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Argonne National Laboratory

ENGINEERING DEVELOPMENT OF FLUID-BED FLUORIDE VOLATILITY PROCESSES

Part 9. Computer Programs for Alloy-fuel Process Calculations

by

John T. Holmes and D. Ramaswami

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John T. Holmes and D. Ramaswami

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- Part 1: Bench-scale Investigation of a Process for Zirconium-Uranium Alloy Fuel, by D. Ramaswami, N. M. Levitz, J. T. Holmes, and A. A. Jonke (ANL-6829).
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ABSTRACT

In the processing of uranium alloy fuels, the metal is chlorinated in a bed of alumina particles fluidized by hydrogen chloride gas. The uranium is separated in this step since the alloying metal chlorides are relatively volatile and leave the fluid bed. In the second step, the nonvolatile uranium chlorides are fluorinated with anhydrous hydrogen fluoride and fluorine to give uranium hexafluoride, which is volatile and thus separated from the alumina. During the process studies, three digital-computer programs were developed to calculate material balances and to process experimental data. In the first program, material balances for the hydrochlorination step were calculated for a conceptual plant assuming values for alloy processing rates, equipment efficiencies, and input material flows. The calculated quantities are basic for economic evaluation studies of the hydrochlorination process. In the second program, pressure, temperature, and flow-chart readings from a hydrochlorination-fluorination experiment were used as computer input data from which values of reaction rates, gas utilization, and concentrations were calculated. In the third program, uranium material balances were computed from analytical data, weight, and volumes of materials. Each computer program and an illustrative calculation are presented. The three programs are applicable to other processes, such as the decladding of zirconium or aluminum from low-enriched uranium dioxide fuels.

Computer programs useful in the above applications for data correlation and for predicting properties of materials are outlined briefly.

I. INTRODUCTION

Development studies on fluid-bed fluoride volatility (FBV) reprocessing of highly-enriched uranium-alloy fuels were conducted at Argonne National Laboratory (ANL). These process-development studies at ANL have culminated in the issuance of several topical reports (ANL-6829, ANL-6830, ANL-6973, and ANL-6994) wherein various aspects of the FBV process are described. During these studies, computer programs were developed and used for either processing the data accumulated during runs

or for calculating material flow rates for conceptual process flowsheets. These programs can also be used in the development studies on low-enriched uranium dioxide fuels clad with either zirconium or aluminum.

The FBV reprocessing of highly-enriched uranium-alloy fuels includes two major processing steps which are conducted in fluid beds. The first step involves separation of the cladding and alloying material from the uranium using gaseous HCl to produce relatively nonvolatile uranium chlorides and volatile alloy-

108-8268 Rev. 1

Fig. 1. Volatility Flowsheet for Reprocessing Alloy Fuels

rides and volatile alloy-chlorides. The uranium is recovered as UF_6 by reacting the chlorides with HF followed by fluorine. A schematic FBV flowsheet is shown in Fig. 1.

The development work at ANL was conducted in three fluid-bed facilities: a) a $1\frac{1}{2}$ -in.-diam reactor with nonirradiated fuels to establish

the process operating conditions that would result in recoveries of uranium greater than 99% of that in the charge, b) a 6-in.-diam reactor with non-irradiated fuels to demonstrate this process by means of full-scale fuel subassemblies, and c) a shielded, $1\frac{1}{2}$ -in.-diam system with highly irradiated fuels to establish the decontamination factors and effects of fission products on the process.

The manual computations were laborious and time-consuming, but could be completed in a few minutes with a computer. The formulation of the models, or the sequence for these estimations, was developed with computer programs. The sequence of calculations can be adopted for any other use.

The computer programs presented in this report were useful in analysis and correlation of the run data in all three facilities and also in calculating scaleup flow rates and material balances, which are important in feasibility studies and in economic analyses. Although these programs were developed for specific reaction sequences and equipment sizes, the techniques can be applied to similar processes such as the decladding of low-enrichment fuels, or processes involving volatilization separations. Also, with appropriate modifications, these programs can be used to predict any desirable process changes after a full-scale plant is constructed.

II. CONCEPTUAL FLOWSHEET CALCULATIONS FOR THE HYDROCHLORINATION STEP

Any process should be evaluated economically at every stage of its development and in its full-scale operation. Initially, available data are evaluated by people highly skilled in these economic procedures. As more data become available, the evaluation is repeated to upgrade process concepts. The repetitive evaluation is usually laborious and time-consuming as more detailed information becomes available.

The use of high-speed digital computers for the repetitive-type calculations such as material-balance studies can reduce the cost of process evaluation and development. However, the use of computers requires accurate problem formulation. This has been done for the hydrochlorination step of the FBV process in which the fissionable uranium is separated from Zircaloy-2 or aluminum cladding.

Previous development work (ANL-6829, ANL-6830, ANL-6973, and ANL-6994) for uranium-alloy fuels established that the cladding and alloying metals in these fuels can be chlorinated with HCl to free the uranium from the cladding and alloying metals. This hydrochlorination step affects the economics of the reprocessing of these nuclear fuels since it requires the longest reaction time and large masses of HCl.

A basic material-balance program, which can be adapted readily for either economic evaluation and/or process control, was developed and tested. Although the program was developed for the processing of highly-enriched uranium alloy fuels, it can be used for the decladding step of Zircaloy or aluminum-clad ceramic oxide fuels as well.

A. Sequence of Calculations

A flowsheet for the hydrochlorination step was suggested previously (ANL-6829, p. 48), which, under ideal conditions, results in the use of only 0.0006 mole of HCl per mole of zirconium in the fuel to be processed. This flowsheet is used as the basis for the material-balance program and includes recycle of HCl gas stream coupled with an optional scrub system similar to the commercial HCl recovery process. A schematic flowsheet with identification numbers for the various process schemes is presented in Fig. 2.

A batch of fuel (Item 11) is charged to the fluid-bed hydrochlorinator and reacted with HCl which contains hydrogen (Item 1), the product of the reaction recycled in the gas stream.

08-8954

Fig. 2. Flowsheet for Process Scaleup and Economic Evaluation

The gaseous reaction products (Item 2), containing the volatile chlorides of the cladding element from the hydrochlorinator, are reacted with steam (Item 6) in the pyrohydrolyzer to convert the cladding element to its solid oxide waste. The HCl is regenerated as a result of this.

The gaseous products from the pyrohydrolyzer, viz., HCl along with excess steam, is condensed (Items 3 and 14). The temperature of the condenser may be selected based on process and economic considerations.

The stream of undissolved HCl and hydrogen from the condenser (Item 7) is then recycled to the hydrochlorinator. A fraction of this gas stream (Item 8) is bled to limit the amount of hydrogen and inerts in the feed gas to the hydrochlorinator and to remove all the hydrogen produced in the process.

The bleed stream is scrubbed by the water needed for the pyrohydrolysis reaction, to recover a part of the HCl. The scrubber temperature is based on economic considerations.

The remaining HCl and hydrogen from the scrubber (Item 20) are fed to an optional scrub system. In this system, the HCl is scrubbed with dilute hydrochloric acid (20.3 w/o HCl azeotrope). The exhaust hydrogen (Item 27) contains only 0.03 v/o HCl. With this scheme, the concentrated acid is fed to a stripper-condenser combination. The HCl leaves the top of the condenser (Item 10) and is fed back to the hydrochlorinator as makeup HCl, while the dilute hydrochloric acid (azeotrope) from the bottom of the stripper is pumped back to the scrub tower as scrubbing liquor.

The sequence of the program includes (a) reading of input constants to specify the stoichiometry, etc.; (b) reading of a set of input data; (c) calculation of the mass flow rates, volume flow rates, and concentration of various process streams; (d) writing out the desired information; and (e) repeating the sequence of operations (b) to (d) for another set or sets of input data. The input and output information is defined in Section B below.

The program provides the calculation sequence only when the optional scrub system is needed. However, when this system is not needed, the same sequence can be used with modifications for trial-and-error calculations to balance the masses in the various streams.

B. Program Information

This section describes the appropriate input and output information.

1. Title: Conceptual Flowsheet Calculations.
2. Program Library: 1624/CEN-111.

3. Programmer: Fred L. Clark, Applied Mathematics Division.
4. Machine: 704F, OOPS monitor compatible.
5. Running Time: Less than 10 sec per case.
6. Input Information Required:

<u>Card Type</u>	<u>Format</u>	<u>Contents of Card</u>
1	2I6	N = number of cases. III = 1 for punched output, 0 otherwise.
2	72H	Title.
3	4E15.6	Number of reacting molecules of components 1, 2, 3, and 4.
4	4E15.6	Molecular weights of components 1, 2, 3, and 4 (refer to Fig. 2).
5	4E15.6	Number of reacting molecules of components 5, 6, 7, and 8.
6	4E15.6	Molecular weights of components 5, 6, 7, and 8.
7, 8, ..., N+6	6E8.3	<div style="display: flex; align-items: center;"> <div style="flex: 1;"> Fuel rate Efficiency of hydrochlorinator Percent hydrogen to hydrochlorinator Efficiency of pyrohydrolyzer Percent water to pyrohydrolyzer Percent water from condenser </div> <div style="font-size: 3em; margin: 0 10px;">}</div> <div style="flex: 1; text-align: center;"> One card for each case. </div> </div>

7. Possible Output (for each case):

- a. Program title.
- b. User's title.
- c. First five items on input card 6 + i.
- d. Volume of HCl, hydrogen, water, etc. at various stages of processing, expressed as kg/hr, cu ft/min (cfm), or v/o.
(See sample output in Table III.)
- e. If III = 1, the volumes in kg/hr are punched on a card.

The FORTRAN statement is listed in Table I.

C. Sample Problem

The input data for processing U-Al fuel, where 28 cases were computed, are listed in Table II. The calculated output for Case 1 is presented in Table III. A separate output sheet is printed for each case given as input.

TABLE I. FORTRAN Statements for CEN-111

```

C      PROCESS SCALE-UP AND ECONOMIC EVALUATION
96 FORMAT(6E8.3)
97 FORMAT(2I6)
98 FORMAT(72H
X      )
99 FORMAT(18H1TITLE 1624/CEN111//)
100 FORMAT(4E15.6)
101 FORMAT(12HOFUEL RATE =F6.2,1X,5HKG/HR)
102 FORMAT(33HOEFFICIENCY OF HYDROCHLORINATOR =F6.2)
103 FORMAT(39HOPERCENT HYDROGEN TO HYDROCHLORINATOR =F6.2)
104 FORMAT(31HOEFFICIENCY OF PYROHYDROLYSER =F6.2)
105 FORMAT(34HOPERCENT WATER TO PYROHYDROLYSER =F6.2)
106 FORMAT(22HOOPTIONAL SCRUB SYSTEM)
107 FORMAT(32HOSCRUBBING LIQUOR          21C)
109 FORMAT(32HOTO HYDROCHLORINATOR      350C)
110 FORMAT(9X,3HHCL5X,3F12.3)
111 FORMAT(9X,2HH26X,3F12.3)
112 FORMAT(32H0OUT FROM HYDROCHLORINATOR 400C)
115 FORMAT(9X,3HFCL5X,3F12.3)
116 FORMAT(24H0OUT FROM PYROHYDROLYSER)
117 FORMAT(9X,2HFD6X,F12.3)
118 FORMAT(32HCFEED WATER                )
119 FORMAT(9X,3HH2O5X,2F12.3)
120 FORMAT(32HOFROM BOILER                100C)
122 FORMAT(9X,3HH2O5X,3F12.3)
123 FORMAT(32HOGAS OUT FROM CONDENSER     )
126 FORMAT(32HOTO DISPOSAL                20C)
129 FORMAT(8HORECYCLE)
130 FORMAT(32HOMAKE UP HCL                20C)
131 FORMAT(9X,3HHCL5X,2F12.3)
132 FORMAT(1H1)
210 FORMAT(23X,5HKG/HR9X,3HCFM8X,3HV/O)
211 FORMAT(33HOOPTIONAL SCRUB SYSTEM NOT NEEDED)
215 FORMAT(1HQ,F4.1,15F5.2)
      DIMENSIONFKG(400),EHY(400),PCH21(400),EPY(400),PCH206(400),
      XPCH20C(400)
1 READ INPUT TAPE 7, 97, N, III
  READ INPUT TAPE 7,98
  WRITE OUTPUT TAPE 6,99
  READ INPUT TAPE 7,100,A1,B1,C1,D1,WTAL,WB1,WTC1,WD1,A2,B2,C2,D2,
  XWTAL,WB2,WTC2,WD2
2 READ INPUT TAPE 7,96,(FKG(I),EHY(I),PCH21(I),EPY(I),PCH206(I),
  XPCH20C(I),I=1,N)
3 DO 75 I=1,N
  H2OM6=(PCH206(I)/18.016)/((100.0-PCH206(I))/36.465+PCH206(I)/
  X18.016)
  H2OM16=H2OM6
  H2OM29=H2OM6
  H2OM28=(PCH20C(I)/18.016)/((100.0-PCH20C(I))/36.465+PCH20C(I)/
  X18.016)
5 RHCL1=(100.0-PCH21(I))/PCH21(I)
      HYDROCHLORINATOR
      FMOLES=FKG(I)/WTAL
      H2HY=FMOLES*D1/A1
6 FCL=FMOLES*C1/A1
  HCLHY=FMOLES*B1/A1
  HCL1=HCLHY*100.0/EHY(I)

```

TABLE I. (Contd.)

```

HCL2=HCL1-HCLHY
7 H21=HCL1*PCH21(I)/(100.0-PCH21(I))
  H22=H21+H2HY
  PCHCL1=HCL1/(H21+HCL1)
  PPCH21=H21/(H21+HCL1)
8 SVH21=0.08206*(273.15+350.0)/1.00010
  VH21=H21*1000.0*SVH21/(28.32*60.0)
  VHCL1=VH21*PCHCL1/PPCH21
  WH21=H21*2.016
9 WHCL1=HCL1*36.465
  PCHCL2=HCL2/(H22+HCL2+FCL)
  PCH22=H22/(H22+HCL2+FCL)
  PCFCL=FCL/(H22+HCL2+FCL)
10 SVH22=0.08206*(273.15+400.0)/1.00011
  VH22=H22*1000.0*SVH22/(28.32*60.0)
  VHCL2=VH22*PCHCL2/PCH22
  VFCL=VH22*PCFCL/PCH22
11 WHCL2=HCL2*36.465
  WH22=H22*2.016
  WFCL=FCL*WTC1
C   PYROHYDROLYSER
12 HCL13=HCL2
  H2OPY=FCL*B2/A2
  H2O4=H2OPY
  H2O6=H2OPY*100.0/EPY(I)
  FO=FCL*C2/A2
  HCLPY=FCL*D2/A2
13 HCL6=H2O6*(1.0-H2OM6)/H2OM6
  HCL3=HCL13+HCLPY+HCL6
  H213=H22
  H23=H213
  H2O3=H2O6-H2OPY
14 WFO=FO*WTC2
C   CONDENSER
  H2O14=H2O3
  H214=H23
  HCL14=HCL3
  H2O16=H2O14
15 HCL16=H2O14*(1.0-H2OM16)/H2OM16
  HCL7=HCL14-HCL16
  H27=H214
C   RECYCLE
  RHCL7=HCL7/H27
  RHCL9=RHCL7
  RHCL8=RHCL7
20 H29=H21
  H28=H27-H21
  H220=H28
  HCL8=RHCL8*H28
  HCLM26=1.0-H2OM16
  HCL26=H2O4*HCLM26/H2OM16
  IF(HCL8-HCL26)44,45,45
44 HCL80 = HCL8
  HCL260=HCL26
43 HCL26=HCL8
  HCL6=HCL26+HCL16
  HCL3=HCL6+HCLPY
  HCL14=HCL3
42 HCL7=HCL14-HCL16
  RHCL7=HCL7/H27
  RHCL9=RHCL7
  RHCL8=RHCL7

```

TABLE I. (Contd.)

```

HCL81=RHCL8*H28
IF(ABSF((HCL8-HCL81)/HCL81)-.01)45,45,40
40 HCL8=HCL81
GO TO 43
45 HCL20=HCL8-HCL26
21 HCL10=HCL20
HCL9=RHCL9*H29
PCHCL9=RHCL9/(1.0+RHCL9)
PCH29=1.0-PCHCL9
WHCL9=HCL9*36.465
WH29=H29*2.016
WH204=H204*18.016
PCH220=H220/(HCL20+H220)
PCHC20=1.0-PCH220
SVH220=.08206*(273.15+21.0)/1.00016
VH220=H220*SVH220*1000.0/(28.32*60.0)
VHCL20=VH220*(1.0-PCH220)/PCH220
WHCL20=HCL20*36.465
23 WH220=H220*2.016
WHCL10=HCL10*36.465
SVHCL9=.08206*(273.15+21.001)/1.00017
24 VHCL10=HCL10*SVHCL9*1000.0/(28.32*60.0)
145 VHCL9=HCL9*SVHCL9*1000.0/(28.32*60.0)
VH29=H29*SVHCL9*1000.0/(28.32*60.0)
PCH205=H206/(HCL6+H206)
PCHCL6=HCL6/(HCL6+H206)
SVHCL6=.08206*(273.15+100.01)/1.00013
17 VHCL6=HCL6*1000.0*SVHCL6/(28.32*60.0)
VH206=PCH205*VHCL6/PCHCL6
WHCL6=HCL6*36.465
WH206=H206*18.016
PCH27=H27/(H27+HCL7)
18 PCHCL7=HCL7/(H27+HCL7)
SVH27=.08206*(273.15+21.0)/1.00014
VH27=H27*1000.0*SVH27/(28.32*60.0)
VHCL7=VH27*PCHCL7/PCH27
WH27=H27*2.016
19 WHCL7=HCL7*36.465
C      SCRUBBER - STRIPPER
IF(HCL80-HCL260)53,54,54
53 INDEX = 1
GO TO 57
45 HCL29=HCL20*H20M28*(1.-H20M29)/(H20M28*(1.-H20M29)
X-H20M29*(1.0-H20M28))
50 HCL28 = HCL20*H20M29*(1.0-H20M28)/(H20M28*(1.0-H20M29)
X-H20M29*(1.0-H20M28))
H2028=HCL20*H20M28*H20M29/(H20M28*(1.0-H20M29)-H20M29*
X(1.0-H20M28))
H2029=H2028
WHCL28=HCL28*36.465
WH2028=H2028*18.016
C      END OF SUBROUTINES
57 PCHCL1=100.0*PCHCL1
PCHCL2=100.0*PCHCL2
25 PCH22=100.0*PCH22
PCFCL=100.0*PCFCL
PCHCL6=100.0*PCHCL6
PCH205=100.0*PCH205
PCHCL7=100.0*PCHCL7
PCH27=100.0*PCH27
26 PCH29=100.0*PCH29
PCHCL9=100.0*PCHCL9

```


TABLE I. (Contd.)

```

PCHC20=100.0*PCHC20
PCH220=100.0*PCH220
WRITE OUTPUT TAPE 6,98
27 WRITE OUTPUT TAPE 6,101,FKG(I)
  WRITE OUTPUT TAPE 6,102,EHY(I)
  WRITE OUTPUT TAPE 6,103,PCH21(I)
  WRITE OUTPUT TAPE 6,104,EPY(I)
  WRITE OUTPUT TAPE 6,105,PCH206(I)
  WRITE OUTPUT TAPE 6,210
  WRITE OUTPUT TAPE 6,109
  WRITE OUTPUT TAPE 6,110,WHCL1,VHCL1,PCHCL1
  WRITE OUTPUT TAPE 6,111,WH21,VH21,PCH21(I)
  WRITE OUTPUT TAPE 6,112
29 WRITE OUTPUT TAPE 6,110,WHCL2,VHCL2,PCHCL2
  WRITE OUTPUT TAPE 6,111,WH22,VH22,PCH22
  WRITE OUTPUT TAPE 6,115,WFC1,VFCL,PCFCL
  WRITE OUTPUT TAPE 6,116
  WRITE OUTPUT TAPE 6,117,WFO
30 WRITE OUTPUT TAPE 6,118
  WRITE OUTPUT TAPE 6,119,WH204
  WRITE OUTPUT TAPE 6,120
  WRITE OUTPUT TAPE 6, 110,WHCL6,VHCL6,PCHCL6
  WRITE OUTPUT TAPE 6,122,WH206,VH206,PCH205
  WRITE OUTPUT TAPE 6,123
  WRITE OUTPUT TAPE 6,110,WHCL7,VHCL7,PCHCL7
  WRITE OUTPUT TAPE 6,111,WH27,VH27,PCH27
31 WRITE OUTPUT TAPE 6,126
  WRITE OUTPUT TAPE 6,110,WHCL20,VHCL20,PCHC20
  WRITE OUTPUT TAPE 6,111,WH220,VH220,PCH220
  WRITE OUTPUT TAPE 6,129
  WRITE OUTPUT TAPE 6, 110,WHCL9,VHCL9,PCHCL9
  WRITE OUTPUT TAPE 6, 111,WH29,VH29,PCH29
59 IF(INDEX-1)33,61,33
33 WRITE OUTPUT TAPE 6, 130
  WRITE OUTPUT TAPE 6,131,WHCL10,VHCL10
  WRITE OUTPUT TAPE 6, 106
  WRITE OUTPUT TAPE 6,107
  WRITE OUTPUT TAPE 6, 110,WHCL28
  WRITE OUTPUT TAPE 6, 122,WH2028
GO TO 60
61 WRITE OUTPUT TAPE 6, 211
60 GO TO (32,75),III
32 WRITE OUTPUT TAPE 6, 215,FKG(I),WHCL1,WH21,WHCL2,WH22,WFC1,
  XWFO,WH204,WHCL6,WH206,WHCL7,WHCL20,WH220,WH29,WHCL28,
  XWH2028
75 WRITE OUTPUT TAPE 6,132
GOTO1
END ( 1 , 1 , 0 , 1 , 0 )

```

TABLE II. Input Data for Processing U-Al Fuel (CEN-111).

28	1	FLOWSHEET FOR ENRICHED U-ALUMINUM ALLOY FUEL REPROCESSING			
	1.0	3.0	.5	1.5	
	26.97	36.465	266.682	2.016	
	1.0	3.0	1.0	6.0	
	266.682	18.016	101.94	36.465	
.1	5.	10.	33.3	58.	79.7
2.	5.	10.	33.3	58.	79.7
5.	5.	10.	33.3	58.	79.7
10.	5.	10.	33.3	58.	79.7
.1	5.	80.	33.3	58.	79.7
2.	5.	80.	33.3	58.	79.7
5.	5.	80.	33.3	58.	79.7
10.	5.	80.	33.3	58.	79.7
.1	10.	80.	33.3	58.	79.7
2.	10.	80.	33.3	58.	79.7
5.	10.	80.	33.3	58.	79.7
10.	10.	80.	33.3	58.	79.7
.1	20.	80.	33.3	58.	79.7
2.	20.	80.	33.3	58.	79.7
5.	20.	80.	33.3	58.	79.7
10.	20.	80.	33.3	58.	79.7
.1	40.	80.	33.3	58.	79.7
2.	40.	80.	33.3	58.	79.7
5.	40.	80.	33.3	58.	79.7
10.	40.	80.	33.3	58.	79.7
.1	60.	80.	33.3	58.	79.7
2.	60.	80.	33.3	58.	79.7
5.	60.	80.	33.3	58.	79.7
10.	60.	80.	33.3	58.	79.7
.1	80.	80.	33.3	58.	79.7
2.	80.	80.	33.3	58.	79.7
5.	80.	80.	33.3	58.	79.7
10.	80.	80.	33.3	58.	79.7

TABLE III. Output Results for Case 1, Processing U-Al Fuel (CEN-111)

TITLE 1624/CEN111

FLOW SHEET FOR ENRICHED URANIUM ALUMINUM ALLOY FUEL REPROCESSING

FUEL RATE = 0.10 KG/HR

EFFICIENCY OF HYDROCHLORINATOR = 5.00

PERCENT HYDROGEN TO HYDROCHLORINATOR = 10.00

EFFICIENCY OF PYROHYDROLYSER = 33.30

PERCENT WATER TO PYROHYDROLYSER = 58.00

	KG/HR	CFM	V/O
TO HYDROCHLORINATOR 350C			
HCL	8.112	6.694	90.000
H2	0.050	0.744	10.000
OUT FROM HYDROCHLORINATOR 400C			
HCL	7.707	6.870	86.146
H2	0.061	0.984	12.343
FCL	0.494	0.121	1.511
OUT FROM PYROHYDROLYSER			
FO	0.189		
FEED WATER			
H2O	0.100		
FROM BOILER 100C			
HCL	0.218	0.108	26.350
H2O	0.301	0.301	73.650
GAS OUT FROM CONDENSER			
HCL	8.185	3.188	88.113
H2	0.061	0.430	11.887
TO DISPOSAL 20C			
HCL	1.431	0.557	87.585
H2	0.011	0.079	12.415
RECYCLE			
HCL	6.682	2.602	88.113
H2	0.050	0.351	11.887
MAKE UP HCL 20C			
HCL	1.431	0.557	
OPTIONAL SCRUB SYSTEM			
SCRUBBING LIQUOR 21C			
HCL	0.776		
H2O	3.048		

III. DATA PROCESSING DURING THE HYDROCHLORINATION STEP FOR THE THREE EXPERIMENTAL FACILITIES

The purpose of this program (CEN-139) is to calculate and plot values of reaction rates, HCl utilization, velocities, and gas concentrations as a function of time, starting with orifice, rotameter, pressure, and temperature readings directly as the direct input data. This program will perform calculations on data from the 1½- and 6-in.-diam facilities used for the hydrochlorination of either aluminum or zirconium fuels. These fuels normally contain less than 5 w/o uranium and other alloying materials. The details of these facilities are presented in ANL-6829, ANL-6830, ANL-6973, and ANL-6994.

A. Sequence of Calculations

The general sequence of calculations is shown schematically in Fig. 3. A more detailed description of each operation follows.

1. Operations 1-3

The input constants for the reactor diameter and the flow-rate calibration pressures are chosen, depending on which facility is being used.

2. Operations 4-5

The input constants for the reaction stoichiometry and the reagent molecular weights are chosen, depending on the type of fuel being processed. The assumed reactions are:

The reaction of uranium and other alloy components is assumed to be insignificant in comparison with the zirconium or aluminum reaction.

3. Operations 6-7

The input calibration constants and raw data are read in. The calibration constants for the flow and pressure calibrations are of the form:

$$\text{Flow} = a + b(\text{Scale Reading}) + c(\text{Scale Reading})^2 + \dots ;$$

$$\text{Pressure} = a + b(\text{Scale Reading}) + c(\text{Scale Reading})^2 + \dots$$

Fig. 3. Sequence of Calculations for CEN-139

The flow rates are corrected for the pressure of the system. The raw data are taken directly from instrument charts. The constants (a, b, ...) in the calibration equations are determined by means of ANME-209 as described in Section V-A of this report.

4. Operations 8-9

The flow rate of nitrogen blow-back gas to the pyrohydrolysis filters is calculated for the pilot-plant facility only. The rate is calculated directly from the initial and final pressures on the nitrogen blow-back reservoir.

5. Operations 10-13

The flow rates are calculated from the calibration equations, and the sum of the flows is compared with the total amount of material fed to the system. A correction factor is defined as the (amount of material fed)/(amount calculated from integrating the flow rate). The individual flow rates are then corrected by this factor.

6. Operations 14-20

The reaction rate of the metal, percent metal remaining, HCl utilization, reactor velocities, gas compositions at the inlet to the reactor, at the inlet to the filter, at the inlet to pyrohydrolyzer, and at the outlet from the pyrohydrolyzer, along with the oxide production rate, are calculated as a function of time. Averages are then calculated over any given segment of time. Finally, these calculated values are tabulated and plotted as illustrated for a sample problem in Section III-C below.

B. Program Information

This section describes the appropriate input and output information.

1. Title: Calculations for Fluid-bed Uranium Processing.
2. Program Library: 2026/CEN-139.
3. Programmer: Anthony J. Strecok, Applied Mathematics Division.
4. Machine: 3600F, SCOPE monitor compatible.
5. Running Time: Less than 4 min per case.

6. Input Information Required:

Card Type	No. of Cards	Format	Contents of Card
1	1	I6	Number of cases to be processed. This is needed in order to position and end of file after the last graph on the plotter tape.
2	1	E12.4	SIZE, the number of X units per inch on the graph. Hence a 30-in. graph will always be generated, points for which $X > (30)(SIZE)$ will be ignored.
3	1	6I1	1 or 0 in first six columns. Graph number K ($K \leq 6$) will be processed if column K contains 1 and will be ignored otherwise.
4	1	2I6	NAV = the number of time-averaging periods. NORUN = a case identification number (run number).
5	$\frac{NAV + 5}{6}$	6E12.4	TAVE(K) = Start of time-averaging period K ($K \leq NAV$), six values or less per card.
6	$\frac{NAV + 5}{6}$	6E12.4	DAVE(K) = End of time-averaging period K ($K \leq NAV$), six values or less per card.
7	1	16	NOP, the option number (1) - Bench Scale, (2) = Hot Cell, (3) = Pilot Plant.
8	1	4E12.4	PGPT1, PGPT2, PGPT3, PGPT4.

The PGPT values are the nitrogen purge flow rates (CFM) at the points 1 through 4 on the flow diagram (Fig. 4). At purge point 1 (PGPT1), include all the nitrogen purge entering the system before PGPT1. At purge point 2 (PGPT2), include all the nitrogen purge entering the system before PGPT2 and including PGPT1. At purge point 3 (PGPT3), include all the nitrogen purge entering between PGPT2 and PGPT3. At purge point 4 (PGPT4), include all the nitrogen purge entering between PGPT3 and PGPT4.

9	1	6E12.4	DIA1, ALTY, CHRG, ZER, HYCL, STM.
---	---	--------	-----------------------------------

DIA1 is the diameter of the fluid-bed reactor: 1.610 in. for options 1 and 2, and 6.065 in. for option 3. ALTY is the type of alloy: 1.0 for zirconium, or 2.0 for aluminum. CHRG is the weight of the fuel element charged in kg. ZER is the thermal-conductivity base-line reading for N₂-sample vs N₂-reference. HYCL is the total weight of HCl introduced to the halogenation reactor in kg. STM is the total weight of water introduced to the pyrohydrolyzer in kg.

Fig. 4
Nitrogen Purge Locations
(Hydrochlorination step)

108-8272 Rev.

Card types 10-19 contain calibration data for the various flow- and pressure-measuring instruments. A least-square polynomial-fit program (ANME-209 discussed in Section V-A of this report) is used to determine the constants from calibration data in the following equation:

$$Y = CA1 + CA2X + CA3X^2 + CA4X^3 + CA5X^4.$$

Values of CA1 and CA2 are used if the calibration is a linear function of X. Additional constants are used if the calibration is a nonlinear function of X.

Card Type	No. of Cards	Format	Contents of Card
10	1	5E12.4	CA1, CA2, CA3, CA4, CA5 = Calibration constants for nitrogen flow rate.
11	1	5E12.4	CB1, CB2, CB3, CB4, CB5 = Calibration constants for HCl flow rate.
12	1	5E12.4	CC1, CC2, CC3, CC4, CC5 = Calibration constants for hydrogen concentration.
13	1	5E12.4	CD1, CD2, CD3, CD4, CD5 = Calibration constants for the steam flow rate to the pyrohydrolysis reactor.
14	1	5E12.4	CE1, CE2, CE3, CE4, CE5 = Calibration constants for total pressure.
15	1	5E12.4	CF1, CF2, CF3, CF4, CF5 = Calibration constants for total nitrogen-purge flow rate.
16	1	5E12.4	CG1, CG2, CG3, CG4, CG5 = Calibration constants for reactor bed ΔP .
17	1	5E12.4	CH1, CH2, CH3, CH4, CH5 = Calibration constants for packed-bed filter ΔP .

Card Type	No. of Cards	Format	Contents of Card
18	1	5E12.4	CI1, CI2, CI3, CI4, CI5 = Calibration constants for pyrohydrolysis bed ΔP .
19	1	5E12.4	CJ1, CJ2, CJ3, CJ4, CJ5 = Calibration constants for pyrohydrolysis filter ΔP .
20	1	I6	NS = Number of data sets.
21 NS Pairs	1	12E6.0	TIME, TOPR, EN2DIL, HCLMAN, EMVOUT, EN2PRG, PURP, TREA, TDF2, TALLOY, EN2BB, STMTRAT.
	1	9E6.0	STMPR, THYDRO, DELREA, DELDF2, DELHR, DELHFR, TINLET, TWALL, TOGAS.

Card type 21 includes the run data as a function of time. TIME is in minutes. TOPR is the total pressure at the inlet to the halogenation reactor. EN2DIL is the nitrogen dilution flow to the halogenation reactor. HCLMAN is the HCl flow to the halogenation reactor. EMVOUT is the output from the thermal-conductivity cell. EN2PRG is the total nitrogen-purge flow rate. PURP is the static pressure (psig). TREA is the temperature ($^{\circ}\text{C}$) of the fluid-bed reactor. TDF2 is the temperature ($^{\circ}\text{C}$) of the packed-bed filter. TALLOY is the temperature ($^{\circ}\text{C}$) of the fuel element. EN2BB is the pressure of the nitrogen blow-back reservoir for the pyrohydrolyzer filters. These data need only be given at time = 0, when the reservoir is refilled, and at the end of the run. STMTRAT is the steam flow rate. STMPR is the static pressure (psig) on the steam flowmeter. THYDRO is the temperature ($^{\circ}\text{C}$) of the pyrohydrolysis reactor bed. DELREA is the pressure drop across the reactor bed. DELDF2 is the pressure drop across the packed-bed filter. DELHR is the pressure drop across the pyrohydrolyzer fluid bed. DELHFR is the pressure drop across the pyrohydrolyzer filters. TINLET is the temperature ($^{\circ}\text{C}$) of the gas entering the halogenation reactor. TWALL is the wall temperature ($^{\circ}\text{C}$) of the halogenation reactor. TOGAS is temperature ($^{\circ}\text{C}$) of the gas leaving the pyrohydrolyzer. The location of thermocouples and pressure traps is shown in Fig. 5.

Fig. 5
Temperature and Pressure
Measuring Locations

7. Possible Output

- a. Program identification.
- b. Labeled listing of input data.
- c. Labeled listing of correction factors and other intermediate and final quantities generated during calculations.
- d. Labeled listing of time-averaged values for efficiencies, temperatures, volumes, pressures, velocities, and other quantities.
- e. Labeled graphs.

Table IV lists the FORTRAN program for CEN-139, and Table V lists the words used to write the program and describes the values used for the graphs plotted by the computer.

C. Sample Problem

The input data for a pilot-plant experiment involving the processing uranium-aluminum fuel charge are listed in Table VI. The calculated output from that experiment is shown on Table VII, and one of the plotted graphs from another similar experiment is shown in Fig. 6. At index number 32 on the output sheets (Table VII), a negative number appears in some columns. These were present because of a poor fit (using ANME-209) of the N_2 - H_2 thermal-conductivity calibration curve in the region of low hydrogen concentrations. This effect does not significantly alter the overall results.

This program significantly reduces the computation time compared to hand calculation of the same values. Typically, the computer time was less than 3 min for one experiment. The program also increases the accuracy of calculations since it automatically corrects the flow rates if an independent measurement of the total amount of material introduced is known.

TABLE IV. FORTRAN Statements for CEN-139

```

PROGRAM CEN139
  DIMENSION TIME(200),TOPR(200),EN2CIL(200),HCLMAN(200),EMVOUT(200),
  XEN2PRG(200),PURP(200),TREAC(200),TDF2(200),TALLOY(200),EN2BB(200),
  XSTMRT(200),STMPR(200),THYDRO(200),DELREA(200),DELDF2(200),DELHR(2
  X00),DELHFR(200),SQRUP(200),TOPPY(200),PURRAT(200),TM(200),PH2(200)
  X,HYGEN(200),XVOH(200),HYDCL(200),STEEM(200),HYCLP(200),RATMET(200)
  X,PRATMT(200),ROX(200),XPPHTW(200),USPHCL(200),RTV(200),VOHCL(200),
  XVON2(200),PPRHCL(200),PPRN2(200),REAVEL(200),REXTV(200),XVOHCL(200
  X),XPPHCL(200),XVOCL4(200),XPPCL4(200),XVON2(200),XPPN2(200),TAVE(2
  X5),DAVE(25),TWA(200),DFFVEL(200),KUNT(11),TINLET(200),TWALL(200)
  DIMENSION HRSTM(200),HRN2(200),HRITVT(200),HRVOHC(200),TOGAS(200),
  XHRVOCL(200),HRVOH2(200),HXPPH2(200),HRVOST(200),HRVON2(200),
  XHRPPHC(200),HRPPCL(200),HRPPH2(200),HRPPST(200),HXPPN2(200),
  XHRPPN2(200),HRVEL(200),HRXPRE(200),HRXSTM(200),HRXN2(200),
  XHRXTVT(200),HXVOHC(200),HXVOH2(200),HXVOST(200),HXVON2(200),
  XHXPPHC(200),HXPPST(200),HRXTV(200),HRPRE(200),XITPR(200),SIT(200),
  XARRAY(10000)
  COMMON ARRAY
  C NRUNZ=NO OF DISTINCT RUNS,IS NEEDED FOR PROPER POSITIONING OF
  C END OF FILE MARK FOR CALCOMP DATA TAPE.
  READ INPUT TAPE 7,4001,NRUNZ
  CALL PLOTS(ARRAY,10000,5)
  TWTY4=22414.
  CAP=14.7
  CCON=TWTY4/28.32
  1 WRITE OUTPUT TAPE 6,4000
  NRUNZ=NRUNZ-1
  READ INPUT TAPE 7,4002,SIZE
  SIM=30.*SIZE
  READ INPUT TAPE 7,4017,(KUNT(K),K=1,6)
  READ INPUT TAPE 7,4001,NAV,NORUN
  WRITE OUTPUT TAPE 6,4027,NORUN
  READ INPUT TAPE 7,4002,(TAVE(K),K=1,NAV)
  READ INPUT TAPE 7,4002,(DAVE(K),K=1,NAV)
  READ INPUT TAPE 7,4001,NOP
  READ INPUT TAPE 7,4002,PGPT1,PGPT2,PGPT3,PGPT4
  WRITE OUTPUT TAPE 6,4078,PGPT1,PGPT2,PGPT3,PGPT4
  NON=NOP-3
  IF (NOP-2) 567,568,569
  567 WRITE OUTPUT TAPE 6,4028
  GO TO 570
  568 WRITE OUTPUT TAPE 6,4029
  GO TO 570
  569 WRITE OUTPUT TAPE 6,4030
  C READ INPUT PARAMETERS
  570 READ INPUT TAPE 7,4002,DIA1,ALTY,CHRG,ZER,HYCL,STM
  WRITE OUTPUT TAPE 6,4019,(TAVE(K),K=1,NAV)
  WRITE OUTPUT TAPE 6,4020,(DAVE(K),K=1,NAV)
  WRITE OUTPUT TAPE 6,4010,DIA1,ALTY,CHRG,ZER,HYCL,STM
  C INITIALIZATION FOR REACTOR SIZE
  IF (DIA1-5.)2,2,3
  2 DIA1=1.61
  DIA2=DIA1
  DIA3=0.
  CALPR1=CAP
  CALPR2=0.
  GO TO 4
  3 DIA1=6.065
  DIA2=9.125
  DIA3=DIA1
  CALPR1=24.7
  CALPR2=19.7

```

TABLE IV (Contd.)

4	AREA1=.005454*DIA1**2
	AREA2=.005454*DIA2**2
	AREA3=.005454*DIA3**2
	C1=1.
	A2=C1
	C2=C1
	WTB1=36.465
	WTD1=2.016
	WTB2=18.016
	WTD2=WTB1
C	INITIALIZATION FOR THE ALLOY TYPE
	IF(ALT-1.5)5,5,6
5	A1=1.
	B1=4.
	WTA1=91.22
	WTC1=233.048
	WTC2=123.22
	GO TO 7
6	A1=2.
	B1=6.
	WTA1=26.97
	WTC1=133.34
	WTC2=101.94
7	WTA2=WTC1
	D1=.5*B1
	B2=D1
	D2=B1
	DWAW=D1/A1
C	READ INPUT CALIBRATION CONSTANTS FOR N2
	READ INPUT TAPE 7,4002,CA1,CA2,CA3,CA4,CA5
	WRITE OUTPUT TAPE 6,4004,CA1,CA2,CA3,CA4,CA5
C	READ INPUT CALIBRATION CONSTANTS FOR HCL
	READ INPUT TAPE 7,4002,CB1,CB2,CB3,CB4,CB5
	WRITE OUTPUT TAPE 6,4004,CB1,CB2,CB3,CB4,CB5
C	READ INPUT CALIBRATION CONSTANTS FOR H2
	READ INPUT TAPE 7,4002,CC1,CC2,CC3,CC4,CC5
	WRITE OUTPUT TAPE 6,4004,CC1,CC2,CC3,CC4,CC5
C	STEAM CALIBRATION FOR THE HYDROLYSIS REACTOR
31	READ INPUT TAPE 7,4002,CD1,CD2,CD3,CD4,CD5
	WRITE OUTPUT TAPE 6,4004,CD1,CD2,CD3,CD4,CD5
C	READ INPUT CALIBRATION CONSTANTS FOR TOTAL PRESSURE
30	READ INPUT TAPE 7,4002,CE1,CE2,CE3,CE4,CE5
	WRITE OUTPUT TAPE 6,4004,CE1,CE2,CE3,CE4,CE5
C	READ INPUT CALIBRATION CONSTANTS FOR N2 PURGE
	READ INPUT TAPE 7,4002,CF1,CF2,CF3,CF4,CF5
	WRITE OUTPUT TAPE 6,4004,CF1,CF2,CF3,CF4,CF5
C	READ INPUT CALIBRATION CONSTANTS FOR REACTOR BED DELTA P
	READ INPUT TAPE 7,4002,CG1,CG2,CG3,CG4,CG5
	WRITE OUTPUT TAPE 6,4004,CG1,CG2,CG3,CG4,CG5
C	READ INPUT CALIBRATION CONSTANTS FOR DFF
	READ INPUT TAPE 7,4002,CH1,CH2,CH3,CH4,CH5
	WRITE OUTPUT TAPE 6,4004,CH1,CH2,CH3,CH4,CH5
C	READ INPUT CALIBRATION CONSTANTS FOR PYROHYDROLYSIS BED DELTA P
	READ INPUT TAPE 7,4002,CI1,CI2,CI3,CI4,CI5
	WRITE OUTPUT TAPE 6,4004,CI1,CI2,CI3,CI4,CI5
C	READ INPUT CALIBRATION CONSTANTS FOR PYROHYDROLYSIS FILTER DELTA P
	READ INPUT TAPE 7,4002,CJ1,CJ2,CJ3,CJ4,CJ5
	WRITE OUTPUT TAPE 6,4004,CJ1,CJ2,CJ3,CJ4,CJ5
	READ INPUT TAPE 7,4001,NSET
	SUMHY=0.
	SUMST=0.
	SUMHCL=0.

TABLE IV (Contd.)

```

      TM(1)=0.
      BLOOK=C1/WT A1*B2/A1*COON
      K1=1
      K2=50
565 WRITE OUTPUT TAPE 6,4025
      IF (NSET-K2) 563,564,564
563 K2=NSET
564 DO 57 K=K1,K2
      10 READ INPUT TAPE 7,4005,TIME(K),TOPR(K),EN2DIL(K),HCLMAN(K),
        XEMVOUT(K),EN2PRG(K),PURP(K),TREAC(K),TDF2(K),TALLOY(K),EN2BB(K),
        XSTM RAT(K),STMPR(K),THYDRO(K),DELREA(K),DELDF2(K),DELHR(K),
        XDELHFR(K),TINLET(K),TWALL(K),TOGAS(K)
        WRITEOUTPUTTAPE 6,4006,K,TIME(K),TOPR(K),EN2DIL(K),HCLMAN(K),
        XEMVOUT(K),EN2PRG(K),PURP(K),TREAC(K),TDF2(K),TALLOY(K),EN2BB(K),
        XSTM RAT(K),STMPR(K),THYDRO(K),DELREA(K),DELDF2(K),DELHR(K),
        XDELHFR(K),TINLET(K),TWALL(K),TOGAS(K)
      ZZ=TOPR(K)
      TOPR(K)=CE1+ZZ*(CE2+ZZ*(CE3+ZZ*(CE4+ZZ*CE5)))
      ZZ=EN2PRG(K)
      EN2PRG(K)=CF1+ZZ*(CF2+ZZ*(CF3+ZZ*(CF4+ZZ*CF5)))
      ZZ=DELREA(K)
      DELREA(K)=CG1+ZZ*(CG2+ZZ*(CG3+ZZ*(CG4+ZZ*CG5)))
      ZZ=DELDF2(K)
      DELDF2(K)=CH1+ZZ*(CH2+ZZ*(CH3+ZZ*(CH4+ZZ*CH5)))
      ZZ=DELHR(K)
      DELHR(K)=CI1+ZZ*(CI2+ZZ*(CI3+ZZ*(CI4+ZZ*CI5)))
      ZZ=DELHFR(K)
      DELHFR(K)=CJ1+ZZ*(CJ2+ZZ*(CJ3+ZZ*(CJ4+ZZ*CJ5)))
      8 IF (EN2DIL(K)) 50,50,51
      51 TEMP=CA1+EN2DIL(K)*(CA2+EN2DIL(K)*(CA3+EN2DIL(K)*(CA4+CA5*EN2DIL
        X(K))))
      TOPPY(K)=TEMP*SQR TF((CAP+TOPR(K))/CALPR1)
      GO TO 52
      50 TOPPY(K)=0.
      52 SQURP(K)=SQR TF((CAP+PURP(K))/CAP)
      PURRAT(K)=EN2PRG(K)*SQURP(K)
      ZZ=EMVOUT(K)-ZER
      IF (ZZ) 54,54,53
      54 PH2(K)=0.
      GO TO 55
      53 PH2(K)=CC1+ZZ*(CC2+ZZ*(CC3+ZZ*(CC4+CC5*ZZ)))
      55 IF (K-2) 29,32,32
      32 TM(K )=TIME(K)-TIME(K-1)
      IF (TM(K )) 34,29,29
      34 STOP 34343
      29 IF (HCLMAN(K)) 58,58,56
      58 HYCLP(K)=0.
      GO TO 57
      56 HYCLP(K)=CB1+HCLMAN(K)*(CB2+HCLMAN(K)*(CB3+HCLMAN(K)*(CB4+CB5*
        XHCLMAN(K))))
      57 CONTINUE
C      BLOWBACK SECTION, ENDS AT 20.
      K1=K1+50
      K2=K2+50
      IF (K1-NSET) 565,565,566
566 IF (NON)20,35,35
      35 K=0
      16 BL=EN2BB(K+1)
      TY=TIME(K+1)
      KLM=K+1
      13 K=K+1
      IF (EN2BB(K+1)) 17,13,17

```

TABLE IV (Contd.)

17	K=K+1
	COO=(EN2BB(K)-BL)/(TIME(K)-TY)*.1031
	DO 18 KAY=KLM,K
18	EN2BB(KAY)=-COO
	IF (K-NSET) 16,20,20
20	DO 21 K=1,NSET
	HYDCL(K)=TM(K)*HYCLP(K)
	CNIT =TM(K)*(TOPPY(K)+PURRAT(K) +EN2BB(K))
	HYGEN(K)=CNIT *PH2(K)/(100.-PH2(K))
	SUMHY=SUMHY+HYGEN(K)
	SUMHCL=SUMHCL+HYDCL(K)
	IF (STM) 21,21,26
26	IF (STMRAT(K)) 60,60,59
60	STEEM(K)=0.
	GO TO 21
59	TEMP=CD1+STMRAT(K)*(CD2+STMRAT(K)*(CD3+STMRAT(K)*(CD4+CD5*STMRAT(K
	X))))
	STEEM(K)=TEMP*SQRTE((CAP+STMPR(K))/CALPR2)*.04786
	SUMST=SUMST+STEEM(K)*TM(K)
21	CONTINUE
	HIDL=CHRG/WTAL*COON*DWAW
	CORH=HIDL/SUMHY
	WRITE OUTPUT TAPE 6,4007,CORH
	CORHCL=HYCL/SUMHCL*COON/WTB1
	IF (HYCL) 4900,4900,4901
4900	CORHCL=1.
4901	WRITE OUTPUT TAPE 6,4008,CORHCL
	CORST=STM/SUMST*COON/WTB2
	IF (STM) 4902,4902,4903
4902	CORST=1.
4903	WRITE OUTPUT TAPE 6,4009,CORST
	ZRUM=0.
	DO 27 K=1,NSET
	HYGEN(K)=HYGEN(K)*CORH
	HYDCL(K)=HYDCL(K)*CORHCL
	HYCLP(K)=CORHCL*HYCLP(K)
	STEEM(K)=CORST*STEEM(K)
	RATMET(K)=HYGEN(K)/TM(K)*WTAL/COON*60./D1*A1
	ZRUM=ZRUM+RATMET(K)/60.*TM(K)
	PRATMT(K)= (CHRG-ZRUM)/CHRG*100.
36	TEMP=B1*HYGEN(K)/D1
	RXHCL=60.*(HYDCL(K)-TEMP)/TM(K)
	USPHCL(K)=TEMP/HYDCL(K)*100.
	RINN2=TOPPY(K)*60.+SQURP(K)*PGPT1
	RINHCL=HYDCL(K)/TM(K)*60.
	RTV(K)=RINN2+RINHCL
	VCHCL(K)=RINHCL/RTV(K)*100.
	VON2(K)=100.-VOHCL(K)
	TOTAM=1.+TOPR(K)/CAP
	PPRHCL(K)=TOTAM*VOHCL(K)/100.
	PPRN2(K)=TOTAM-PPRHCL(K)
	REAVEL(K)= (273.+TREAC(K))*RTV(K)/(3600.*AREA1*TOTAM)/298.
	XITPR(K)=TOTAM-DELREA(K)/CAP
	RXCL4=RATMET(K)/WTAL*COON
	RXH2=HYGEN(K)/TM(K)*60.
	RXN2=RINN2+SQURP(K)*PGPT2
	REXTV(K)=RXHCL+RXCL4+RXH2+RXN2
	XVOHCL(K)=100.*RXHCL/REXTV(K)
	XYTPR=XITPR(K)*.01
	XPPHCL(K)=XVOHCL(K)*XYTPR
	XVOH2=100.*RXH2/REXTV(K)
	XPPH2=XYTPR*XVOH2

TABLE IV (Contd.)

	$XVOCL4(K) = 100. * RXCL4 / REXTV(K)$
	$XPPCL4(K) = XYTPR * XVOCL4(K)$
	$XVON2(K) = 100. - XVOH2 - XVOCL4(K) - XVOHCL(K)$
	$XPPN2(K) = XITPR(K) - XPPH2 - XPPCL4(K) - XPPHCL(K)$
	$DIFFVLL = (273. + TDF2(K)) * REXTV(K) / (3600. * AREA2 * XITPR(K) * 298.)$
	$DIFFVEL(K) = DIFFVLL$
	$RTV(K) = RTV(K) / 60.$
	$REXTV(K) = REXTV(K) / 60.$
	$XVOH(K) = XVOH2$
	$XPPHTW(K) = XPPH2$
	IF (NON) 27, 28, 28
28	$RQX(K) = RATMET(K) / WTA1 * WTC2 / A1$
	$HRPRE(K) = XITPR(K) - DELDF2(K) / CAP$
	$HRSTM(K) = STEEM(K) * 60.$
	$HRN2(K) = RINN2 + SQRUP(K) * PGPT3$
	$HRITV = HRN2(K) + RXCL4 + RXH2 + RXHCL + HRSTM(K)$
	$HRITVT(K) = HRITV / 60.$
	$HORROR = 100. / HRITV$
	$HRVOHC(K) = RXHCL * HORROR$
	$HRVOCL(K) = RXCL4 * HORROR$
	$HRVOH2(K) = RXH2 * HORROR$
	$HRVOST(K) = HRSTM(K) * HORROR$
	$HRVON2(K) = 100. - HRVOHC(K) - HRVOCL(K) - HRVOH2(K) - HRVOST(K)$
	$HYDRED = HRPRE(K) * .01$
	$HRPPHC(K) = HYDRED * HRVOHC(K)$
	$HRPPCL(K) = HYDRED * HRVOCL(K)$
	$HRPPH2(K) = HYDRED * HRVOH2(K)$
	$HRPPST(K) = HYDRED * HRVOST(K)$
	$HRPPN2(K) = HRPRE(K) - HRPPHC(K) - HRPPCL(K) - HRPPH2(K) - HRPPST(K)$
	$HRVEL(K) = (273. + THYDRO(K)) * HRITV / (1072800. * AREA3 * HRPRE(K))$
	$HRXPRE(K) = HRPRE(K) - DELHR(K) / CAP$
	$HRXSTM(K) = HRSTM(K) - RATMET(K) * BLOOK$
	$HRXN2(K) = RINN2 + SQRUP(K) * PGPT4$
	$HRXTVT(K) = HRXSTM(K) + HRXN2(K) + RXH2 + HYCLP(K) * 60.$
	$HRXTV(K) = HRXTVT(K) / 60.$
	$HXVOHC(K) = HYCLP(K) / HRXTV(K) * 100.$
	$HYM = HRXTVT(K) * .01$
	$HXVOH2(K) = RXH2 / HYM$
	$HXVOST(K) = HRXSTM(K) / HYM$
	$HXVON2(K) = 100. - HXVOHC(K) - HXVOH2(K) - HXVOST(K)$
	$HUMP = HRXPRE(K) / 100.$
	$HXPPHC(K) = HUMP * HXVOHC(K)$
	$HXPPST(K) = HUMP * HXVOST(K)$
	$HXPPH2(K) = HUMP * HXVOH2(K)$
	$HXPPN2(K) = HRXPRE(K) - HXPPHC(K) - HXPPST(K) - HXPPH2(K)$
27	CONTINUE
	LIST = -3
603	K1 = 1
	K2 = 50
601	IF (NSET - K2) 602, 600, 600
602	K2 = NSET
600	IF (LIST) 610, 614, 614
610	IF (LIST + 2) 611, 612, 613
611	WRITE OUTPUT TAPE 6, 4013
	GO TO 609
612	WRITE OUTPUT TAPE 6, 4014
	GO TO 609
613	WRITE OUTPUT TAPE 6, 4015
	GO TO 609
614	IF (NON) 702, 703, 703
703	WRITE OUTPUT TAPE 6, 4016
	GO TO 609

TABLE IV (Contd.)

702	WRITE OUTPUT TAPE 6,4066
609	DO 608 K=K1,K2
	IF (LIST)615,1607,1607
1607	IF(NON)704,607,607
704	WRITE OUTPUT TAPE 6,4036,K,TIME(K),XVOH(K),XVOCL4(K),XPPHCL(K), XXPPN2(K),XPPHTW(K),XPPCL4(K),DFFVEL(K)
	GO TO 608
615	IF (LIST+2) 616,617,618
616	WRITE OUTPUT TAPE 6,4012,K,TIME(K),TM(K),TINLET(K),TREAC(K),TWALL(XK),TDF2(K),TALLOY(K),THYDRO(K),TOGAS(K),TOPR(K),DELREA(K),DELDF2(K X),DELHR(K)
	GO TO 608
617	WRITE OUTPUT TAPE 6,4034,K,TIME(K),DELHFR(K),TOPPY(K),PURRAT(K),EN X2BB(K),PH2(K),HYCLP(K),RATMET(K),PRATMT(K),USPHCL(K)
	GO TO 608
618	WRITE OUTPUT TAPE 6,4035,K,TIME(K),RTV(K),VOHCL(K),VON2(K),PPRHCL(XK),PPRN2(K),REAVEL(K),REXTV(K),XVCHCL(K),XVON2(K)
	GO TO 608
607	WRITE OUTPUT TAPE 6,4036,K,TIME(K),XVOH(K),XVOCL4(K),XPPHCL(K),XPP XN2(K),XPPHTW(K),XPPCL4(K),DFFVEL(K),STEEM(K),ROX(K)
608	CONTINUE
	K1=K1+50
	K2=K2+50
	IF (K1-NSET) 601,601,619
619	LIST=LIST+1
	IF (LIST-1)603,542,542
542	MIST=-2
	IF (NON)604,541,541
541	K1=1
	K2=50
540	IF (NSET-K2)539,537,537
539	K2=NSET
537	IF (MIST+1)536,535,534
536	WRITE OUTPUT TAPE 6,4011
	GO TO 533
535	WRITE OUTPUT TAPE 6,4031
	GO TO 533
534	WRITE OUTPUT TAPE 6,4032
533	DO 538 K=K1,K2
	IF (MIST+1)532,531,530
532	WRITE OUTPUT TAPE 6,4037,K,TIME(K),HRITVT(K),HRVOHC(K),HRVON2(K), XHRVOH2(K),HRVOCL(K),HRVOST(K),HRPPHC(K),HRPPN2(K),HRPPH2(K)
	GO TO 538
531	WRITE OUTPUT TAPE 6,4038,K,TIME(K),HRPPCL(K),HRPPST(K),HRVEL(K), XHRXTV (K),HXVOHC(K),HXVON2(K),HXVCH2(K),HXVOST(K),HXPPHC(K)
	GO TO 538
530	WRITE OUTPUT TAPE 6,4039,K,TIME(K),HXPPN2(K),HXPPH2(K),HXPPST(K)
538	CONTINUE
	K1=K1+50
	K2=K2+50
	IF (K1-NSET)540,540,529
529	MIST=MIST+1
	IF (MIST)541,541,604
604	DO 555 KAY=1,NAV
	TUMME=0.
	SOHCL=0.
	SON2=0.
	SOPR=0.
	SVEL=0.
	SRATEM=0.
	SUST=0.
	SREAC=0.

TABLE IV (Contd.)

	SWALL=0.
	SINLET=0.
	SALLOY=0.
	SVOHCL=0.
	SVON2=0.
	SVOCL4=0.
	SVOH=0.
	SITPR=0.
	SFFVEL=0.
	SDF2=0.
	SRVOHC=0.
	SRVON2=0.
	SRVOCL=0.
	SRVOH2=0.
	SRVOST=0.
	SRPRE=0.
	SRVEL=0.
	SROX=0.
	SHYDRO=0.
	SOGAS=0.
	TLOW=TAVE(KAY)
	TBIG=DAVE(KAY)
	WRITE OUTPUT TAPE 6,4003,NORUN,TLCW,TBIG
	DO 556 K=1,NSET
	IF (TIME(K)-TLOW) 556,557,557
557	IF (TIME(K)-TBIG) 558,558,556
558	TUMME=TUMME+TM(K)
	SCHCL=SCHCL+VOHCL(K)*TM(K)
	SON2=SON2+VON2(K)*TM(K)
	SOPR=SOPR+TOPR(K)*TM(K)
	SVEL=SVEL+REAVEL(K)*TM(K)
	SRATEM=SRATEM+RATMET(K)*TM(K)
	SUST=USPHCL(K)*TM(K)+SUST
	SREAC=SREAC+TREAC(K)*TM(K)
	SWALL=SWALL+TWALL(K)*TM(K)
	SINLET=SINLET+TINLET(K)*TM(K)
	SALLOY=SALLOY+TALLOY(K)*TM(K)
	SVOHCL=SVOHCL+XVOHCL(K)*TM(K)
	SVON2=SVON2+XVON2(K)*TM(K)
	SVOCL4=SVOCL4+XVOCL4(K)*TM(K)
	SVOH=SVOH+XVOH(K)*TM(K)
	SITPR=SITPR+XITPR(K)*TM(K)
	SFFVEL=SFFVEL+DFFVEL(K)*TM(K)
	SDF2=SDF2+TDF2(K)*TM(K)
	IF (NON)556,701,701
701	SRVOHC=SRVOHC+HRVOHC(K)*TM(K)
	SRVON2=SRVON2+HRVON2(K)*TM(K)
	SRVOCL=SRVOCL+HRVOCL(K)*TM(K)
	SRVOH2=SRVOH2+HRVOH2(K)*TM(K)
	SRVOST=SRVOST+HRVOST(K)*TM(K)
	SRPRE=SRPRE+HRPRE(K)*TM(K)
	SRVEL=SRVEL+HRVEL(K)*TM(K)
	SROX=SROX+ROX(K)*TM(K)
	SHYDRO=SHYDRO+THYDRO(K)*TM(K)
	SOGAS=SOGAS+TOGAS(K)*TM(K)
556	CONTINUE
	SCHCL=SCHCL/TUMME
	SON2=SON2/TUMME
	SOPR=SOPR/TUMME
	SVEL=SVEL/TUMME
	SRATEM=SRATEM/TUMME
	SUST=SUST/TUMME

TABLE IV (Contd.)

```

SREAC=SREAC/TUMME
SWALL=SWALL/TUMME
SINLET=SINLET/TUMME
SALLOY=SALLOY/TUMME
SVOHCL=SVOHCL/TUMME
SVON2=SVON2/TUMME
SVOCL4=SVOCL4/TUMME
SVOH=SVOH/TUMME
SITPR=SITPR/TUMME
SITPR=(SITPR-1.)*14.7
SFFVEL=SFFVEL/TUMME
SCF2=SCF2/TUMME
WRITE OUTPUT TAPE 6,4022,SOHCL,SON2,SOPR,SVEL,SRATEM,SUST,SREAC,SW
XALL,SINLET,SALLOY,SVOHCL,SVON2,SVOCL4,SVOH,SITPR,SFFVEL,SCF2
IF (NON)555,700,700
700 SRVOHC=SRVOHC/TUMME
SRVON2=SRVON2/TUMME
SRVOCL=SRVOCL/TUMME
SRVOH2=SRVOH2/TUMME
SRVOST=SRVOST/TUMME
SRPRE=SRPRE/TUMME
SRPRE=(SRPRE-1.)*14.7
SRVEL=SRVEL/TUMME
SROX=SROX/TUMME
SHYDRO=SHYDRO/TUMME
SOGAS=SOGAS/TUMME
WRITE OUTPUT TAPE 6,4023,SRVOHC,SRVON2,SRVOCL,SRVOH2,SRVOST,SRPRE,
XSRVEL,SROX,SHYDRO,SOGAS
555 CONTINUE
DO 559 K=1,NSET
IF (TIME(K)-SIM) 901,901,401
401 NSET=K
GO TO 400
901 SIT(K)=TIME(K)/SIZE
559 CONTINUE
400 IF (KUNT(1))909,909,902
902 CALL AXIS(0.,0.,42H RATE, EFFICIENCY, HCL CONCENTRATION (V/O),-42,
X30.,0.,0.,SIZE)
CALL AXIS(0.,0.,1H ,1,10.,90.,0.,10.)
DO 903 K=1,NSET
IF (NON)801,800,800
801 RATMET(K)=RATMET(K)*50.
800 RATMET(K)=20.*RATMET(K)
RATMET(K)=MINIF(100.,MAX1F(RATMET(K),0.))*1
903 CALL SYMBOL(SIT(K),RATMET(K),.07,12,0.,-1)
DO 951 K=1,NSET
USPHCL(K)=MINIF(100.,MAX1F(USPHCL(K),0.))*1
951 CALL SYMBOL(SIT(K),USPHCL(K),.07,0,0.,-1)
DO 950 K=1,NSET
VOHCL(K)=MINIF(100.,MAX1F(VOHCL(K),0.))*1
950 CALL SYMBOL(SIT(K),VOHCL(K),.07,3,0.,-1)
CALL PLOT(35.,0,-3)
909 IF (KUNT(2))918,918,910
910 CALL AXIS(0.,0.,32H REACTOR AND FILTER TEMPERATURES,-32,30.,0.,0.,
XSIZE)
CALL AXIS(0.,0.,1H ,1,10.,90.,0.,10.)
DO 911 K=1,NSET
TREAC(K)=(TREAC(K)-200.)/5.
TREAC(K)=MINIF(100.,MAX1F(TREAC(K),0.))*1
911 CALL SYMBOL(SIT(K),TREAC(K),.07,12,0.,-1)
DO 948 K=1,NSET
TWALL(K)=(TWALL(K)-200.)/5.

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TABLE IV (Contd.)

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      TWALL(K)=MIN1F(100.,MAX1F( TWALL(K),0.))*1
948 CALL SYMBOL(SIT(K),TWALL(K),.07,0,0.,-1)
      DO 946 K=1,NSET
      TCF2(K)=(TDF2(K)-200.)/5.
      TCF2(K)=MIN1F(100.,MAX1F( TDF2(K),0.))*1
946 CALL SYMBOL(SIT(K),TDF2(K),.07,4,0.,-1)
      DO 941 K=1,NSET
      TALLOY(K)=(TALLOY(K)-200.)/5.
      TALLOY(K)=MIN1F(100.,MAX1F(TALLOY(K),0.))*1
941 CALL SYMBOL(SIT(K),TALLOY(K),.07,3,0.,-1)
      CALL PLOT(35.,0,-3)
918 IF (KUNTL(3))926,926,919
919 CALL AXIS(0.,0.,42H REACTOR AND FILTER VELCCITY AND PRESSURE,-42,
      X30.,0.,0.,SIZE)
      CALL AXIS(0.,0.,1H ,1,10.,90.,0.,10.)
      DO 924 K=1,NSET
      REAVEL(K)=50.*REAVEL(K)
      REAVEL(K)=MIN1F(100.,MAX1F(REAVEL(K),0.))*1
924 CALL SYMBOL(SIT(K),REAVEL(K),.07,12,0.,-1)
      DO 939 K=1,NSET
      IF (NON) 906,904,904
906 DFFVEL(K)=.5*DFFVEL(K)
904 DFFVEL(K)=100.*DFFVEL(K)
      DFFVEL(K)=MIN1F(100.,MAX1F(DFFVEL(K),0.))*1
939 CALL SYMBOL(SIT(K),DFFVEL(K),.07,0,0.,-1)
      DO 937 K=1,NSET
      TCPR(K)=5.*TOPR(K)
      TCPR(K)=MIN1F(100.,MAX1F( TOPR(K),0.))*1
937 CALL SYMBOL(SIT(K),TOPR(K),.07,4,0.,-1)
      CALL PLOT(35.,0,-3)
926 IF (KUNTL(4))935,935,927
927 CALL AXIS(0.,0.,32H REACTOR EXIT COMPOSITION (V/O),-32,30.,0.,0.,
      XSIZE)
      CALL AXIS(0.,0.,1H ,1,10.,90.,0.,10.)
      DO 933 K=1,NSET
      XVOHCL(K)=MIN1F(100.,MAX1F(XVOHCL(K),0.))*1
933 CALL SYMBOL(SIT(K),XVOHCL(K),.07,12,0.,-1)
      DO 932 K=1,NSET
      XVOH(K)=MIN1F(100.,MAX1F( XVOH(K),0.))*1
932 CALL SYMBOL(SIT(K),XVOH(K),.07,0,0.,-1)
      DO 930 K=1,NSET
      XVOCL4(K)=MIN1F(100.,MAX1F(XVOCL4(K),0.))*1
930 CALL SYMBOL(SIT(K),XVOCL4(K),.07,4,0.,-1)
      DO 928 K=1,NSET
      XVON2(K)=MIN1F(100.,MAX1F( XVON2(K),0.))*1
928 CALL SYMBOL(SIT(K),XVON2(K),.07,3,0.,-1)
      CALL PLOT(35.,0,-3)
935 IF (KUNTL(5))944,944,936
936 CALL AXIS(0.,0.,38H PYROHYDROLYSER BED COMPOSITION (V/O),-38,30.,
      X0.,0.,SIZE)
      CALL AXIS(0.,0.,1H ,1,10.,90.,0.,10.)
      DO 942 K=1,NSET
      HRVOHC(K)=MIN1F(100.,MAX1F(HRVOHC(K),0.))*1
942 CALL SYMBOL(SIT(K),HRVOHC(K),.07,12,0.,-1)
      DO 922 K=1,NSET
      HRVOH2(K)=MIN1F(100.,MAX1F(HRVOH2(K),0.))*1
922 CALL SYMBOL(SIT(K),HRVOH2(K),.07,0,0.,-1)
      DO 920 K=1,NSET
      HRVOCL(K)=MIN1F(100.,MAX1F(HRVOCL(K),0.))*1
920 CALL SYMBOL(SIT(K),HRVOCL(K),.07,4,0.,-1)
      DO 916 K=1,NSET
      HRVOST(K)=MIN1F(100.,MAX1F(HRVOST(K),0.))*1

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TABLE IV (Contd.)

```

916 CALL SYMBOL(SIT(K),HRVOST(K),.07,3,0.,-1)
    CALL PLOT(35.,0,-3)
944 IF (KUNT(6))953,953,945
945 CALL AXIS(0.,0.,50H PYROHYDROLYSER RATE, TEMP, VELOCITY AND PRESS
    XURE,-50,30.,0.,0.,SIZE)
    CALL AXIS(0.,0.,1H ,1,10.,90.,0.,10.)
    DO 446 K=1,NSET
    ROX(K)=10.*ROX(K)
    ROX(K)=MIN1F(100.,MAX1F( ROX(K),0.))*0.1
446 CALL SYMBOL(SIT(K),ROX(K),.07,12,0.,-1)
    DO 915 K=1,NSET
    THYDRO(K)=(THYDRO(K)-200.)/5.
    THYDRO(K)=MIN1F(100.,MAX1F(THYDRO(K),0.))*0.1
915 CALL SYMBOL(SIT(K),THYDRO(K),.07,0,0.,-1)
    DO 913 K=1,NSET
    HRVEL(K)=50.*HRVEL(K)
    HRVEL(K)=MIN1F(100.,MAX1F( HRVEL(K),0.))*0.1
913 CALL SYMBOL(SIT(K),HRVEL(K),.07,4,0.,-1)
    DO 907 K=1,NSET
    HRPRE(K)=5.*HRPRE(K)
    HRPRE(K)=MIN1F(100.,MAX1F( HRPRE(K),0.))*0.1
907 CALL SYMBOL(SIT(K),HRPRE(K),.07,3,0.,-1)
    CALL PLOT(35.,0,-3)
953 IF (NRUNZ)954,954,1
954 END FILE 5

GO TO 1
4000 FORMAT (14H1 2026/CEN 139)
4001 FORMAT (2I6)
4002 FORMAT(6E12.4)
4003 FORMAT (8H1 RUN NO15,27H URANIUM ALLOY PROCESSING/24H0TIME AVERA
    XGES FOR TIME F4.0,5H TO F4.0,5H MIN/27H0HALOGENATION REACTOR INL
    XET/52H0HCL VOL N2 VOL TOTAL PRES VELOCITY METAL RATE/52H PER
    XCENT PERCENT PSIG FT/SEC KG/HR)
4004 FORMAT (23H0 REGRESSION CONSTANTS 5E19.6)
4005 FORMAT (12E6.0)
4006 FORMAT (I4,F5.0,3F6.1,F6.1,2F7.2,3F5.0,F5.0,2F6.1,F5.0,4F5.1,3F5.0
    X)
4007 FORMAT (24H0 CORRECTION FACTOR H2 =F8.4)
4008 FORMAT (25H0 CORRECTION FACTOR HCL =F8.4)
4009 FORMAT (31H0 CORRECTION FACTOR FOR STEAM =F8.4)
4010 FORMAT (68H0 DIA1 ALLOY TYPE CHARGE ZERO HCL
    X STEAM/F10.3,F13.0,F12.3,F10.1,2F12.2)
4011 FORMAT (115H1 INDEX TIME HR IN HR IN HR IN
    2 HR IN HR IN HR IN HR IN HR IN HR IN/115H
    3 CU FT/MIN V/O HCL V/O N2 V/O H2 V/O
    4 CLID V/O STM PPR HCL PPR N2 PPR H2)
4012 FORMAT (I4,F7.0,F9.0,4F7.0,2F8.0,F7.0,F8.1,F11.1,2F10.1)
4013 FORMAT (111H1INDEX TIME TIME TINLET TREAC TWALL TDFF TALL
    XOY THYDRO TOGAS TOT PR DELTA REA DELTA DFF DELTA HR/111H
    X INTERVAL DEG C DEG C DEG C DEG C DEG C DEG C DEG C
    XC PSIG PSIG PSIG PSIG)
4014 FORMAT (115H1 INDEX TIME DELTA HRF NITROGEN PURGE RATE BLO
    2W BACK PERCENT HCL METAL RATE PERCENT PERCENT/115H
    3 PSIG CU FT/MIN CU FT/MIN CU FT/MIN HYD
    4ROGEN CU FT/MIN KG/HR METAL HCL UTIL)
4015 FORMAT (115H1 INDEX TIME REA IN REA IN REA IN
    2REA IN REA IN REAC VEL REA XIT REA XIT REA XIT/115H
    3 CU FT/MIN V/O HCL V/O N2 PPR HCL P
    4PR N2 FT/SEC CU FT/MIN V/O HCL V/O N2)
4016 FORMAT (115H1 INDEX TIME REA XIT REA XIT REA XIT R
    2EA XIT REA XIT REA XIT DFF VEL STEAM OXIDE RATE/115H
    3 V/O H2 V/O CLID PPR HCL PPR N2 P

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TABLE IV (Contd.)

4PR H2	PPR CLID	FT/SEC	CUFT/MIN	KG/HR	)
4017	FORMAT(7211)				
4019	FORMAT (19H0 TIME LOWER RANGES/(1CF12.0))				
4020	FORMAT (19H0 TIME UPPER RANGES/(1CF12.0))				
4022	FORMAT (2F8.1,F12.1,F10.2,F14.4/57H0	HCL	BED TEMP	WALL TE	
1MP	INLET TEMP	METAL TEMP/57H	EFFICIENCY	DEG C	DEG C
2	DEG C	DEG C/F12.2,F10.0,F11.0,2F12.0	////13H	FILTER	INLET
3/46H	OHCL VOL	N2 VOL	CLID VOL	H2 VOL	TOTAL PRES/46H
4CENT	PERCENT	PERCENT	PSIG/2F8.1,F10.1,F8.1,F12.1/20H	VELO	PER
5CITY	FILT TEMP/20H	FT/SEC	DEG C/F9.2,F11.0	////	
4023	FORMAT	(29H PYROHYDROLYSIS REACTOR INLET/45H	OHCL V		
1OL	N2 VOL	CLID VOL	H2 VOL	STEAM VOL/45H	PERCENT PERCENT PERC
2ENT	PERCENT	PERCENT/2F8.1,F10.1,F8.1,F11.1/55H	OPRESSURE	VELOCIT	
3Y	OXIDE RATE	BED TEMP	OFF GAS TEMP/55H	PSIG	FT/SEC
4	KG/HR	DEG C	DEG C/F9.1,F9.2,F12.2,F10.0,F15.0)		
4024	FORMAT (14,9F12.4)				
4025	FORMAT (8H1 INPUT)				
4027	FORMAT (38H URANIUM ALLOY PROCESSING CALCULATIONS,7X,11H	RUN NUMBER			
X 12)					
4028	FORMAT (13H0 BENCH SCALE)				
4029	FORMAT (10H0 HOT CELL)				
4030	FORMAT (13H0 PILOT PLANT)				
4031	FORMAT (115H1 INDEX	TIME	HR IN	HR IN	HR VEL
2HR	XIT	HR XIT	HR XIT	HR XIT	HR XIT/115H
3		PPR CLID	PPR STM	FT/SEC	CU FT/MIN V/
40	HCL	V/O N2	V/O H2	V/O STM	PPR HCL)
4032	FORMAT (115H1 INDEX	TIME	HR XIT	HR XIT	HR XIT
2					/115H
3		PPR N2	PPR H2	PPR STM	
4					)
4034	FORMAT (2H	I3,F11.0,F11.1,2F11.3,F11.2,F11.1,F11.3,F11.4,2F11.1)			
4035	FORMAT (2H	I3,F11.0,F11.3,2F11.1,3F11.2,F11.3,2F11.1)			
4036	FORMAT (2H	I3,F11.0,2F11.1,7F11.2)			
4037	FORMAT (2H	I3,F11.0,F11.2,5F11.1,3F11.2)			
4038	FORMAT (2H	I3,F11.0,4F11.2,4F11.1,F11.2)			
4039	FORMAT (2H	I3,F11.0,3F11.2)			
4066	FORMAT (115H1 INDEX	TIME	REA XIT	REA XIT	REA XIT R
2EA	XIT	REA XIT	REA XIT	OFF VEL	/115H
3		V/O H2	V/O CLID	PPR HCL	PPR N2 P
4PR	H2	PPR CLID	FT/SEC		)
4078	FORMAT (13H PGPT VALUES 4F5.1)				
END					

TABLE V. Nomenclature for CEN-139

A. Program Nomenclature

Input or Calculated Value		Output Label
Δ_k	TIME INTERVAL	(Minutes)
TINLET _k	TINLET DEG C	(Inlet to halogenation reactor)
TREA _k	TREA DEG C	(Halogenation reactor fluid bed)
TWALL _k	TWALL DEG C	(Halogenation reactor wall)
TDF2 _k	TDFF DEG C	(Packed-bed filter)
TALLOY _k	TALLOY DEG C	(Reacting metal temperature)
THYDRO _k	THYDRO DEG C	(Pyrohydrolyzer fluid bed)
TOGAS _k	TOGAS DEG C	(Pyrohydrolyzer off gas)
TOPR _k	TOT PR PSIG	(Pressure at inlet to halogenation reactor)
DELREA _k	DELTA REA PSIG	(ΔP across halogenation reactor bed)
DELDF2 _k	DELTA DFF PSIG	(ΔP across packed-bed filter)
DELHR _k	DELTA HR PSIG	(ΔP across pyrohydrolyzer bed)
DELHFR _k	DELTA HRF PSIG	(ΔP across pyrohydrolyzer filters)
TOPPY _k	NITROGEN CU FT/MIN	(Nitrogen to halogenation reactor)
PURRAT _k	PURGE RATE CU FT/MIN	(Nitrogen purge)
EN2BB _k	BLOW BACK CU FT/MIN	(Nitrogen blow back)
PH2 _k	PERCENT HYDROGEN	(In off-gas from pyrohydrolyzer)
HYCLP _k	HCL CU FT/MIN	(HCl to halogenation reactor)
RATMET _k	METAL RATE KG/HR	(Reactor rate)
PRATMT _k	PERCENT METAL	(Percentage of charge remaining unreacted)
USPHCL _k	PERCENT HCL UTIL	(Utilization efficiency)
RTV _k	REA IN CU FT/MIN	(Total flow at inlet to halogenation reactor)
VOHCL _k	REA IN V/O HCL	(Volume percent at reactor inlet)
VON2 _k	REA IN V/O N2	(Volume percent at reactor inlet)
PPRHCL _k	REA IN PPR HCL	(Partial pressure at halogenation reactor inlet)
PPRN2 _k	REA IN PPR N2	(Partial pressure at halogenation reactor inlet)
REAVEL _k	REAC VEL FT/SEC	(Superficial, open-column velocity)
REXTV _k	REA XIT CU FT/MIN	(Total flow at exit from halogenation reactor)
XVOHCL _k	REA XIT V/O HCL	(Volume percent at exit from halogenation reactor)
XVON2 _k	REA XIT V/O N2	(Volume percent at exit from halogenation reactor)
XVOH _k	REA XIT V/O H2	(Volume percent at exit from halogenation reactor)
XVOCL4 _k	REA XIT V/O CLID	(Volume percent at exit from halogenation reactor)
XPPHCL _k	REA XIT PPR HCL	(Partial pressure at exit from halogenation reactor)
XPPN2 _k	REA XIT PPR N2	(Partial pressure at exit from halogenation reactor)
XPPHTW _k	REA XIT PPR H2	(Partial pressure at exit from halogenation reactor)
XPPCL4 _k	REA XIT PPR CLID	(Alloy chloride AlCl ₃ or ZrCl ₄ from halogenation reactor)

TABLE V (Contd.)

Input or Calculated Value	Output Label	
DFFVEL _k	DFF VEL FT/SEC	(Superficial velocity in filter)
STEEM _k	STEAM CU FT/MIN	(Steam to pyrohydrolyzer)
ROX _k	OXIDE RATE KG/HR	(Zr or Al oxide production rate)
HRITVT _k	HR IN CU FT/MIN	(Total flow at inlet to pyrohydrolyzer)
HRVOHC _k	HR IN V/O HCL	(Volume percent at pyrohydrolyzer)
HRVON _{2k}	HR IN V/O N ₂	(Volume percent at pyrohydrolyzer)
HRVOH _{2k}	HR IN V/O H ₂	(Volume percent at pyrohydrolyzer)
HRVOCL _k	HR IN V/O CLID	(Volume percent at pyrohydrolyzer)
HRVOST _k	HR IN V/O STM	(Volume percent at pyrohydrolyzer)
HRPPHC _k	HR IN PPR HCL	(Partial pressure at pyrohydrolyzer inlet)
HRPPN _{2k}	HR IN PPR N ₂	(Partial pressure at pyrohydrolyzer inlet)
HRPPH _{2k}	HR IN PPR H ₂	(Partial pressure at pyrohydrolyzer inlet)
HRDPCL _k	HR IN PPR CLID	(Partial pressure at pyrohydrolyzer inlet)
HRPPST _k	HR IN PPR STM	(Partial pressure at pyrohydrolyzer inlet)
HRVEL _k	HR VEL FT/SEC	(Superficial velocity in pyrohydrolyzer)
HRXTV _k	HR XIT CU FT/MIN	(Volume at pyrohydrolyzer exit)
HXVOHC _k	HR XIT V/O HCL	(Volume percent at pyrohydrolyzer exit)
HXVON _{2k}	HR XIT V/O N ₂	(Volume percent at pyrohydrolyzer exit)
HXVOH _{2k}	HR XIT V/O H ₂	(Volume percent at pyrohydrolyzer exit)
HXVOST _k	HR XIT V/O STM	(Volume percent at pyrohydrolyzer exit)
HXPPHC _k	HR XIT PPR HCL	(Partial pressure at pyrohydrolyzer exit)
HXPPN _{2k}	HR XIT PPR N ₂	(Partial pressure at pyrohydrolyzer exit)
HXPPH _{2k}	HR XIT PPR H ₂	(Partial pressure at pyrohydrolyzer exit)
HXPPST _k	HR XIT PPR STM	(Partial pressure at pyrohydrolyzer exit)
<u>Averages at Halogenation Reactor Inlet</u>		
SOHCL	HCL VOL PERCENT	
SON ₂	N ₂ VOL PERCENT	
SUPR	TOTAL PRES PSIG	
SVEL	VELOCITY FT/SEC	
STRATEM	METAL RATE KG/HR	
SUST	HCL EFFICIENCY	
SREAC	BED TEMP DEG C	
SWALL	WALL TEMP DEG C	
SINLET	INLET TEMP DEG C	
SALLOY	METAL TEMP DEG C	

TABLE V (Contd.)

Input or Calculated Value	Output Label
<u>Averages at Filter Inlet</u>	
SVOHCL	HCL VOL PERCENT
SVON2	N2 VOL PERCENT
SVOCL4	CLID VOL PERCENT
SVOH	H2 VOL PERCENT
SITPR	TOTAL PRES PSIG
SFFVEL	VELOCITY FT/SEC
SDF2	FILT TEMP DEG C
<u>Averages at Pyrohydrolysis Reactor</u>	
SRVOHC	HCL VOL PERCENT
SRVON2	N2 VOL PERCENT
SRVOCL	CLID VOL PERCENT
SRVOH2	H2 VOL PERCENT
SRVOST	STEAM VOL PERCENT
SRPRE	PRESSURE PSIG
SRVEL	VELOCITY FT/SEC
SROX	OXIDE RATE KG/HR
SHYDRO	BED TEMP DEG C
SOGAS	OFF GAS TEMP DEG C

B. Graph Nomenclature and Scaling

Graph No.	Symbol	Value Plotted	Graph Label
1	12	$20(\text{RATMET}_k)$ if $\text{NOP} = 3$, or $1000(\text{RATMET}_k)$ otherwise	RATE, EFFICIENCY, AND V/O HCL
1	0	USPHCL_k	
1	3	VOHCL_k	
2	12	$(\text{TREAC}_k - 200)/5$	REACTOR AND FILTER TEMPERATURES
2	0	$(\text{TWALL}_k - 200)/5$	
2	4	$(\text{TDF2}_k - 200)/5$	
2	3	$(\text{TALLOY}_k - 200)/5$	
3	12	$50(\text{REAVEL}_k)$	REACTOR AND FILTER VELOCITY AND PRESSURE
3	0	$100(\text{DFFVEL}_k)$ if $\text{NOP} = 3$, or $50(\text{DFFVEL}_k)$ otherwise	
3	4	$5(\text{TOPR}_k)$	

TABLE V (Contd.)

Graph No.	Symbol	Value Plotted	Graph Label
4	12	$XVOHCL_k$	REACTOR EXIT COMPOSITION (V/O)
4	0	$XVOH_k$	
4	4	$XVOCL_4k$	
4	3	$XVON_2k$	
5	12	$HRVOHC_k$	PYROHYDROLYZER BED COMPOSITION (V/O)
5	0	$HRVOH_2k$	
5	4	$HRVOCL_k$	
5	3	$HRVOST_k$	
6	12	$10(ROX_k)$	PYROHYDROLYZER RATE, TEMP, VELOCITY, AND PRESSURE
6	0	$(THYDRO_k - 200)/5$	
6	4	$50(HRVEL_k)$	
6	3	$5(HRPRE_k)$	

Symbol 0 = □

Symbol 3 = +

Symbol 4 = x

Symbol 12 = X

TABLE VI (Contd.)

269.	53.	20.	47.	59.5	7.3	29.8	393.	250.	380.	0.	92.
7.9	349.	36.	93.	24.	19.	334.	344.	214.			
270.	51.	20.	43.	58.3	7.3	29.8	392.	250.	377.	0.	92.
8.0	348.	35.	91.	24.	19.	335.	343.	213.			
275.	51.	20.	43.	58.5	7.3	29.8	392.	250.	377.	0.	92.
8.0	348.	35.	91.	24.	19.	335.	343.	213.			
290.	51.	20.	43.	56.6	7.3	29.8	392.	250.	385.	0.	92.
8.0	348.	35.	92.	24.	19.	335.	343.	213.			
305.	52.	20.	43.	48.1	7.3	29.8	380.	250.	386.	0.	92.
8.0	348.	35.	93.	24.	19.	334.	345.	213.			
320.	52.	20.	43.	42.2	7.3	29.8	366.	250.	374.	0.	92.
8.0	347.	34.	94.	24.	19.	335.	345.	213.			
335.	51.	20.	43.	32.0	7.3	29.8	363.	250.	361.	0.	92.
8.0	346.	34.	93.	24.	20.	338.	343.	214.			
350.	49.	20.	43.	23.0	7.2	29.8	357.	250.	352.	0.	92.
8.0	344.	34.	90.	24.	20.	339.	344.	215.			
365.	47.	20.	43.	18.5	7.2	29.8	351.	250.	349.	0.	92.
8.0	343.	33.	84.	23.	21.	337.	345.	215.			
380.	45.	20.	43.	8.7	7.2	29.8	348.	250.	343.	0.	92.
8.0	344.	33.	80.	22.	21.	336.	346.	214.			
396.	45.	20.	43.	2.5	7.2	29.8	345.	250.	342.	0.	92.
8.0	343.	33.	79.	22.	21.	336.	346.	214.			
397.	45.	160.	0.	2.0	7.2	29.8	344.	250.	343.	0.	92.
8.0	343.	33.	79.	22.	21.	335.	346.	213.			
412.	44.	160.	0.	2.0	7.2	29.8	343.	250.	343.	1540.	92.
8.0	343.	33.	79.	22.	21.	335.	346.	213.			
500.	43.	160.	0.	2.0	7.2	29.8	343.	250.	343.	0.	92.
8.0	343.	33.	79.	22.	21.	335.	346.	213.			

TABLE VII. Calculated Output for Hydrochlorination Step (CEN-139)

2026/CEN 139						
URANIUM ALLOY PROCESSING CALCULATIONS				RUN NUMBER 18		
PGPT VALUES 1.5 3.0 3.0 6.8						
PILOT PLANT						
TIME LOWER RANGES						
16 270 16						
TIME UPPER RANGES						
270 396 396						
DIA1	ALLOY TYPE	CHARGE	ZERO	HCL	STEAM	
6.065	2	5.965	2.0	53.30	47.00	
REGRESSION CONSTANTS		-1.825600+001		3.400500-002	-0.000000+000	-0.000000+000
REGRESSION CONSTANTS		-4.347300+001		7.975000-002	-0.000000+000	-0.000000+000
REGRESSION CONSTANTS		-1.296375+000		6.564001-001	-7.012249-003	1.085441-004
REGRESSION CONSTANTS		3.288700+000		2.294700+000	-4.821600-002	5.702300-004
REGRESSION CONSTANTS		-9.857000-002		2.522700-001	-0.000000+000	-0.000000+000
REGRESSION CONSTANTS		3.379600-004		4.296800-002	-3.494100-004	3.120200-005
REGRESSION CONSTANTS		-2.181000-002		1.000700-002	-0.000000+000	-0.000000+000
REGRESSION CONSTANTS		-3.800000+000		9.950000-002	-0.000000+000	-0.000000+000
REGRESSION CONSTANTS		4.905000-002		5.951000-002	-0.000000+000	-0.000000+000
REGRESSION CONSTANTS		-2.478000-002		1.006000-001	-0.000000+000	-0.000000+000

TABLE VII (Contd.)

INPUT																					
1	0	29.0	160.0	0.0	2.0	7.50	29.80	387	252	247	2130	92.0	7.1	335	37.0	56.0	14.0	18.0	350	400	169
2	15	30.0	160.0	0.0	2.0	7.50	29.80	397	252	247	0	92.0	7.5	341	38.0	56.0	15.0	18.0	349	400	172
3	16	31.0	20.0	47.0	2.0	7.50	29.80	407	252	247	0	92.0	7.5	347	38.0	56.0	15.0	18.0	348	400	174
4	20	37.0	21.0	47.0	21.5	7.50	29.80	407	252	394	0	92.0	7.7	347	38.0	56.0	15.0	18.0	347	400	174
5	30	40.0	21.0	47.0	52.8	7.50	29.80	401	252	560	0	92.0	7.8	348	38.0	63.0	16.0	18.0	347	399	176
6	35	43.0	22.0	47.0	63.4	7.50	29.80	384	252	564	0	92.0	7.5	352	38.0	74.0	17.0	19.0	348	398	180
7	50	47.0	22.0	47.0	64.7	7.40	29.80	379	252	507	0	92.0	7.4	354	38.0	80.0	19.0	20.0	350	373	189
8	65	49.0	22.0	47.0	66.1	7.40	29.80	390	251	433	0	92.0	7.7	353	38.0	83.0	20.0	20.0	340	349	198
9	80	49.0	22.0	47.0	65.5	7.40	29.80	395	251	402	0	92.0	7.9	353	38.0	84.0	21.0	20.0	330	348	202
10	95	50.0	22.0	47.0	66.3	7.40	29.80	396	249	398	0	92.0	7.8	353	38.0	85.0	22.0	20.0	331	345	205
11	110	51.0	23.0	47.0	64.2	7.40	29.80	399	248	396	0	92.0	7.9	353	38.0	88.0	24.0	20.0	333	344	207
12	125	51.0	23.0	47.0	62.7	7.40	29.80	392	249	392	0	92.0	8.1	352	38.0	90.0	25.0	20.0	334	345	208
13	145	52.0	24.0	47.0	62.1	7.40	29.80	394	249	388	0	92.0	8.0	351	38.0	91.0	25.0	20.0	335	344	209
14	155	52.0	24.0	47.0	61.4	7.30	29.80	395	248	387	0	92.0	7.8	351	38.0	90.0	25.0	20.0	335	344	210
15	170	52.0	22.0	47.0	61.1	7.30	29.80	395	248	388	0	92.0	7.9	351	38.0	90.0	25.0	20.0	335	345	211
16	185	52.0	21.0	47.0	60.5	7.30	29.80	393	249	388	0	92.0	8.0	350	38.0	91.0	25.0	20.0	335	343	212
17	200	52.0	21.0	47.0	59.8	7.30	29.80	390	250	386	0	92.0	8.0	350	38.0	91.0	25.0	20.0	335	341	214
18	215	52.0	21.0	47.0	61.2	7.30	29.80	390	250	385	0	92.0	8.1	350	38.0	91.0	25.0	20.0	334	342	214
19	230	52.0	21.0	47.0	61.2	7.30	29.80	392	250	384	0	92.0	8.2	349	38.0	93.0	25.0	20.0	333	342	214
20	245	52.0	21.0	47.0	59.7	7.30	29.80	392	250	382	0	92.0	8.1	348	37.0	93.0	25.0	20.0	333	343	215
21	260	53.0	21.0	47.0	59.8	7.30	29.80	392	250	382	0	92.0	7.9	350	37.0	95.0	24.0	20.0	333	345	214
22	269	53.0	20.0	47.0	59.5	7.30	29.80	393	250	380	0	92.0	7.9	349	36.0	93.0	24.0	19.0	334	344	214
23	270	51.0	20.0	43.0	58.3	7.30	29.80	392	250	377	0	92.0	8.0	348	35.0	91.0	24.0	19.0	335	343	213
24	275	51.0	20.0	43.0	58.5	7.30	29.80	392	250	377	0	92.0	8.0	348	35.0	91.0	24.0	19.0	335	343	213
25	290	51.0	20.0	43.0	56.6	7.30	29.80	392	250	385	0	92.0	8.0	348	35.0	92.0	24.0	19.0	335	343	213
26	305	52.0	20.0	43.0	48.1	7.30	29.80	380	250	386	0	92.0	8.0	348	35.0	93.0	24.0	19.0	334	345	213
27	320	52.0	20.0	43.0	42.2	7.30	29.80	366	250	374	0	92.0	8.0	347	34.0	94.0	24.0	19.0	335	345	213
28	335	51.0	20.0	43.0	32.0	7.30	29.80	363	250	361	0	92.0	8.0	346	34.0	93.0	24.0	20.0	338	343	214
29	350	49.0	20.0	43.0	23.0	7.20	29.80	357	250	352	0	92.0	8.0	344	34.0	90.0	24.0	20.0	339	344	215
30	365	47.0	20.0	43.0	18.5	7.20	29.80	351	250	349	0	92.0	8.0	343	33.0	84.0	23.0	21.0	337	345	215
31	380	45.0	20.0	43.0	8.7	7.20	29.80	348	250	343	0	92.0	8.0	344	33.0	80.0	22.0	21.0	336	346	214
32	396	45.0	20.0	43.0	2.5	7.20	29.80	345	250	342	0	92.0	8.0	343	33.0	79.0	22.0	21.0	336	346	214
33	397	45.0	160.0	0.0	2.0	7.20	29.80	344	250	343	0	92.0	8.0	343	33.0	79.0	22.0	21.0	335	346	213
34	412	44.0	160.0	0.0	2.0	7.20	29.80	343	250	343	1540	92.0	8.0	343	33.0	79.0	22.0	21.0	335	346	213
35	500	43.0	160.0	0.0	2.0	7.20	29.80	343	250	343	0	92.0	8.0	343	33.0	79.0	22.0	21.0	335	346	213

CORRECTION FACTOR W2 = 1.2381

CORRECTION FACTOR WCL = 0.9467

CORRECTION FACTOR FOR STEAM = 1.0274

TABLE VII (Contd.)

INDEX	TIME	TIME INTERVAL	TINLET DEG C	TREAC DEG C	TWALL DEG C	TDFE DEG C	TALLOY DEG C	THYDRO DEG C	TOGAS DEG C	TOT PR PSIG	DELTA REA PSIG	DELTA DFF PSIG	DELTA HR PSIG
1	0	0	350	387	400	252	247	335	169	7.2	0.3	1.8	0.9
2	15	15	349	397	400	252	247	341	172	7.5	0.4	1.8	0.9
3	16	1	348	407	400	252	247	347	174	7.7	0.4	1.8	0.9
4	20	4	347	407	400	252	394	347	174	9.2	0.4	1.8	0.9
5	30	10	347	401	399	252	560	348	176	10.0	0.4	2.5	1.0
6	35	5	348	384	398	252	564	352	180	10.7	0.4	3.6	1.1
7	50	15	350	379	373	252	507	354	189	11.8	0.4	4.2	1.2
8	65	15	340	390	349	251	433	353	198	12.3	0.4	4.5	1.2
9	80	15	330	395	348	251	402	353	202	12.3	0.4	4.6	1.3
10	95	15	331	396	345	249	398	353	205	12.5	0.4	4.7	1.4
11	110	15	333	399	344	248	396	353	207	12.8	0.4	5.0	1.5
12	125	15	334	392	345	249	392	352	208	12.8	0.4	5.2	1.5
13	145	20	335	394	344	249	388	351	209	13.0	0.4	5.3	1.5
14	155	10	335	395	344	248	387	351	210	13.0	0.4	5.2	1.5
15	170	15	335	395	345	248	388	351	211	13.0	0.4	5.2	1.5
16	185	15	335	393	343	249	388	350	212	13.0	0.4	5.3	1.5
17	200	15	335	390	341	250	386	350	214	13.0	0.4	5.3	1.5
18	215	15	334	390	342	250	385	350	214	13.0	0.4	5.3	1.5
19	230	15	333	392	342	250	384	349	214	13.0	0.4	5.5	1.5
20	245	15	333	392	343	250	382	348	215	13.0	0.3	5.5	1.5
21	260	15	333	392	345	250	382	350	214	13.3	0.3	5.7	1.5
22	269	9	334	393	344	250	380	349	214	13.3	0.3	5.5	1.5
23	270	1	335	392	343	250	377	348	213	12.8	0.3	5.3	1.5
24	275	5	335	392	343	250	377	348	213	12.8	0.3	5.3	1.5
25	290	15	335	392	343	250	385	348	213	12.8	0.3	5.4	1.5
26	305	15	334	380	345	250	386	348	213	13.0	0.3	5.5	1.5
27	320	15	335	366	345	250	374	347	213	13.0	0.3	5.6	1.5
28	335	15	338	363	343	250	361	346	214	12.8	0.3	5.5	1.5
29	350	15	339	357	344	250	352	344	215	12.3	0.3	5.2	1.5
30	365	15	337	351	345	250	349	343	215	11.8	0.3	4.6	1.4
31	380	15	336	348	346	250	343	344	214	11.3	0.3	4.2	1.4
32	396	16	336	345	346	250	342	343	214	11.3	0.3	4.1	1.4
33	397	1	335	344	346	250	343	343	213	11.3	0.3	4.1	1.4
34	412	15	335	343	346	250	343	343	213	11.0	0.3	4.1	1.4
35	500	88	335	343	346	250	343	343	213	10.7	0.3	4.1	1.4

TABLE VII (Contd.)

INDEX	TIME	DELTA HRF PSIG	NITROGEN CU FT/MIN	PURGE RATE CU FT/MIN	BLOW BACK CU FT/MIN	PERCENT HYDROGEN	HCL CU FT/MIN	METAL RATE KG/HR	PERCENT METAL	PERCENT HCL UTIL
1	0	1.8	4.953	0.542	0.15	0.0	0.000	0.0000	100.0	0.0
2	15	1.8	4.982	0.542	0.15	0.0	0.000	0.0000	100.0	0.0
3	16	1.8	0.474	0.542	0.15	0.0	3.137	0.0000	100.0	0.0
4	20	1.8	0.523	0.542	0.15	9.6	3.137	0.2185	99.8	10.2
5	30	1.8	0.531	0.542	0.15	28.2	3.137	0.8089	97.5	37.8
6	35	1.9	0.574	0.542	0.15	37.7	3.137	1.2907	95.7	60.4
7	50	2.0	0.585	0.535	0.15	39.0	3.137	1.3712	89.9	64.1
8	65	2.0	0.591	0.535	0.15	40.6	3.137	1.4666	83.8	68.6
9	80	2.0	0.591	0.535	0.15	39.9	3.137	1.4274	77.8	66.8
10	95	2.0	0.594	0.535	0.15	40.8	3.137	1.4832	71.6	69.4
11	110	2.0	0.632	0.535	0.15	38.5	3.137	1.3908	65.8	65.1
12	125	2.0	0.632	0.535	0.15	37.0	3.137	1.3028	60.3	60.9
13	145	2.0	0.671	0.535	0.15	36.4	3.137	1.3072	53.0	61.1
14	155	2.0	0.671	0.528	0.15	35.7	3.137	1.2622	49.5	59.0
15	170	2.0	0.599	0.528	0.15	35.4	3.137	1.1797	44.5	55.2
16	185	2.0	0.563	0.528	0.15	34.8	3.137	1.1178	39.9	52.3
17	200	2.0	0.563	0.528	0.15	34.2	3.137	1.0856	35.3	50.8
18	215	2.0	0.563	0.528	0.15	35.5	3.137	1.1512	30.5	53.8
19	230	2.0	0.563	0.528	0.15	35.5	3.137	1.1512	25.7	53.8
20	245	2.0	0.563	0.528	0.15	34.1	3.137	1.0811	21.1	50.6
21	260	2.0	0.566	0.528	0.15	34.2	3.137	1.0879	16.6	50.9
22	269	1.9	0.529	0.528	0.15	33.9	3.137	1.0431	13.9	48.8
23	270	1.9	0.525	0.528	0.15	32.8	2.835	0.9890	13.7	51.2
24	275	1.9	0.525	0.528	0.15	33.0	2.835	0.9971	12.3	51.6
25	290	1.9	0.525	0.528	0.15	31.3	2.835	0.9234	8.4	47.8
26	305	1.9	0.527	0.528	0.15	24.7	2.835	0.6658	5.6	34.5
27	320	1.9	0.527	0.528	0.15	20.8	2.835	0.5335	3.4	27.6
28	335	2.0	0.525	0.528	0.15	15.0	2.835	0.3580	1.9	18.5
29	350	2.0	0.520	0.521	0.15	10.4	2.835	0.2329	0.9	12.1
30	365	2.1	0.515	0.521	0.15	8.1	2.835	0.1764	0.2	9.1
31	380	2.1	0.510	0.521	0.15	2.8	2.835	0.0577	-0.1	3.0
32	396	2.1	0.510	0.521	0.15	-1.0	2.835	-0.0191	-0.0	-1.0
33	397	2.1	5.390	0.521	0.15	0.0	0.000	0.0000	-0.0	0.0
34	412	2.1	5.364	0.521	0.15	0.0	0.000	0.0000	-0.0	0.0
35	500	2.1	5.337	0.521	0.02	0.0	0.000	0.0000	-0.0	0.0

TABLE VII (Contd.)

INDEX	TIME	REA IN CU FT/MIN	REA IN V/O HCL	REA IN V/O N2	REA IN PPR HCL	REA IN PPR N2	REAC VEL FT/SEC	REA XIT CU FT/MIN	REA XIT V/O HCL	REA XIT V/O N2
1	0	4.997	0.0	100.0	0.00	1.49	0.62	5.084	0.0	100.0
2	15	5.025	0.0	100.0	0.00	1.51	0.62	5.112	0.0	100.0
3	16	3.655	85.8	14.2	1.31	0.22	0.45	3.742	83.8	16.2
4	20	3.704	84.7	15.3	1.38	0.25	0.43	3.737	75.4	17.5
5	30	3.712	84.5	15.5	1.42	0.26	0.42	3.601	54.2	18.4
6	35	3.755	83.6	16.4	1.45	0.28	0.40	3.526	35.3	20.0
7	50	3.766	83.3	16.7	1.50	0.30	0.38	3.518	32.0	20.4
8	65	3.771	83.2	16.8	1.53	0.31	0.38	3.500	28.1	20.6
9	80	3.771	83.2	16.8	1.53	0.31	0.38	3.509	29.7	20.6
10	95	3.774	83.1	16.9	1.54	0.31	0.38	3.498	27.5	20.7
11	110	3.813	82.3	17.7	1.54	0.33	0.38	3.560	30.8	21.4
12	125	3.813	82.3	17.7	1.54	0.33	0.38	3.581	34.2	21.3
13	145	3.852	81.4	18.6	1.54	0.35	0.38	3.619	33.7	22.2
14	155	3.852	81.4	18.6	1.54	0.35	0.38	3.630	35.4	22.1
15	170	3.780	83.0	17.0	1.57	0.32	0.37	3.578	39.3	20.4
16	185	3.744	83.8	16.2	1.58	0.31	0.37	3.557	42.1	19.5
17	200	3.744	83.8	16.2	1.58	0.31	0.37	3.565	43.3	19.5
18	215	3.744	83.8	16.2	1.58	0.31	0.37	3.549	40.8	19.5
19	230	3.744	83.8	16.2	1.58	0.31	0.37	3.549	40.8	19.5
20	245	3.744	83.8	16.2	1.58	0.31	0.37	3.566	43.5	19.4
21	260	3.746	83.7	16.3	1.59	0.31	0.36	3.567	43.2	19.5
22	269	3.710	84.6	15.4	1.61	0.29	0.36	3.542	45.4	18.6
23	270	3.403	83.3	16.7	1.56	0.31	0.34	3.248	42.6	20.2
24	275	3.403	83.3	16.7	1.56	0.31	0.34	3.246	42.3	20.2
25	290	3.403	83.3	16.7	1.56	0.31	0.34	3.264	45.3	20.1
26	305	3.406	83.2	16.8	1.57	0.32	0.33	3.330	55.8	19.7
27	320	3.406	83.2	16.8	1.57	0.32	0.32	3.362	61.0	19.6
28	335	3.403	83.3	16.7	1.56	0.31	0.32	3.403	67.9	19.3
29	350	3.398	83.4	16.6	1.53	0.30	0.33	3.428	72.7	19.0
30	365	3.393	83.5	16.5	1.50	0.30	0.33	3.437	74.9	18.8
31	380	3.389	83.7	16.3	1.48	0.29	0.33	3.461	79.5	18.5
32	396	3.389	83.7	16.3	1.48	0.29	0.33	3.480	82.3	18.4
33	397	5.434	0.0	100.0	0.00	1.77	0.53	5.521	0.0	100.0
34	412	5.407	0.0	100.0	0.00	1.75	0.53	5.494	0.0	100.0
35	500	5.381	0.0	100.0	0.00	1.73	0.53	5.468	0.0	100.0

TABLE VII (Contd.)

INDEX	TIME	REA XIT V/O H2	REA XIT V/O CLID	REA XIT PPR HCL	REA XIT PPR N2	REA XIT PPR H2	REA XIT PPR CLID	DFF VEL FT/SEC	STEAM CUFT/MIN	OXIDE RATE KG/HR
1	0	0.0	0.0	0.00	1.47	0.00	0.00	0.22	0.17	0.00
2	15	0.0	0.0	0.00	1.48	0.00	0.00	0.22	4.09	0.00
3	16	0.0	0.0	1.26	0.24	0.00	0.00	0.16	4.09	0.00
4	20	4.3	2.9	1.21	0.28	0.07	0.05	0.15	4.11	0.41
5	30	16.5	11.0	0.90	0.30	0.27	0.18	0.14	4.12	1.53
6	35	26.9	17.9	0.60	0.34	0.46	0.31	0.13	4.09	2.44
7	50	28.6	19.1	0.57	0.36	0.51	0.34	0.13	4.08	2.59
8	65	30.7	20.5	0.51	0.37	0.56	0.37	0.12	4.11	2.77
9	80	29.8	19.9	0.54	0.37	0.54	0.36	0.13	4.13	2.70
10	95	31.1	20.7	0.50	0.38	0.57	0.38	0.12	4.12	2.80
11	110	28.7	19.1	0.57	0.40	0.53	0.35	0.12	4.13	2.63
12	125	26.7	17.8	0.63	0.39	0.49	0.33	0.12	4.14	2.46
13	145	26.5	17.7	0.63	0.41	0.49	0.33	0.12	4.14	2.47
14	155	25.5	17.0	0.66	0.41	0.47	0.32	0.13	4.12	2.39
15	170	24.2	16.1	0.73	0.38	0.45	0.30	0.12	4.13	2.23
16	185	23.1	15.4	0.78	0.36	0.43	0.29	0.12	4.14	2.11
17	200	22.3	14.9	0.81	0.36	0.42	0.28	0.12	4.14	2.05
18	215	23.8	15.9	0.76	0.36	0.44	0.30	0.12	4.14	2.18
19	230	23.8	15.9	0.76	0.36	0.44	0.30	0.12	4.15	2.18
20	245	22.2	14.8	0.81	0.36	0.41	0.28	0.12	4.14	2.04
21	260	22.4	14.9	0.81	0.37	0.42	0.28	0.12	4.13	2.06
22	269	21.6	14.4	0.85	0.35	0.41	0.27	0.12	4.13	1.97
23	270	22.3	14.9	0.79	0.37	0.41	0.27	0.11	4.14	1.87
24	275	22.5	15.0	0.78	0.37	0.42	0.28	0.11	4.14	1.88
25	290	20.8	13.8	0.84	0.37	0.38	0.26	0.11	4.14	1.75
26	305	14.7	9.8	1.04	0.37	0.27	0.18	0.12	4.14	1.26
27	320	11.6	7.8	1.14	0.36	0.22	0.14	0.12	4.14	1.01
28	335	7.7	5.1	1.25	0.36	0.14	0.10	0.12	4.14	0.68
29	350	5.0	3.3	1.32	0.34	0.09	0.06	0.12	4.14	0.44
30	365	3.8	2.5	1.33	0.33	0.07	0.04	0.12	4.14	0.33
31	380	1.2	0.8	1.39	0.32	0.02	0.01	0.13	4.14	0.11
32	396	-0.4	-0.3	1.44	0.32	-0.01	-0.00	0.13	4.14	-0.04
33	397	0.0	0.0	0.00	1.74	0.00	0.00	0.20	4.14	0.00
34	412	0.0	0.0	0.00	1.73	0.00	0.00	0.20	4.14	0.00
35	500	0.0	0.0	0.00	1.71	0.00	0.00	0.21	4.14	0.00

TABLE VII (Contd.)

INDEX	TIME	HR IN CU FT/MIN	HR IN V/O HCL	HR IN V/O N2	HR IN V/O H2	HR IN V/O CLID	HR IN V/O STM	HR IN PPR HCL	HR IN PPR N2	HR IN PPR H2
1	0	5.26	0.0	96.7	0.0	0.0	3.3	0.00	1.30	0.00
2	15	9.20	0.0	55.6	0.0	0.0	44.4	0.00	0.76	0.00
3	16	7.83	40.1	7.7	0.0	0.0	52.2	0.55	0.11	0.00
4	20	7.85	35.9	8.3	2.0	1.4	52.4	0.53	0.12	0.03
5	30	7.72	25.3	8.6	7.7	5.1	53.3	0.38	0.13	0.11
6	35	7.62	16.3	9.3	12.4	8.3	53.7	0.24	0.14	0.18
7	50	7.60	14.8	9.4	13.2	8.8	53.7	0.22	0.14	0.20
8	65	7.61	12.9	9.5	14.1	9.4	54.0	0.20	0.14	0.21
9	80	7.64	13.7	9.4	13.7	9.1	54.0	0.20	0.14	0.21
10	95	7.62	12.6	9.5	14.3	9.5	54.1	0.19	0.14	0.22
11	110	7.69	14.3	9.9	13.3	8.9	53.7	0.21	0.15	0.20
12	125	7.73	15.9	9.9	12.4	8.2	53.6	0.24	0.15	0.18
13	145	7.75	15.7	10.3	12.4	8.2	53.3	0.24	0.16	0.19
14	155	7.75	16.6	10.3	12.0	8.0	53.1	0.25	0.16	0.18
15	170	7.70	18.3	9.5	11.2	7.5	53.6	0.28	0.14	0.17
16	185	7.69	19.5	9.0	10.7	7.1	53.8	0.29	0.14	0.16
17	200	7.70	20.1	9.0	10.3	6.9	53.7	0.30	0.14	0.16
18	215	7.69	18.8	9.0	11.0	7.3	53.9	0.28	0.14	0.17
19	230	7.70	18.8	9.0	11.0	7.3	53.9	0.28	0.13	0.16
20	245	7.71	20.1	9.0	10.3	6.9	53.7	0.30	0.13	0.15
21	260	7.69	20.0	9.0	10.4	6.9	53.6	0.30	0.14	0.16
22	269	7.67	21.0	8.6	10.0	6.7	53.8	0.32	0.13	0.15
23	270	7.38	18.7	8.9	9.8	6.6	56.0	0.28	0.13	0.15
24	275	7.38	18.6	8.9	9.9	6.6	56.0	0.28	0.13	0.15
25	290	7.40	20.0	8.9	9.2	6.1	55.9	0.30	0.13	0.14
26	305	7.47	24.9	8.8	6.5	4.4	55.4	0.37	0.13	0.10
27	320	7.50	27.4	8.8	5.2	3.5	55.2	0.41	0.13	0.08
28	335	7.54	30.6	8.7	3.5	2.3	54.9	0.45	0.13	0.05
29	350	7.56	33.0	8.6	2.3	1.5	54.7	0.48	0.13	0.03
30	365	7.57	34.0	8.5	1.7	1.1	54.6	0.50	0.13	0.03
31	380	7.60	36.2	8.4	0.6	0.4	54.4	0.53	0.12	0.01
32	396	7.62	37.6	8.4	-0.2	-0.1	54.3	0.55	0.12	-0.00
33	397	9.66	0.0	57.2	0.0	0.0	42.8	0.00	0.84	0.00
34	412	9.63	0.0	57.1	0.0	0.0	42.9	0.00	0.83	0.00
35	500	9.60	0.0	56.9	0.0	0.0	43.1	0.00	0.82	0.00

TABLE VII (Contd.)

INDEX	TIME	HR IN PPR CLID	HR IN PPR STM	HR VEL FT/SEC	HR XIT CU FT/MIN	HR XIT V/O HCL	HR XIT V/O N2	HR XIT V/O H2	HR XIT V/O STM	HR XIT PPR HCL
1	0	0.00	0.04	0.66	5.37	0.0	96.8	0.0	3.2	0.00
2	15	0.00	0.61	1.16	9.31	0.0	56.1	0.0	43.9	0.00
3	16	0.00	0.72	0.98	7.94	39.5	9.0	0.0	51.5	0.52
4	20	0.02	0.78	0.91	8.01	39.2	9.6	2.0	49.3	0.56
5	30	0.08	0.79	0.90	8.03	39.1	9.6	7.4	43.9	0.55
6	35	0.12	0.79	0.91	8.04	39.0	10.1	11.8	39.1	0.54
7	50	0.13	0.80	0.89	8.04	39.0	10.3	12.5	38.2	0.55
8	65	0.14	0.81	0.88	8.08	38.8	10.3	13.3	37.5	0.55
9	80	0.14	0.81	0.89	8.10	38.7	10.3	12.9	38.0	0.55
10	95	0.14	0.82	0.88	8.09	38.8	10.3	13.5	37.4	0.55
11	110	0.13	0.81	0.89	8.14	38.5	10.7	12.5	38.2	0.54
12	125	0.12	0.80	0.90	8.16	38.5	10.7	11.7	39.1	0.53
13	145	0.12	0.80	0.90	8.19	38.3	11.2	11.7	38.8	0.54
14	155	0.12	0.80	0.89	8.17	38.4	11.2	11.3	39.1	0.54
15	170	0.11	0.81	0.89	8.10	38.7	10.4	10.7	40.2	0.54
16	185	0.11	0.81	0.89	8.08	38.8	10.0	10.2	41.0	0.54
17	200	0.10	0.81	0.89	8.08	38.8	10.0	9.9	41.3	0.54
18	215	0.11	0.81	0.89	8.09	38.8	10.0	10.4	40.8	0.54
19	230	0.11	0.80	0.90	8.10	38.7	9.9	10.4	40.9	0.54
20	245	0.10	0.80	0.90	8.09	38.8	10.0	9.8	41.4	0.54
21	260	0.10	0.80	0.89	8.07	38.9	10.0	9.9	41.2	0.54
22	269	0.10	0.81	0.88	8.03	39.0	9.6	9.5	41.8	0.55
23	270	0.10	0.83	0.86	7.74	36.6	9.9	9.4	44.1	0.51
24	275	0.10	0.83	0.86	7.74	36.6	9.9	9.5	44.0	0.51
25	290	0.09	0.83	0.86	7.74	36.6	9.9	8.8	44.7	0.51
26	305	0.07	0.83	0.87	7.74	36.6	9.9	6.3	47.1	0.51
27	320	0.05	0.82	0.87	7.74	36.6	9.9	5.1	48.4	0.51
28	335	0.03	0.81	0.88	7.74	36.6	9.9	3.4	50.1	0.50
29	350	0.02	0.80	0.89	7.73	36.7	9.9	2.2	51.3	0.50
30	365	0.02	0.80	0.89	7.73	36.7	9.8	1.7	51.8	0.50
31	380	0.01	0.80	0.89	7.72	36.7	9.7	0.5	53.0	0.50
32	396	0.00	0.80	0.89	7.72	36.7	9.7	-0.2	53.7	0.51
33	397	0.00	0.63	1.13	9.77	0.0	57.7	0.0	42.3	0.00
34	412	0.00	0.62	1.14	9.74	0.0	57.5	0.0	42.5	0.00
35	500	0.00	0.62	1.15	9.71	0.0	57.4	0.0	42.6	0.00

TABLE VII (Contd.)

INDEX	TIME	HR XIT PPR N2	HR XIT PPR H2	HR XIT PPR SIM
1	0	1.25	0.00	0.04
2	15	0.73	0.00	0.57
3	16	0.12	0.00	0.68
4	20	0.14	0.03	0.70
5	30	0.14	0.10	0.62
6	35	0.14	0.16	0.54
7	50	0.15	0.18	0.54
8	65	0.15	0.19	0.53
9	80	0.15	0.18	0.54
10	95	0.15	0.19	0.53
11	110	0.15	0.18	0.54
12	125	0.15	0.16	0.54
13	145	0.16	0.16	0.54
14	155	0.16	0.16	0.55
15	170	0.15	0.15	0.57
16	185	0.14	0.14	0.57
17	200	0.14	0.14	0.58
18	215	0.14	0.15	0.57
19	230	0.14	0.14	0.57
20	245	0.14	0.14	0.57
21	260	0.14	0.14	0.57
22	269	0.14	0.13	0.59
23	270	0.14	0.13	0.61
24	275	0.14	0.13	0.61
25	290	0.14	0.12	0.62
26	305	0.14	0.09	0.66
27	320	0.14	0.07	0.67
28	335	0.14	0.05	0.69
29	350	0.13	0.03	0.70
30	365	0.13	0.02	0.71
31	380	0.13	0.01	0.73
32	396	0.13	0.00	0.74
33	397	0.79	0.00	0.58
34	412	0.78	0.00	0.58
35	500	0.77	0.00	0.57

TABLE VII (Contd.)

RUN NO 18 URANIUM ALLOY PROCESSING

TIME AVERAGES FOR TIME 16 TO 396 MIN

HALOGENATION REACTOR INLET

HCL VOL	N2 VOL	TOTAL PRES	VELOCITY	METAL RATE
PERCENT	PERCENT	PSIG	FT/SEC	KG/HR
83.3	16.7	12.5	0.36	0.9394
HCL	BED TEMP	WALL TEMP	INLET TEMP	METAL TEMP
EFFICIENCY	DEG C	DEG C	DEG C	DEG C
44.59	383	348	336	393

FILTER INLET

HCL VOL	N2 VOL	CLID VOL	H2 VOL	TOTAL PRES
PERCENT	PERCENT	PERCENT	PERCENT	PSIG
47.5	19.9	13.0	19.6	12.1
VELOCITY	FILT TEMP			
FT/SEC	DEG C			
0.12	250			

PYROHYDROLYSIS REACTOR INLET

HCL VOL	N2 VOL	CLID VOL	H2 VOL	STEAM VOL
PERCENT	PERCENT	PERCENT	PERCENT	PERCENT
21.7	9.1	6.0	9.0	54.1
PRESSURE	VELOCITY	OXIDE RATE	BED TEMP	OFF GAS TEMP
PSIG	FT/SEC	KG/HR	DEG C	DEG C
7.2	0.89	1.78	349	208

TABLE VII (Contd.)

RUN NO 18 URANIUM ALLOY PROCESSING

TIME AVERAGES FOR TIME 16 TO 270 MIN

HALOGENATION REACTOR INLET

HCL VOL PERCENT	N2 VOL PERCENT	TOTAL PRES PSIG	VELOCITY FT/SEC	METAL RATE KG/HR
83.2	16.8	12.6	0.38	1.2118
HCL EFFICIENCY	BED TEMP DEG C	WALL TEMP DEG C	INLET TEMP DEG C	METAL TEMP DEG C
56.70	393	350	336	408

FILTER INLET

HCL VOL	N2 VOL	CLID VOL	H2 VOL	TOTAL PRES
PERCENT	PERCENT	PERCENT	PERCENT	PSIG
38.1	20.2	16.7	25.0	12.2
VELOCITY		FILT TEMP		
FT/SEC		DEG C		
0.13		250		

PYROHYDROLYSIS REACTOR INLET

HCL VOL PERCENT	N2 VOL PERCENT	CLID VOL PERCENT	H2 VOL PERCENT	STEAM VOL PERCENT
17.6	9.4	7.7	11.6	53.7
PRESSURE PSIG	VELOCITY FT/SEC	OXIDE RATE KG/HR	BED TEMP DEG C	OFF GAS TEMP DEG C
7.3	0.89	2.29	351	206

TABLE VII (Contd.)

RUN NO 18 URANIUM ALLOY PROCESSING

TIME AVERAGES FOR TIME 270 TO 396 MIN

HALOGENATION REACTOR INLET

HCL VOL	N2 VOL	TOTAL PRES	VELOCITY	METAL RATE
PERCENT	PERCENT	PSIG	FT/SEC	KG/HR
83.4	16.6	12.3	0.33	0.3928
HCL	BED TEMP	WALL TEMP	INLET TEMP	METAL TEMP
EFFICIENCY	DEG C	DEG C	DEG C	DEG C
20.33	364	345	336	362

FILTER INLET

HCL VOL	N2 VOL	CLID VOL	H2 VOL	TOTAL PRES
PERCENT	PERCENT	PERCENT	PERCENT	PSIG
66.4	19.2	5.8	8.7	12.0
VELOCITY	FILT TEMP			
FT/SEC	DEG C			
0.12	250			

PYROHYDROLYSIS REACTOR INLET

HCL VOL	N2 VOL	CLID VOL	H2 VOL	STEAM VOL
PERCENT	PERCENT	PERCENT	PERCENT	PERCENT
30.0	8.6	2.6	3.9	55.0
PRESSURE	VELOCITY	OXIDE RATE	BED TEMP	OFF GAS TEMP
PSIG	FT/SEC	KG/HR	DEG C	DEG C
7.0	0.88	0.74	345	214

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Fig. 6. Reaction Rate, HCl Utilization, and HCl Concentration as a Function of Time

IV. URANIUM MATERIAL BALANCE

The purpose of this program (CEN-145) is to compile the uranium material balance from analytical results and the weights and volumes of material in the FBV reaction system. A balance is made for each step in the overall process: (1) HCl step, (2) HF step, and (3) fluorine step, as well as a summary of the overall recovery, the losses, and the total accountability. This program can be applied to all three uranium alloy processing facilities.

A. Sequence of Calculations

The calculations are separated into four parts: the HCl step, the HF step, the F₂ step, and summary. The sequence of calculations (shown schematically in Fig. 7) is outlined below with the corresponding program card number.

108-8400

Fig. 7. Sequence of Calculations for CEN-145

1. The HCl Step

FORTTRAN
Card No.
(21710-)

a.	HCl-step reactor-bed weight = final
reactor-bed weight + HCl-step reactor-bed
samples + HF-step reactor-bed samples +
F ₂ -step reactor-bed samples	100
b.	HCl-step filter-bed weight = final filter-bed
weight + F ₂ -step filter samples	101, 102
c.	HCl-step uranium in the reactor bed = w/o
of uranium in HCl-step reactor bed x HCl-
step reactor-bed weight x 0.01	103
d.	HCl-step uranium removed in samples =
w/o of uranium in HCl-step reactor bed x
HCl-step reactor-bed sample weight x 0.01	104, 105
e.	Uranium in HCl-step condensate = mg/ml
of uranium in condensate x liters of
condensate	106
f.	Uranium in HCl-step scrubber = mg/ml of
uranium in scrubber x liters of scrub
solution	107
g.	Uranium in pyrohydrolysis reactor = w/o
of uranium in pyrohydrolyzer x
pyrohydrolyzer-bed weight x 0.01	108
h.	HCl-step uranium in the filter bed = ura-
nium in charge - uranium in HCl-step reac-
tor bed - uranium in HCl-step condensate -
uranium in HCl-step scrubber - uranium in
pyrohydrolyzer - uranium removed in HCl-
step samples	109

2. The HF Step

a.	HF-step reactor-bed weight = final reactor-
bed weight + HF-step reactor-bed sample
weight + F ₂ -step reactor-bed sample weight	111
b.	HF-step filter-bed weight = F ₂ -step filter-
bed weight	112, 101
c.	HF-step uranium in reactor bed = w/o of
uranium in HF-step reactor bed x HF-step
reactor-bed weight x 0.01	113

FORTTRAN
Card No.
(21710-)

d.	HF-step uranium in filter bed = HCl-step
uranium in filter bed	114
e.	HF-step uranium in samples removed =
w/o of uranium in HF-step reactor bed x
HF-step reactor-bed sample weight x 0.01	115
3. <u>The F₂ Step</u>		
a.	F ₂ -step reactor-bed weight = final reactor-
bed weight + F ₂ -step reactor-bed sample
weight	117
b.	F ₂ -step uranium retained in reactor bed =
w/o of uranium in F ₂ -step reactor bed x
F ₂ -step reactor-bed weight x 0.01	118
c.	F ₂ -step uranium retained in filter bed =
w/o of uranium in F ₂ -step filter bed x
F ₂ -step filter-bed weight x 0.01	119
d.	F ₂ -step uranium in samples removed =
(w/o of uranium in F ₂ -step reactor bed x
F ₂ -step reactor-bed sample weight + w/o of
uranium in filter bed x F ₂ -step filter-bed
sample weight) x 0.01	120, 121
e.	Uranium equivalent in reactor bed = HCl-
step reactor-bed weight x w/o of uranium in
F ₂ -step reactor bed x 0.01	126
f.	Uranium equivalent in filter bed = HCl-step
filter-bed weight x w/o of uranium in F ₂ -
step filter bed x 0.01	127
g.	Uranium in collection device = weight frac-
tion or mg/ml of uranium in collection de-
vice x g or liters, respectively, of collection
device	122
h.	Uranium in activated alumina = mg/ml of
leach of activated alumina x liters of leach
solution	123
i.	Uranium in F ₂ -step scrubber = mg/ml of
uranium in scrubber x liters	124

4. Summary

FORTTRAN
Card No.
(21710-)

a. Uranium not recovered = (uranium equivalent in reactor bed + uranium equivalent in filter bed) x 100/(uranium in charge)	128
b. Total uranium recovered = uranium in collection device + uranium in activated alumina + uranium in F ₂ -step scrubber + uranium removed in HCl-step samples + uranium removed in HF-step samples	129
c. Uranium accounted for = total uranium recovered + uranium in pyrohydrolyzer + uranium removed in F ₂ -step samples + uranium in HCl-step condensate and scrubber + uranium in F ₂ -step reactor bed + uranium in F ₂ -step filter bed	130, 131
d. Percent of uranium accounted for = uranium accounted for x 100/(uranium in charge)	132
e. Percent of uranium unaccounted for = 100 - percent of uranium accounted for	133
f. Total uranium lost = uranium in scrubber + uranium in pyrohydrolyzer + uranium in reactor bed + uranium in filter bed	134

B. Program Information

This section describes the appropriate input and output information.

1. Title: Summary of Uranium Usage.
2. Program Library: 2171/CEN-145.
3. Programmer: Anthony J. Strecok, Applied Mathematics Division.
4. Machine: 704F, OOPS monitor compatible.
5. Running Time: Less than 1 min per case.

6. Information Input:

<u>Card Type</u>	<u>Format</u>	<u>Contents of Card</u>
1	I6	A four-digit number used as a case identification label.
2	6E12.4	Uranium charged (g), w/o of uranium in HCl-step reactor bed, HCl-step reactor-bed sample weight (g), Concentration of uranium in HCl-step scrub solution (mg/ml), Volume of HCl-step scrub solution (liters), Concentration of uranium in condensate (mg/ml).
3	6E12.4	Volume of condensate (liters), w/o of uranium in pyrohydrolyzer bed, Pyrohydrolyzer-bed weight (g), Final reactor-bed weight (g), Final filter-bed weight (g), w/o of uranium in HF-step reactor bed.
4	6E12.4	HF-step reactor-bed sample weight (g), w/o of uranium in F ₂ -step reactor bed, w/o of uranium in F ₂ -step filter bed, F ₂ -step reactor-bed sample weight (g), Volume of collection device (g or liters).
5	5E12.4	Concentration of uranium in collection device (weight fraction or mg/ml), Volume of activated alumina (liters), Concentration of uranium on activated alumina (mg/ml), Concentration of uranium in F ₂ -step scrub solution (mg/ml), Volume of F ₂ -step scrub solution (liters).

The input data for a sample problem are listed in Table I.

7. Possible Output:

- a. Program identification.
- b. Input data.
- c. Labeled blocks of HCl step, HF step, F₂ step, and uranium usage data.
- d. Labeled summary of important results for each step, along with overall recovery and loss results.

A complete list of the FORTRAN instructions is given in Table VIII. The pertinent nomenclature is listed in Table IX.

TABLE VIII. FORTRAN Statements for CEN-145

```

C      2171 CEN 145
4000 FORMAT (14H1 2171/CEN 145/6H INPUT)
4001 FORMAT (6E12.4)
4002 FORMAT (7H1 INPUT)
4003 FORMAT (14H0U CHARGED (G),29X,F12.4/17H W/O U IN HCL BED,26X,F12.421710004
X/26H HCL BED SAMPLE WEIGHT (G),17X,F12.4/30H U CONC. IN SCRUB SOLN21710005
X (MG/ML),13X,F12.4/25H VOLUME OF SCRUB SOLN (L),18X,F12.4/30H U CO21710006
XNC. IN CONDENSATE (MG/ML),13X,F12.4/25H VOLUME OF CONDENSATE (L),121710007
X8X,F12.4/24H W/O U IN PYROHYDROLYSER,19X,F12.4/18H HR BED WEIGHT (21710008
XG),25X,F12.4/29H FINAL REACTOR BED WEIGHT (G),14X,F12.4/28H FINAL 21710009
XFILTER BED WEIGHT (G),15X,F12.4/16H W/O U IN HF BED,27X,F12.4) 21710010
4004 FORMAT (25H HF BED SAMPLE WEIGHT (G),18X,F12.4/16H W/O U IN F2 BED21710011
X,27X,F12.4/19H W/O U IN F2 FILTER,24X,F12.4/25H F2 BED SAMPLE WEIG21710012
XHT (G),18X,F12.4/28H F2 FILTER SAMPLE WEIGHT (G),15X,F12.4/34H VOL21710013
XUME OF COLLECTION DEVICE (G,L),9X,F12.4/45H CONC OF U IN COLLECTIO21710014
XN DEVICE (WT FR,MG/ML),F10.4/32H VOLUME OF ACTIVATED ALUMINA (L),121710015
X1X,F12.4/40H CONC. OF U ON ACTIVATED ALUMINA (MG/ML),3X,F12.4/37H 21710016
XU CONC. IN SCRUB SOLUTION,F2 (MG/ML),6X,F12.4/32H VOLUME OF SCRUB 21710017
XSOLUTION,F2 (L),11X,F12.4) 21710018
4008 FORMAT (12I6) 21710019
4009 FORMAT (1H1/7H OUTPUT/18H0HYDROCHLORINATION/40H0HCL BED WEIGHT21710020
X (G) F19.4/40H HCL FILTER WEIGHT (G) 21710021
X F19.4) 21710022
4010 FORMAT (40H HCL TOTAL URANIUM BED (G) F19.2/40H HCL T21710023
XOTAL URANIUM FILTER (G) F19.2/40H W/O U IN HCL BED 21710024
X F19.3) 21710025
4011 FORMAT (40H HCL U21710026
X REMOVED IN SAMPLES (G) F19.4) 21710027
4012 FORMAT (40H HCL BED SAMPLE WEIGHT (G) F19.1) 21710028
4013 FORMAT (40H U LOST TO CONDENSATE HCL (G) F19.4/40H U LOS21710029
XT TO SCRUB HCL (G) F19.4) 21710030
4014 FORMAT (40H U LOST TO HR HCL (G) F19.4/40H U CON21710031
XCENTRATION IN SCRUB SOLN (MG/ML) F19.7) 21710032
4015 FORMAT (40H VOLUME OF SCRUB SOLUTION (L) F19.1/40H U CON21710033
XCENTRATION IN CONDENSATE (MG/ML) F19.7) 21710034
4016 FORMAT (40H VOLUME OF CONDENSATE (L) F19.1/40H W/O U21710035
X IN PYROHYDROLYSIS REACTOR F19.3) 21710036
4017 FORMAT (18H HR BED WEIGHT (G),22X,F19.2/42H FINAL REACTOR BED WT. 21710037
XWITHOUT SAMPLES (G)F17.4/41H FINAL FILTER BED WT. WITHOUT SAMPLES 21710038
X(G)F18.4) 21710039
4018 FORMAT (18H0HYDROFLUORINATION/25H0HF BED WEIGHT (G) F19.4/2521710040
XH HF FILTER WEIGHT (G) F19.4/25H HF TOTAL U BED (G) F19.2/21710041
X25H HF TOTAL U FILTER (G) F19.2/25H W/O U IN HF BED F19.21710042
X3,27H /28H HF U REMOVED IN SAMPLES (G)F121710043
X6.4/25H HF BED SAMPLE WEIGHT (G)F19.1) 21710044
4019 FORMAT (13H0FLUORINATION/40H0F2 BED WEIGHT (G) 21710045
X F19.4/40H F2 FILTER WEIGHT (G) F19.4/40H F2,T021710046
XTAL U IN BED (G) F19.4/40H F2,TOTAL U IN FILTER (21710047
XG) F19.4/40H W/O U IN F2 BED 21710048
XF19.3/40H W/O U IN F2 FILTER F19.3) 21710049
4020 FORMAT (27H F2,U REMOVED IN SAMPLE (G),18X,F14.4/25H F2,BED SAMPLE21710050
X WEIGHT (G),20X,F14.1/28H F2,FILTER SAMPLE WEIGHT (G),17X,F14.1/4521710051
XH *CONC* OF U IN COLLECTION DEVICE (MG/ML,W/O)F14.3/36H *VOLUME* 021710052
XF COLLECTION DEVICE (L,G),9X,F14.1/41H *CONC* OF U IN ACTIVATED AL21710053
XUMINA (MG/ML),4X,F14.3/35H *VOLUME* OF ACTIVATED ALUMINA (L) ,10X,21710054
XF14.4/45H U CONCENTRATION IN SCRUB SOLUTION,F2 (MG/ML)F14.7/32H VO21710055
XLUME OF SCRUB SOLUTION,F2 (L),13X,F14.1/43H URANIUM RECOVERED IN C21710056
XCOLLECTION DEVICE (G),2X,F14.3/31H TOTAL U RECOVERED AFTER F2 (G),121710057
X4X,F14.3/30H U IN ACTIVATED ALUMINA,F2 (G),15X,F14.4/21H U IN SCRUB21710058
XBBER,F2 (G),24X,F14.4) 21710059
4022 FORMAT (14H1URANIUM USAGE/38H0U NOT REMOVED FROM BED (G) 21710060
X F11.4/30H U NOT REMOVED FROM FILTER (G)F19.4/30H O/O U NOT REMOVE21710061

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TABLE VIII (Contd.)

	XD	F19.2/30H U ACCOUNTED (G)	F19.4/30H PERCENTAGE U UNACCOUNTED	21710062
	XENTAGE U ACCOUNTED	F19.2/30H PERCENTAGE U UNACCOUNTED		F121710063
	X9.2/30H U CHARGED (G)	F19.4/30H TOTAL U LOST (G)		21710064
	X	F19.4)		21710065
4023	FORMAT (12H1 RUN NUMBER14/1H0/18H0HYDROCHLORINATION/22HOTOTAL URAN21710066			
	XIUM CHARGED,11X,7H(GRAMS)F12.2/21H TOTAL URANIUM IN BED,12X,7H(GRA21710067			
	XMS)F12.2/24H TOTAL URANIUM IN FILTER,9X,7H(GRAMS)F12.2/26H URANIUM21710068			
	X IN PYROHYDROLYSER,7X,7H(GRAMS)F12.4)			21710069
4024	FORMAT (22H URANIUM IN CONDENSATE,11X,7H(GRAMS)F12.4/20H URANIUM I21710070			
	XN SCRUBBER,13X,7H(GRAMS)F12.4/19H URANIUM IN SAMPLES,14X,7H(GRAMS)21710071			
	XF12.4/1H0/18H0HYDROFLUORINATION/21HOTOTAL URANIUM IN BED,12X,7H(GR21710072			
	XAMS)F12.2/24H TOTAL URANIUM IN FILTER,9X,7H(GRAMS)F12.2/19H URANIU21710073			
	XM IN SAMPLES,14X,7H(GRAMS)F12.4)			21710074
4025	FORMAT (1H0/13H0FLUORINATION/21HOTOTAL URANIUM IN BED,12X,7H(GRAMS21710075			
	X)F12.4/15H URANIUM IN BED,18X,7H(W/O) F12.4/24H TOTAL URANIUM IN 21710076			
	XFILTER,9X,7H(GRAMS)F12.4/18H URANIUM IN FILTER,15X,7H(W/O) F12.4/21710077			
	X27H URANIUM COLLECTED IN TRAPS,6X,7H(GRAMS)F12.2/29H URANIUM IN AC21710078			
	XTIVATED ALUMINA,4X,7H(GRAMS)F12.4/20H URANIUM IN SCRUBBER,13X,7H(G21710079			
	XRAMS)F12.4/19H URANIUM IN SAMPLES,14X,7H(GRAMS)F12.4)			21710080
4026	FORMAT (1H0/8H0SUMMARY/22HOTOTAL URANIUM CHARGED,11X,7H(GRAMS)F12.21710081			
	X2/26H TOTAL URANIUM RECOVERABLE,7X,7H(GRAMS)F12.2/24H URANIUM NOT 21710082			
	XRECOVERABLE,9X,7H(GRAMS)F12.4/29H URANIUM NOT REMOVED FROM BED,4X,21710083			
	X7H(GRAMS)F12.4/40H URANIUM NOT REMOVED FROM FILTER (GRAMS)F12.4/2821710084			
	XH PERCENT URANIUM NOT REMOVED,5X,7H(O/O) F12.2/24H TOTAL URANIUM 21710085			
	XACCOUNTED,9X,7H(GRAMS)F12.2/26H PERCENT URANIUM ACCOUNTED,7X,7H(O/21710086			
	XO) F12.2)			21710087
1	WRITE OUTPUT TAPE 6,4000			21710088
C	INPUT DATA			21710089
	READ INPUT TAPE 7,4008,NORUN			21710090
	READ INPUT TAPE 7,4001,UCHRG,UHCLB,HCLBSW,USRB,VSRB,UCON			21710091
	READ INPUT TAPE 7,4001,VCON,UHR,HRBW,FRBW,FFBW,UHFB			21710092
	READ INPUT TAPE 7,4001,HFBSW,UF2B,UF2Z,F2BSW,F2FSW,VCD			21710093
	READ INPUT TAPE 7,4001,CUCD,VAA,CUAA,USRBZ,VSRBZ			21710094
	WRITE OUTPUT TAPE 6,4003,UCHRG,UHCLB,HCLBSW,USRB,VSRB,UCON,VCON,			21710095
	1UHR,HRBW,FRBW,FFBW,UHFB			21710096
	WRITE OUTPUT TAPE 6,4004,HFBSW,UF2B,UF2Z,F2BSW,F2FSW,VCD,CUCD,VAA,			21710097
	1CUAA,USRBZ,VSRBZ			21710098
C	HYDROCHLORINATION STEP			21710099
	HCLBW=FRBW+HCLBSW+HFBSW+F2BSW			21710100
	F2FW=FFBW+F2FSW			21710101
	HCLFW=F2FW			21710102
	HCLTUB=UHCLB*HCLBW*.01			21710103
	HCLURS=UHCLB*HCLBSW			21710104
	HCLURS=HCLURS*.01			21710105
	HCLCON=UCON*VCON			21710106
	HCLSRB=USRB*VSRB			21710107
	UINHR=UHR*HRBW*.01			21710108
	HCLTUZ=UCHRG-HCLTUB-HCLCON-HCLSRB-UINHR-HCLURS			21710109
C	HYDROFLUORINATION STEP			21710110
	HFBW=FRBW+HFBSW+F2BSW			21710111
	HFFW=F2FW			21710112
	HFTUB=UHFB*HFBW*.01			21710113
	HFTUZ=HCLTUZ			21710114
	HFURS=UHFB*HFBSW*.01			21710115
C	FLUORINATION STEP			21710116
	F2BW=FRBW+F2BSW			21710117
	F2TUB=UF2B*F2BW*.01			21710118
	F2TUZ=UF2Z*F2FW*.01			21710119
	F2URS=UF2B*F2BSW+UF2Z*F2FSW			21710120
	F2URS=F2URS*.01			21710121
	URCD=CUCD*VCD			21710122
	UAA=CUAA*VAA			21710123

TABLE VIII (Contd.)

	USRB=USRBZ*VSRBZ	21710124
C	SUMMARY	21710125
	UIB=HCLBW*UF2B*.01	21710126
	UIZ=HCLFW*UF2Z*.01	21710127
	UNR=(UIB+UIZ)/UCHRG*100.	21710128
	TUREC=URCD+UAA+USRB+HCLURS+HFURS	21710129
	UACC=TUREC+UINHR+ F2URS+HCLCON+HCLSRB	21710130
	UACC=UACC+F2TUB+F2TUZ	21710131
	UPACC=UACC/UCHRG*100.	21710132
	UPUAC=100.-UPACC	21710133
	TUL=HCLCON+HCLSRB+UINHR+UIB+UIZ+F2URS	21710134
C	HYDROCHLORINATION STEP	21710135
	WRITE OUTPUT TAPE 6,4009,HCLBW,HCLFW	21710136
	WRITE OUTPUT TAPE 6,4010,HCLTUB,HCLTUZ,UHCLB	21710137
	WRITE OUTPUT TAPE 6,4011,HCLURS	21710138
	WRITE OUTPUT TAPE 6,4012,HCLBSW	21710139
	WRITE OUTPUT TAPE 6,4013,HCLCON,HCLSRB	21710140
	WRITE OUTPUT TAPE 6,4014,UINHR,USRB	21710141
	WRITE OUTPUT TAPE 6,4015,VSRB,UCON	21710142
	WRITE OUTPUT TAPE 6,4016,VCON,UHR	21710143
	WRITE OUTPUT TAPE 6,4017,HRBW,FRBW,FFBW	21710144
C	HYDROFLUORINATION STEP	21710145
	WRITE OUTPUT TAPE 6,4018,HFBW,HFFW,HFTUB,HFTUZ,UHFB,HFURS,HFBSW	21710146
C	FLUORINATION STEP	21710147
	WRITE OUTPUT TAPE 6,4019,F2BW,F2FW,F2TUB,F2TUZ,UF2B,UF2Z	21710148
	WRITE OUTPUT TAPE 6,4020,F2URS,F2BSW,F2FSW,CUCD,VCD,CUAA,	21710149
X	VAA,USRBZ,VSRBZ,URCD,TUREC,UAA,USRB	21710150
	WRITE OUTPUT TAPE 6,4022,UIB,UIZ,UNR,UACC,UPACC,UPUAC,UCHRG,TUL	21710151
C	SUMMARY	21710152
	WRITE OUTPUT TAPE 6,4023,NORUN,UCHRG,HCLTUB,HCLTUZ,UINHR	21710153
	WRITE OUTPUT TAPE 6,4024,HCLCON,HCLSRB,HCLURS,HFTUB,HFTUZ,HFURS	21710154
	WRITE OUTPUT TAPE 6,4025,F2TUB,UF2B,F2TUZ,UF2Z,URCD,UAA,USRB,F2URS	21710155
	WRITE OUTPUT TAPE 6,4026,UCHRG,TUREC,TUL,UIB,UIZ,UNR,UACC,UPACC	21710156
	GO TO 1	21710157

TABLE IX. Nomenclature for CEN-145

FORTRAN Word	Definition	Units
HCLBW	HCl-step reactor-bed weight	g
HCLFW	HCl-step filter-bed weight	g
HCLTUB	HCl-step total uranium in reactor bed	g
HCLTUZ	HCl-step total uranium in filter bed	g
UHCLB	w/o of uranium in HCl-step reactor bed	w/o
UHCLZ	w/o of uranium in HCl-step filter bed	w/o
HCLURS	HCl-step uranium removed in samples	g
HCLBSW	HCl-step reactor-bed sample weight	g
HCFLSW	HCl-step filter-bed sample weight	g
HCLCON	HCl-step uranium in condensate	g
HCLSRB	HCl-step uranium in scrubber	g
UINHR	Uranium in pyrohydrolyzer	g
USRB	Uranium concentration in scrubber	mg/ml
VSRB	Volume of scrub solution	liters
UCON	Uranium concentration in condensate	mg/ml
VCON	Volume of condensate	liters
UHR	Uranium concentration in pyrohydrolyzer	w/o
HRBW	Pyrohydrolyzer-bed and product weight	g
FRBW	Final reactor-bed weight (after sampling)	g
FFBW	Final filter-bed weight (after sampling)	g
HFBW	HF-step reactor-bed weight	g
HFFW	HF-step filter-bed weight	g
HFTUB	HF-step total uranium in reactor bed	g
HFTUZ	HF-step total uranium in filter bed	g
UHFB	w/o of uranium in HF-step reactor bed	w/o
UHFZ	w/o of uranium in HF-step filter bed	w/o
HFURS	HF-step uranium removed in samples	g
HFBSW	HF-step reactor-bed sample weight	g
HFFSW	HF-step filter-bed sample weight	g

TABLE IX (Contd.)

FORTRAN Word	Definition	Units
F2BW	F ₂ -step reactor-bed weight	g
F2FW	F ₂ -step filter-bed weight	g
F2TUB	F ₂ -step total uranium in reactor bed	g
F2TUZ	F ₂ -step total uranium in filter bed	g
UF2B	w/o of uranium in F ₂ -step reactor bed	w/o
UF2Z	w/o of uranium in F ₂ -step filter bed	w/o
F2URS	F ₂ -step in uranium removed in samples	g
F2BSW	F ₂ -step reactor-bed sample weight	g
F2FSW	F ₂ -step filter-bed sample weight	g
VCD	Volume of collection device	g or liters
CUCD	Concentration of uranium in collection device	Weight fraction or mg/ml*
CUAA	Concentration of uranium in activated alumina leach	mg/ml
VAA	Volume of activated alumina leach	liters
USRBZ	Concentration of uranium in F ₂ -step scrub solution	mg/ml
VSRBZ	Volume of F ₂ -step scrub solution	liters
URCD	Uranium recovered in collection device	g
TUREC	Total uranium recovered	g
UAA	Uranium in activated alumina	g
USRB	Uranium in scrubber	g
UIB	Equivalent uranium not removed from reactor bed	g
UIF	Equivalent uranium not removed from filter bed	g
UNR	Percent of uranium not removed	%
UACC	Total uranium accounted for	g
UPACC	Percent of total uranium accounted for	%

*If grams are used for VCD, use weight fraction for CUCD; if liters are used for VCD, use mg/ml for CUCD.

TABLE IX (Contd.)

FORTRAN		Units
Word	Definition	
UPUAC	Percent of total uranium unaccounted for	%
UCHRG	Total uranium charged	g
TUL	Total uranium lost	g

C. Sample Problem

The important results for the test case (Table X) are summarized in Table XI.

TABLE X. Input Data for Uranium Material Balance (CEN-145)

Card Type						
1	9					
2	841.3	0.03	347.1	0.000006	189.0	0.00004
3	601.0	0.0055	5768.0	40500.0	11250.0	0.03
4	321.0	0.0015	0.021	0.0	0.0	15676.0
5	0.0529	25.582	0.085	0.0	0.0	

TABLE XI. Calculated Output for Uranium Material
Balance (CEN-145)

RUN NUMBER 9		
HYDROCHLORINATION		
TOTAL URANIUM CHARGED	(GRAMS)	841.30
TOTAL URANIUM IN BED	(GRAMS)	12.36
TOTAL URANIUM IN FILTER	(GRAMS)	825.63
URANIUM IN PYROHYDROLYSER	(GRAMS)	3.1724
URANIUM IN CONDENSATE	(GRAMS)	0.0240
URANIUM IN SCRUBBER	(GRAMS)	0.0011
URANIUM IN SAMPLES	(GRAMS)	0.1122
HYDROFLUORINATION		
TOTAL URANIUM IN BED	(GRAMS)	12.25
TOTAL URANIUM IN FILTER	(GRAMS)	825.63
URANIUM IN SAMPLES	(GRAMS)	0.0963
FLUORINATION		
TOTAL URANIUM IN BED	(GRAMS)	0.6075
URANIUM IN BED	(W/O)	0.0015
TOTAL URANIUM IN FILTER	(GRAMS)	2.3625
URANIUM IN FILTER	(W/O)	0.0210
URANIUM COLLECTED IN TRAPS	(GRAMS)	829.26
URANIUM IN ACTIVATED ALUMINA	(GRAMS)	2.1745
URANIUM IN SCRUBBER	(GRAMS)	0.
URANIUM IN SAMPLES	(GRAMS)	0.
SUMMARY		
TOTAL URANIUM CHARGED	(GRAMS)	841.30
TOTAL URANIUM RECOVERABLE	(GRAMS)	831.64
URANIUM NOT RECOVERABLE	(GRAMS)	6.1780
URANIUM NOT REMOVED FROM BED	(GRAMS)	0.6179
URANIUM NOT REMOVED FROM FILTER	(GRAMS)	2.3625
PERCENT URANIUM NOT REMOVED	(O/O)	0.35
TOTAL URANIUM ACCOUNTED	(GRAMS)	837.81
PERCENT URANIUM ACCOUNTED	(O/O)	99.59

V. STANDARD PROGRAMS USED IN DATA PROCESSING CALCULATIONS

A. Least-square Polynomial Fit

This routine (ANME-209) was used to fit polynomials to the flow-rate, pressure-drop, and thermal-conductivity calibration data for use with CEN-139. The details of the program and its use can be obtained from the ANL Applied Mathematics Division.

The program determines the constants CA1, CA2, ..., CA8 in the following equation by means of a least-square error-minimization technique:

$$Y = CA1 + CA2X + CA3X^2 + \dots + CA8X^7.$$

The required input is a table of X and Y values obtained experimentally and a weighting factor for each X and Y. The output includes: (1) the square error matrix, (2) the coefficients of the fitting polynomial and their associated standard deviations, and (3) the weighted sum of the squared deviations.

B. Stepwise Multiple Regression

While the data obtained in a bench-scale fluid-bed unit with nonirradiated uranium-alloy fuels were being evaluated, stepwise multiple-regression analysis was made. For this analysis, two computer programs (RIMD-34 and ERMPR-2) were used. The results of this study were reported previously in ANL-6830.

The results of this analysis, which involved 41 sets of experimental data, indicated that those conditions that tended to decrease the partial pressure of UF₆ in gas stream during fluorination resulted in lower retention of uranium by alumina. This analysis led to the postulation of a semi-empirical relation, which represented the data from the bench-scale unit with nonirradiated fuels and predicted, within the experimental error, the results from the pilot-scale unit with nonirradiated fuels, and the results from the bench-scale unit with highly-irradiated fuels.

C. The Properties of Gases and Multicomponent Gas Mixtures

To describe the transport phenomena in a process involving gaseous reactants and products such as the FBV processes, one must be able to evaluate the physical properties of the gas or multicomponent gas mixture of interest. A knowledge of the properties is necessary for the prediction of momentum, heat, and mass-transfer rates in reacting and nonreacting systems. These rates are necessary for determining reaction mechanisms, kinetics of reactions, process scaleup parameters, and optimum process conditions.

The physical properties commonly of interest are gas density, heat capacity, viscosity, thermal conductivity, and diffusion coefficients. The data in the literature that give these properties for gases are usually for a temperature and pressure such that they must be extrapolated to be applied to practical situations. The experimentally determined physical properties of gas mixtures are seldom available, especially in the FBV processes. It is therefore important to be able to extrapolate or estimate the pure component and multicomponent physical properties of gases easily by means of data that are commonly available in the literature.

The evaluation and compilation of the physical properties at various temperatures and pressures for a number of gases, and for a number of multicomponent gas mixtures, are extremely time-consuming if performed with a desk calculator. Therefore, a computer program (CEN-144) was developed to minimize the time and effort involved. The computer program provides a means of determining the physical properties of gases and mixtures of gases by extrapolation of experimental physical-property data for the pure components. If experimental data are not available, the properties are estimated from the critical and molecular data of each gas by using relations suggested by theory but containing constants based on experimental data. The use of this program is detailed by Holmes and Baerns in ANL-6951.

VI. CONCLUSIONS AND RECOMMENDATIONS

The processing of the experimental data was greatly facilitated by the use of a high-speed digital computer during the development of the FBV process for the highly-enriched uranium-alloy fuels. Accurate data were obtained more easily by the computer calculations than by manual calculations. Most of the computer programs written for these calculations are also applicable to the decladding of low-enriched uranium dioxide fuels clad with either Zircaloy-2 or aluminum. The benefits derived from the computer-calculated results suggest that computer programs be written for the processing of the decladded uranium dioxide.

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