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ORNL-1837

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

S. B. Watson R. H. Rainey

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Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
Price: Printed Copy \$5.45; Microfiche \$2.25

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ORNL-TM-5123
UC-77 - Gas-Cooled
Reactor Technology

Contract No. W-7405-eng-26

COMPUTER SCIENCES DIVISION
CHEMICAL TECHNOLOGY DIVISION

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THE PUREX SOLVENT EXTRACTION SYSTEM

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DECEMBER 1975

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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. Groenier¹ 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 Richardson² 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 ORGRAPH⁵ 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):

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

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

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

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

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

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

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

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

$$U_{os} = \frac{0.5T}{1.0 + 0.046T} \quad (5)$$

$$Pu_{os} = \frac{0.5T}{1.0 + 0.09T} \quad (6)$$

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

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:

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

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

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

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

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 equations²:

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

$$K_{hl}^* = 0.135n_a^{0.82} + 0.0052n_a^{3.44} \quad (13)$$

$$K_{h2}^* \approx K_{h2}^* \quad (14)$$

where

$$n_a = h_a + 2u_a + 4pu_a + s_a \quad (15)$$

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

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

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

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

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

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

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:

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

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

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

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

Free (uncomplexed) TBP concentration is calculated as follows:

$$\begin{aligned} (TBP)_o = T - 2(UO_2(NO_3)_2 \cdot 2TBP)_o - 2(Pu(NO_3)_4 \cdot 2TBP)_o \\ - (HNO_3 \cdot TBP)_o - 2(HNO_3 \cdot 2TBP)_o. \end{aligned} \quad (24)$$

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

$$\begin{aligned} (TBP)_o = T - 2K_u (TBP)_o^2 - 2K_{pu} (TBP)_o^2 - K_{h1} (TBP)_o \\ - 2K_{h2} (TBP)_o^2. \end{aligned}$$

Solving the quadratic equation gives

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

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 $(\text{TBP})_o$ 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.
<u>Program Cards</u>			
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.
<u>Feed Stream Cards</u>			
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)
<u>Initial Profile Cards</u> (required only for non-zero initial profile)			
PRØFIL	One card for each stage	1-8	FØRMAT (8F8.0) 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 (<u>M</u>)
		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 (<u>M</u>)
		49-56	TPRØF(J,1) - temperature in stage J
		57-64	X(4,J,1) - aqueous-phase nitrate concentration in stage J (<u>M</u>)
<u>Outgoing Stream Data</u> (other than aqueous raffinate and organic product)			
FLØWS	One card for each out-going 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.
<u>Phase Ratio Cards</u> (used only if phase ratio $\neq$ 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
<u>Stage Volumes</u> (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	1	1-8	For IVØL=3 stage volumes are equal and specified FØRMAT (F8.0) VØL - stage volume for all stages
<u>Graph Cards</u> (ICALPL=1,2,3)			
PLØTR	1	1-80	<u>Profile graphs</u> (ICALPL=1 or 3) FØRMAT (10A8) TTL - title for all profile graphs
	2	1-80	FØRMAT (10A8) XTAG - x-axis label for all profile graphs
	One card for each profile graph	1-80	FØRMAT (10A8) YTAG - y-axis label for each profile graph
			<u>Transient graphs</u> (ICALPL=2 or 3)
	1	1-2	FØRMAT (25I2) 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 \$.			
<u>Next Case</u>			
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

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

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

³SEPHIS 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/ft²

Volume of a Theoretical Stage

$$\begin{aligned} & \left[\left(\frac{6.065}{2} \right)^2 \times \pi \times 3.2 \times 12 \right] - \left[\left(\frac{6}{2} \right)^2 \times \pi \times 0.125 \times \frac{3.2 \times 12}{2} \times 0.77 \right] \\ & + 3 \left[\left(\frac{.25}{2} \right)^2 \times \pi \times 3.2 \times 12 \right] = 1047 \text{ in.}^3 \text{ or } 0.6059 \text{ ft.}^3 \end{aligned}$$

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 SEPHEIS
C ORNL MODIFICATION OF THE RICHARDSON-NANCE 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
C
C DIMENSION TITLE(10)
C DIMENSION AOUT(25),OOUT(25),STVOL(25),DF(4),SOLIN(3),SOLCUT(3),
C 1 AOUT(25),ORGOUT(25)
C DIMENSION AA(25),TT(25),OO(25),RATIO(25)
C DIMENSION CPA(4),CPO(4)
C COMMON/FLWS/ IRATIO,IOUT,IVOL,RECY(25),ICHNGE,ALVRT(25),OLVRT(25)
C COMMON/STGS/ NSOLU,CODUM(25),AR(25),OR(25),AT(25),OT(25)
C COMMON/FEED/ NTOST,AFDRT(25),OPDET(25)
C COMMON/PROF/ IPRO,X(4,25,2),Y(4,25,2),XPD(4,25),YFD(4,25),
C 1 TPROF(25,2),AFDTEM(25),OPDTEM(25)
C COMMON/REC/ A(25),O(25),RAIO(25),RCYCA(25),RCYCO(25)
C COMMON/DIST/ CTBP,ARY(4),DTRY(4),TO,RN(25,2),RNP(25)
C
C NSOLU = 4
C
C NEXT CASE IS NEW
C
C 10 CONTINUE
C READ 1001,TITLE,CTBP,NTOST,IPRO,IRATIO,ICALC,IOUT,IVOL,IPR,IPNCH,
C 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 VOLUMES 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 ZEROING OF ARRAYS
C
C DO 15 J=1,NTOST
C CODUM(J)=0.0
C STVOL(J) = 0.0
C DO 15 K=1,2
C RN(J,K) = 0.0
C TPROF(J,K) = 25.0
C DO 15 I=1,NSOLU
C DF(I) = 0.0
C X(I,J,K) = 0.0
C Y(I,J,K) = 0.0
C 15 CONTINUE
C ICHNGE = 0
C
C NEXT CASE INVOLVES ONLY A CHANGE IN FEED FLOWS, COMP,TEMP
C
C 20 CONTINUE
C DO 25 J=1,NTOST
C A(J) = 0.0
C O(J) = 0.0
C AFDRT(J) = 0.0
C OFDRT(J) = 0.0
C ALVRT(J) = 0.0
C OLVRT(J) = 0.0

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      RNPD(J) = 0.0
      APDTEM(J) = 25.0
      OPDTEM(J) = 25.0
25  CONTINUE
      DO 30 I=1,NSOLU
      CPA(I)=0.
      CFO(I)=0.
      DO 30 J=1,NTOST
      XPD(I,J) = 0.0
      YPD(I,J) = 0.0
30  CONTINUE
C
C
C  PROFIL SETS INITIAL CONCENTRATIONS FOR TIME ZERO, ALSO DEFINES FEED STREAMS
C
C  CALL PRCPIL
C
C  WRITE FEED STREAM DATA
C
C  PRINT 1002, TITLE
C  WRITE(6,1003)
C  DO 40 I=1,NTOST
C  IF(APDRT(I).LE.0.) GO TO 40
C  PRINT 1004,I,XPD(1,I),XPD(2,I),XPD(3,I),XPD(4,I),APDRT(I),
C  1  APDTEM(I)
C
C
C  CONVERT TO MOLARITY
C
C  XPD(1,I)=XPD(1,I)/238.
C  XPD(2,I)=XPD(2,I)/239.
C  AQUEOUS STAGE FLOW RATES (APDRT) AND AQUEOUS CONTENT
C  OF STAGE (XPD) CONVERTED FROM VOLUME UNITS TO
C  SOLUTE-FREE VOLUME UNITS
C
C  DENOMA = 1.0-0.0724*XPD(1,I)-0.13*XPD(2,I)-0.0309*XPD(3,I)
C  1-.031*XPD(4,I)
C  IF(XPD(2,I).LT.0.) DENOMA = DENOMA + .13*XPD(2,I)
C  APDRT(I) = APDRT(I)* DENOMA
C  DO 35 J = 1,4
C  XPD(J,I) = XPD(J,I)/DENOMA
C  IF(XPD(2,I).LT.0) RNPD(I) = XPD(2,I)
35  CONTINUE
C
C  FO IS MOLARITY OF DRY, SOLUTE-FREE TBP
C
C  40  CONTINUE
C  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
C  US = 0.5*TO/(1.0+0.046*TO)
C  PUS = 0.5*TO/(1.0+0.09*TO)
C  DO 50 I=1,NTOST
C
C  SET ACID IN ALL STAGES TO SCRUB ACID CONCENTRATION
C
C  IF(IPRO.EQ.0) X(3,I,1)=XPD(3,1)
C
C  IF(OPDRT(I).LE.0.) GO TO 50
C  PRINT 1005,CTBP,I,YPD(1,I),YPD(2,I),YPD(3,I),YPD(4,I),OPDRT(I),
C  1  OPDTEM(I)
C
C  CONVERT TO MOLARITY
C
C  YPD(1,I)=YPD(1,I)/238.
C  YPD(2,I)=YPD(2,I)/239.
C
C  ORGANIC STAGE FLOW (OPDRT) AND ORGANIC CONTENT
C  OF STAGE (YPD) CONVERTED FROM VOLUME UNITS TO
C  SOLUTE-FREE VOLUME UNITS
C
C  WO=(3.95-0.0144*OPDTEM(I))*CTBP**1.65
C  HS= TO* (1.0-0.00609*WO)/(1.0+0.043*TO)
C  WC = WO*(1.0-YPD(1,I)/US-YPD(2,I)/PUS-0.65*YPD(3,I)/HS)
C  DENOMO= 1.0-0.097*YPD(1,I)-0.139*YPD(2,I)-.043*YPD(3,I)-0.0174*WC
C  OPDRT(I) =OPDRT(I)*DENOMO
C  DO 45 J=1,3
C  YPD(J,I) = YPD(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
C  50  CONTINUE
C  CALL FLOWS(STVOL)
C
C  PRINT OUTGOING STREAMS (ALVRT AND OLVRT) IN SOLUTE-FREE VOLUME UNITS

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C
C
C IF NO EXTRA OUTGOING STREAMS, AVOID PRINT OF ALVRT AND OLVRT
C
C   IF(IOUT.EQ.0) GO TO 65
C
C   PRINT 1006
C   DO 55 I=1,NTOST
C   IF(ALVRT(I).LE.0.) GO TO 55
C   PRINT 1007,I,ALVRT(I)
55  CONTINUE
C   DO 60 I=1,NTOST
C   IF(OLVRT(I).LE.0.) GO TO 60
C   PRINT 1008,I,OLVRT(I)
60  CONTINUE
C
C PRINT INITIAL PROFILE BEFORE UNIT CONVERSION
C
C   CONTINUE
C   PRINT 1009
C   DO 70 J=1,NTOST
C   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)
C   ,TPROP(J,1)
70  CONTINUE
C
C CHECK FOR NON-ZERO INITIAL PROFILE
C
C   IF(IPRO.EQ.0.AND.ICHNGE.EQ.0) GO TO 85
C
C   DO 80 J=1,NTOST
C
C   CONVERT TO MOLARITY
C
C   X(1,J,1)=X(1,J,1)/238.
C   Y(1,J,1)=Y(1,J,1)/238.
C   X(2,J,1)=X(2,J,1)/239.
C   Y(2,J,1)=Y(2,J,1)/239.
C
C   CONVERT INITIAL PROFILE (X AND Y) TO SOLUTE-FREE CONCENTRATIONS
C
C   DENOMA=1.0-0.0724*X(1,J,1)-0.13*X(2,J,1)-0.0309*X(3,J,1)
C   - 0.031*X(4,J,1)
C   WO = (3.95 - 0.0144*TPROP(J,1))*CTBP**1.65
C   HS= TO*(1.0-0.00609*WO)/(1.0+0.043*TO)
C   WC=WO*(1.0-Y(1,J,1)/US-Y(2,J,1)/PUS-0.65*Y(3,J,1)/HS)
C   DENOMO=1.0-0.097*Y(1,J,1)-0.139*Y(2,J,1)-0.043*Y(3,J,1)-0.0174*WC
C   DO 75 I = 1,4
C   X(I,J,1)=X(I,J,1)/DENOMA
C   Y(I,J,1)=Y(I,J,1)/DENOMO
75  CONTINUE
C
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
C   CONTINUE
85  CONTINUE
C
C PRINT APPROPRIATE TITLE FOR IRATIO
C
C   IF(IRATIO.EQ.0) GO TO 90
C   PRINT 1011
C   GO TO 95
90  CONTINUE
C   PRINT 1012
95  CONTINUE
C
C PRINT PHASE RATIOS
C
C   DO 110 I=1,NTOST
C   IF(I.EQ.1) GO TO 100
C   IF(PRATIO.EQ.RAIO(I)) GO TO 105
C   IK=I-1
C   PRINT 1013,NST,IK,PRATIO
100  CONTINUE
C   PRATIO=RAIO(I)
C   NST=I
105  CONTINUE
C   IF(I.LT.NTOST) GO TO 110
C   PRINT 1013,NST,I,PRATIO
110  CONTINUE
C   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)*RATIO(I)/(1.0+RATIO(I))
OR(I) = RECY(I)/(1.0+RATIO(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),CT(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(DP(1),DP(2),DP(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)+OPDRT(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
TPROP(J,1)=TPROP(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
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

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      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
      DFI(I)=0.
      GO TO 180
175  CONTINUE
      DFI(I)=ABS((SOLIN(I)-SOLOUT(I))/SOLIN(I))
180  CONTINUE
      ADF = AMAX1(DFI(1),DFI(2),DFI(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 99% STEADY STATE AND ICEN=0
C
      IF(DDF.LT.0.010) GO TO 200
      JJK=K+100*ICEN
      PPDF = 100.*(1.0 - DDF)
      DDF = 0.005
      GO TO 210
C
C IF 99.5% STEADY 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 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)

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      WOH=(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*WOH
      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))
      CPO(JJ)=AMAX1(Y(JJ,J,2),CPO(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 N,PERFORM STAGE CALCULATIONS FOR ANOTHER
C  TIME INTERVAL
C
      IF(K.LE.N) GO TO 145
C
C  IF SHUTDOWN (ICALC=0), BYPASS PRINTOUT OF PERCENT STEADY STATE
C
      IF (ICALC.EQ.0) GO TO 260
C
C  PRINT PERCENT STEADY STATE AFTER EVERY 100 TIME INTERVALS
C  AND OTHER CASES WHEN K=N
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

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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*ICEN,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 TPROP(J,1),X(4,J,1)
275 CONTINUE
C
C READ NEXT CASE
C
280 CONTINUE
    READ 1034,ICHNGE,IDIIF
    IF (IDIIF.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('1 CALCULATIONS FOR A SOLVENT EXTRACTION PROCESS',
1 ' HAVING 3 INTERACTING SOLUTES',16X,10A4)
1003 FORMAT('0 FEED 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',14,4(3X,1PE10.4),3X,E9.3,3X,OPF7.1)
1005 FORMAT(19X,2PF6.1,' - TBP',14,4(3X,1PE10.4),3X,E9.3,
1 3X,OPF7.1)
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('0 INITIAL 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,14,6(3X,1PE10.4),3X,OPF6.1)
1011 FORMAT('OPHASE RATIOS DO NOT EQUAL FLOW RATIOS',3X,
1 'STAGE NO.',2X,'A/C PHASE RATIO',/)
1012 FORMAT('OPHASE RATIOS EQUAL FLOW RATIOS',11X,'STAGE NO.',
1 2X,'A/O PHASE RATIO',/)
1013 FORMAT(40X,14,1PE10.3)
1014 FORMAT(/,9X,'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',/,14X,'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',/,10X,'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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CC

CCC

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C          DO 35 J=1,NTOST                PROF 530
          TPROF(J,1)=APDTEM(1)            PROF 540
35        CONTINUE                        PROF 550
          RETURN                          PROF 560
C          FOR A NON-ZERO INITIAL PROFILE, VALUES ARE NOW READ    PROF 570
C          CONTINUE                        PROF 580
          DO 45 J=1,NTOST                PROF 590
          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 600
          IF (TPROF(J,1).EQ.0.) TPROF(J,1)=25.0    PROF 610
45        CONTINUE                        PROF 620
C          1001 FORMAT(2I2,5P8.0,I2,P8.0)    PROF 630
C          1002 FORMAT (8P8.0)                PROF 640
C          RETURN                          PROF 650
          END                            PROF 660
          PROF 670
          PROF 680
          PROF 690
          PROF 700
          PROF 710
          PROF 720
          PROF 730

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          SUBROUTINE FLOWS(STVOL)          FLOWS 10
          COMMON/PLWS/ IRATIO,IOUT,IVOL,RECY(25),ICHNGE,ALVRT(25),OLVRT(25) FLOWS 20
          COMMON/FEED/ NTOST,APDRT(25),OPDRT(25) FLOWS 30
          COMMON/REC/ A(25),O(25),RAIO(25),RCYCA(25),RCYCO(25) FLOWS 40
          DIMENSION STVOL(25)             FLOWS 50
          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          IF(IOUT.EQ.0) GO TO 25             FLOW 150
C          READ OUTGOING STREAM DATA         FLOW 160
C          FLOW 170
C          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          ORGANIC STREAM                    FLOW 240
C          OLVRT(I)=OTRT                     FLOW 250
C          GO TO 20                          FLOW 260
C          AQUEOUS STREAM                    FLOW 270
C          15 CONTINUE                       FLOW 280
          ALVRT(I)=OTRT                     FLOW 290
C          MORE CARDS?                       FLOW 300
C          20 CONTINUE                       FLOW 310
          IF(INDEX.EQ.1) GO TO 10           FLOW 320
C          WE DO NOT PROVIDE FOR RETURNING STREAMS FLOW 330
C          FLOW 340
C          FLOW 350
C          FLOW 360
C          SET AQUEOUS AND ORGANIC INTERSTAGE FLOW (A AND O) FLOW 370
C          FLOW 380
25        CONTINUE                         FLOW 390
          DO 35 I=1,NTOST                  FLOW 400
          IF(I.GT.1) GO TO 30              FLOW 410
          A(I)=APDRT(I)-ALVRT(I)           FLOW 420
          O(NTOST)=OPDRT(NTOST)-OLVRT(NTOST) FLOW 430
          GO TO 35                         FLOW 440
30        CONTINUE                         FLOW 450
          A(I)=A(I-1)+APDRT(I)-ALVRT(I)    FLOW 460
          NST = NTOST+1-I                  FLOW 470
          O(NST) = O(NST+1)+OPDRT(NST)-OLVRT(NST) FLOW 480
35        CONTINUE                         FLOW 490
C          THE INTERSTAGE FLOWS ARE NOW SET FLOW 500
C          FLOW 510
C          DEFINE PHASE RATIOS              FLOW 520
C          DO 40 I=1,NTOST                  FLOW 530
          RCYCA(I) = 0.0                  FLOW 540
          RCYCO(I) = 0.0                  FLOW 550
40        CONTINUE                         FLOW 560
          FLOW 570
          FLOW 580
          FLOW 590
          FLOW 600
          FLOW 610
          FLOW 620
          FLOW 630
          FLOW 640

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      FLOMAX = 0.0
      K = 1
      IF (IRATIO.EQ.1) GO TO 50
C
C  DEFINE PHASE RATIO WHEN IRATIO=0, PHASE RATIO=FLOW RATIO
C
      DO 45 I=1, NTOST
      RAIO(I) = (ALVRT(I) + A(I)) / (OLVRT(I) + O(I))
45    CONTINUE
      GO TO 60
C
C  DO NOT REDEFINE PHASE RATIO IF ICHNGE=1
C
50    CONTINUE
      IF (ICHNGE.EQ.1) GO TO 70
C
C  DEFINE PHASE RATIOS WHEN IRATIO=1, PHASE RATIOS DO NOT EQUAL
C  FLOW RATIOS
C  I=NUMBER OF STAGES HAVING PHASE RATIO SHOWN
C
      READ 1002, I, RATIO
      I=K+I-1
      DO 55 J=K, I
      RAIO(J) = RATIO
55    CONTINUE
      IF (I.EQ. NTOST) GO TO 70
      K=I+1
      GO TO 50
C
C  CALCULATE NECESSARY RECYCLE FLOWS
C  TYPE 1 IS RECYCLE OF ONE PHASE ONLY, TO SATISFY PHASE RATIO
C  USED WHEN IRATIO = 1
C  TYPE 2 IS RECYCLE OF BOTH PHASES WITH PHASE RATIO RAIO(I)
C  TO ALLOW TOTAL STAGE FLOW TO EQUAL FLOMAX
C  USED WHEN IVOL = 0,2
C  RECYCLE VOLUMES AND RATIOS ARE SOLUTE-FREE VALUES
C
C  CALCULATE FLOTOT, RECY, AND FLOMAX FOR IRATIO=0; IVOL=0,2,3
C  FOR IVOL=1, RECY SET TO 0.0
C  FLOTOT - TOTAL FLOW LEAVING STAGE
C  FLOMAX - GREATEST TOTAL FLOW FROM A STAGE
C
60    CONTINUE
      IF (IVOL.EQ.1) GO TO 100
      DO 65 I=1, NTOST
      FLOTOT = ALVRT(I) + A(I) + OLVRT(I) + O(I)
      RECY(I) = FLOTOT
      FLOMAX = AMAX1(FLOTOT, FLOMAX)
65    CONTINUE
      IF (IVOL.EQ.0) GO TO 90
      IF (IVOL.EQ.1) GO TO 100
      IF (IVOL.EQ.2.OR.IVOL.EQ.3) GO TO 110
C
C  CALCULATE FLOTOT, RCYCA, RCYCO, RECY, FLOMAX FOR IRATIO=1
C  AND IVOL=0,1,2,3
C  AFL - TOTAL AQUEOUS FLOW LEAVING A STAGE
C  OPL - TOTAL ORGANIC FLOW LEAVING A STAGE
C  RFL - RATIO OF AQUEOUS TO ORGANIC FLOW LEAVING A STAGE (AFL/OPL)
C  RCYCA - AQUEOUS RECYCLE TO SATISFY PHASE RATIO
C  RCYCO - ORGANIC RECYCLE TO SATISFY PHASE RATIO
C
70    CONTINUE
      DO 85 I=1, NTOST
      AFL = ALVRT(I) + A(I)
      OPL = OLVRT(I) + O(I)
      FLOTOT = AFL + OPL
      RFL = AFL/OPL
C
C  COMPARISON CP FLOW RATIO (RFL) TO PHASE RATIO (RAIO)
C
      IF (RFL.GT.RAIO(I)) GO TO 75
      IF (RFL.EQ.RAIO(I)) GO TO 80
      FLOTOT=FLOTOT*(RAIO(I)+1.0)/(RFL+1.0)
      RCYCA(I) = FLOTOT - AFL - OPL
      GO TO 80
75    CONTINUE
      FLOTOT=FLOTOT*RFL*(RAIO(I)+1.0)/(RAIO(I)*(RFL+1.0))
      RCYCO(I) = FLOTOT - AFL - OPL
80    CONTINUE
      RECY(I)=FLOTOT
      FLOMAX = AMAX1(FLOTOT, FLOMAX)
85    CONTINUE
C
C  FLOMAX CONTAINS THE LARGEST TOTAL FLOW FROM A STAGE - STAGES HAVING AFL
C  TOTAL FLOW LESS THAN FLOMAX MUST EXHIBIT RECYCLE
C  OF TYPE 2
C
      IF (IVOL.EQ.0) GO TO 90
      IF (IVOL.EQ.1) GO TO 100
      IF (IVOL.EQ.2.OR.IVOL.EQ.3) GO TO 110
C
C  IVOL=0; IRATIO=0,1
90    CONTINUE

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FLOW 650
FLOW 660
FLOW 670
FLOW 680
FLOW 690
FLOW 700
FLOW 710
FLOW 720
FLOW 730
FLOW 740
FLOW 750
FLOW 760
FLOW 770
FLOW 780
FLOW 790
FLOW 800
FLOW 810
FLOW 820
FLOW 830
FLOW 840
FLOW 850
FLOW 860
FLOW 870
FLOW 880
FLOW 890
FLOW 900
FLOW 910
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FLOW 940
FLOW 950
FLOW 960
FLOW 970
FLOW 980
FLOW 990
FLO 1000
FLO 1010
FLO 1020
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FLO 1070
FLO 1080
FLO 1090
FLO 1100
FLO 1110
FLO 1120
FLO 1130
FLO 1140
FLO 1150
FLO 1160
FLO 1170
FLO 1180
FLO 1190
FLO 1200
FLO 1210
FLO 1220
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FLO 1370
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FLO 1490
AFLO 1500
FLO 1510
FLO 1520
FLO 1530
FLO 1540
FLO 1550
FLO 1560
FLO 1570
FLO 1580
FLO 1590

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DO 95 I=1,NTOST
  RECY(I) = FLOWMAX - RECY(I)
95 CONTINUE
  RETURN
C
C
C IVOL=1; IRATIO=0,1
C
100 CONTINUE
  DO 105 I=1,NTOST
    RECY(I) = 0.0
  105 CONTINUE
  RETURN
C
C DETERMINE STAGE VOLUME
C STAGE VOLUMES ARE ZERO FOR IVOL=0,1
C
C IF ICHNGE=0, READ STAGE VOLUMES
C IF ICHNGE=1, BYPASS READING OF STAGE VOLUMES
C
110 CONTINUE
  IF(ICHNGE.EQ.1) GO TO 125
  IF(IVOL.EQ.2) GO TO 120
C
C IVOL=3; STAGE VOLUMES ARE EQUAL AND SPECIFIED
C IRATIO=0,1
C
  READ 1003,VOL
  DO 115 J=1,NTOST
    STVOL(J)=VOL
  115 CONTINUE
  GO TO 125
C
C IVOL=2; STAGE VOLUMES ARE INDEPENDENTLY UNEQUAL
C
120 CONTINUE
  READ 1004,(STVOL(J),J=1,NTOST)
C
C STAGE VOLUMES ARE SOLUTE-FREE VOLUMES
C
C CALCULATE LENGTH OF TIME INTERVAL (TIMIN) AND RECY FOR IVOL=2,3
C
125 CONTINUE
  TIMIN=0.0
  DO 130 I=1,NTOST
    RECY(I) = RECY(I)/STVOL(I)
    TIMIN = AMAX1(RECY(I),TIMIN)
  130 CONTINUE
  FLOWMAX = TIMIN
  DO 135 I = 1,NTOST
    RECY(I) = (FLOWMAX - RECY(I))*STVOL(I)
  135 CONTINUE
C
C
1001 FORMAT(2I2,F8.0,I2)
1002 FORMAT(I2,F8.0)
1003 FORMAT(F8.0)
1004 FORMAT(10F8.0)
C
C
  RETURN
  END

```

```

FLO 1600
FLO 1610
FLO 1620
FLO 1630
FLO 1640
FLO 1650
FLO 1660
FLO 1670
FLO 1680
FLO 1690
FLO 1700
FLO 1710
FLO 1720
FLO 1730
FLO 1740
FLO 1750
FLO 1760
FLO 1770
FLO 1780
FLO 1790
FLO 1800
FLO 1810
FLO 1820
FLO 1830
FLO 1840
FLO 1850
FLO 1860
FLO 1870
FLO 1880
FLO 1890
FLO 1900
FLO 1910
FLO 1920
FLO 1930
FLO 1940
FLO 1950
FLO 1960
FLO 1970
FLO 1980
FLO 1990
FLO 2000
FLO 2010
FLO 2020
FLO 2030
FLO 2040
FLO 2050
FLO 2060
FLO 2070
FLO 2080
FLO 2090
FLO 2100
FLO 2110
FLO 2120
FLO 2130
FLO 2140
FLO 2150
FLO 2160
FLO 2170
FLO 2180
FLO 2190
FLO 2200
FLO 2210
FLO 2220
FLO 2230
FLO 2240

```

```

SUBROUTINE STAGES (SPH)
  DIMENSION AIN(4),OIN(4)
  COMMON/STGS/ NSOLU,CODUM(25),AR(25),OR(25),AT(25),OT(25)
  COMMON/FEEC/ NTOST,AFDRT(25),OPDRT(25)
  COMMON/FEOF/ IPRO,X(4,25,2),Y(4,25,2),YFD(4,25),YFD(4,25),
  1 TPROP(25,2),AFDTEM(25),OPDTEM(25)
  COMMON/REC/ A(25),O(25),RAIO(25),RCYCA(25),RCYCO(25)
  COMMON/DIST/ CTBP,ARY(4),DTRY(4),TO,RN(25,2),RNF(25)
C
C PERFORM STAGE CALCULATIONS FOR CURRENT TIME INTERVAL - CONSIDER
C INPUTS FROM ADJACENT STAGES, FEED STREAMS, AND MOST IMPORTANTLY
C RECYCLE WITHIN THE STAGE - RECYCLE A RESULT OF STAGE FLOW BEING
C LESS THAN FLOWMAX (TYPE 2) AND PHASE RATIO NOT EQUAL TO FLOW
C RATIO (TYPE 1)
C
C AR - AQUEOUS RECYCLE TO FILL STAGE
C OR - ORGANIC RECYCLE TO FILL STAGE
C RCYCA - AQUEOUS RECYCLE TO SATISFY PHASE RATIO
C RCYCO - ORGANIC RECYCLE TO SATISFY PHASE RATIO
C AT - TOTAL AQUEOUS FLOW WITHIN A STAGE =

```

```

STAGE 10
STAGE 20
STAGE 30
STAGE 40
STAGE 50
STAGE 51
STAGE 60
STAGE 70
STAGE 80
STAGE 90
STAG 100
STAG 110
STAG 120
STAG 130
STAG 140
STAG 150
STAG 160
STAG 170
STAG 180
STAG 190

```



```

      IF(MCK.EQ.20) GO TO 75
C
C IF ALL SOLUTES HAVE NOT CONVERGED, REPEAT CALL TO UCOR
C WITH NEW VALUES OF ARY
C
      IF(MDEX.GT.0) GO TO 65
75  CONTINUE
      DO 80 I=1,NSOLU
      Y(I,J,2)=X(I,J,2)*DTRY(I)
80  CONTINUE
      CODUM(J)=MCK
85  CONTINUE
90  RETURN
      END

```

```

STA 1100
STA 1110
STA 1120
STA 1130
STA 1140
STA 1150
STA 1160
STA 1170
STA 1180
STA 1190
STA 1200
STA 1210
STA 1220
STA 1230

```

```

      SUBROUTINE UCOR(TEMPC,J)
      COMMON/IST/ CTBP,ARY(4),DTRY(4),TO,RN(25,2),RNPD(25)
C
C UCOR RETURNS A VALUE OF THE DISTRIBUTION COEFFICIENT = Y/X FOR EACH
C VALUE OF X TRIED
C
      PUTOT=ARY(2)-RN(J,2)
      F=CTBP
      UAM = ARY(1)
      PUAM = ARY(2)
      HAM = ARY(3)
      SNITR = ARY(4)
      IF(UAM.LT.0) UAM = 0.
      IF(PUAM.LT.0) PUAM = 0.
      IF(HAM.LT.0) HAM = 0.
      IF(SNITR.LT.0) SNITR = 0.
      PUIII = PUTOT - PUAM
      IF(PUIII.LT.0) PUIII = 0.
      TNM = HAM + 2.*UAM + 2.*PUAM + SNITR + 4.*PUIII
      IF (TNM.EQ.0.0) TNM = 1.0
      TEMPRK = 1000./(TEMPC + 273.16)
      DRT = TEMPRK - 3.3539
      UK = 3.7*TNM**1.57 + 1.4*TNM**3.9 + 0.011*TNM**7.3
      UK = UK*(4.*P**(-0.17) - 3.)
      PUK = UK*(.20 + .55*P**1.25 + .0074*TNM**2)
      HK1 = 0.135*TNM**0.82 + 0.0052*TNM**3.44
      IF (P.LT.1.) HK1 = HK1*(1. - 0.54*EXP(-15.*P))
      IF (TEMPC.NE.25.) UK = UK*EXP(2.5*DRT)
      IF (TEMPC.NE.25.) PUK = PUK*EXP(-.2*DRT)
      IF (TEMPC.NE.25.) HK1 = HK1*EXP(0.34*DRT)
      HK2 = HK1
      A = 2.*(UK*UAM + PUK*PUAM + HK2*HAM)
      B = HK1*HAM + 1.
      C = -TO
      IF(A.GE.1.E-6) GO TO 10
      TF=-C/B
      GO TO 15
10  CONTINUE
      TF = (-B + SQRT(B**2 - 4.*A*C))/(2.*A)
15  CONTINUE
      DH1 = HK1*TF
      DH2 = HK2*TF**2
      DH = DH1 + DH2
      DU = UK*TF**2
      DPU = PUK*TF**2
      DTRY(1) = DU
      DTRY(2) = DPU
      DTRY(3) = DH
20  RETURN
      END

```

```

UCOR 10
UCOR 20
UCOR 30
UCOR 40
UCOR 50
UCOR 60
UCOR 70
UCOR 80
UCOR 90
UCOR 100
UCOR 110
UCOR 120
UCOR 130
UCOR 140
UCOR 150
UCOR 160
UCOR 170
UCOR 180
UCOR 190
UCOR 200
UCOR 210
UCOR 220
UCOR 230
UCOR 240
UCOR 250
UCOR 260
UCOR 270
UCOR 280
UCOR 290
UCOR 300
UCOR 310
UCOR 320
UCOR 330
UCOR 340
UCOR 350
UCOR 360
UCOR 370
UCOR 380
UCOR 390
UCOR 400
UCOR 410
UCOR 420
UCOR 430
UCOR 440
UCOR 450
UCOR 460
UCOR 470
UCOR 480
UCOR 490
UCOR 500

```

```

      SUBROUTINE PLOTB(KOUNT,ICALPL,NTOST,CFA,CPO)
C
C THIS ROUTINE GENERATES CALCOMP PLOTS OF TWO KINDS:
C ICALPL=1 PROFILE GRAPHS (LOG OF REDUCED CONCENTRATION
C VS STAGE NUMBER)
C ICALPL=2 TRANSIENT GRAPHS (REDUCED CONCENTRATION
C VS TIME FOR A SPECIFIED STAGE)
C
C KOUNT-TOTAL NUMBER OF TIME INTERVALS
C NTOST-TOTAL NUMBER OF STAGES
C CFA AND CPO-MAXIMUM CONCENTRATIONS

```

```

PLOTB 10
PLOTB 20
PLOTB 30
PLOTB 40
PLOTB 50
PLOTB 60
PLOTB 70
PLOTB 80
PLOTB 90
PLOTB 100
PLOTB 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
C DIMENSION CPA(4),CPO(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', ' TIMES ' /,
1 DESCR1(13) / '1/8 OF S', 'TEADY ST', 'ATE TIME', '$1/4 OF ',
2 'STEADY S', 'TATE TIN', 'ES1/2 OF', ' STEADY ',
3 'STATE TI', 'MESSTEAD', 'Y STATE ', 'OPERATIO',
4 'NS' /
INTEGER*4 ISYMB(4) / 1,2,3,4 /
INTEGER*4 ISYMBP(4) / 4,3,2,1 /
C
REAL*8 TLEG2(2) / 'COMPONEN', 'TS$ ' /,
1 DESCR2(4) / 'URANIUMS', 'PLUTONIUM', 'N$NITRIC', ' ACIDS ' /
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) CPA,CPO
DO 25 I=1,KOUNT
DO 25 J=1,NTOST
READ(11) L,X,Y
DO 20 K=1,4
IF(CPA(K).EQ.0.) GO TO 15
X(K)=X(K)/CPA(K)*100.
15 CONTINUE
IF(CPO(K).EQ.0.) GO TO 20
Y(K)=Y(K)/CPO(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.C(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

```

```

PLOT 120
PLOT 130
PLOT 140
PLOT 150
PLOT 160
PLOT 170
PLOT 180
PLOT 190
PLOT 200
PLOT 201
PLOT 202
PLOT 203
PLOT 204
PLOT 210
PLOT 220
PLOT 230
PLOT 240
PLOT 241
PLOT 250
PLOT 260
PLOT 270
PLOT 280
PLOT 290
PLOT 300
PLOT 310
PLOT 320
PLOT 330
PLOT 340
PLOT 350
PLOT 360
PLOT 370
PLOT 380
PLOT 390
PLOT 400
PLOT 410
PLOT 420
PLOT 430
PLOT 440
PLOT 450
PLOT 460
PLOT 470
PLOT 480
PLOT 490
PLOT 500
PLOT 510
PLOT 520
PLOT 530
PLOT 540
PLOT 550
PLOT 560
PLOT 570
PLOT 580
PLOT 590
PLOT 600
PLOT 610
PLOT 620
PLOT 630
PLOT 640
PLOT 650
PLOT 660
PLOT 670
PLOT 680
PLOT 690
PLOT 700
PLOT 710
PLOT 720
PLOT 730
PLOT 740
PLOT 750
PLOT 760
PLOT 770
PLOT 780
PLOT 790
PLOT 800
PLOT 810
PLOT 820
PLOT 830
PLOT 840
PLOT 850
PLOT 860
PLOT 870
PLOT 880
PLOT 881
PLOT 890
PLOT 900
PLOT 910
PLOT 920
PLOT 930
PLOT 940
PLOT 950
PLOT 960
PLOT 970
PLOT 980
PLOT 990
PLOT 1000

```

```

55  CONTINUE                                PLO 1010
C                                         PLO 1020
  CALL FIXPLT(XMIN,XMAX,YMIN,YMAX,'YLOG','MECH',0.,0.,
1  BUFFER,4000,'S.B.WATSON$')           PLO 1030
C                                         PLO 1031
                                         PLO 1040
  READ(5,1003) YTAG                       PLO 1050
  CALL TITLE(0.4,TTL,XTAG,YTAG)          PLO 1060
C                                         PLO 1070
  MNTOST=-NTOST                           PLO 1080
  DO 65 J=1,4                             PLO 1090
  DO 60 II=1,NTOST                         PLO 1100
  IF(A(II,J,I).EQ.0.) CALL PPL(A(1,J,I),4-J+1,NTOST,665) PLO 1110
60  CONTINUE                              PLO 1120
  CALL LINPLT(1.,A(1,J,I),MNTOST,4-J+1,0) PLO 1130
65  CONTINUE                              PLO 1140
                                         PLO 1150
  CALL LEGEND(TLEG1,ISYMBP,4,DESCR1,2,3.,1.5) PLO 1160
C                                         PLO 1170
C  ORGANIC                                PLO 1180
C                                         PLO 1190
  DO 70 II=1,NTOST                         PLO 1200
  DO 70 JJ=1,4                             PLO 1210
  IF(O(II,JJ,I).GT.0.) GC TO 75            PLO 1220
70  CONTINUE                              PLO 1230
  GO TO 90                                PLO 1240
75  CONTINUE                              PLO 1250
C                                         PLO 1260
  CALL FIXPLT(XMIN,XMAX,YMIN,YMAX,'YLOG','MECH',0.,0.,
1  BUFFER,4000,'S.B.WATSON$')           PLO 1270
C                                         PLO 1271
                                         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
                                         PLO 1380
  CALL LEGEND(TLEG1,ISYMBP,4,DESCR1,2,3.,1.5) PLO 1390
C                                         PLO 1400
90  CONTINUE                              PLO 1410
C                                         PLO 1420
  IP(ICALEL.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.,
1  BUFFER,4000,'S.B.WATSON$')           PLO 1680
C                                         PLO 1681
                                         PLO 1690
  READ(5,1003) YTAG                       PLO 1700
  CALL TITLE(0.4,TTL,XTAG,YTAG)          PLO 1710
C                                         PLO 1720
  DO 110 J=1,KOUNT                         PLO 1730
  DO 105 K=1,NTOST                         PLO 1740
  READ(10) L,X,Y                           PLO 1750
  IF(K.NE.NSTA(I)) GO TO 105              PLO 1760
  XPOINT=L                                PLO 1770
  DO 100 II=1,3                            PLO 1780
  CALL PNTPLT(XPOINT,X(II),II,-1)        PLO 1790
100  CONTINUE                              PLO 1800
105  CONTINUE                              PLO 1810
110  CONTINUE                              PLO 1820
  REWIND 10                               PLO 1830
C                                         PLO 1840
  CALL LEGEND(TLEG2,ISYMB,3,DESCR2,2,-3.,1.) PLO 1850
C                                         PLO 1860
C  ORGANIC                                PLO 1870
C                                         PLO 1880
  CALL FIXPLT(XMIN,XMAX,YMIN,YMAX,'LINE','MECH',0.,0.,
1  BUFFER,4000,'S.B.WATSON$')           PLO 1890
C                                         PLO 1891
                                         PLO 1900
  READ(5,1003) YTAG                       PLO 1910

```

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	PPL 130
END	PPL 140

APPENDIX B

Sample Input and Output

Two Examples of Input to SEPHIS

Case 1

Case 2

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	C.C	3.000E-01	25.0
AQUEOUS	4	6.7700E 01	4.4300E 00	3.2000E 00	C.C	1.000E 00	25.0
15.3 - TBE	11	0.0	C.C	0.0	0.0	1.800E 00	25.C

INITIAL PROFILE	STAGE NO.	URANIUM (G/L)	ACUIOUS PHASE PLUTONIUM (G/L)	HNO3 (M)	URANIUM (G/L)	ORGANIC PHASE PLUTONIUM (G/L)	HNO3 (M)	TEMP DEG C
	1	0.0	C.C	2.1317E 00	0.0	0.0	0.0	25.0
	2	0.0	C.C	2.1317E 00	C.C	0.0	0.0	25.0
	3	0.0	0.0	2.1317E 00	C.C	0.0	0.0	25.0
	4	0.0	C.C	2.1317E 00	0.0	0.0	0.0	25.0
	5	0.0	C.C	2.1317E 00	0.0	0.0	0.0	25.0
	6	0.0	0.0	2.1317E 00	C.C	0.0	0.0	25.0
	7	0.0	C.C	2.1317E 00	0.0	0.0	0.0	25.0
	8	0.0	C.C	2.1317E 00	0.0	0.0	0.0	25.0
	9	0.0	0.0	2.1317E 00	C.C	0.0	0.0	25.0
	10	0.0	C.C	2.1317E 00	0.0	0.0	0.0	25.0
	11	0.0	C.C	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	ACUIOUS PHASE RECYCLE 2 TO FILL STAGE	RECYCLE 1 FOR PHASE RATIO	TOTAL AQUEOUS FLOW
1	1.568E-01	2.815E-01	0.0	C.C	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	C.C	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	C.C	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	C.C	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	C.C	1.795E 00
2	2.076E 00	0.0	1.795E 00	0.0	0.0	1.795E 00
3	2.076E 00	C.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	C.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	C.0	1.795E 00	0.0	0.0	1.795E 00
10	2.954E 00	0.0	1.795E 00	0.0	C.C	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

TIME INTERVAL	STAGE NO.	AQUEOUS PHASE			
		URANIUM (G/L)	FIUTONIUM (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-C1
	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

STAGE NO.	ORGANIC PHASE				ITERA- TIONS	TEMP DEG C
	URANIUM (G/L)	FIUTONIUM (G/L)	HNO3 (M)	FLOW OUT OF STAGE		
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

TIME INTERVAL	STAGE NO.	AQUEOUS PHASE			
		URANIUM (G/L)	FIUTONIUM (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-C1
	3	1.224E 01	1.866E 00	1.674E 00	2.563E-01
	4	7.696E 00	1.184E 00	2.829E 00	1.275E 00
	5	4.766E-01	2.076E-01	2.631E 00	1.243E 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

STAGE NO.	ORGANIC PHASE				ITERA- TIONS	TEMP DEG C
	URANIUM (G/L)	FIUTONIUM (G/L)	HNO3 (M)	FLOW OUT OF STAGE		
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	6.954E-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

TIME INTERVAL	STAGE NO.	AQUEOUS PHASE			
		URANIUM (G/L)	FIUTONIUM (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	2.579E-01
	3	1.214E 01	1.865E 00	1.693E 00	2.985E-01
	4	1.114E 01	1.879E 00	3.056E 00	1.267E 00
	5	4.559E-01	1.963E-01	2.700E 00	1.265E 00
	6	2.689E-02	3.388E-C2	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

STAGE NO.	ORGANIC PHASE				ITERA- TIONS	TEMP DEG C
	URANIUM (G/L)	FIUTONIUM (G/L)	HNO3 (M)	FLOW OUT OF STAGE		
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	1.290E 00	9.802E-02	1.828E 00	5.	25.0
4	3.611E 01	2.056E 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

TIME INTERVAL	STAGE NO.	ACQUEOUS PHASE			FICW OUT CF STAGE
		URANIUM (G/L)	PLUTONIUM (G/L)	HNO3 (M)	
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	5.653E-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	1.254E 00
	8	1.319E-04	1.943E-03	3.367E 00	1.294E 00
	9	5.865E-06	2.417E-04	3.358E 00	1.254E 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

STAGE NO.	ORGANIC PHASE			FICW CUT CF STAGE	ITERA- TIONS	TEMP DEG C
	URANIUM (G/L)	PLUTONIUM (G/L)	HNO3 (M)			
1	3.691E 01	2.414E 00	9.027E-02	1.834E 00	1.	25.0
2	3.597E 01	3.106E 00	8.075E-02	1.836E 00	1.	25.0
3	4.091E 01	3.479E 00	6.736E-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	5.952E-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	1.5200E 01	4.1000E 00	0.0	1.000E 00	25.0
15.0 - TBE	10	0.0	0.0	0.0	0.0	9.000E-01	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

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	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	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

TIME INTERVAL	STAGE NO.	URANIUM (G/L)	AQUEOUS PHASE			FLOW OUT OF STAGE	ITERA- TIONS	TEMP DEG C
			FIUTONIUM (G/L)	HNO3 (M)				
1	1	0.0	0.0	1.153E 00		1.070E-C1		
	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		
	STAGE NO.	URANIUM (G/L)	ORGANIC PHASE			FLOW OUT OF STAGE	ITERA- TIONS	TEMP DEG C
			FIUTONIUM (G/L)	HNO3 (M)				
	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 C1	3.171E-01		5.155E-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
TIME INTERVAL	STAGE NO.	URANIUM (G/L)	AQUEOUS PHASE			FLOW OUT OF STAGE	ITERA- TIONS	TEMP DEG C
			FIUTONIUM (G/L)	HNO3 (M)				
2	1	0.0	0.0	1.562E 00		1.084E-01		
	2	0.0	0.0	1.153E 00		1.070E-C1		
	3	0.0	8.002E 00	2.164E 00		1.111E-01		
	4	0.0	4.129E 00	3.752E 00		1.056E 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		
	STAGE NO.	URANIUM (G/L)	ORGANIC PHASE			FLOW OUT OF STAGE	ITERA- TIONS	TEMP DEG C
			FIUTONIUM (G/L)	HNO3 (M)				
	1	0.0	0.0	1.626E-01		5.059E-C1	4.	25.0
	2	0.0	0.0	1.069E-01		9.038E-01	1.	25.0
	3	0.0	1.503E C1	1.908E-01		5.144E-C1	8.	25.0
	4	0.0	1.556E 01	3.207E-01		9.197E-01	4.	25.0
	5	0.0	4.082E 00	3.811E-01		5.160E-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		5.065E-C1	3.	25.0
TIME INTERVAL	STAGE NO.	URANIUM (G/L)	AQUEOUS PHASE			FLOW OUT OF STAGE	ITERA- TIONS	TEMP DEG C
			FIUTONIUM (G/L)	HNO3 (M)				
3	1	0.0	0.0	1.562E 00		1.084E-01		
	2	0.0	9.507E 00	1.817E 00		1.059E-C1		
	3	0.0	7.944E 00	2.180E 00		1.112E-01		
	4	0.0	5.356E 00	3.984E 00		1.105E 00		
	5	0.0	7.450E-C1	3.618E 00		1.088E 00		
	6	0.0	1.356E-C1	3.414E 00		1.060E 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		
	STAGE NO.	URANIUM (G/L)	ORGANIC PHASE			FLOW OUT OF STAGE	ITERA- TIONS	TEMP DEG C
			FIUTONIUM (G/L)	HNO3 (M)				
	1	0.0	0.0	1.626E-01		5.059E-C1	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-C1	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-C1	1.	25.0

INTERMEDIATE STATES OMITTED TO SAVE SPACE

TIME INTERVAL	STAGE NO.	AQUEOUS PHASE			FICW OUT OF STAGE
		URANIUM (G/L)	PLUTONIUM (G/L)	HNO3 (M)	
24	1	0.0	1.331E C1	2.152E 00	1.114E-C1
	2	0.0	1.240E 01	2.463E 00	1.125E-01
	3	0.0	9.586E 00	2.965E 00	1.143E-C1
	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-C2	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	1.055E 00

STAGE NO.	URANIUM (G/L)	ORGANIC PHASE		FICW OUT OF STAGE	ITERA- TIONS	TEMP DEG C
		PLUTONIUM (G/L)	HNO3 (M)			
1	0.0	2.093E 01	1.691E-01	9.165E-01	1.	25.0
2	0.0	2.251E C1	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	5.219E-C1	1.	25.0
5	0.0	8.066E 00	3.945E-01	9.185E-01	1.	25.0
6	0.0	1.757E 00	4.382E-01	5.169E-01	1.	25.0
7	0.0	3.156E-01	4.481E-01	9.166E-01	2.	25.0
8	0.0	5.405E-C2	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	5.156E-C1	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 C1
 TOTAL MOLES HNO3 IN: 4.3200E 00, OUT: 4.3199E 00

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