K_{h1} = K_{h2} = K_{h1}^*(1.0 - 0.54e^{(-15F)})e^{(340\tau)} \tag{19}$$

where $\tau = \frac{1}{\tau_o} - \frac{1}{298}$ and τ_o = equilibrium temperature, °K. The change in the distribution with TBP concentration is estimated as follows:

$$D_u = \frac{(UO_2(NO_3)_2 \cdot 2TBP)_o}{(UO_2^{2+})_a} = K_u(TBP)_o^2 \tag{20}$$

$$D_{pu} = \frac{(Pu(NO_3)_4 \cdot 2TBP)_o}{(Pu^{4+})_a} = K_{pu}(TBP)_o^2 \tag{21}$$

$$D_{h1} = \frac{(HNO_3 \cdot TBP)_o}{(H^+)_a} = K_{h1}(TBP)_o \tag{22}$$

$$D_{h2} = \frac{(HNO_3 \cdot 2TBP)_o}{(H^+)_a} = K_{h2}(TBP)_o^2 \ . \tag{23}$$

Free (uncomplexed) TBP concentration is calculated as follows:

$$(TBP)_o = T - 2(UO_2(NO_3)_2 \cdot 2TBP)_o - 2(P_u(NO_3)_4 \cdot 2TBP)_o$$

$$- (HNO_3 \cdot TBP)_o - 2(HNO_3 \cdot 2TBP)_o . \tag{24}$$

Substitution of Eqs. (20) through (23) into (24) produces

$$(TBP)_o = T - 2K_u u_a (TBP)_o^2 - 2K_{pu} pu_a (TBP)_o^2 - k_{h1} h_a (TBP)_o$$

$$- 2K_{h2} h_a (TBP)_o^2 \ .$$

Solving the quadratic equation gives

$$(TBP)_o = \frac{-(k_{h1}h_a + 1) + \sqrt{(K_{h1}h_a + 1)^2 + 8(K_u u_a + K_{pu}pu_a + K_{h2}h_a)(3.651F)}}{4(K_u u_a + K_{pu}pu_a + K_{h2}h_a)} \tag{25}$$

assuming T = 3.651F.

Thus, given u_a, pu_a, h_a, s_a, and r, the distribution coefficients are calculated by forming n_a which is used to evaluate (12) - (19), then solving (25) for $(TBP)_o$ and replacing it in (20) - (23).

IV. USER INFORMATION

The current version of SEPHIS is written in the IBM System/360 and System/370 FORTRAN IV language. The program is compiled using the H-level compiler and has been executed on both the IBM 360/91 and 360/75 at ORNL. The program requires about 140 K (K = 1024 bytes; bytes = 8 bits) of core storage for execution. Approximately 1/20 sec. of computing time on the IBM 360/91 is required for each time interval when calculating 10 stages.

The remainder of this section describes the content of the card input which must be prepared in order to execute the program and the output produced by the program. Sample input and the corresponding output are presented in Appendix B.

Input

The input data are to be prepared in the order shown in Table 1. Referring to Table 1, "Subroutine" indicates the subroutine in which the card is read. "Card Number" denotes the order within the group (Program Cards, Feed Stream Cards, etc.) or quantity of cards for each group to be input. "Columns" refers to the actual columns on the card in which the data must be punched. "Remarks, Variables, etc." gives an explanation as to the variable name, definition, and form of the data to be punched on the cards. The FORMAT descriptor indicates the content and length of the fields on the card. In the FORMAT descriptor the letter "A" denotes alphabetic data; "I" refers to integer data (no decimal point) which must always be right-justified in the field; "F"

Table 1. Input to SEPHIS Code

Subroutine	Card Number	Columns	Remarks, Variables, etc.
		Program Cards	
MAIN	1		FØRMAT (10A4)
		1-40	TITLE - problem title
	2		FØRMAT (F8.0,9I2)
		1-8	CTBP - volume fraction of dry TBP
		9-10	NTØST - total number of stages - must not exceed 25
		11-12	IPRØ - 0 for a zero initial concentration profile 1 for a non-zero initial profile
		13-14	IRATIØ - 0 if phase ratio = flow ratio 1 if phase ratio values are to be input
		15-16	ICALC - 0 for shutdown calculations (no U or Pu in feed streams) 1 for start-up or interruption
		17-18	IØUT - 0 if there are no extra outgoing streams 1 if there are outgoing streams in addition to end streams
		19-20	IVØL - 0 stage volumes are equal

Table 1. (continued)

Subroutine	Card Number	Columns	Remarks, Variables, etc.
MAIN (cont.)			IVØL - 1 stage volumes are unequal but according to total flow 2 stage volumes are independently unequal 3 stage volumes are equal and specified (Options 2 or 3 should be used for HAN* calculations to correct for stage residence time) (*Hydroxylamine Nitrate - Ref. 3)
		21-22	IPR - 0 print out all time intervals 1 print only last interval -1 print every 20th time interval
		23-24	IPNCH - 0 no punched card output desired 1 final profile output punched on cards
		25-26	ICALPL - 0 no Calcomp plots 1 profile graphs (log of concentration vs stage number at 1/8 steady state, 1/4 steady state, 1/2 steady state, and steady state) 2 transient graphs (concentration vs time interval at specified stages for each time block) 3 plot both 1 and 2

Table 1. (continued)

Subroutine	Card Number	Columns	Remarks, Variables, etc.
			Feed Stream Cards
PRØFIL	One card for each input stream		FØRMAT (2I2,5F8.0,I2,F8.0)
		1-2	I - stage number that feed enters
		3-4	JHAS - 1 for aqueous feed 0 for organic feed
		5-12	FDRT - feed flow rate (volume units)
		13-20	CØN1 - uranium content (g/l)
		21-28	CØN2 - plutonium content (g/l)
		29-36	CØN3 - acid molarity
		37-44	TEMP - temperature in degrees C
		45-46	INDEX - 1 more cards to follow 0 last card
		47-54	CØN4 - nitrate normality from inextractable salts, including the reductant
			(Enter Pu reductant normality as negative Pu concentration)
			Initial Profile Cards (required only for non-zero initial profile)
PRØFIL	One card for each stage		FØRMAT (8F8.0)
		1-8	X(1,J,1) - aqueous-phase uranium concentration in stage J (g/l)

Table 1. (continued)

Subroutine	Card Number	Columns	Remarks, Variables, etc.
PRØFIL (cont.)		9-16	X(2,J,1) - aqueous-phase plutonium concentration in stage J (g/l)
		17-24	X(3,J,1) - aqueous-phase nitric acid concentration in stage J (M)
		25-32	Y(1,J,1) - organic-phase uranium concentration in stage J (g/l)
		33-40	Y(2,J,1) - organic-phase plutonium concentration in stage J (g/l)
		41-48	Y(3,J,1) - organic-phase nitric acid concentration in stage J (M)
		49-56	TPRØF(J,1) - temperature in stage J
		57-64	X(4,J,1) - aqueous-phase nitrate concentration in stage J (M)
Outgoing Stream Data (other than aqueous raffinate and organic product)			
FLØWS	One card for each outgoing stream		FØRMAT (2I2,F8.0,I2)
		1-2	I - stage number that stream leaves
		3-4	JHAS - 1 for aqueous stream 0 for organic stream
		5-12	ØTRT - exit flow rate (volume units)
		13-14	INDEX - 1 more cards follow 0 last card

Table 1. (continued)

Subroutine	Card Number	Columns	Remarks, Variables, etc.
			Phase Ratio Cards (used only if phase ratio ≠ flow ratio)
FLØWS	One card for each region of constant phase ratio		FØRMAT (I2,F8.0)
		1-2	I - number of stages having phase ratio shown
		3-12	RATIØ - aqueous/organic phase ratio
			Stage Volumes (for IVØL=2 and IVØL=3)
FLØWS			For IVØL=2 stage volumes are unequal and not flow related
	1		FØRMAT (10A8)
		1-8	STVØL(1)
		⋮	⋮
		72-80	STVØL(10)
	2		FØRMAT (10A8)
		1-8	STVØL(11)
		⋮	⋮
		72-80	STVØL(20)
	3		FØRMAT (10A8)
		1-8	STVØL(21)
		⋮	⋮
		32-40	STVØL(25)
Only NTØST stage volumes need to be entered; that is, 1 to 3 cards are needed for input.			

Table 1. (continued)

Subroutine	Card Number	Columns	Remarks, Variables, etc.
FLØWS			For IVØL=3 stage volumes are equal and specified
	1		FØRMAT (F8.0)
		1-8	VØL - stage volume for all stages
			Graph Cards (ICALPL=1,2,3)
PLØTR			Profile graphs (ICALPL=1 or 3)
	1		FØRMAT (10A8)
		1-80	TTL - title for all profile graphs
	2		FØRMAT (10A8)
		1-80	XTAG - x-axis label for all profile graphs
	One card for each profile graph		FØRMAT (10A8)
		1-80	YTAG - y-axis label for each profile graph
			Transient graphs (ICALPL=2 or 3)
	1		FØRMAT (25I2)
		1-2	NSTA(1) - stage no. for 1st set of transient graph
		⋮	⋮
		49-50	NSTA(25) - stage no. for 25th set of transient graphs
			Two graphs are plotted for each I such that NSTA(I)≠0. For NSTA(I)=0 no graphs are plotted.

Table 1. (continued)

Subroutine	Card Number	Columns	Remarks, Variables, etc.
PLØTR (cont.)	2		FØRMAT (10A8)
		1-80	TTL - title for all transient graphs
	3		FØRMAT (10A8)
		1-80	XTAG - x-axis label for all transient graphs
	One card for each transient graph		FØRMAT (10A8)
		1-80	YTAG - y-axis label for each transient graph
Note: Character strings input as TTL, XTAG, and YTAG must end with $.			
		Next Case	
MAIN	1		FØRMAT (2I2)
		1-2	ICHNGE - 0 next case is new 1 new Feed Stream Cards and Outgoing Stream Data required for each feed and exit stream - no Program Cards, Initial Profile Cards, Phase Ratio Cards, or Stage Volume Cards are required 2 stop
		3-4	IDIF - 0 no changes in Program Card parameters - 1 changes in at least one of these Program Card parameters - ICALC, IØUT, IPR, IPNCH, ICALPL (these parameters are explained in the section Program Cards)

Table 1. (continued)

Subroutine	Card Number	Columns	Remarks, Variables, etc.
If IDIF = 1, input a card of the following form; if IDIF = 0, omit this card.			
	2		FØRMAT (5I2)
		1-2	ICALC
		3-4	IØUT
		5-6	IPR
		7-8	IPNCH
		9-10	ICALPL
			See Program Cards for explanation of these parameters

indicates a real number with or without a signed exponent (decimal point should be punched). The variable names are those used in the FORTRAN program. Two examples of sample input are included in Appendix B.

Output

Two examples of program printout are given in Appendix B. A general explanation of these examples and hence all output is herein described.

The first page of printed output provides a synopsis of input and various initial conditions. Included are the feed stream data, initial profile, phase ratios, and stage flows. The remainder of the printout consists of transient behavior results for each time interval. Printout for each time interval includes aqueous- and organic-phase concentrations, aqueous and organic flows, temperature, and number of iterations required for convergence in the stage calculations; all of which are printed for each stage.

After every time interval which is a multiple of 100 and upon convergence of the transient calculations, the percent steady state and the time intervals at which 90%, 95%, 99%, and 99.5% steady state have been reached are printed.

If desired, output may also be obtained in the form of Calcomp plots. Profile graphs (concentration vs stage number) and/or transient graphs (concentration vs time interval) may be produced by (1) requesting plots on the "Program Cards" and (2) entering the correct input as prescribed in "Graph Cards" (see Input).

V. APPLICATION OF THE SEPHIS PROGRAM TO PUREX SOLVENT EXTRACTION PROCESSING PROBLEMS

The procedure used in the SEPHIS calculations makes this program very useful for several types of design, optimization, and evaluation problems in a solvent extraction system. Starting with any combination of concentrations of uranium, plutonium, and nitric acid in each stage of a countercurrent contactor and any combination of feed stream compositions and flow rates, the program calculates the step-by-step change in the concentration of the uranium, plutonium, and nitric acid of each stage. This type calculation provides a means of evaluating both transient and steady-state effects of start-up or shutdown procedures, of modifications of flowsheet conditions, of operational changes due to equipment malfunction, of errors in operational procedure, etc. A comparison of the steady-state concentrations of uranium, plutonium, and nitric acid calculated by the original and the revised computer codes with the values determined by a laboratory countercurrent batch extraction is given in Table 2. Examples of calculations at transient conditions are given in Appendix B. The concentrations of uranium, plutonium, and nitric acid resulting from these calculations may be used in evaluating product losses, in determining the critical (nuclear) safety of the equipment, in estimating the loading of the solvent so that decontamination from fission products may be estimated from other data, etc. Due to the reflux of extracting components in a multistaged countercurrent contactor system, the concentration of any extractable material may reach a higher value in the column than in the feed or exit streams.

Table 2. Comparison of Steady-State Purex Conditions Calculated by the Original and Revised SEPHIS Programs with Data from a Laboratory Experiment

Flowsheet Conditions: Scrub: 2 M HNO_3, 0.3 volume, stage 1; Feed: 27.7 g U/l, 4.43 g Pu/l, 3.2 M HNO_3, 1.0 volume, stage 4; Organic: 15.3 v/o TBP--84.7 v/o n-dodecane, 1.8 volume, stage 11

Stage	Uranium (g/l)			Plutonium (g/l)			Acid (M)		
	Original[1]	Experimental[2]	Revised[3]	Original	Experimental	Revised	Original	Experimental	Revised
					Aqueous Phase				
1	21.0	18.5	18.8	5.20	4.1	4.22	1.85	2.07	1.93
2	28.2	23.0	24.6	9.10	5.8	6.48	1.82	2.10	1.96
3	30.6	18.5	24.5	11.2	4.2	6.84	1.96	2.90	2.19
4	24.5	18.2	19.1	7.23	3.75	4.61	3.13	3.00	3.21
5	2.57	2.72	1.43	1.91	0.9	0.96	3.33	2.90	3.35
6	0.12×10^{-3}	0.11	6.67×10^{-2}	0.23	0.091	0.13	3.36	3.10	3.37
7	5.69×10^{-4}	0.01	2.97×10^{-3}	2.45×10^{-2}	0.015	1.56×10^{-2}	3.36	3.10	3.37
8	2.53×10^{-5}		1.31×10^{-4}	2.63×10^{-3}	0.003	1.94×10^{-3}	3.36	3.10	3.37
9	1.13×10^{-7}		5.86×10^{-6}	2.81×10^{-4}	0.001	2.42×10^{-4}	3.36	3.07	3.36
10	5.10×10^{-8}		2.63×10^{-7}	3.03×10^{-5}	0.001	3.04×10^{-5}	3.31	3.01	3.30
11	2.80×10^{-8}		1.29×10^{-8}	3.95×10^{-6}	0.010	4.15×10^{-6}	2.75	2.64	2.86
					Organic Phase				
1	37.6	38.8	36.9	2.46	2.53	2.41	0.12	0.21	0.09
2	41.1	42.1	39.9	3.33	2.91	3.11	0.10	0.21	0.08
3	42.3	43.6	40.9	3.98	3.05	3.48	0.09	0.24	0.09
4	42.7	43.7	40.9	4.33	3.21	3.54	0.12	0.26	0.13
5	17.7	13.9	13.6	5.22	2.65	3.27	0.27	0.29	0.30
6	1.85	1.28	1.02	1.38	0.50	0.68	0.41	0.34	0.39
7	9.17×10^{-2}	0.07	4.72×10^{-2}	0.16	0.074	8.88×10^{-2}	0.44	0.34	0.40
8	4.11×10^{-3}	0.02	2.10×10^{-3}	1.77×10^{-2}	0.009	1.11×10^{-2}	0.44	0.34	0.40
9	1.83×10^{-4}		9.33×10^{-5}	1.89×10^{-3}	0.002	1.37×10^{-3}	0.44	0.35	0.40
10	8.12×10^{-6}		4.14×10^{-6}	2.00×10^{-4}	0.001	1.68×10^{-4}	0.44	0.34	0.39
11	3.48×10^{-8}		1.78×10^{-7}	1.90×10^{-5}	0.004	1.86×10^{-5}	0.40	0.30	0.34

[1]The original SEPHIS code as reported in ORNL-4746.

[2]Laboratory data reported, p. 11, ORNL-4746.

[3]SEPHIS code in its present form.

Changes in operating conditions can then result in transient high concentrations in the exit streams. During such transient conditions nuclear criticality in tankage may be approached, a situation that would not occur during steady-state conditions. The SEPHIS program may be used to detect such occurrences. The program perhaps has its greatest utility as an aid to the planning of laboratory tests designed to determine optimum values for flowsheet parameters and as a diagnostic tool when operating solvent extraction systems.

The number of theoretical stages required to give a specified loss or separation of uranium and plutonium with a given flowsheet may be determined by varying the number of stages used in the calculation until the desired results are obtained. Similarly, the height equivalent to a theoretical stage in a solvent extraction column or the stage efficiency of a mixer-settler can be determined by adjusting the numbers of stages in the calculations until the calculated effluent concentrations match experimental data. In these calculations it is well to remember the interdependence of the two parts of a compound extraction cascade when analyzing the variation in the reflux of the extractable species with operating conditions. It is therefore necessary to simultaneously determine the number of stages in each end of a compound cascade when performing calculations.

The time unit given by the program is that for one volumetric displacement of an ideal mixer-settler contactor. The real-time equivalent, therefore, is equal to the volume of one theoretical stage divided by the sum of the flow rates to the stage. An example of such a calculation

is given in Table 3, where the calculational time unit is equivalent to 0.85 min of real time. In this example, the column contained 11-1/4 theoretical stages and the time for the volumetric displacement of the column is about 10 min.

Table 3. Calculation of the Time for the Volumetric Displacement of a Theoretical Stage in a Pulsed Column

Column Conditions

6 in. pipe, schedule 40, ID 6.065 in.

Pulse plates, 1/8 in. thick, 23% free space, 6 in. diam., 2 in. spacing

Support rods, 3 ea., 1/4 in. diameter

Total length, 36 ft.

HETS, 3.2 ft.

Flow rate at 80% flooding, 1 in. pulse, 60 pulse/min. = 1600 gal/hr/ft^2

Volume of a Theoretical Stage

$$\left[\left(\frac{6.065}{2}\right)^2 \times \pi \times 3.2 \times 12\right] - \left[\left(\frac{6}{2}\right)^2 \times \pi \times 0.125 \times \frac{3.2 \times 12}{2} \times 0.77\right]$$

$$+ 3\left[\left(\frac{.25}{2}\right)^2 \times \pi \times 3.2 \times 12\right] = 1047 \text{ in.}^3 \text{ or } 0.6059 \text{ ft.}^3$$

Flow rate through column

$$1600 \frac{\text{gal}}{\text{ft}^2 \cdot \text{hr}} \times \frac{\text{ft}^3}{7.48 \text{ gal}} \times \frac{\text{hr}}{60 \text{ min}} \times \left[\left(\frac{6.056}{2 \times 12}\right)^2 \times \pi\right] \text{ft}^2 = 0.7153 \frac{\text{ft}^3}{\text{min}}$$

Displacement Time

$$0.6059 \text{ ft}^3 \times \frac{\text{min}}{0.7154 \text{ ft}^3} = 0.85 \text{ min}$$

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APPENDIX A

Program Listing

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CCC
C   PROGRAM SEPHIS
C    ORNL MODIFICATION OF THE RICHARDSON-WANCE REVISED VERSION
C
C   TRANSIENT STAGE CALCULATIONS FOR PUREX SOLVENT EXTRACTION PROCESS.
C   CALCULATIONS VALID FOR 3 TRANSFERRING COMPONENTS.  INCLUDES SALTING
C   EFFECT FROM NON-TRANSFERRING NITRATE SALTS.  PLUTONIUM PARTITION
C   CALCULATIONS CAN BE MADE BY ENTERING THE REDUCTANT NORMALITY AS A
C   NEGATIVE PLUTONIUM CONCENTRATION ON THE APPROPRIATE FEED CARD.
C     COMPONENT 1 = URANIUM          COMPONENT 3 = NITRIC ACID
C     COMPONENT 2 = PLUTONIUM        COMPONENT 4 = SALT NITRATE
C   STAGE VOLUMES EQUAL UNLESS NOTED OTHERWISE.
CCC
      DIMENSION TITLE(10)
      DIMENSION AOUT(25),OOUT(25),STVOL(25),DF(4),SOLIN(3),SOLOUT(3),
     1  AQOUT(25),ORGOUT(25)
      DIMENSION AA(25),TT(25),OO(25),RATIO(25)
      DIMENSION CFA(4),CFO(4)
      COMMON/FLWS/ IRATIO,IOUT,IVOL,RECY(25),ICHNGE,ALVRT(25),OLVRT(25)
      COMMON/STGS/ NSOLU,CODUM(25),AR(25),OR(25),AT(25),OT(25)
      COMMON/FEED/ NTOST,AFDRT(25),OFDRT(25)
      COMMON/PROF/ IPRO,X(4,25,2),Y(4,25,2),XFD(4,25),YFD(4,25),
     1  TPROF(25,2),AFDTEM(25),OFDTEM(25)
      COMMON/REC/ A(25),O(25),RAIO(25),RCYCA(25),RCYCO(25)
      COMMON/DIST/ CTBP,ARY(4),DTRY(4),TO,RN(25,2),RNFD(25)
C
      NSOLU = 4
C
C   NEXT CASE IS NEW
C
 10   CONTINUE
      READ 1001,TITLE,CTBP,NTOST,IPRO,IRATIO,ICALC,IOUT,IVOL,IPR,IPNCH,
     1   ICALPL
C
C   TITLE IS THE PROBLEM TITLE.  40 SPACES ARE ALLOWED.
C   NTOST = TOTAL NUMBER OF STAGES, MUST NOT EXCEED 25
C   NSOLU = NUMBER OF SOLUTES, MAXIMUM 4
C    CTBP = VOLUME FRACTION OF DRY TBP
C    IPRO = 0 FOR A ZERO INITIAL CONCENTRATION PROFILE
C           1 FOR A NON-ZERO INITIAL PROFILE
C  IRATIO = 0 IF PHASE RATIO = FLOW RATIO
C           1 IF PHASE RATIO CARDS FOLLOW
C   ICALC = 0 FOR SHUT-DOWN CALCULATIONS (NO U OR PU IN FEED STREAMS)
C           1 FOR START-UP OR INTERRUPTION
C    IOUT = 0 IF THERE ARE NO EXTRA OUTGOING STREAMS
C           1 IF THERE ARE OUT GOING STREAMS IN ADDITION TO END STREAMS.
C    IVOL = 0 IF STAGE VOLUMES ARE ALL EQUAL
C           1 IF STAGE VOUMES ARE UNEQUAL BUT ACCORDING TO TOTAL FLOW
C           2 IF STAGE VOLUMES ARE INDEPENDENTLY UNEQUAL
C           3 IF STAGE VOLUMES ARE EQUAL AND SPECIFIED.  (OPTIONS 2 OR 3
C             SHOULD BE USED FOR HAN CALCULATIONS TO CORRECT FOR STAGE
C             RESIDENCE TIME.)
C     IPR = 0 TO PRINT OUT ALL TIME INTERVALS
C           1 TO PRINT ONLY LAST INTERVAL
C          -1 TO PRINT EVERY 20TH TIME INTERVAL
C ICHNGE = 0 IF NEXT CASE IS NEW
C           1 IF NEXT CASE INVOLVES ONLY A CHANGE IN FEED FLOWS, COMP, AND TEMP
C           2 STOP
C  IPNCH = 0 IF NO PUNCHED CARD OUTPUT DESIRED
C           1 FOR FINAL PROFILE OUTPUT ON PUNCHED CARDS
C  ICALPL = 0 NO CALCOMP PLOTS
C         = 1 PROFILE GRAPHS OF LOGORITHM OF CONCENTRATION
C             VS STAGE NUMBER AT STEADY STATE, 1/2, 1/4,
C             AND 1/8 OF STEADY STATE TIME
C         = 2 TRANSIENT GRAPHS OF CONCENTRATION VS TIME AT
C             SPECIFIED STAGES FOR EACH TIME BLOCK
C         = 3 PLOT BOTH 1 AND 2
C
C
C   ZEROING OF ARRAYS
C
      DO 15 J=1,NTOST
      CODUM(J)=0.0
      STVOL(J) = 0.0
      DO 15 K=1,2
      RN(J,K) = 0.0
      TPROF(J,K) = 25.0
      DO 15 I=1,NSOLU
      DF(I) = 0.0
      X(I,J,K) = 0.0
      Y(I,J,K) = 0.0
 15   CONTINUE
      ICHNGE = 0
C
C   NEXT CASE INVOLVES ONLY A CHANGE IN FEED FLOWS, COMP,TEMP
C
 20   CONTINUE
      DO 25 J=1,NTOST
      A(J) = 0.0
      O(J) = 0.0
      AFDRT(J) = 0.0
      OFDRT(J) = 0.0
      ALVRT(J) = 0.0
      OLVRT(J) = 0.0
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      RNFD(J)  = 0.0
      AFDTEM(J)  = 25.0
      OFDTEM(J)  = 25.0
 25   CONTINUE
      DO 30 I=1,NSOLU
      CFA(I)=0.
      CFO(I)=0.
      DO 30 J=1,NTOST
      XFD(I,J)  = 0.0
      YFD(I,J)  = 0.0
 30   CONTINUE
C
C
C  PROFIL SETS INITIAL CONCENTRATIONS FOR TIME ZERO, ALSO DEFINES FEED STREAMS
C
      CALL PROFIL
C
C
C  WRITE FEED STREAM DATA
C
      PRINT 1002, TITLE
      WRITE(6,1003)
      DO 40 I=1,NTOST
      IF(AFDRT(I).LE.0.) GO TO 40
      PRINT 1004,I,XFD(1,I),XFD(2,I),XFD(3,I),XFD(4,I),AFDRT(I),
     1   AFDTEM(I)
C
C
C  CONVERT TO MOLARITY
C
      XFD(1,I)=XFD(1,I)/238.
      XFD(2,I)=XFD(2,I)/239.
C  AQUEOUS STAGE FLOW RATES  (AFDRT)  AND AQUEOUS CONTENT
C  OF STAGE  (XFD) CONVERTED FROM VOLUME UNITS TO
C  SOLUTE-FREE VOLUME UNITS
C
      DENOMA = 1.0-0.0724*XFD(1,I)-0.13*XFD(2,I)-0.0309*XFD(3,I)
     1-.031*XFD(4,I)
      IF(XFD(2,I).LT.0.) DENOMA = DENOMA + .13*XFD(2,I)
      AFDRT(I)  = AFDRT(I)* DENOMA
      DO 35 J = 1,4
      XFD(J,I)  = XFD(J,I)/DENOMA
      IF(XFD(2,I).LT.0)  RNFD(I)  = XFD(2,I)
 35   CONTINUE
C
C
C TO IS MOLARITY OF DRY, SOLUTE-FREE TBP
C
 40   CONTINUE
      TO = 3.65145 * CTBP
C
C   US,PUS,AND HS ARE MOLARITIES OF U,PU,AND HNO3 REQUIRED TO SATURATE THE TBP
C   WO,WC, AND WOM ARE CALCULATED WATER CONCENTRATIONS IN THE TBP PHASE
C
      US = 0.5*TO/(1.0+0.046*TO)
      PUS = 0.5*TO/(1.0+0.09*TO)
      DO 50 I=1,NTOST
C
C  SET ACID IN ALL STAGES TO SCRUB ACID CONCENTRATION
C
      IF(IPRO.EQ.0)  X(3,I,1)=XFD(3,1)
C
      IF(OFDRT(I).LE.0.) GO TO 50
      PRINT 1005,CTBP,I,YFD(1,I),YFD(2,I),YFD(3,I),YFD(4,I),OFDRT(I),
     1   OFDTEM(I)
C
C  CONVERT TO MOLARITY
C
      YFD(1,I)=YFD(1,I)/238.
      YFD(2,I)=YFD(2,I)/239.
C
C  ORGANIC STAGE FLOW  (OFDRT)  AND ORGANIC CONTENT
C  OF STAGE  (YFD) CONVERTED FROM VOLUME UNITS TO
C  SOLUTE-FREE VOLUME UNITS
C
      WO=(3.95-0.0144*OFDTEM(I))*CTBP**1.65
      HS= TO*  (1.0-0.00609*WO)/(1.0+0.043*TO)
      WC = WO*(1.0-YFD(1,I)/US-YFD(2,I)/PUS-0.65*YFD(3,I)/HS)
      DENOMO= 1.0-0.097*YFD(1,I)-0.139*YFD(2,I)-.043*YFD(3,I)-0.0174*WC
      OFDRT(I)  =OFDRT(I)*DENOMO
      DO 45 J=1,3
      YFD(J,I)= YFD(J,I)/DENOMO
 45   CONTINUE
C
C
C  FEED CONCENTRATIONS AND VOLUMES ARE NOW ON A SOLUTE-FREE BASIS
C
C
C  FLOWS SETS ALL INTERSTAGE FLOW RATES, DEFINES OUTGOING STREAMS AND FLOW
C      RATIOS, AND CALCULATES NECESSARY RECYCLE FLOWS
C
 50   CONTINUE
      CALL FLOWS(STVOL)
C
C  PRINT OUTGOING STREAMS (ALVRT AND OLVRT) IN SOLUTE-FREE VOLUME UNITS
```

```
C
C
C  IF NO EXTRA OUTGOING STREAMS, AVOID PRINT OF ALVRT AND OLVRT
C
      IF(IOUT.EQ.0) GO TO 65
C
      PRINT 1006
      DO 55 I=1,NTOST
      IF(ALVRT(I).LE.0.) GO TO 55
      PRINT 1007,I,ALVRT(I)
 55   CONTINUE
      DO 60 I=1,NTOST
      IF(OLVRT(I).LE.0.) GO TO 60
      PRINT 1008,I,OLVRT(I)
 60   CONTINUE
C
C  PRINT INITIAL PROFILE BEFORE UNIT CONVERSION
C
 65   CONTINUE
      PRINT 1009
      DO 70 J=1,NTOST
      PRINT 1010,J,X(1,J,1),X(2,J,1),X(3,J,1),Y(1,J,1),Y(2,J,1),Y(3,J,1)
     1 ,TPROF(J,1)
 70   CONTINUE
C
C  CHECK FOR NON-ZERO INITIAL PROFILE
C
      IF(IPRO.EQ.0.AND.ICHNGE.EQ.0) GO TO 85
C
      DO 80 J=1,NTOST
C
C  CONVERT TO MOLARITY
C
      X(1,J,1)=X(1,J,1)/238.
      Y(1,J,1)=Y(1,J,1)/238.
      X(2,J,1)=X(2,J,1)/239.
      Y(2,J,1)=Y(2,J,1)/239.
C
C  CONVERT INITIAL PROFILE (X AND Y) TO SOLUTE-FREE CONCENTRATIONS
C
      DENOMA=1.0-0.0724*X(1,J,1)-0.13*X(2,J,1)-0.0309*X(3,J,1)
     1- 0.031*X(4,J,1)
      WO = (3.95 - 0.0144*TPROF(J,1))*CTBP**1.65
      HS= TO*(1.0-0.00609*WO)/(1.0+0.043*TO)
      WC=WO*(1.0-Y(1,J,1)/US-Y(2,J,1)/PUS-0.65*Y(3,J,1)/HS)
      DENOMO=1.0-0.097*Y(1,J,1)-0.139*Y(2,J,1)-0.043*Y(3,J,1)-0.0174*WC
      DO 75 I = 1,4
      X(I,J,1)=X(I,J,1)/DENOMA
      Y(I,J,1)=Y(I,J,1)/DENOMO
 75   CONTINUE
C
      X(2,J,1) = X(2,J,1) + RN(J,1)
 80   CONTINUE
C
C  PROFILE CONCENTRATIONS ARE NOW ON SOLUTE-FREE BASIS
C
 85   CONTINUE
C
C  PRINT APPROPRIATE TITLE FOR IRATIO
C
      IF(IRATIO.EQ.0) GO TO 90
      PRINT 1011
      GO TO 95
 90   CONTINUE
      PRINT 1012
 95   CONTINUE
C
C  PRINT PHASE RATIOS
C
      DO 110 I=1,NTOST
      IF(I.EQ.1) GO TO 100
      IF(PRATIO.EQ.RAIO(I)) GO TO 105
      IK=I-1
      PRINT 1013,NST,IK,PRATIO
 100  CONTINUE
      PRATIO=RAIO(I)
      NST=I
 105  CONTINUE
      IF(I.LT.NTOST) GO TO 110
      PRINT 1013,NST,I,PRATIO
 110  CONTINUE
      PRINT 1014
C
C  A IS AQUEOUS INTERSTAGE FLOW
C  O IS ORGANIC INTERSTAGE FLOW
C  AA IS TOTAL AQUEOUS FLOW LEAVING STAGE
C  OO IS TOTAL ORGANIC FLOW LEAVING STAGE
C  RCYCA IS AQUEOUS RECYCLE TO SATISFY PHASE RATIO
C  RCYCO IS ORGANIC RECYCLE TO SATISFY PHASE RATIO
C  AR IS AQUEOUS RECYCLE TO FILL STAGE
C  OR IS ORGANIC RECYCLE TO FILL STAGE
C  AT IS TOTAL AQUEOUS FLOW WITHIN A STAGE
C  OT IS TOTAL ORGANIC FLOW WITHIN A STAGE
C  TT IS TOTAL FLOW ON TO A STAGE
C
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```
      DO 115 I=1,NTOST
      AA(I)=ALVRT(I)+A(I)
      OO(I)=OLVRT(I)+O(I)
      RATIO(I)=AA(I)/OO(I)
      AR(I)  = RECY(I)*RAIO(I)/(1.0+RAIO(I))
      OR(I)  = RECY(I)/(1.0+RAIO(I))
      AT(I)=AA(I)+AR(I)+RCYCA(I)
      OT(I)=OO(I)+OR(I)+RCYCO(I)
      TT(I)=AT(I)+OT(I)
 115  CONTINUE
C
C  PRINT STAGE FLOWS
C
      DO 120 J=1,NTOST
      PRINT 1015,J,RATIO(J),AA(J),AR(J),RCYCA(J),AT(J)
 120  CONTINUE
      PRINT 1016
      DO 125 J=1,NTOST
      PRINT 1017,J,TT(J),STVOL(J),OO(J),OR(J),RCYCO(J),OT(J)
 125  CONTINUE
      WRITE(6,1018)
C
C  M - IS 100 OR LAST TIME INTERVAL
C  ICEN - COUNTS BY 100'S NUMBER OF ITERATIONS
C  ADF - MAX(DF(1),DF(2),DF(3)) FOR A GIVEN TIME INTERVAL
C  BDF - ADF FOR PREVIOUS TIME INTERVAL
C  CDF - SET EQUAL TO ADF IF ADF=BDF (CONVERGENCE HAS OCCURRED)
C  DDF - DETERMINES PDF,PPDF,PPPDF,PPPPDF (PERCENT STEADY STATE)
C
      M=100
      ICEN = 0
      BDF = 0.
      CDF = 0.
      DDF = 0.10
C
C  INITIALIZATION OF TOTAL MOLES IN (SOLIN) AND TOTAL MOLES OUT (SOLOUT)
C
      DO 130 I = 1,3
      SOLIN(I) = 0.0
      SOLOUT(I)=0.0
 130  CONTINUE
      DO 135 I = 1,3
      DO 135 J=1,NTOST
      SOLIN(I)=SOLIN(I)+AFDRT(J)*XFD(I,J)+OFDRT(J)*YFD(I,J)
      IF(XFD(I,J).LT.0) SOLIN(I) = SOLIN(I) - AFDRT(J)*XFD(I,J)
 135  CONTINUE
C
      SPH = 0.399*CTBP + 0.321*(1.0 - CTBP)
C
C  K - TIME INTERVAL COUNTER (MOD 100)
C
 140  CONTINUE
      K=1
C
C  STAGES PERFORMS STAGE CALCULATIONS FOR EACH TIME INTERVAL
C
 145  CONTINUE
      CALL STAGES(SPH)
      DO 150 J=1,NTOST
      TPROF(J,1)=TPROF(J,2)
      DO 150 I=1,4
      X(I,J,1)=X(I,J,2)
      Y(I,J,1)=Y(I,J,2)
      RN(J,1)=RN(J,2)
 150  CONTINUE
C
C  IF NUMBER OF TIME INTERVALS IS LESS THAN THE NUMBER OF STAGES,
C  OMIT CALCULATION OF SOLIN,SOLOUT, AND PERCENT STEADY STATE
C
      IF(ICEN.EQ.0.AND.K.LT.NTOST) GO TO 210
C
C  IF SHUTDOWN (ICALC=0), CHECK FOR NEAR ZERO CONCENTRATION
C
      IF(ICALC.EQ.1) GO TO 160
C
C  FOR SHUTDOWN, ICALC=0, TEST FOR COMPONENTS 1 AND 2 = 0, NOT COMPONENT 3
C
      DO 155 J=1,NTOST
      IF(X(1,J,1).GT.0.000001) GO TO 210
      IF(Y(1,J,1).GT.0.000001) GO TO 210
      IF(X(2,J,1).GT.0.000001) GO TO 210
      IF(Y(2,J,1).GT.0.000001) GO TO 210
 155  CONTINUE
      GO TO 205
C
C  CALCULATION OF PERCENT STEADY STATE
C
C
C
C  CALCULATE TOTAL MOLES IN (SOLIN) AND TOTAL MOLES OUT (SOLOUT)
C
 160  CONTINUE
      DO 165 I = 1,3
      SOLOUT(I)=A(NTOST)*X(I,NTOST,1)+O(1)*Y(I,1,1)
      DO 165 J=1,NTOST
```

```
      SOLOUT(I)=SOLOUT(I)+ALVRT(J)*X(I,J,1)+OLVRT(J)*Y(I,J,1)
  165 CONTINUE
      DO 170 J = 1,NTOST
      SOLOUT(2)=SOLOUT(2)-ALVRT(J)*RN(J,1)
  170 CONTINUE
      SOLOUT(2)=SOLOUT(2)-A(NTOST)*RN(NTOST,1)
C
      DO 180 I = 1,3
      IF(SOLIN(I).GT.0.) GO TO 175
      DF(I)=0.
      GO TO 180
  175 CONTINUE
      DF(I)=ABS((SOLIN(I)-SOLOUT(I))/SOLIN(I))
  180 CONTINUE
      ADF = AMAX1(DF(1),DF(2),DF(3))
C
C  IF ADF=BDF (PERCENT STEADY STATE FOR CURRENT TIME INTERVAL
C  SAME AS PREVIOUS TIME INTERVAL), TERMINATE CALCULATIONS
C
      IF(ADF.NE.BDF) GO TO 185
      CDF=ADF
      GO TO 205
C
  185 CONTINUE
      BDF=ADF
      IF(ICEN.GE.3.AND.DDF.LT.0.004) DDF = 2.*DDF
      IF(ADF.GT.DDF) GO TO 210
C
C  90% STEADY STATE
C
      IF(DDF.LT.0.100) GO TO 190
      JK=K+100*ICEN
      PDF = 100. * (1.0-DDF)
      DDF = 0.05
      GO TO 210
C
C  95% STEADY STATE
C
  190 CONTINUE
      IF(DDF.LT.0.05) GO TO 195
      JJK=K+100*ICEN
      PPDF = 100. * (1.0-DDF)
      DDF = 0.010
      GO TO 210
C
C  IF 99% STEADY STATE HAS BEEN REACHED AND ICEN>0, PRINT TIME INTERVAL
C  AND PERCENT STEADY STATE
C
  195 CONTINUE
      IF(ICEN.GT.0) GO TO 205
C
C
C  99% STEADY STATE AND ICEN=0
C
      IF(DDF.LT.0.010) GO TO 200
      JJJK=K+100*ICEN
      PPPDF = 100.*(1.0 - DDF)
      DDF = 0.005
      GO TO 210
C
C  IF 99.5% STAEDY STATE HAS BEEN REACHED AND ICEN>0, PRINT
C  TIME INTERVAL AND PERCENT STEADY STATE
C
  200 CONTINUE
      IF(ICEN.GT.0) GO TO 205
C
C  99.5% STEADY STATE AND ICEN=0
C
      IF(DDF.LT.0.005) GO TO 205
      JJJJK=K+100*ICEN
      PPPPDF = 100.*(1.0-DDF)
      DDF = 0.001
      GO TO 210
C
  205 CONTINUE
      M=K
  210 CONTINUE
C
C  DETERMINE IF TIME INTERVAL IS TO BE PRINTED
C
      IF(IPR.EQ.0) GO TO 215
      IF(IPR.EQ.-1.AND.(K.EQ.20.OR.K.EQ.40.OR.K.EQ.60.OR.K.EQ.80.OR.
     1  K.EQ.M)) GO TO 215
      IF(IPR.EQ.1.AND.K.EQ.M) GO TO 215
      GO TO 255
C
  215 CONTINUE
C
C
C  CONVERSION BACK TO VOLUME UNITS
C
      DO 230 J=1,NTOST
      IF(RN(J,1).LT.0.) X(2,J,2)=X(2,J,2)-RN(J,2)
      DENA=1.0+0.0724*X(1,J,2)+0.13*X(2,J,2)+0.0309*X(3,J,2)+
     1  0.031*X(4,J,2)
```

```
      WOM=(4.2-0.015*TPROF(J,2))*(1.0-2.0*(Y(1,J,2)+Y(2,J,2))/
     1  TO-0.6*Y(3,J,2)/TO)*CTBP**1.69
      DENO=1.0+0.097*Y(1,J,2)+0.139*Y(2,J,2)+0.043*Y(3,J,2)+
     1  0.0174*WOM
      AOUT(J)=(A(J)+ALVRT(J))*DENA
      OOUT(J)=(O(J)+OLVRT(J))*DENO
      IF(IOUT.EQ.0) GO TO 220
      AQOUT(J)=-ALVRT(J)*DENA
      ORGOUT(J)=-OLVRT(J)*DENO
 220  CONTINUE
      DO 225 I=1,3
      X(I,J,2)=X(I,J,2)/DENA
      Y(I,J,2)=Y(I,J,2)/DENO
 225  CONTINUE
C
C  CONVERT TO G/L
      X(1,J,2)=X(1,J,2)*238.
      Y(1,J,2)=Y(1,J,2)*238.
      X(2,J,2)=X(2,J,2)*239.
      Y(2,J,2)=Y(2,J,2)*239.
C
 230  CONTINUE
C
C  PRINT X AND Y ON DISK (UNIT 10) FOR CALCOMP PLOTS
C
      L=K+100*ICEN
      DO 235 J=1,NTOST
      WRITE(11) L,(X(I,J,2),I=1,4),(Y(I,J,2),I=1,4)
      DO 235 JJ=1,4
      CFA(JJ)=AMAX1(X(JJ,J,2),CFA(JJ))
      CFO(JJ)=AMAX1(Y(JJ,J,2),CFO(JJ))
 235  CONTINUE
C
C  PRINTOUT FOR A GIVEN TIME INTERVAL
C
      PRINT 1019
      DO 245 J=1,NTOST
      IF(J.GT.1) GO TO 240
      L=K+100*ICEN
      PRINT 1020,L,J,(X(I,J,2),I=1,3),AOUT(J)
      IF(ALVRT(J).GT.0.) PRINT 1021,AQOUT(J)
      GO TO 245
 240  CONTINUE
      PRINT 1022,J,(X(I,J,2),I=1,3),AOUT(J)
      IF(ALVRT(J).GT.0.) PRINT 1021,AQOUT(J)
 245  CONTINUE
      PRINT 1023
      DO 250 J=1,NTOST
      IF(OLVRT(J).GT.0.) PRINT 1021,ORGOUT(J)
      PRINT 1024, J,(Y(I,J,2),I=1,3), OOUT(J),CODUM(J),
     1  TPROF(J,2)
 250  CONTINUE
C
C
C
C  INCREMENT TIME INTERVAL COUNTER
C
 255  CONTINUE
      K=K+1
C
C
C  IF K LESS THAN OR EQUAL TO M,PERFORM STAGE CALCULATIONS FOR ANOTHER
C  TIME INTERVAL
C
      IF(K.LE.M) GO TO 145
C
C
C  IF SHUTDOWN (ICALC=0), BYPASS PRINTOUT OF PERCENT STEADY STATE
C
      IF (ICALC.EQ.0) GO TO 260
C
C
C  PRINT PERCENT STEADY STATE AFTER EVERY 100 TIME INTERVALS
C  AND OTHER CASES WHEN K=M
C
      APDF = 100.*(1.0 - ADF)
      PRINT 1025, APDF
      IF(DDF.LT.0.1) PRINT 1026,PDF,JK
      IF(DDF.LT.0.05) PRINT 1026,PPDF,JJK
      IF(DDF.LT.0.01) PRINT 1026,PPPDF,JJJK
      IF(DDF.LT.0.005) PRINT 1026,PPPPDF,JJJJK
      IF(IOUT.GT.0) PRINT 1027
C
C  CHECK FOR CONVERGENCE
C
      IF(ADF.NE.CDF) GO TO 260
C
      PRINT 1028
 260  CONTINUE
      IF(M.LT.100) GO TO 265
      ICEN=ICEN+1
      IF(ICEN.EQ.15) GO TO 265
      GO TO 140
C
C  CONVERT TOTAL MOLES IN AND OUT TO G/L AND PRINT
```

```
C
 265  CONTINUE
      SOLIN(1)=SOLIN(1)*238.
      SOLOUT(1)=SOLOUT(1)*238.
      SOLIN(2)=SOLIN(2)*239.
      SOLOUT(2)=SOLOUT(2)*239.
      PRINT 1029,SOLIN(1),SOLOUT(1)
      PRINT 1030,SOLIN(2),SOLOUT(2)
      PRINT 1031,SOLIN(3),SOLOUT(3)
C
C  PRINT MINUTES PER TIME INTERVAL
C
      TIMINT=STVOL(1)/(AT(1)+OT(1))
      IF(IVOL.GE.2) PRINT 1032, TIMINT
C
C  CALCOMP PLOTTER OUTPUT
C
      IF(ICALPL.EQ.0) GO TO 270
      CALL PLOTR(M+100*ICPN,ICALPL,NTOST,CFA,CFO)
 270  CONTINUE
C
C  PUNCHED CARD OUTPUT
C
      IF(IPNCH.LE.0) GO TO 280
      DO 275 J=1,NTOST
      PUNCH 1033,(X(I,J,2),I=1,3),(Y(I,J,2),I=1,3),
     1  TPROF(J,1),X(4,J,1)
 275  CONTINUE
C
C
C  READ NEXT CASE
C
 280  CONTINUE
      READ 1034,ICHNGE,IDIF
      IF(IDIF.EQ.1) READ 1034,ICALC,IOUT,IPR,IPNCH,ICALPL
      IF(ICHNGE.EQ.0) GO TO 10
      IF(ICHNGE.EQ.2) STOP
C
C  IF ICHNGE = 1, NEW FEED STREAM AND OUT CARDS ARE REQUIRED FOR EACH
C     FEED AND EXIT STREAM,EVEN IF NO CHANGE IS MADE. NO PROFILE CARDS
C     ARE REQUIRED.
C
C ICHNGE=1
C
C INITIAL PROFILE IS SET AS THAT AT END OF LAST CALCULATION.
C
      IPRO=0
      DO 285 I=1,4
      DO 285 J=1,NTOST
      X(I,J,1)=X(I,J,2)
      Y(I,J,1)=Y(I,J,2)
 285  CONTINUE
      GO TO 20
C
C
 1001 FORMAT(10A4,/,F8.0,9I2)
 1002 FORMAT('1CALCULATIONS FOR A SOLVENT EXTRACTION PROCESS',
     1  ' HAVING 3 INTERACTING SOLUTES',16X,10A4)
 1003 FORMAT('0FEED STREAM DATA',16X,'STAGE',3X,'URANIUM',5X,
     1  'PLUTONIUM',6X,'HNO3',6X,' SALT NO3 ',3X,'FLOW RATE',6X,
     2  'TEMP',/,34X,'NO.',5X,'(G/L)',8X,'(G/L)',8X,'(M)',10X,
     3  '(M)',6X,'(VOL.UNITS)', 5X,'DEG C'/)
 1004 FORMAT(24X,'AQUEOUS ',I4,4(3X,1PE10.4),3X,E9.3,3X,0PF7.1)
 1005 FORMAT(19X,2PF6.1,' - TBP ',I4,4(3X,1PE10.4),3X,E9.3,
     1  3X,0PF7.1)
 1006 FORMAT('0')
 1007 FORMAT(' AQUEOUS STREAM REMOVED AT STAGE',I3,'.  FLOW =',
     1  1PE9.3,' (SOLUTE-FREE VOLUME UNITS).')
 1008 FORMAT(' ORGANIC STREAM REMOVED AT STAGE',I3,'.  FLOW =',
     1  1PE9.3,' (SOLUTE-FREE VOLUME UNITS).')
 1009 FORMAT('0INITIAL PROFILE',17X,'STAGE',13X,'AQUEOUS PHASE',26X,
     1  'ORGANIC PHASE',10X,/,34X,'NO.',4X,'URANIUM',5X,
     2  'PLUTONIUM',6X,'HNO3',8X,'URANIUM',5X,'PLUTONIUM',6X,
     3  'HNO3',7X,'TEMP',/,31X,'(OUTFLOW)',2X,'(G/L)',8X,
     4  '(G/L)',8X,'(M)',10X,'(G/L)',8X,'(G/L)',8X,'(M)',8X,'DEG C',/)
 1010 FORMAT (32X,I4,6(3X,1PE10.4),3X,0PF6.1)
 1011 FORMAT('0PHASE RATIOS DO NOT EQUAL FLOW RATIOS',3X,
     1  'STAGE NO.',2X,'A/O PHASE RATIO',/)
 1012 FORMAT('0PHASE RATIOS EQUAL FLOW RATIOS',11X,'STAGE NO.',
     1  2X,'A/O PHASE RATIO',/)
 1013 FORMAT(40X,I4,'  -',I4,4X,1PE10.3)
 1014 FORMAT(/,' STAGE FLOWS (SOLUTE-FREE VOLUMES):',/,51X,
     1  'AQUEOUS PHASE',/,47X,'RECYCLE 2  RECYCLE 1    TOTAL',/,
     2  ' STAGE    FLOW',22X,'FLOW OUT    TO FILL   FOR PHASE',
     3  '   AQUEOUS',/,'H  NO.     RATIO',21X,'OF STAGE     STAGE',
     4  '       RATIO      FLOW')
 1015 FORMAT(2X,I2,4X,1PE9.3,17X,4(2X,E9.3))
 1016 FORMAT(/,9X,'OVERALL',36X,'ORGANIC PHASE',/,10X,'TOTAL',
     1  32X,'RECYCLE 2  RECYCLE 1    TOTAL',/,' STAGE    STAGE',
     2  21X,'FLOW OUT    TO FILL   FOR PHASE   ORGANIC',/,
     3  'H  NO.     FLOW     STAGE VOL.',7X,'OF STAGE',
     4  '     STAGE      RATIO      FLOW')
 1017 FORMAT(2X,I2,2X,2(2X,1PE9.3),6X,4(2X,E9.3))
 1018 FORMAT (27H1TRANSIENT BEHAVIOR RESULTS,10X,49HSOLUTE CONCENTRATION
     1S IN EFFLUENT FROM EACH STAGE)
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```
 1019 FORMAT(///,31X,'AQUEOUS PHASE',/,3X,'TIME',4X,'STAGE',
     1  3X,'URANIUM',3X,'PLUTONIUM',4X,'HNO3',5X,
     2  'FLOW OUT',/,' INTERVAL',3X,'NO.',5X,'(G/L)',
     3  6X,'(G/L)',7X,'(M)',5X,'OF STAGE')
 1020 FORMAT(1X,I4,7X,I2,2X,4(2X,1PE9.3))
 1021 FORMAT(12X,3(10X,'*'),5X,1PE10.3)
 1022 FORMAT(12X,I2,2X,5(2X,1PE9.3),13X,E9.3)
 1023 FORMAT(/,31X,'ORGANIC PHASE',/,11X,'STAGE',3X,
     1  'URANIUM',3X,'PLUTONIUM',4X,'HNO3',5X,'FLOW OUT',
     2  6X,'ITERA-',2X,'TEMP',/,12X,'NO.',5X,'(G/L)',
     3  6X,'(G/L)',7X,'(M)',5X,'OF STAGE',6X,'TIONS',3X,'DEG C')
 1024 FORMAT(12X,I2,2X,4(2X,1PE9.3),6X,0PF3.0,4X,F4.1)
 1025 FORMAT('0',F7.2,' PERCENT STEADY STATE BY OVERALL MATERIAL',
     1  ' BALANCE')
 1026 FORMAT(' ',F6.1,2X,'PERCENT OF STEADY STATE AFTER TIME',
     1  ' INTERVAL',I6)
 1027 FORMAT(1H0,'  *  SIDE STREAM REMOVED FROM INTERSTAGE FLOW BETWEEN
     1THE INDICATED STAGES.')
 1028 FORMAT(1H0,'CALCULATION TERMINATED BY CONVERGENCE AT INDICATED _ S
     1TEADY STATE.')
 1029 FORMAT(/,' TOTAL  G/L  URANIUM IN:',2X,1PE11.4,
     1  ', OUT:',E11.4)
 1030 FORMAT(' TOTAL  G/L  PLUTONIUM IN:',1PE11.4,
     1  ', OUT:',E11.4)
 1031 FORMAT(' TOTAL MOLES HNO3 IN:',5X,1PE11.4,
     1  ', OUT:',E11.4)
 1032 FORMAT(/,' MINUTES/TIME INTERVAL:',F7.3)
 1033 FORMAT(2(F8.6,F8.7,F8.6),F8.4)
 1034 FORMAT(5I2)
C
C
      END
```

```
      SUBROUTINE PROFIL
      COMMON/PROF/ IPRO,X(4,25,2),Y(4,25,2),XFD(4,25),YFD(4,25),
     1  TPROF(25,2),AFDTEM(25),OFDTEM(25)
      COMMON/FEED/ NTOST,AFDRT(25),OFDRT(25)
C
C  DEFINE FEED STREAMS
C     I = STAGE NUMBER THAT FEED ENTERS   JHAS = 1 FOR AQUEOUS FEED
C  FDRT = FEED FLOW RATE (VOLUME UNITS)          0 FOR ORGANIC FEED
C  CON1 = URANIUM CONTENT IN G/L          INDEX = 1 IF MORE FEED CARDS FOLLOW
C  CON2 = PLUTONIUM CONTENT IN G/L                0 FOR LAST CARD
C  CON3 = ACID MOLARITY                    TEMP = TEMPERATURE IN DEGREES C
C  CON4 = NITRATE MOLARITY FROM INEXTRACTABLE SALTS, INCLUDING THE REDUCTANT
C  ENTER PU REDUCTANT NORMALITY AS NEGATIVE PU CONCENTRATION.
C
 10   CONTINUE
      READ(5,1001)I,JHAS,FDRT,CON1,CON2,CON3,TEMP,INDEX ,CON4
      IF(JHAS.EQ.1) GO TO 20
C
C  ORGANIC FEED
C
      OFDRT(I)=FDRT
      IF(TEMP.EQ.0.) GO TO 15
      OFDTEM(I) = TEMP
 15   CONTINUE
      YFD(1,I) = CON1
      YFD(2,I) = CON2
      YFD(3,I) = CON3
      YFD(4,I) = CON4
      GO TO 30
C
C  AQUEOUS FEED
C
 20   CONTINUE
      AFDRT(I) = FDRT
      IF(TEMP.EQ.0.) GO TO 25
      AFDTEM(I) = TEMP
 25   CONTINUE
      XFD(1,I) = CON1
      XFD(2,I) = CON2
      XFD(3,I) = CON3
      XFD(4,I) = CON4
C
C  MORE CARDS?
C
 30   CONTINUE
      IF(INDEX.EQ.1) GO TO 10
C
C
C  CHECK FOR NON-ZERO INITIAL PROFILE
C
      IF(IPRO.GT.0) GO TO 40
C
C  FOR IPRO = 0, THE ZERO PROFILE IS ALREADY IN X AND Y ARRAYS
```

```
C                                                                       PROF 530
      DO 35 J=1,NTOST                                                   PROF 540
      TPROF(J,1)=AFDTEM(1)                                              PROF 550
 35   CONTINUE                                                          PROF 560
      RETURN                                                            PROF 570
C                                                                       PROF 580
C  FOR A NON-ZERO INITIAL PROFILE, VALUES ARE NOW READ                  PROF 590
C                                                                       PROF 600
 40   CONTINUE                                                          PROF 610
      DO 45 J=1,NTOST                                                   PROF 620
      READ(5,1002)  (X(I,J,1),I=1,3),(Y(I,J,1),I=1,3),TPROF(J,1),X(4,J,1) PROF 630
      IF (TPROF(J,1).EQ.0.) TPROF(J,1)=25.0                             PROF 640
 45   CONTINUE                                                          PROF 650
C                                                                       PROF 660
C                                                                       PROF 670
 1001 FORMAT(2I2,5F8.0,I2,F8.0)                                         PROF 680
 1002 FORMAT (8F8.0)                                                    PROF 690
C                                                                       PROF 700
C                                                                       PROF 710
      RETURN                                                            PROF 720
      END                                                               PROF 730
```

```
      SUBROUTINE FLOWS(STVOL)                                           FLOWS 10
      COMMON/FLWS/ IRATIO,IOUT,IVOL,RECY(25),ICHNGE,ALVRT(25),OLVRT(25) FLOWS 20
      COMMON/FEED/ NTOST,AFDRT(25),OFDRT(25)                            FLOWS 30
      COMMON/REC/ A(25),O(25),RAIO(25),RCYCA(25),RCYCO(25)              FLOWS 40
      DIMENSION STVOL(25)                                               FLOWS 50
C                                                                       FLOWS 60
C  DEFINE OUTGOING STREAMS OTHER THAN AQUEOUS RAFFINATE AND ORGANIC PRODUCT
C     I = STAGE NUMBER THAT STREAM LEAVES JHAS = 1 FOR AQUEOUS STREAM
C INDEX = 1 IF MORE CARDS FOLLOW                  0 FOR ORGANIC STREAM
C         0 FOR LAST CARD                  OTRT = EXIT FLOW RATE (VOLUME UNITS)
C (FLOWS GIVEN IN SOLUTE-FREE VOLUME UNITS)                             FLOW 110
C                                                                       FLOW 120
C                                                                       FLOW 130
C  CHECK FOR OUTGOING STREAMS (IOUT=0-NO,IOUT=1-YES)                    FLOW 140
C                                                                       FLOW 150
      IF(IOUT.EQ.0) GO TO 25                                            FLOW 160
C                                                                       FLOW 170
C  READ OUTGOING STREAM DATA                                            FLOW 180
C                                                                       FLOW 190
C                                                                       FLOW 200
 10   CONTINUE                                                          FLOW 210
      READ 1001,I,JHAS,OTRT,INDEX                                       FLOW 220
      IF(JHAS.EQ.1) GO TO 15                                            FLOW 230
C                                                                       FLOW 240
C  ORGANIC STREAM                                                       FLOW 250
C                                                                       FLOW 260
      OLVRT(I)=OTRT                                                     FLOW 270
      GO TO 20                                                          FLOW 280
C                                                                       FLOW 290
C  AQUEOUS STREAM                                                       FLOW 300
C                                                                       FLOW 310
 15   CONTINUE                                                          FLOW 320
      ALVRT(I)=OTRT                                                     FLOW 330
C                                                                       FLOW 340
C  MORE CARDS?                                                          FLOW 350
C                                                                       FLOW 360
 20   CONTINUE                                                          FLOW 370
      IF(INDEX.EQ.1) GO TO 10                                           FLOW 380
C                                                                       FLOW 390
C  WE DO NOT PROVIDE FOR RETURNING STREAMS                              FLOW 400
C                                                                       FLOW 410
C                                                                       FLOW 420
C  SET AQUEOUS AND ORGANIC INTERSTAGE FLOW (A AND O)                    FLOW 430
C                                                                       FLOW 440
 25   CONTINUE                                                          FLOW 450
      DO 35 I=1,NTOST                                                   FLOW 460
      IF(I.GT.1) GO TO 30                                               FLOW 470
      A(1)=AFDRT(1)-ALVRT(1)                                            FLOW 480
      O(NTOST)=OFDRT(NTOST)-OLVRT(NTOST)                                FLOW 490
      GO TO 35                                                          FLOW 500
 30   CONTINUE                                                          FLOW 510
      A(I)=A(I-1)+AFDRT(I)-ALVRT(I)                                     FLOW 520
      NST = NTOST+1-I                                                   FLOW 530
      O(NST) = O(NST+1)+OFDRT(NST)-OLVRT(NST)                           FLOW 540
 35   CONTINUE                                                          FLOW 550
C                                                                       FLOW 560
C  THE INTERSTAGE FLOWS ARE NOW SET                                     FLOW 570
C                                                                       FLOW 580
C  DEFINE PHASE RATIOS                                                  FLOW 590
C                                                                       FLOW 600
      DO 40 I=1,NTOST                                                   FLOW 610
      RCYCA(I) = 0.0                                                    FLOW 620
      RCYCO(I) = 0.0                                                    FLOW 630
 40   CONTINUE                                                          FLOW 640
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      FLOMAX = 0.0                                                      FLOW 650
      K = 1                                                             FLOW 660
      IF(IRATIO.EQ.1) GO TO 50                                          FLOW 670
C                                                                       FLOW 680
C  DEFINE PHASE RATIO WHEN IRATIO=0,PHASE RATIO=FLOW RATIO              FLOW 690
C                                                                       FLOW 700
      DO 45 I=1,NTOST                                                   FLOW 710
      RAIO(I) = (ALVRT(I)+A(I))/(OLVRT(I)+O(I))                         FLOW 720
 45   CONTINUE                                                          FLOW 730
      GO TO 60                                                          FLOW 740
C                                                                       FLOW 750
C  DO NOT REDEFINE PHASE RATIO IF ICHNGE=1                              FLOW 760
C                                                                       FLOW 770
 50   CONTINUE                                                          FLOW 780
      IF(ICHNGE.EQ.1) GO TO 70                                          FLOW 790
C                                                                       FLOW 800
C  DEFINE PHASE RATIOS WHEN IRATIO=1, PHASE RATIOS DO NOT EQUAL         FLOW 810
C  FLOW RATIOS                                                          FLOW 820
C  I=NUMBER OF STAGES HAVING PHASE RATIO SHOWN                          FLOW 830
C                                                                       FLOW 840
      READ 1002,I,RATIO                                                 FLOW 850
      I=K+I-1                                                           FLOW 860
      DO 55 J=K,I                                                       FLOW 870
      RAIO(J) = RATIO                                                   FLOW 880
 55   CONTINUE                                                          FLOW 890
      IF(I.EQ.NTOST) GO TO 70                                           FLOW 900
      K=I+1                                                             FLOW 910
      GO TO 50                                                          FLOW 920
C                                                                       FLOW 930
C  CALCULATE NECESSARY RECYCLE FLOWS                                    FLOW 940
C       TYPE 1 IS RECYCLE OF ONE PHASE ONLY, TO SATISFY PHASE RATIO     FLOW 950
C                 USED WHEN IRATIO = 1                                  FLOW 960
C       TYPE 2 IS RECYCLE OF BOTH PHASES WITH PHASE RATIO RAIO(I)       FLOW 970
C                 TO ALLOW TOTAL STAGE FLOW TO EQUAL FLOMAX             FLOW 980
C                 USED WHEN IVOL = 0,2                                  FLOW 990
C  RECYCLE VOLUMES AND RATIOS ARE SOLUTE-FREE VALUES                    FLO 1000
C                                                                       FLO 1010
C                                                                       FLO 1020
C                                                                       FLO 1030
C  CALCULATE FLOTOT,RECY,AND FLOMAX FOR IRATIO=0; IVOL=0,2,3            FLO 1040
C  FOR IVOL=1, RECY SET TO 0.0                                          FLO 1050
C  FLOTOT - TOTAL FLOW LEAVING STAGE                                    FLO 1060
C  FLOMAX - GREATEST TOTAL FLOW FROM A STAGE                            FLO 1070
C                                                                       FLO 1080
 60   CONTINUE                                                          FLO 1090
      IF(IVOL.EQ.1) GO TO 100                                           FLO 1100
      DO 65 I=1,NTOST                                                   FLO 1110
      FLOTOT = ALVRT(I) + A(I) + OLVRT(I) + O(I)                        FLO 1120
      RECY(I) = FLOTOT                                                  FLO 1130
      FLOMAX = AMAX1(FLOTOT,FLOMAX)                                     FLO 1140
 65   CONTINUE                                                          FLO 1150
      IF(IVOL.EQ.0) GO TO 90                                            FLO 1160
      IF(IVOL.EQ.1) GO TO 100                                           FLO 1170
      IF(IVOL.EQ.2.OR.IVOL.EQ.3) GO TO 110                              FLO 1180
C                                                                       FLO 1190
C  CALCULATE FLOTOT,RCYCA,RCYCO,RECY,FLOMAX FOR IRATIO=1                FLO 1200
C  AND IVOL=0,1,2,3                                                     FLO 1210
C  AFL - TOTAL AQUEOUS FOLW LEAVING A STAGE                             FLO 1220
C  OFL - TOTAL ORGANIC FLOW LEAVING A STAGE                             FLO 1230
C  RFL - RATIO OF AQUEOUS TO ORGANIC FLOW LEAVING A STAGE (AFL/OFL)     FLO 1240
C  RCYCA - AQUEOUS RECYCLE TO SATISFY PHASE RATIO                       FLO 1250
C  RCYCO - ORGANIC RECYCLE TO SATISFY PHASE RATIO                       FLO 1260
C                                                                       FLO 1270
 70   CONTINUE                                                          FLO 1280
      DO 85 I=1,NTOST                                                   FLO 1290
      AFL = ALVRT(I) + A(I)                                             FLO 1300
      OFL = OLVRT(I) + O(I)                                             FLO 1310
      FLOTOT = AFL + OFL                                                FLO 1320
      RFL = AFL/OFL                                                     FLO 1330
C                                                                       FLO 1340
C  COMPARISON OF FLOW RATIO (RFL) TO PHASE RATIO (RAIO)                 FLO 1350
C                                                                       FLO 1360
      IF(RFL.GT.RAIO(I)) GO TO 75                                       FLO 1370
      IF(RFL.EQ.RAIO(I)) GO TO 80                                       FLO 1380
      FLOTOT=FLOTOT*(RAIO(I)+1.0)/(RFL+1.0)                             FLO 1390
      RCYCA(I) = FLOTOT - AFL - OFL                                     FLO 1400
      GO TO 80                                                          FLO 1410
 75   CONTINUE                                                          FLO 1420
      FLOTOT=FLOTOT*RFL*(RAIO(I)+1.0)/(RAIO(I)*(RFL+1.0))               FLO 1430
      RCYCO(I) = FLOTOT - AFL - OFL                                     FLO 1440
 80   CONTINUE                                                          FLO 1450
      RECY(I)=FLOTOT                                                    FLO 1460
      FLOMAX = AMAX1(FLOTOT,FLOMAX)                                     FLO 1470
 85   CONTINUE                                                          FLO 1480
C                                                                       FLO 1490
C  FLOMAX CONTAINS THE LARGEST TOTAL FLOW FROM A STAGE - STAGES HAVING AFLO 1500
C    TOTAL FLOW LESS THAN FLOMAX MUST EXHIBIT RECYCLE                   FLO 1510
C      OF TYPE 2                                                        FLO 1520
C                                                                       FLO 1530
      IF(IVOL.EQ.0) GO TO 90                                            FLO 1540
      IF(IVOL.EQ.1) GO TO 100                                           FLO 1550
      IF(IVOL.EQ.2.OR.IVOL.EQ.3) GO TO 110                              FLO 1560
C                                                                       FLO 1570
C  IVOL=0; IRATIO=0,1                                                   FLO 1580
 90   CONTINUE                                                          FLO 1590
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      DO 95 I=1,NTOST                                                   FLO 1600
      RECY(I) = FLOMAX - RECY(I)                                        FLO 1610
 95   CONTINUE                                                          FLO 1620
      RETURN                                                            FLO 1630
C                                                                       FLO 1640
C                                                                       FLO 1650
C  IVOL=1; IRATIO=0,1                                                   FLO 1660
C                                                                       FLO 1670
 100  CONTINUE                                                          FLO 1680
      DO 105 I=1,NTOST                                                  FLO 1690
      RECY(I) = 0.0                                                     FLO 1700
 105  CONTINUE                                                          FLO 1710
      RETURN                                                            FLO 1720
C                                                                       FLO 1730
C  DETERMINE STAGE VOLUME                                               FLO 1740
C  STAGE VOLUMES ARE ZERO FOR IVOL=0,1                                  FLO 1750
C                                                                       FLO 1760
C                                                                       FLO 1770
C  IF ICHNGE=0, READ STAGE VOLUMES                                      FLO 1780
C  IF ICHNGE=1, BYPASS READING OF STAGE VOLUMES                         FLO 1790
C                                                                       FLO 1800
 110  CONTINUE                                                          FLO 1810
      IF(ICHNGE.EQ.1) GO TO 125                                         FLO 1820
C                                                                       FLO 1830
      IF(IVOL.EQ.2) GO TO 120                                           FLO 1840
C                                                                       FLO 1850
C  IVOL=3; STAGE VOLUMES ARE EQUAL AND SPECIFIED                        FLO 1860
C  IRATIO=0,1                                                           FLO 1870
C                                                                       FLO 1880
      READ 1003,VOL                                                     FLO 1890
      DO 115 J=1,NTOST                                                  FLO 1900
      STVOL(J)=VOL                                                      FLO 1910
 115  CONTINUE                                                          FLO 1920
      GO TO 125                                                         FLO 1930
C                                                                       FLO 1940
C  IVOL=2; STAGE VOLUMES ARE INDEPENDENTLY UNEQUAL                      FLO 1950
C                                                                       FLO 1960
 120  CONTINUE                                                          FLO 1970
      READ 1004,(STVOL(J),J=1,NTOST)                                    FLO 1980
C                                                                       FLO 1990
C   STAGE VOLUMES ARE  SOLUTE-FREE VOLUMES                              FLO 2000
C                                                                       FLO 2010
C                                                                       FLO 2020
C  CALCULATE LENGTH OF TIME INTERVAL(TIMIN) AND RECY FOR IVOL=2,3       FLO 2030
C                                                                       FLO 2040
 125  CONTINUE                                                          FLO 2050
      TIMIN=0.0                                                         FLO 2060
      DO 130 I=1,NTOST                                                  FLO 2070
      RECY(I) = RECY(I)/STVOL(I)                                        FLO 2080
      TIMIN = AMAX1(RECY(I),TIMIN)                                      FLO 2090
 130  CONTINUE                                                          FLO 2100
      FLOMAX = TIMIN                                                    FLO 2110
      DO 135 I = 1,NTOST                                                FLO 2120
      RECY(I) = (FLOMAX - RECY(I))*STVOL(I)                             FLO 2130
 135  CONTINUE                                                          FLO 2140
C                                                                       FLO 2150
C                                                                       FLO 2160
 1001 FORMAT(2I2,F8.0,I2)                                               FLO 2170
 1002 FORMAT(I2,F8.0)                                                   FLO 2180
 1003 FORMAT(F8.0)                                                      FLO 2190
 1004 FORMAT(10F8.0)                                                    FLO 2200
C                                                                       FLO 2210
C                                                                       FLO 2220
      RETURN                                                            FLO 2230
      END                                                               FLO 2240
```

```
      SUBROUTINE STAGES(SPH)                                            STAGE 10
      DIMENSION AIN(4),OIN(4)                                           STAGE 20
      COMMON/STGS/ NSOLU,CODUM(25),AR(25),OR(25),AT(25),OT(25)          STAGE 30
      COMMON/FEED/ NTOST,AFDRT(25),OFDRT(25)                            STAGE 40
      COMMON/PROF/ IPRO,X(4,25,2),Y(4,25,2),XFD(4,25),YFD(4,25),        STAGE 50
     1  TPROF(25,2),AFDTEM(25),OFDTEM(25)                               STAGE 51
      COMMON/REC/ A(25),O(25),RAIO(25),RCYCA(25),RCYCO(25)              STAGE 60
      COMMON/DIST/ CTBP,ARY(4),DTRY(4),TO,RN(25,2),RNFD(25)             STAGE 70
C                                                                       STAGE 80
C  PERFORM STAGE CALCULATIONS FOR CURRENT TIME INTERVAL - CONSIDER      STAGE 90
C    INPUTS FROM ADJACENT STAGES, FEED STREAMS, AND MOST IMPORTANTLY    STAG 100
C      RECYCLE WITHIN THE STAGE - RECYCLE A RESULT OF STAGE FLOW BEING  STAG 110
C        LESS THAN FLOMAX (TYPE 2) AND PHASE RATIO NOT EQUAL TO FLOW    STAG 120
C          RATIO (TYPE 1)                                               STAG 130
C                                                                       STAG 140
C  AR - AQUEOUS RECYCLE TO FILL STAGE                                   STAG 150
C  OR - ORGANIC RECYCLE TO FILL STAGE                                   STAG 160
C  RCYCA - AQUEOUS RECYCLE TO SATISFY PHASE RATIO                       STAG 170
C  RCYCO - ORGANIC RECYCLE TO SATISFY PHASE RATIO                       STAG 180
C  AT - TOTAL AQUEOUS FLOW WITHIN A STAGE =                             STAG 190
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C       TOTAL AQUEOUS FLOW LEAVING A STAGE + AQUEOUS RECYCLE                STAG 200
C       TO FILL STAGE + AQUEOUS RECYCLE TO SATISFY PHASE RATIO              STAG 210
C   OT - TOTAL ORGANIC FLOW WITHIN A STAGE =                                STAG 220
C       TOTAL ORGANIC FLOW LEAVING A STAGE + ORGANIC RECYCLE                STAG 230
C       TO FILL STAGE + ORGANIC RECYCLE TO SATISFY PHASE RATIO              STAG 240
C   XFD - AQUEOUS FEED CONTENT OF STAGE                                     STAG 250
C   YFD - ORGANIC FEED CONTENT OF STAGE                                     STAG 260
C   AFDRT - AQUEOUS STAGE FLOW RATE                                         STAG 270
C   OFDRT - ORGANIC STAGE FLOW RATE                                         STAG 280
C   X - SOLUTE CONCENTRATION IN AQUEOUS PHASE FOR A GIVEN STAGE             STAG 290
C   Y - SOLUTE CONCENTRATION IN ORGANIC PHASE FOR A GIVEN STAGE             STAG 300
C   AFDTEM - TEMPERATURE OF AQUEOUS FEED                                    STAG 310
C   OFDTEM - TEMPERATURE OF ORGANIC FEED                                    STAG 320
C   TPROF - TEMPERATURE OF SOLUTE IN A GIVEN STAGE                          STAG 330
C   ARY - TRIAL AQUEOUS PHASE COMPOSITION                                   STAG 340
C   DTRY - DISTRIBUTION RATIOS                                              STAG 350
      DO 85 J=1,NTOST                                                       STAG 360
      JJ = J-1                                                              STAG 370
      JJJ= J+1                                                              STAG 380
      IF(J.GT.1) GO TO 10                                                   STAG 390
      RN(J,2)=(AFDRT(J)*RNFD(J)+(AR(J)+RCYCA(J))*RN(J,1))/AT(J)             STAG 400
      GO TO 15                                                              STAG 410
 10   CONTINUE                                                              STAG 420
      RN(J,2)=(AFDRT(J)*RNFD(J)+(AR(J)+RCYCA(J))*RN(J,1)  +                 STAG 430
     1  A(JJ)*RN(JJ,1))/AT(J)                                               STAG 431
 15   CONTINUE                                                              STAG 440
      DO 40 I=1,NSOLU                                                       STAG 450
      IF(J.GT.1) GO TO 20                                                   STAG 460
      AIN(I)=AFDRT(J)*XFD(I,J)+(AR(J)+RCYCA(J))*X(I,J,1)                    STAG 470
      GO TO 25                                                              STAG 480
 20   CONTINUE                                                              STAG 490
      AIN(I)=AFDRT(J)*XFD(I,J)+(AR(J)+RCYCA(J))*X(I,J,1)+                   STAG 500
     1  A(JJ)*X(I,JJ,1)                                                     STAG 501
 25   CONTINUE                                                              STAG 510
      IF(J.EQ.NTOST) GO TO 30                                               STAG 520
      OIN(I)=OFDRT(J)*YFD(I,J)+(OR(J)+RCYCO(J))*Y(I,J,1)+                   STAG 530
     1  O(JJJ)*Y(I,JJJ,1)                                                   STAG 531
      GO TO 35                                                              STAG 540
 30   CONTINUE                                                              STAG 550
      OIN(I)=OFDRT(J)*YFD(I,J)+(OR(J)+RCYCO(J))*Y(I,J,1)                    STAG 560
 35   CONTINUE                                                              STAG 570
      AIN(I)= AIN(I)/AT(J)                                                  STAG 580
      OIN(I)= OIN(I)/OT(J)                                                  STAG 590
      ARY(I)  = X(I,J,1)                                                    STAG 600
      IF(ARY(2).LT.0) ARY(2)  =  (AIN(2)*RAIO(J)  + OIN(2))/RAIO(J)         STAG 610
      ARY(4)  = AIN(4)                                                      STAG 620
 40   CONTINUE                                                              STAG 630
      IF(J.GT.1) GO TO 45                                                   STAG 640
      AHTIN=AFDRT(J)*AFDTEM(J)+(AR(J)+RCYCA(J))*TPROF(J,1)                  STAG 650
      GO TO 50                                                              STAG 660
 45   CONTINUE                                                              STAG 670
      AHTIN=AFDRT(J)*AFDTEM(J)+(AR(J)+RCYCA(J))*TPROF(J,1)+                 STAG 680
     1  A(JJ)*TPROF(JJ,1)                                                   STAG 681
 50   CONTINUE                                                              STAG 690
      IF(J.EQ.NTOST) GO TO 55                                               STAG 700
      OHTIN=SPH*(OFDRT(J)*OFDTEM(J)+(OR(J)+RCYCO(J))*                       STAG 710
     1  TPROF(J,1)+O(JJJ)*TPROF(JJJ,1))                                     STAG 711
      GO TO 60                                                              STAG 720
 55   CONTINUE                                                              STAG 730
      OHTIN=SPH*(OFDRT(J)*OFDTEM(J)+(OR(J)+RCYCO(J))*TPROF(J,1))            STAG 740
 60   CONTINUE                                                              STAG 750
      TPROF(J,2)=(AHTIN+OHTIN)/(AT(J)+SPH*OT(J))                            STAG 760
      TEMPC=TPROF(J,2)                                                      STAG 770
      CCD = 0.001                                                           STAG 780
C                                                                           STAG 790
C   MCK  IS THE ITERATION COUNTER                                           STAG 800
C   MDEX IS THE FIT COUNTER                                                 STAG 810
C                                                                           STAG 820
      MCK  = 0                                                              STAG 830
 65   CONTINUE                                                              STAG 840
      MDEX = 0                                                              STAG 850
C                                                                           STAG 860
C   UCOR CALCULATES DISTRIBUTION RATIOS (DTRY) FOR EACH TRIAL AQUEOUS PHASE
C     COMPOSITION (ARY) AT THE STAGE EQUILIBRIUM TEMPERATURE (TEMPC)        STAG 880
C                                                                           STAG 890
      CALL UCOR(TEMPC,J)                                                    STAG 900
      DO 70 I=1,NSOLU                                                       STAG 910
      TSIN = AIN(I)*RAIO(J)  + OIN(I)                                       STAG 920
      IF(TSIN.LT.0.) DTRY(I)  = 0.                                          STAG 930
      DTRY(4)  = 0.                                                         STAG 940
      X(I,J,2)=TSIN/(RAIO(J)+DTRY(I))                                       STAG 950
      IF(X(I,J,2).LT.1.E-6) GO TO 70                                        STAG 960
      DI=(X(I,J,2)-ARY(I))/X(I,J,2)                                         STAG 970
      DIF = ABS(DI)                                                         STAG 980
      ARY(I)=X(I,J,2)                                                       STAG 990
      IF(DIF.LE.CCD) GO TO 70                                               STA 1000
C                                                                           STA 1010
C   MDEX COUNTS NUMBER OF SOLUTES THAT NOT CONVERGED                        STA 1020
C                                                                           STA 1030
      MDEX = MDEX + 1                                                       STA 1040
 70   CONTINUE                                                              STA 1050
      MCK = MCK + 1                                                         STA 1060
C                                                                           STA 1070
C   ALLOW ONLY 20 ITERATIONS                                                STA 1080
C                                                                           STA 1090
```

```
      IF(MCK.EQ.20) GO TO 75                                            STA 1100
C                                                                       STA 1110
C  IF ALL SOLUTES HAVE NOT CONVERGED,  REPEAT CALL TO UCOR              STA 1120
C  WITH NEW VALUES OF ARY                                               STA 1130
C                                                                       STA 1140
      IF(MDEX.GT.0) GO TO 65                                            STA 1150
 75   CONTINUE                                                          STA 1160
      DO 80 I=1,NSOLU                                                   STA 1170
      Y(I,J,2)=X(I,J,2)*DTRY(I)                                         STA 1180
 80   CONTINUE                                                          STA 1190
      CODUM(J)=MCK                                                      STA 1200
 65   CONTINUE                                                          STA 1210
 90   RETURN                                                            STA 1220
      END                                                               STA 1230
```

```
      SUBROUTINE UCOR(TEMPC,J)                                          UCOR  10
      COMMON/DIST/ CTBP,ARY(4),DTRY(4),TO,RN(25,2),RNFD(25)             UCOR  20
C                                                                       UCOR  30
C  UCOR RETURNS A VALUE OF THE DISTRIBUTION COEFFICIENT = Y/X FOR EACH  UCOR  40
C    VALUE OF X TRIED                                                   UCOR  50
C                                                                       UCOR  60
      PUTOT=ARY(2)-RN(J,2)                                              UCOR  70
      F=CTBP                                                            UCOR  80
      UAM = ARY(1)                                                      UCOR  90
      PUAM = ARY(2)                                                     UCOR 100
      HAM = ARY(3)                                                      UCOR 110
      SNITR = ARY(4)                                                    UCOR 120
      IF(UAM.LT.0) UAM = 0.                                             UCOR 130
      IF(PUAM.LT.0) PUAM = 0.                                           UCOR 140
      IF(HAM.LT.0) HAM = 0.                                             UCOR 150
      IF(SNITR.LT.0) SNITR = 0.                                         UCOR 160
      PUIII = PUTOT - PUAM                                              UCOR 170
      IF(PUIII.LT.0) PUIII = 0.                                         UCOR 180
      TNM = HAM + 2.*UAM + 2.*PUAM + SNITR  + 4.*PUIII                  UCOR 190
      IF (TNM.EQ.0.0) TNM = 1.0                                         UCOR 200
      TEMPRK = 1000./(TEMPC + 273.16)                                   UCOR 210
      DRT = TEMPRK - 3.3539                                             UCOR 220
      UK = 3.7*TNM**1.57 + 1.4*TNM**3.9 + 0.011*TNM**7.3                UCOR 230
      UK = UK*(4.*F**(-0.17) - 3.)                                      UCOR 240
      PUK = UK*(.20 + .55*F**1.25 + .0074*TNM**2)                       UCOR 250
      HK1 = 0.135*TNM**0.82 + 0.0052*TNM**3.44                          UCOR 260
      IF (F.LT.1.) HK1 = HK1*(1. - 0.54*EXP(-15.*F))                    UCOR 270
      IF (TEMPC.NE.25.) UK = UK*EXP(2.5*DRT)                            UCOR 280
      IF (TEMPC.NE.25.) PUK = PUK*EXP(-.2*DRT)                          UCOR 290
      IF (TEMPC.NE.25.) HK1 = HK1*EXP(0.34*DRT)                         UCOR 300
      HK2 = HK1                                                         UCOR 310
      A = 2.*(UK*UAM + PUK*PUAM + HK2*HAM)                              UCOR 320
      B = HK1*HAM + 1.                                                  UCOR 330
      C = -TO                                                           UCOR 340
      IF(A.GE.1.E-6) GO TO 10                                           UCOR 350
      TF=-C/B                                                           UCOR 360
      GO TO 15                                                          UCOR 370
 10   CONTINUE                                                          UCOR 380
      TF = (-B + SQRT(B**2 -4.*A*C))/(2.*A)                             UCOR 390
 15   CONTINUE                                                          UCOR 400
      DH1 = HK1*TF                                                      UCOR 410
      DH2 = HK2*TF**2                                                   UCOR 420
      DH = DH1 + DH2                                                    UCOR 430
      DU = UK*TF**2                                                     UCOR 440
      DPU = PUK*TF**2                                                   UCOR 450
      DTRY(1) = DU                                                      UCOR 460
      DTRY(2) = DPU                                                     UCOR 470
      DTRY(3) = DH                                                      UCOR 480
 20   RETURN                                                            UCOR 490
      END                                                               UCOR 500
```

```
      SUBROUTINE PLOTR(KOUNT,ICALPL,NTOST,CFA,CFO)                      PLOTR 10
C                                                                       PLOTR 20
C  THIS ROUTINE GENERATES CALCOMP PLOTS OF TWO KINDS:                   PLOTR 30
C     ICALPL=1 PROFILE GRAPHS (LOG OF REDUCED CONCENTRATION             PLOTR 40
C              VS STAGE NUMBER)                                         PLOTR 50
C     ICALPL=2 TRANSIENT GRAPHS (REDUCED CONCENTRATION                  PLOTR 60
C              VS TIME FOR A SPECIFIED STAGE                            PLOTR 70
C                                                                       PLOTR 80
C  KOUNT-TOTAL NUMBER OF TIME INTERVALS                                 PLOTR 90
C  NTOST-TOTAL NUMBER OF STAGES                                         PLOT 100
C  CFA AND CFO-MAXIMUM CONCENTRATIONS                                   PLOT 110
```

```
C  X AND A-REDUCED AQUEOUS CONCENTRATIONS
C  Y AND O-REDUCED ORGANIC CONCENTRATIONS
C  TTL-GRAPH TITLE
C  XTAG-X AXIS LABEL
C  YTAG-Y AXIS LABEL
C
      DIMENSION CFA(4),CFO(4),X(4),Y(4),A(25,4,4),O(25,4,4),NSTA(25)
      REAL*8 TTL(10),XTAG(10),YTAG(10)
      REAL*8 TLEG1(4)/'FRACTION',' OF STEA','DY STATE',' TIME$  '/,
     1  DESCR1(13)/'1/8 OF S','TEADY ST','ATE TIME','$1/4 OF ',
     2              'STEADY S','TATE TIM','E$1/2 OF',' STEADY ',
     3              'STATE TI','ME$STEAD','Y STATE ','OPERATIO',
     4              'N$      '/
      INTEGER*4 ISYMB(4)/1,2,3,4/
      INTEGER*4 ISYMBP(4)/4,3,2,1/
C
      REAL*8 TLEG2(2)/'COMPONEN','TS$     '/,
     1  DESCR2(4)/'URANIUM$','PLUTONIU','M$NITRIC',' ACID$  '/
C
C  ZERO REDUCED CONCENTRATION ARRAYS
C
      DO 10 I=1,25
      DO 10 J=1,4
      DO 10 K=1,4
      A(I,J,K)=0.
      O(I,J,K)=0.
 10   CONTINUE
C
C  CALCULATE REDUCED CONCENTRATIONS
C  UNIT 10 HOLDS PRINTOUT FOR EACH TIME INTERVAL
C
      REWIND 11
      WRITE(6,1001) CFA,CFO
      DO 25 I=1,KOUNT
      DO 25 J=1,NTOST
      READ(11) L,X,Y
      DO 20 K=1,4
      IF(CFA(K).EQ.0.) GO TO 15
      X(K)=X(K)/CFA(K)*100.
 15   CONTINUE
      IF(CFO(K).EQ.0.) GO TO 20
      Y(K)=Y(K)/CFO(K)*100.
 20   CONTINUE
      WRITE(10) L,X,Y
      WRITE(6,1002) L,X,Y
 25   CONTINUE
      REWIND 10
      REWIND 11
C
      IF(ICALPL.EQ.2) GO TO 95
C
C  SET UP ARRAYS A AND C FOR PROFILE GRAPHS
C  WILL PLOT CURVES FOR KOUNT, 1/2 KOUNT, 1/4 KOUNT, AND 1/8KOUNT
C
      DO 40 I=1,4
      II=4-I+1
      INDEX=2*KOUNT/2**II
 30   CONTINUE
      DO 35 K=1,NTOST
      READ(10) L,(A(K,I,J),J=1,4),(O(K,I,J),J=1,4)
 35   CONTINUE
      IF(L.NE.INDEX) GO TO 30
 40   CONTINUE
      REWIND 10
C
C  PLOT PROFILE GRAPHS
C
      READ(5,1003) TTL
      READ(5,1003) XTAG
      XMIN=1.
      XMAX=NTOST
C
C  DETERMINE MAX AND MIN FOR Y AXIS
C
      YMAX=0.
      YMIN=1.E10
      DO 45 I=1,NTOST
      DO 45 J=1,4
      DO 45 K=1,3
      YMAX=AMAX1(A(I,J,K),O(I,J,K),YMAX)
      IF(A(I,J,K).EQ.0..AND.O(I,J,K).EQ.0.) GO TO 45
      IF(A(I,J,K).NE.0..AND.O(I,J,K).NE.0.) YMIN=AMIN1(A(I,J,K),
     1  O(I,J,K),YMIN)
      IF(A(I,J,K).EQ.0.) YMIN=AMIN1(O(I,J,K),YMIN)
      IF(O(I,J,K).EQ.0.) YMIN=AMIN1(A(I,J,K),YMIN)
 45   CONTINUE
      DO 90 I=1,3
C
C  AQUEOUS
C
      DO 50 II=1,NTOST
      DO 50 JJ=1,4
      IF(A(II,JJ,I).GT.0.) GO TO 55
 50   CONTINUE
      GO TO 90
```

```
 55   CONTINUE                                                          PLO 1010
C                                                                       PLO 1020
      CALL FIXPLT(XMIN,XMAX,YMIN,YMAX,'YLOG','MECH',0.,0.,              PLO 1030
     1  BUFFER,4000,'S.B.WATSON$')                                      PLO 1031
C                                                                       PLO 1040
      READ(5,1003) YTAG                                                 PLO 1050
      CALL TITLE(0.4,TTL,XTAG,YTAG)                                     PLO 1060
C                                                                       PLO 1070
      MNTOST=-NTOST                                                     PLO 1080
      DO 65 J=1,4                                                       PLO 1090
      DO 60 II=1,NTOST                                                  PLO 1100
      IF(A(II,J,I).EQ.0.) CALL PPL(A(1,J,I),4-J+1,NTOST,865)            PLO 1110
 60   CONTINUE                                                          PLO 1120
      CALL LINPLT(1.,A(1,J,I),MNTOST,4-J+1,0)                           PLO 1130
 65   CONTINUE                                                          PLO 1140
C                                                                       PLO 1150
      CALL LEGEND(TLEG1,ISYMBP,4,DESCR1,2,3.,1.5)                       PLO 1160
C                                                                       PLO 1170
C  ORGANIC                                                              PLO 1180
C                                                                       PLO 1190
      DO 70 II=1,NTOST                                                  PLO 1200
      DO 70 JJ=1,4                                                      PLO 1210
      IF(O(II,JJ,I).GT.0.) GO TO 75                                     PLO 1220
 70   CONTINUE                                                          PLO 1230
      GO TO 90                                                          PLO 1240
 75   CONTINUE                                                          PLO 1250
C                                                                       PLO 1260
      CALL FIXPLT(XMIN,XMAX,YMIN,YMAX,'YLOG','MECH',0.,0.,              PLO 1270
     1  BUFFER,4000,'S.B.WATSON$')                                      PLO 1271
C                                                                       PLO 1280
      READ(5,1003) YTAG                                                 PLO 1290
      CALL TITLE(0.4,TTL,XTAG,YTAG)                                     PLO 1300
C                                                                       PLO 1310
      DO 85 J=1,4                                                       PLO 1320
      DO 80 II=1,NTOST                                                  PLO 1330
      IF(O(II,J,I).EQ.0.) CALL PPL(O(1,J,I),4-J+1,NTOST,885)            PLO 1340
 80   CONTINUE                                                          PLO 1350
      CALL LINPLT(1.,O(1,J,I),MNTOST,4-J+1,0)                           PLO 1360
 85   CONTINUE                                                          PLO 1370
C                                                                       PLO 1380
      CALL LEGEND(TLEG1,ISYMBP,4,DESCR1,2,3.,1.5)                       PLO 1390
C                                                                       PLO 1400
 90   CONTINUE                                                          PLO 1410
C                                                                       PLO 1420
      IF(ICALPL.EQ.1) GO TO 135                                         PLO 1430
C                                                                       PLO 1440
C  TRANSIENT GRAPHS                                                     PLO 1450
C                                                                       PLO 1460
 95   CONTINUE                                                          PLO 1470
      XMIN=0.                                                           PLO 1480
      XMAX=KOUNT                                                        PLO 1490
      IF(XMAX.GT.100) CALL QCSIZE(XMAX/10.,10.)                         PLO 1500
      YMIN=0.                                                           PLO 1510
      YMAX=100.                                                         PLO 1520
C                                                                       PLO 1530
C  READ STAGES TO BE PLOTTED                                            PLO 1540
C                                                                       PLO 1550
      READ(5,1004) (NSTA(I),I=1,NTOST)                                  PLO 1560
C                                                                       PLO 1570
      READ(5,1003) TTL                                                  PLO 1580
      READ(5,1003) XTAG                                                 PLO 1590
C                                                                       PLO 1600
C  WILL GENERATE 2 PLOTS FOR EACH NONZERO VALUE OF NSTA                 PLO 1610
C                                                                       PLO 1620
      DO 130 I=1,NTOST                                                  PLO 1630
      IF(NSTA(I).EQ.0) GO TO 130                                        PLO 1640
C                                                                       PLO 1650
C  AQUEOUS                                                              PLO 1660
C                                                                       PLO 1670
      CALL FIXPLT(XMIN,XMAX,YMIN,YMAX,'LINE','MECH',0.,0.,              PLO 1680
     1  BUFFER,4000,'S.B.WATSON$')                                      PLO 1681
C                                                                       PLO 1690
      READ(5,1003) YTAG                                                 PLO 1700
      CALL TITLE(0.4,TTL,XTAG,YTAG)                                     PLO 1710
C                                                                       PLO 1720
      DO 110 J=1,KOUNT                                                  PLO 1730
      DO 105 K=1,NTOST                                                  PLO 1740
      READ(10) L,X,Y                                                    PLO 1750
      IF(K.NE.NSTA(I)) GO TO 105                                        PLO 1760
      XPOINT=L                                                          PLO 1770
      DO 100 II=1,3                                                     PLO 1780
      CALL PNTPLT(XPOINT,X(II),II,-1)                                   PLO 1790
 100  CONTINUE                                                          PLO 1800
 105  CONTINUE                                                          PLO 1810
 110  CONTINUE                                                          PLO 1820
      REWIND 10                                                         PLO 1830
C                                                                       PLO 1840
      CALL LEGEND(TLEG2,ISYMB,3,DESCR2,2,-3.,1.)                        PLO 1850
C                                                                       PLO 1860
C  ORGANIC                                                              PLO 1870
C                                                                       PLO 1880
      CALL FIXPLT(XMIN,XMAX,YMIN,YMAX,'LINE','MECH',0.,0.,              PLO 1890
     1  BUFFER,4000,'S.B.WATSON$')                                      PLO 1891
C                                                                       PLO 1900
      READ(5,1003) YTAG                                                 PLO 1910
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      CALL TITLE(0.4,TTL,XTAG,YTAG)                                     PLO 1920
      DO 125 J=1,KOUNT                                                  PLO 1930
      DO 120 K=1,NTOST                                                  PLO 1940
      READ(10) L,X,Y                                                    PLO 1950
      IF(K.NE.NSTA(I)) GO TO 120                                        PLO 1960
      XPOINT=L                                                          PLO 1970
      DO 115 II=1,3                                                     PLO 1980
      CALL PNTPLT(XPOINT,Y(II),II,-1)                                   PLO 1990
 115  CONTINUE                                                          PLO 2000
 120  CONTINUE                                                          PLO 2010
 125  CONTINUE                                                          PLO 2020
      REWIND 10                                                         PLO 2030
C                                                                       PLO 2040
      CALL LEGEND(TLEG2,ISYMB,3,DESCR2,2,-3.,1.)                        PLO 2050
C                                                                       PLO 2060
 130  CONTINUE                                                          PLO 2070
 135  CONTINUE                                                          PLO 2080
C                                                                       PLO 2090
      CALL ADVANS                                                       PLO 2100
C                                                                       PLO 2110
C                                                                       PLO 2120
 1001 FORMAT(' ',1P4E11.3,4X,4E11.3)                                    PLO 2130
 1002 FORMAT(' ',I4,4X,1P4E11.3,4X,4E11.3)                              PLO 2140
 1003 FORMAT(10A8)                                                      PLO 2150
 1004 FORMAT(25I2)                                                      PLO 2160
C                                                                       PLO 2170
C                                                                       PLO 2180
      RETURN                                                            PLO 2190
      END                                                               PLO 2200
```

```
      SUBROUTINE PPL(A,J,NTOST,*)                                       PPL   10
C                                                                       PPL   20
C  PLOT NONZERO POINT ON THE CURVE                                      PPL   30
C                                                                       PPL   40
      DIMENSION A(25)                                                   PPL   50
      DO 10 I=1,NTOST                                                   PPL   60
      IDASH=0                                                           PPL   70
      XPOINT=I                                                          PPL   80
      IF(I.EQ.1) IDASH=-1                                               PPL   90
      IF(I.GT.1.AND.A(I-1).EQ.0.) IDASH=-1                              PPL  100
      IF(A(I).GT.0.) CALL PNTPLT(XPOINT,A(I),J,IDASH)                   PPL  110
 10   CONTINUE                                                          PPL  120
      RETURN 1                                                          PPL  130
      END                                                               PPL  140
```

APPENDIX B

Sample Input and Output

Two Examples of Input to SEPHIS

	1 - 10	11 - 20	21 - 30	31 - 40	41 - 50	51 - 60	61 - 70
Case 1	COEXTRACTION	RUN					
	.153 11	0 0 1 0 1	0 0 0				
	1 1 3.E	-1	0.				
	4 1	1. 6.77E1	0.	2.	25.1	0.	
	11 0 1	18.	0.	4.43			
	0		0.	3.2	25.1	0.	
				0.	25.0	0.	
Case 2	PU EXTRACTION						
	.15 10	0 0 1 0 1	0 0 0				
	1 1 1.1E	-1	0.				
	4 1	1.	0.	2.	25.1	0.	
	10 0 9.E	-1	0.	1.92E1			
	2		0.	4.1	25.1	0.	
				0.	25 0	0.	

UCN-1224
(12-3-11-61)

OUTPUT - CASE 1

CALCULATIONS FOR A SOLVENT EXTRACTION PROCESS HAVING 3 INTERACTING SOLUTES — COEXTRACTION RUN

FEED STREAM DATA	STAGE NO.	URANIUM (G/L)	PLUTONIUM (G/L)	HNO3 (M)	SALT NO3 (M)	FLOW RATE (VOL.UNITS)	TEMP DEG C
AQUEOUS	1	0.0	0.0	2.0000E 00	0.0	3.000E-01	25.0
AQUEOUS	4	6.7700E 01	4.4300E 00	3.2000E 00	0.0	1.000E 00	25.0
15.3 - TBP	11	0.0	0.0	0.0	0.0	1.800E 00	25.0

INITIAL PROFILE	STAGE NO. (OUTFLOW)	URANIUM (G/L)	AQUEOUS PHASE PLUTONIUM (G/L)	HNO3 (M)	URANIUM (G/L)	ORGANIC PHASE PLUTONIUM (G/L)	HNO3 (M)	TEMP DEG C
	1	0.0	0.0	2.1317E 00	0.0	0.0	0.0	25.0
	2	0.0	0.0	2.1317E 00	0.0	0.0	0.0	25.0
	3	0.0	0.0	2.1317E 00	0.0	0.0	0.0	25.0
	4	0.0	0.0	2.1317E 00	0.0	0.0	0.0	25.0
	5	0.0	0.0	2.1317E 00	0.0	0.0	0.0	25.0
	6	0.0	0.0	2.1317E 00	0.0	0.0	0.0	25.0
	7	0.0	0.0	2.1317E 00	0.0	0.0	0.0	25.0
	8	0.0	0.0	2.1317E 00	0.0	0.0	0.0	25.0
	9	0.0	0.0	2.1317E 00	0.0	0.0	0.0	25.0
	10	0.0	0.0	2.1317E 00	0.0	0.0	0.0	25.0
	11	0.0	0.0	2.1317E 00	0.0	0.0	0.0	25.0

PHASE RATIOS EQUAL FLOW RATIOS	STAGE NO.	A/O PHASE RATIO
	1 - 3	1.568E-01
	4 - 11	6.460E-01

STAGE FLOWS (SOLUTE-FREE VOLUMES):

STAGE NO.	FLOW RATIO	FLOW OUT OF STAGE	AQUEOUS PHASE RECYCLE 2 TO FILL STAGE	RECYCLE 1 FOR PHASE RATIO	TOTAL AQUEOUS FLOW
1	1.568E-01	2.815E-01	0.0	0.0	2.815E-01
2	1.568E-01	2.815E-01	0.0	0.0	2.815E-01
3	1.568E-01	2.815E-01	0.0	0.0	2.815E-01
4	6.460E-01	1.160E 00	0.0	0.0	1.160E 00
5	6.460E-01	1.160E 00	0.0	0.0	1.160E 00
6	6.460E-01	1.160E 00	0.0	0.0	1.160E 00
7	6.460E-01	1.160E 00	0.0	0.0	1.160E 00
8	6.460E-01	1.160E 00	0.0	0.0	1.160E 00
9	6.460E-01	1.160E 00	0.0	0.0	1.160E 00
10	6.460E-01	1.160E 00	0.0	0.0	1.160E 00
11	6.460E-01	1.160E 00	0.0	0.0	1.160E 00

STAGE NO.	OVERALL TOTAL STAGE FLOW	STAGE VOL.	FLOW OUT OF STAGE	ORGANIC PHASE RECYCLE 2 TO FILL STAGE	RECYCLE 1 FOR PHASE RATIO	TOTAL ORGANIC FLOW
1	2.076E 00	0.0	1.795E 00	0.0	0.0	1.795E 00
2	2.076E 00	0.0	1.795E 00	0.0	0.0	1.795E 00
3	2.076E 00	0.0	1.795E 00	0.0	0.0	1.795E 00
4	2.954E 00	0.0	1.795E 00	0.0	0.0	1.795E 00
5	2.954E 00	0.0	1.795E 00	0.0	0.0	1.795E 00
6	2.954E 00	0.0	1.795E 00	0.0	0.0	1.795E 00
7	2.954E 00	0.0	1.795E 00	0.0	0.0	1.795E 00
8	2.954E 00	0.0	1.795E 00	0.0	0.0	1.795E 00
9	2.954E 00	0.0	1.795E 00	0.0	0.0	1.795E 00
10	2.954E 00	0.0	1.795E 00	0.0	0.0	1.795E 00
11	2.954E 00	0.0	1.795E 00	0.0	0.0	1.795E 00

TRANSIENT BEHAVIOR RESULTS SOLUTE CONCENTRATIONS IN EFFLUENT FROM EACH STAGE

ACQEOUS PHASE

TIME INTERVAL	STAGE NO.	URANIUM (G/L)	PLUTONIUM (G/L)	HNO3 (M)	FLOW OUT OF STAGE
1	1	0.0	0.0	1.271E 00	2.930E-01
	2	0.0	0.0	1.271E 00	2.930E-01
	3	0.0	0.0	1.271E 00	2.930E-01
	4	7.821E 00	1.210E 00	2.750E 00	1.271E 00
	5	0.0	0.0	1.735E 00	1.225E 00
	6	0.0	0.0	1.735E 00	1.225E 00
	7	0.0	0.0	1.735E 00	1.225E 00
	8	0.0	0.0	1.735E 00	1.225E 00
	9	0.0	0.0	1.735E 00	1.225E 00
	10	0.0	0.0	1.735E 00	1.225E 00
	11	0.0	0.0	1.735E 00	1.225E 00

ORGANIC PHASE

STAGE NO.	URANIUM (G/L)	PLUTONIUM (G/L)	HNO3 (M)	FLOW OUT OF STAGE	ITERATIONS	TEMP DEG C
1	0.0	0.0	1.258E-01	1.809E 00	4.	25.0
2	0.0	0.0	1.258E-01	1.809E 00	4.	25.0
3	0.0	0.0	1.258E-01	1.809E 00	4.	25.0
4	3.148E 01	1.576E 00	1.657E-01	1.835E 00	11.	25.0
5	0.0	0.0	1.907E-01	1.814E 00	3.	25.0
6	0.0	0.0	1.907E-01	1.814E 00	3.	25.0
7	0.0	0.0	1.907E-01	1.814E 00	3.	25.0
8	0.0	0.0	1.907E-01	1.814E 00	3.	25.0
9	0.0	0.0	1.907E-01	1.814E 00	3.	25.0
10	0.0	0.0	1.907E-01	1.814E 00	3.	25.0
11	0.0	0.0	1.907E-01	1.814E 00	3.	25.0

ACQEOUS PHASE

TIME INTERVAL	STAGE NO.	URANIUM (G/L)	PLUTONIUM (G/L)	HNO3 (M)	FLOW OUT OF STAGE
2	1	0.0	0.0	1.675E 00	2.968E-01
	2	0.0	0.0	1.271E 00	2.930E-01
	3	1.224E 01	1.886E 00	1.674E 00	2.963E-01
	4	7.696E 00	1.184E 00	2.829E 00	1.275E 00
	5	4.766E-01	2.076E-01	2.631E 00	1.263E 00
	6	0.0	0.0	1.735E 00	1.225E 00
	7	0.0	0.0	1.735E 00	1.225E 00
	8	0.0	0.0	1.735E 00	1.225E 00
	9	0.0	0.0	1.735E 00	1.225E 00
	10	0.0	0.0	1.735E 00	1.225E 00
	11	0.0	0.0	1.511E 00	1.216E 00

ORGANIC PHASE

STAGE NO.	URANIUM (G/L)	PLUTONIUM (G/L)	HNO3 (M)	FLOW OUT OF STAGE	ITERATIONS	TEMP DEG C
1	0.0	0.0	1.822E-01	1.813E 00	4.	25.0
2	0.0	0.0	1.258E-01	1.809E 00	1.	25.0
3	2.960E 01	1.274E 00	9.693E-02	1.828E 00	7.	25.0
4	3.154E 01	1.592E 00	1.701E-01	1.835E 00	6.	25.0
5	5.120E 00	6.994E-01	2.848E-01	1.825E 00	5.	25.0
6	0.0	0.0	1.907E-01	1.814E 00	1.	25.0
7	0.0	0.0	1.907E-01	1.814E 00	1.	25.0
8	0.0	0.0	1.907E-01	1.814E 00	1.	25.0
9	0.0	0.0	1.907E-01	1.814E 00	1.	25.0
10	0.0	0.0	1.907E-01	1.814E 00	1.	25.0
11	0.0	0.0	1.592E-01	1.811E 00	3.	25.0

ACQEOUS PHASE

TIME INTERVAL	STAGE NO.	URANIUM (G/L)	PLUTONIUM (G/L)	HNO3 (M)	FLOW OUT OF STAGE
3	1	0.0	0.0	1.675E 00	2.968E-01
	2	1.087E 01	1.456E 00	1.650E 00	2.979E-01
	3	1.214E 01	1.885E 00	1.693E 00	2.985E-01
	4	1.114E 01	1.879E 00	1.056E 00	1.267E 00
	5	4.559E-01	1.963E-01	2.700E 00	1.265E 00
	6	2.689E-02	3.388E-02	2.495E 00	1.256E 00
	7	0.0	0.0	1.735E 00	1.225E 00
	8	0.0	0.0	1.735E 00	1.225E 00
	9	0.0	0.0	1.735E 00	1.225E 00
	10	0.0	0.0	1.698E 00	1.224E 00
	11	0.0	0.0	1.511E 00	1.216E 00

ORGANIC PHASE

STAGE NO.	URANIUM (G/L)	PLUTONIUM (G/L)	HNO3 (M)	FLOW OUT OF STAGE	ITERATIONS	TEMP DEG C
1	0.0	0.0	1.822E-01	1.813E 00	1.	25.0
2	2.784E 01	1.037E 00	1.001E-01	1.827E 00	6.	25.0
3	2.968E 01	1.250E 00	9.802E-02	1.828E 00	5.	25.0
4	3.611E 01	2.096E 00	1.563E-01	1.838E 00	10.	25.0
5	5.058E 00	6.907E-01	2.931E-01	1.825E 00	4.	25.0
6	3.118E-01	1.205E-01	2.926E-01	1.822E 00	4.	25.0
7	0.0	0.0	1.907E-01	1.814E 00	1.	25.0
8	0.0	0.0	1.907E-01	1.814E 00	1.	25.0
9	0.0	0.0	1.907E-01	1.814E 00	1.	25.0
10	0.0	0.0	1.855E-01	1.813E 00	2.	25.0
11	0.0	0.0	1.592E-01	1.811E 00	1.	25.0

INTERMEDIATE STATES OMITTED TO SAVE SPACE

AQUEOUS PHASE

TIME INTERVAL	STAGE NO.	URANIUM (G/L)	PLUTONIUM (G/L)	HNO3 (M)	FLOW OUT OF STAGE
87	1	1.880E 01	4.224E 00	1.930E 00	3.019E-01
	2	2.462E 01	6.483E 00	1.962E 00	3.032E-01
	3	2.456E 01	6.841E 00	2.194E 00	3.056E-01
	4	1.919E 01	4.609E 00	3.214E 00	1.259E 00
	5	1.438E 00	9.653E-01	3.352E 00	1.255E 00
	6	6.676E-02	1.255E-01	3.366E 00	1.294E 00
	7	2.973E-03	1.564E-02	3.367E 00	1.294E 00
	8	1.319E-04	1.943E-03	3.367E 00	1.294E 00
	9	5.865E-06	2.417E-04	3.358E 00	1.294E 00
	10	2.637E-07	3.039E-05	3.296E 00	1.291E 00
	11	1.288E-08	4.150E-06	2.858E 00	1.272E 00

ORGANIC PHASE

STAGE NO.	URANIUM (G/L)	PLUTONIUM (G/L)	HNO3 (M)	FLOW OUT OF STAGE	ITERA-TIONS	TEMP DEG C
1	3.691E 01	2.414E 00	9.027E-02	1.834E 00	1.	25.0
2	3.997E 01	3.106E 00	8.075E-02	1.836E 00	1.	25.0
3	4.091E 01	3.479E 00	8.736E-02	1.837E 00	1.	25.0
4	4.086E 01	3.542E 00	1.282E-01	1.840E 00	1.	25.0
5	1.360E 01	3.265E 00	2.958E-01	1.834E 00	1.	25.0
6	1.017E 00	6.830E-01	3.859E-01	1.830E 00	1.	25.0
7	4.724E-02	8.876E-02	3.952E-01	1.829E 00	1.	25.0
8	2.103E-03	1.106E-02	3.958E-01	1.829E 00	1.	25.0
9	9.334E-05	1.372E-03	3.950E-01	1.829E 00	1.	25.0
10	4.140E-06	1.681E-04	3.887E-01	1.828E 00	1.	25.0
11	1.775E-07	1.860E-05	3.399E-01	1.825E 00	1.	25.0

99.90 PERCENT STEADY STATE BY OVERALL MATERIAL BALANCE
90.0 PERCENT OF STEADY STATE AFTER TIME INTERVAL 20
95.0 PERCENT OF STEADY STATE AFTER TIME INTERVAL 28
99.0 PERCENT OF STEADY STATE AFTER TIME INTERVAL 50
99.5 PERCENT OF STEADY STATE AFTER TIME INTERVAL 60

TOTAL G/L URANIUM IN: 6.7700E 01, OUT: 6.7690E 01
TOTAL G/L PLUTONIUM IN: 4.4300E 00, OUT: 4.4256E 00
TOTAL MOLES HNO3 IN: 3.8000E 00, OUT: 3.8001E 00

OUTPUT -- CASE 2

CALCULATIONS FOR A SOLVENT EXTRACTION PROCESS HAVING 3 INTERACTING SOLUTES PU EXTRACTION

FEED STREAM DATA	STAGE NO.	URANIUM (G/L)	PLUTONIUM (G/L)	HNO3 (M)	SALT NO3 (M)	FLOW RATE (VOL.UNITS)	TEMP DEG C
AQUEOUS	1	0.0	0.0	2.0000E 00	0.0	1.100E-01	25.0
AQUEOUS	4	0.0	1.920CE 01	4.1000E 00	0.0	1.000E 00	25.0
15.0 - TBP	10	0.0	0.0	0.0	0.0	9.000E-01	25.0

INITIAL PROFILE	STAGE NO. (OUTFLOW)	AQUEOUS PHASE URANIUM (G/L)	PLUTONIUM (G/L)	HNO3 (M)	ORGANIC PHASE URANIUM (G/L)	PLUTONIUM (G/L)	HNO3 (M)	TEMP DEG C
	1	0.0	0.0	2.1317E 00	0.0	0.0	0.0	25.0
	2	0.0	0.0	2.1317E 00	0.0	0.0	0.0	25.0
	3	0.0	0.0	2.1317E 00	0.0	0.0	0.0	25.0
	4	0.0	0.0	2.1317E 00	0.0	0.0	0.0	25.0
	5	0.0	0.0	2.1317E 00	0.0	0.0	0.0	25.0
	6	0.0	0.0	2.1317E 00	0.0	0.0	0.0	25.0
	7	0.0	0.0	2.1317E 00	0.0	0.0	0.0	25.0
	8	0.0	0.0	2.1317E 00	0.0	0.0	0.0	25.0
	9	0.0	0.0	2.1317E 00	0.0	0.0	0.0	25.0
	10	0.0	0.0	2.1317E 00	0.0	0.0	0.0	25.0

PHASE RATIOS EQUAL FLOW RATIOS

STAGE NO.	A/O PHASE RATIO
1 - 3	1.150E-01
4 - 10	1.076E 00

STAGE FLOWS (SOLUTE-FREE VOLUMES):

STAGE NO.	FLOW RATIO	FLOW OUT OF STAGE	AQUEOUS PHASE RECYCLE 2 TO FILL STAGE	RECYCLE 1 FOR PHASE RATIO	TOTAL AQUEOUS FLOW
1	1.150E-01	1.032E-01	0.0	0.0	1.032E-01
2	1.150E-01	1.032E-01	0.0	0.0	1.032E-01
3	1.150E-01	1.032E-01	0.0	0.0	1.032E-01
4	1.076E 00	9.661E-01	0.0	0.0	9.661E-01
5	1.076E 00	9.661E-01	0.0	0.0	9.661E-01
6	1.076E 00	9.661E-01	0.0	0.0	9.661E-01
7	1.076E 00	9.661E-01	0.0	0.0	9.661E-01
8	1.076E 00	9.661E-01	0.0	0.0	9.661E-01
9	1.076E 00	9.661E-01	0.0	0.0	9.661E-01
10	1.076E 00	9.661E-01	0.0	0.0	9.661E-01

STAGE NO.	OVERALL TOTAL STAGE FLOW	STAGE VOL.	FLOW OUT OF STAGE	ORGANIC PHASE RECYCLE 2 TO FILL STAGE	RECYCLE 1 FOR PHASE RATIO	TOTAL ORGANIC FLOW
1	1.001E 00	0.0	8.975E-01	0.0	0.0	8.975E-01
2	1.001E 00	0.0	8.975E-01	0.0	0.0	8.975E-01
3	1.001E 00	0.0	8.975E-01	0.0	0.0	8.975E-01
4	1.864E 00	0.0	8.975E-01	0.0	0.0	8.975E-01
5	1.864E 00	0.0	8.975E-01	0.0	0.0	8.975E-01
6	1.864E 00	0.0	8.975E-01	0.0	0.0	8.975E-01
7	1.864E 00	0.0	8.975E-01	0.0	0.0	8.975E-01
8	1.864E 00	0.0	8.975E-01	0.0	0.0	8.975E-01
9	1.864E 00	0.0	8.975E-01	0.0	0.0	8.975E-01
10	1.864E 00	0.0	8.975E-01	0.0	0.0	8.975E-01

TRANSIENT BEHAVIOR RESULTS SOLUTE CONCENTRATIONS IN EFFLUENT FROM EACH STAGE

AQUEOUS PHASE

TIME INTERVAL	STAGE NO.	URANIUM (G/L)	PLUTONIUM (G/L)	HNO3 (M)	FLOW OUT OF STAGE
1	1	0.0	0.0	1.153E 00	1.070E-01
	2	0.0	0.0	1.153E 00	1.070E-01
	3	0.0	0.0	1.153E 00	1.070E-01
	4	0.0	4.183E 00	3.686E 00	1.093E 00
	5	0.0	0.0	1.834E 00	1.024E 00
	6	0.0	0.0	1.834E 00	1.024E 00
	7	0.0	0.0	1.834E 00	1.024E 00
	8	0.0	0.0	1.834E 00	1.024E 00
	9	0.0	0.0	1.834E 00	1.024E 00
	10	0.0	0.0	1.834E 00	1.024E 00

ORGANIC PHASE

STAGE NO.	URANIUM (G/L)	PLUTONIUM (G/L)	HNO3 (M)	FLOW OUT OF STAGE	ITERA-TIONS	TEMP DEG C
1	0.0	0.0	1.069E-01	9.038E-01	5.	25.0
2	0.0	0.0	1.069E-01	9.038E-01	5.	25.0
3	0.0	0.0	1.069E-01	9.038E-01	5.	25.0
4	0.0	1.591E 01	3.171E-01	9.195E-01	7.	25.0
5	0.0	0.0	2.000E-01	9.072E-01	3.	25.0
6	0.0	0.0	2.000E-01	9.072E-01	3.	25.0
7	0.0	0.0	2.000E-01	9.072E-01	3.	25.0
8	0.0	0.0	2.000E-01	9.072E-01	3.	25.0
9	0.0	0.0	2.000E-01	9.072E-01	3.	25.0
10	0.0	0.0	2.000E-01	9.072E-01	3.	25.0

AQUEOUS PHASE

TIME INTERVAL	STAGE NO.	URANIUM (G/L)	PLUTONIUM (G/L)	HNO3 (M)	FLOW OUT OF STAGE
2	1	0.0	0.0	1.562E 00	1.084E-01
	2	0.0	0.0	1.153E 00	1.070E-01
	3	0.0	8.002E 00	2.164E 00	1.111E-01
	4	0.0	4.129E 00	3.752E 00	1.096E 00
	5	0.0	7.671E-01	3.556E 00	1.086E 00
	6	0.0	0.0	1.834E 00	1.024E 00
	7	0.0	0.0	1.834E 00	1.024E 00
	8	0.0	0.0	1.834E 00	1.024E 00
	9	0.0	0.0	1.834E 00	1.024E 00
	10	0.0	0.0	1.683E 00	1.019E 00

ORGANIC PHASE

STAGE NO.	URANIUM (G/L)	PLUTONIUM (G/L)	HNO3 (M)	FLOW OUT OF STAGE	ITERA-TIONS	TEMP DEG C
1	0.0	0.0	1.626E-01	9.059E-01	4.	25.0
2	0.0	0.0	1.069E-01	9.038E-01	1.	25.0
3	0.0	1.503E 01	1.908E-01	9.144E-01	8.	25.0
4	0.0	1.596E 01	3.207E-01	9.197E-01	4.	25.0
5	0.0	4.082E 00	3.811E-01	9.160E-01	5.	25.0
6	0.0	0.0	2.000E-01	9.072E-01	1.	25.0
7	0.0	0.0	2.000E-01	9.072E-01	1.	25.0
8	0.0	0.0	2.000E-01	9.072E-01	1.	25.0
9	0.0	0.0	2.000E-01	9.072E-01	1.	25.0
10	0.0	0.0	1.793E-01	9.065E-01	3.	25.0

AQUEOUS PHASE

TIME INTERVAL	STAGE NO.	URANIUM (G/L)	PLUTONIUM (G/L)	HNO3 (M)	FLOW OUT OF STAGE
3	1	0.0	0.0	1.562E 00	1.084E-01
	2	0.0	9.507E 00	1.817E 00	1.099E-01
	3	0.0	7.944E 00	2.180E 00	1.112E-01
	4	0.0	5.396E 00	3.984E 00	1.105E 00
	5	0.0	7.450E-01	3.618E 00	1.088E 00
	6	0.0	1.356E-01	3.414E 00	1.080E 00
	7	0.0	0.0	1.834E 00	1.024E 00
	8	0.0	0.0	1.834E 00	1.024E 00
	9	0.0	0.0	1.818E 00	1.024E 00
	10	0.0	0.0	1.683E 00	1.019E 00

ORGANIC PHASE

STAGE NO.	URANIUM (G/L)	PLUTONIUM (G/L)	HNO3 (M)	FLOW OUT OF STAGE	ITERA-TIONS	TEMP DEG C
1	0.0	0.0	1.626E-01	9.059E-01	1.	25.0
2	0.0	1.391E 01	1.579E-01	9.126E-01	7.	25.0
3	0.0	1.508E 01	1.923E-01	9.145E-01	4.	25.0
4	0.0	1.939E 01	3.104E-01	9.211E-01	6.	25.0
5	0.0	4.052E 00	3.865E-01	9.161E-01	4.	25.0
6	0.0	7.506E-01	3.885E-01	9.146E-01	4.	25.0
7	0.0	0.0	2.000E-01	9.072E-01	1.	25.0
8	0.0	0.0	2.000E-01	9.072E-01	1.	25.0
9	0.0	0.0	1.979E-01	9.072E-01	2.	25.0
10	0.0	0.0	1.793E-01	9.065E-01	1.	25.0

INTERMEDIATE STATES OMITTED TO SAVE SPACE

AQUEOUS PHASE

TIME INTERVAL	STAGE NO.	URANIUM (G/L)	PLUTONIUM (G/L)	HNO3 (M)	FLOW OUT OF STAGE
24	1	0.0	1.331E 01	2.152E 00	1.114E-01
	2	0.0	1.240E 01	2.463E 00	1.125E-01
	3	0.0	9.586E 00	2.965E 00	1.143E-01
	4	0.0	6.678E 00	4.079E 00	1.110E 00
	5	0.0	1.456E 00	4.122E 00	1.108E 00
	6	0.0	2.616E-01	4.131E 00	1.108E 00
	7	0.0	4.509E-02	4.133E 00	1.108E 00
	8	0.0	7.667E-03	4.133E 00	1.107E 00
	9	0.0	1.282E-03	4.116E 00	1.107E 00
	10	0.0	2.014E-04	3.804E 00	1.095E 00

ORGANIC PHASE

STAGE NO.	URANIUM (G/L)	PLUTONIUM (G/L)	HNO3 (M)	FLOW OUT OF STAGE	ITERATIONS	TEMP DEG C
1	0.0	2.093E 01	1.691E-01	9.165E-01	1.	25.0
2	0.0	2.251E 01	1.903E-01	9.161E-01	1.	25.0
3	0.0	2.238E 01	2.306E-01	9.196E-01	1.	25.0
4	0.0	2.200E 01	2.968E-01	9.219E-01	1.	25.0
5	0.0	8.066E 00	3.945E-01	9.165E-01	1.	25.0
6	0.0	1.757E 00	4.382E-01	9.169E-01	1.	25.0
7	0.0	3.156E-01	4.481E-01	9.166E-01	2.	25.0
8	0.0	5.405E-02	4.499E-01	9.165E-01	1.	25.0
9	0.0	9.014E-03	4.491E-01	9.164E-01	2.	25.0
10	0.0	1.301E-03	4.269E-01	9.156E-01	1.	25.0

99.90 PERCENT STEADY STATE BY OVERALL MATERIAL BALANCE
90.0 PERCENT OF STEADY STATE AFTER TIME INTERVAL 10
95.0 PERCENT OF STEADY STATE AFTER TIME INTERVAL 11
99.0 PERCENT OF STEADY STATE AFTER TIME INTERVAL 16
99.5 PERCENT OF STEADY STATE AFTER TIME INTERVAL 18

TOTAL G/L URANIUM IN: 0.0 , OUT: 0.0
TOTAL G/L PLUTONIUM IN: 1.9200E 01, OUT: 1.9182E 01
TOTAL MOLES HNO3 IN: 4.3200E 00, OUT: 4.3199E 00

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