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HW - 18406
CHEMISTRY-SEPARATION
PROCESSES FOR PLUTONIUM
AND URANIUM

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CHEMICAL AND PHYSICAL PROPERTIES VS.
DEGREE OF CONCENTRATION OF URANYL NITRATE-
NITRIC ACID PROCESS STREAMS FOR
METAL CONVERSION PLANT

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CONCENTRATION OF URANYL NITRATE-NITRIC ACID
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by

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July 24, 1950

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CHEMICAL AND PHYSICAL PROPERTIES VS. DEGREE OF
CONCENTRATION OF URANYL NITRATE-NITRIC ACID
. PROCESS STREAMS FOR METAL CONVERSION PLANT

I. INTRODUCTION

Uranium is recovered as an aqueous solution of uranyl nitrate and nitric acid in both the tributyl phosphate metal recovery process and the Redox separation process. The streams are designated as RCU and HIEU in the respective processes. For metal recovery these streams are combined as shown on SK-2-50026 (Engineering Flow Diagram - Feed Storage Tanks - Metal Conversion Plant) to form 96,788 gal./24 hr. of feed (composition in weight per cent - 91.9 H_2O , 6.52 UNH, 1.57 HNO_3 , 0.01 TBP, 0.001 ANN; density 1.07) to the concentrator and nitric acid recovery unit shown on SK-2-50021 (Engineering Flow Diagram - Feed Preparation - Metal Conversion Plant). This unit concentrates the aqueous solution of uranyl nitrate and nitric acid to 2330 gal./24 hr. of nitric free uranyl nitrate feed (composition in weight per cent - 11.6 H_2O , 88.3 UN. H_2O , 0.02 HNO_3 , 0.016 ANN) for the Metal Conversion Plant. The purpose of the nitric removal operation is to minimize equipment corrosion and to restrict contamination of the final uranium oxide (UO_2) with corrosion products which might be formed in the elevated temperature reactor employed for the decomposition of uranyl nitrate to the oxide. Approximately 13,000 pounds of HNO_3 are recovered per day via this scheme.

Because of the large quantities of uranium being processed (10 to 14 tons/day) it is desirable to conduct the concentration of the combined RCU and HIEU streams in a continuous type process to reduce the operating and fixed charges (Ref. 1). Determination of the physical and chemical properties of the dilute aqueous uranyl nitrate - nitric acid system, as it progresses toward an essentially nitric acid free concentrated state, is necessary to define the optimum operating conditions. Such information is also necessary to guide the operation of the production plant on the basis of a minimum number of physical measurements.

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II. OBJECTIVES

The purposes of this laboratory study were:

1. To observe the general behavior of the aqueous system uranyl nitrate - nitric acid during continuous concentration and acid removal.
2. To determine specifically the chemical compositions, viscosities, freezing points, boiling points, and densities of the system as a function of concentrations covering the range from fifty to ninety per cent uranyl nitrate (expressed as anhydrous salt).
3. To determine the reactions and path of tributyl phosphate during concentration.

III. SUMMARY AND CONCLUSIONS

A series of continuous type evaporation studies were made in which an aqueous solution of uranyl nitrate and nitric acid was fed to a simple, all glass, flash evaporator operated at liquid phase temperatures of 120° to 160° C. under atmospheric pressure. The concentrates obtained for this range of boiling points had a composition of 50 to 88 per cent uranyl nitrate and from 15 to 0 per cent free nitric acid. The freezing points increased from 50° to 130° C. with increasing uranyl nitrate concentration. Likewise the densities at the freezing point increased from 2.2 to 3.0 g./ml. The viscosities measured at temperatures of 100° to 125° C. increased from 18 to 65 centipoises and also exhibited 20 to 40 per cent increases for a two fold increase in relative shear rates.

Although analytical problems precluded an accurate determination, it is apparent that less than fifty per cent of the tributyl phosphate (0.2 g./l.) present in the feed stream was removed from the concentrated uranium solution during evaporation to a nitric free condition.

It is concluded that nitric acid free uranium, existing as a solution of uranyl nitrate and uranium oxide, may be obtained by a continuous evaporation of a dilute aqueous solution of uranyl nitrate (0.138 - 0.168 M) and nitric acid (0.249 - 0.340 M) to a uranium concentration expressed as 86 to 87 per cent uranyl nitrate having a boiling point of 144° to 146° C. at atmospheric pressure,

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a freezing point of $106^{\circ}\text{C}.$, a density of 2.84 g./ml. at the freezing point, and a viscosity of 40 - 41 centipoises at 50 rpm and 52 - 53 centipoises at 100 rpm as determined with a No. 2 spindle of a Brookfield viscometer. The resulting solution may exhibit cloudiness due to the precipitation of uranium oxide which first becomes apparent at about $145^{\circ}\text{C}.$ Process control to achieve the desired final solution composition can be exerted by measurement of the boiling point within the evaporator.

• IV. DISCUSSION

A. Equipment and Operational Procedure

The equipment used is illustrated in Figure 11. The evaporator consisted of a one liter glass flask equipped with ground joint necks for feed introduction, vapor take off, concentrate sampling by means of a dip leg, insertion of a thermometer for liquid phase temperature measurement, and introduction of a paddle agitator (cf. Figure 1 of HW-16054, Ref. 2). The flask was electrically heated with a rheostat controlled glas-col mantle equipped with a thermocouple and pyrometer for continuous measurement of mantle temperature. Feed solution was added continuously to the evaporator by a manually adjusted stopcock, and the vapor was removed continuously to a total condenser with essentially no reflux. The heating mantle was maintained at a fixed temperature during a given run while the boiling point was held at the desired temperature by controlling the rate of feed addition during the run. By intermittent application of vacuum to the concentrate sampler, the concentrate was removed in small portions to give a sample representing the composition of the concentrate during one to three hours operation with minimum disturbance to the system.

B. Experimental Conditions

In the described equipment two series of runs were carried out which differed in the following respects: (1) in the first series the concentrate holdup in the evaporator was approximately 160 g. (70 ml.) while in the second the holdup was about 800 g. (300 ml.), (2) results were more reproducible in the second series involving the larger

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more stable systems, (3) heating mantle temperatures were 250-300°C. in the first series and 400°C. in the second, (4) throughputs were on the order of 270 ml. of feed solution for each boiling point in the first series and 700 ml. of feed for each run in the second, (5) the first series utilized feed solutions 1, 2, and 3 of Table I while the second used feed solution No. 4, (6) the concentrate sampling dip leg was used for a slow air sparge for agitation in the first series while the paddle agitator was used in the second. In both series the operating time for each run was about 6 hours with the determination of properties being carried out toward the end of the run. In the summary of results in Table II the two series of runs are distinguishable by the tabulation of the evaporator holdup for each run.

As can be seen by reference to the feed stream compositions in Table I and the results summarized in Table II, the properties of the concentrate obtained at a given boiling point are not appreciably altered by a change in composition of the feed stream (within the range studied). Therefore the results reported should be applicable to concentration of each of the Flowsheet streams which are also summarized in Table I, i. e. RCU from TBP-HW Flowsheet No. 3 (HW-15987, Ref. 3), from No. 4 (HW-18169, Ref. 4), from No. 5 (HW-18232, Ref. 5), and both RCU and IHUEU from the Material Balance Flowsheet - Metal Conversion Plant (SK-2-50004). The essential difference between the RCU streams defined by flowsheets subsequent to TBP-HW No. 3 is the reduction in UNH and HNO_3 concentrations. The Redox IHUEU stream is tenfold or more concentrated in UNH than the RCU stream and of the same order of concentration in nitric acid.

The study was restricted to solution concentration and nitric acid removal as the recovery of nitric acid from the vapor phase stream is a well understood engineering operation.

C. Chemical and Physical Properties and Their Determination

The physical and chemical properties determined and the procedures employed are described below.

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1. Boiling Points

Boiling points were determined by a mercury thermometer with the bulb immersed in the liquid. The thermometer was accurate to $\pm 1.0^{\circ}\text{C}.$, and no stem corrections were applied. As can be seen from the summarization of data in Table II and the graphical presentation of boiling points versus uranyl nitrate in Figure 1, the boiling point remains between $118^{\circ}\text{C}.$ and $120^{\circ}\text{C}.$ as the UN concentration increases from 50 to 73 per cent. At the latter point the boiling point rises rapidly with increasing concentration and reaches $140^{\circ}\text{C}.$ at a UN concentration of 86 per cent. Thereafter, it rises very steeply from $140^{\circ}\text{C}.$ to $160^{\circ}\text{C}.$ at which point the apparent UN concentration reaches 88.5 to 90 per cent.

2. Densities

A sample of the boiling concentrate was removed by application of vacuum to a 10 ml. cylinder attached to the sampling dip leg. The volume of the sample so obtained was measured to the nearest 0.1 ml. at a temperature immediately above the freezing point. The weight of the sample was determined as rapidly thereafter as possible to preclude significant erroneous gains or losses from the sample. The resulting densities have been plotted versus the boiling point in Figure 2. The lowest valued boiling point at $118^{\circ}\text{C}.$ has a concentrate density of 2.2 g./ml. whereas the highest valued boiling point of $160^{\circ}\text{C}.$ is paired with a density of 3.0. Figure 3, a plot of density versus the per cent uranyl nitrate, is parabolic in form with a noticeable increase in slope as the higher concentrations are reached. This curve is similar to the plot of the same quantities presented in Figure c2.4, page 65 of HDC-826 (Ref. 6). Above 83 per cent uranyl nitrate the Figure 3 plot shows higher densities for a given uranyl nitrate concentration than the reference figure. This is attributed to the presence of precipitated UO_3 in the present solutions. Below 70 per cent uranyl nitrate the Figure 3 plot also presents higher densities for a given concentration than the reference figure. This is probably due to the presence of nitric acid in the simulated production plant solutions.

3. Freezing Points

Freezing points were determined by plotting time-temperature cooling curves. This was done with samples in the lower boiling ranges. In the higher boiling regions the freezing points were so sensitive to slight losses of water from the hot sample that it was difficult to get a determination with reproducibility. Therefore the freezing points in the higher regions were obtained directly on the evaporator contents at the end of the run. A plot of the freezing point versus the boiling as shown in Figure 4 is interesting in that the parallel rise in boiling point with freezing point encounters a plateau at a freezing point of 106°C . over the range of boiling points from 140° to 150°C .; thereafter, the rise in freezing point with boiling point is resumed. It is possible, that in this region UO_2 ++ exists at the elevated temperature while at the lower temperatures U_2O_5 ++ exists. The possibility of a uranyl nitrate di or tri hydrate formation under these conditions is also a possibility. A plot of the freezing point against the uranyl nitrate concentration is given in Figure 5 showing breaks at 72 and at 86 per cent UN. The latter break appears to be associated with the formation of a uranium oxide phase. A similar plot with the same general characteristics appears in HDC-826 (page 67, Figure c2.5, Ref. 6; also cf. CL-697, Figure 1 of Chapter IIc, 4, Ref. 7).

4. Compositions

The composition of the concentrate was determined for each boiling point by diluting the evaporator sample with water to give a solution containing approximately 100 g. UNH/l. This solution was then analysed for UNH, free HNO_3 , and total NO_3^- . The analytical compositions of the concentrates summarized in Table II were calculated from the UNH and HNO_3 analyses of the sample solutions.

There appear to be three varying solute concentrations in the system: UN plus excess HNO_3 in the low boiling ranges, neutral UN at the intermediate points, and UN plus excess UO_3 at the upper limits. Consequently the compositions were also expressed in terms

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of acid-base (HNO_3 - UO_3) percentages in Table II. In this case the base percentages were calculated from the UNH analyses and the acid percentages from the total nitrate analyses, with the water percentage determined by difference.

The molar concentrations of uranium, total nitrate, and water in the concentrates were also calculated in order to compare the ratio of nitrate to uranium and water to uranium. The results summarized in Table II indicate that the ratio of nitrate to uranium decreases with rising boiling point. The ratio becomes less than 2 to 1 at boiling points above 140°C . Similarly the ratio of water to uranium becomes less than 6 to 1 at boiling points above 120°C . or freezing points above 60°C ., which compares with the boiling point of 118°C . and the freezing point of 60.2°C . given in the literature for pure UNH. The data indicates that there is still appreciable water present after all the nitric acid has been removed.

A plot of the free nitric acid found versus boiling point is given in Figure 6. The plot indicates that the concentrate becomes stoichiometrically neutral at a boiling point of about 145°C . Figure 7 shows that the free nitric acid decreases almost linearly with increasing uranyl nitrate concentration and reaches zero at about 86 per cent UN in the concentrate.

6. Decomposition

In the series of runs utilizing the smaller evaporator holdup, the solution was observed to turn dark amber color at the 150°C . boiling point, and cloudiness appeared at $155 - 160^\circ\text{C}$. during the boiling point rise to 160°C . However, the concentrate sample from the latter point dissolved completely to give a clear solution on dilution with water.

In the second series with larger feed throughput and larger evaporator holdup, the solution was clear at 140°C . but became cloudy in the middle of the 150° run. Dilution (with water) of the evaporator sample from the latter run did not give a clear solution. Clarification required the addition of nitric acid. During the subsequent 160° run

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precipitation continued and the color continued to deepen. In this case a nitric acid spike was likewise required to give a clear solution of the concentrate sample.

Since precipitation in the evaporator appeared to be a function of time as well as temperature, a run was carried out at 145°C . starting with clear concentrate. Precipitation occurred in this case after several hours running. ●

7. Viscosities

Viscosities were determined for concentrates boiling at 120° , 130° , 140° , and 150°C . The determinations were carried out by transferring approximately 350 ml. of the concentrate to a 600 ml. beaker mounted in a glas-col heating mantle. The viscometer was inserted in the beaker, and the beaker was covered to reduce surface cooling and evaporation losses. After adjustment of the temperature to the required value, readings were taken with Number 1 and Number 2 spindles at rotational rates of 50 and 100 rpm. The data obtained are summarized in Table II. No readings were taken on the concentrate boiling at 160°C . because of rapid surface cooling and crystallization which led to erroneous results. Moisture losses at the higher temperatures were also difficult to control with the equipment used. The viscosities of the concentrates boiling at 120 and 130° were determined at 100°C ., the 140° concentrate at 120°C ., and the 150° concentrate at 125°C . ●

The observed viscosities are plotted against boiling point, freezing point, and per cent uranyl nitrate in Figures 8, 9, and 10 respectively. The viscosity shows a regular increase with increasing UN concentration, and shows a 20 to 40 per cent increase with a two fold increase in shear rate.

8. TBP Behavior During Evaporation

TBP was present in feed streams 1, 2, and 4 (Table I) in the range of concentrations predicted for plant operations. The amount of TBP present in the concentrator as well as in the distillate was determined at the end of the run. The data summarized in Table III, ● although not entirely conclusive because of the analytical difficulties

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encountered, make it apparent that not more than 50 per cent of the TBP was removed from the concentrator. This is in conflict with the findings for RCU concentration reported in HW-15172 (Ref. 8), but is substantiated by the TBP recovery from the RAW concentration described in the same report. However, these latter evaporations were conducted on a batch basis and the results would not necessarily correspond to the data from the present study made on a continuous basis. The path of TBP during the continuous evaporation of aqueous waste (RAW) has been reported in HW-17937 (Ref. 9). In this case, 48 per cent of the TBP was recovered in the evaporator.

An analysis of the concentrate in the evaporator showed no significant change in the total amount of phosphate ion present at the completion of the runs in which TBP behavior was being followed. One may conclude that decomposition to phosphate ion does not constitute a problem, which confirms the results reported in HW-15172 (Ref. 8) and in HW-17937 (Ref. 9) for RAW concentration.

The partial decomposition of TBP to dibutyl phosphate and/or monobutyl phosphate was determined indirectly by observing the effect of the concentration on the uranium distribution ratio E^0/A . Samples of the feed stream as well as samples of the concentrate were diluted to a UNH concentration of 3 g./l. The dilute solutions were then equilibrated with 15 per cent TBP in Deobase and the E^0/A values given in Table IV were determined. As all of the E^0/A values ranged between 0.0019 and 0.0053, well within the range of normal TBP behavior, it is concluded that any MBP or DBP produced was removed from the still.

It has also been reported in HW-17937 (Ref. 9) that only 0.07 per cent of the TBP charged to a continuous type RAW concentrator was found in the recovered 60 per cent nitric acid. Since the behavior of the vapor phase system H_2O-HNO_3 -TBP generated from either concentration of RAW solution or RCU-IIIIEU solution would be the same, it is believed that the 60 per cent HNO_3 recovered from RCU-IIIIEU concentration would be satisfactory for process usage.

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V. FUTURE WORK

An additional problem related to the concentration and nitric acid recovery is the determination of the region of maximum chloride concentration in the nitric acid recovery system. This information is being obtained to allow purging of the chloride from the rectifying tower at the optimum location. No cognizance of the chloride ion was given in the foregoing study, since it is present in low concentrations and would have no bearing on the chemical and physical characteristics of the system exclusive of corrosion problems relative to the process equipment.

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TABLE I
COMPOSITION OF CONCENTRATOR FEED SOLUTIONS
FOR THIS STUDY AND AS PROPOSED FOR PLANT OPERATION

Component		Concentrator Feed Solution (1)				(2)	(3)	(4)	(4)
		No. 1	No. 2	No. 3	No. 4	RCU HW-#3	RCU HW #4-#5	RCU Feed	HIEU Feed
UNH	g./l.	81.7	82.9	84.3	69.5	81.2	66.2	52.8	985.
	Wt. %	7.7	7.8	7.9	6.7	7.7	6.4	5.0	60.0
	M	0.163	0.166	0.168	0.138	0.162	0.132	0.105	1.96
HNO ₃	g./l.	21.4	21.3	21.4	15.7	21.1	8.45	16.9	9.85
	Wt. %	2.0	2.0	2.0	1.5	2.0	0.8	1.6	0.6
	M	0.340	0.338	0.340	0.249	0.335	0.139	0.269	0.156
Total NO ₃	g./l.	40.8	42.5	41.8	31.9				
TBP	g./l.	0.070	0.17	-----	0.31	0.2	0.2	0.13	-----
	Wt. %	0.007	0.02	-----	0.03	0.02	0.02	0.012	-----
	M	0.0003	0.0006	-----	0.0012	0.0008	0.0008	0.0005	-----
Al(NO ₃) ₃ ·9H ₂ O	g./l.	-----	-----	-----	-----	-----	-----	-----	0.625
	Wt. %	-----	-----	-----	-----	-----	-----	-----	0.037
	M	-----	-----	-----	-----	-----	-----	-----	0.002
Water	g./l.	958.5	958.	957.	958.	954.	966.	986.	646.
	Wt. %	90.3	90.2	90.1	91.8	90.3	92.8	93.4	39.4
	M	53.2	53.2	53.1	53.1	52.9	53.6	54.7	35.9
Sp. Gr.		1.0616	1.0622	1.0629	1.0429	1.056	1.041	1.056	1.64

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- (1) The No. 4 feed solution consisted of RCU from 321 Building Demonstration Unit Run 3"-83-RCU. The other three were synthetic solutions prepared in the laboratory.
- (2) Per TBP-HW Flowsheet No. 3 (HW-15987).
- (3) Per TBP-HW Flowsheet No. 4 (HW-18169) and TBP-HW Flowsheet No. 5 (HW-18232).
- (4) Per Material Balance Flowsheet - Metal Conversion Plant (SK-2-50004).

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TABLE II
SUMMARY OF PROPERTIES FOR EACH

Run No.	Feed Solution Used (2)	Evaporator Holdup, g. (3)	Boiling Point (°C.)	Freezing Point (°C.)	Density (g./ml. at F. P.)	Viscosity (cps.) (4)				Analytical Anhyd. UN(7)
						#1 Spindle		#2 Spindle		
						100 RPM	50 RPM	100 RPM	50 RPM	
1	1	143	118	42.5	(2.17)					50.7
2	2	155	120	48.1	(2.07)					61.9
3	2	138	(125.6)	50.5	(2.17)					64.1
4	4	663	120	53.8	2.26	25	18	25	24	69.4
5	4	720 est.	120	59.9	2.19					73.3
6	2	161	(137)	62.9	2.18					(72.2)
7	2	149	(146)	93.5	2.50					79.9
8	4	806	130	96.0	2.55	42	30	42	34	80.9
9	4	788	130	96.0	2.54					(84.7)
10	2	132	140	104.0	2.77					(81.3)
11	4	812	140	106.0	2.92	45	33	53	41	86.0
12	4	877	145	106.0	3.11					86.5
13	3	172	150	106.0	2.84					86.5
14	4	825 est.	150	110.2	2.92					86.7
15	4	812	150	111.0	3.34	60	50	67	50	(83.7)
16	3	161	160		2.95					88.4
17	4	813	160	130.0	3.17					88.9(8)

NOTES

- (1) The values in parentheses are doubtful and are largely associated with the runs involving small quantities of materials.
- (2) This column refers to the Concentrator Feed Solutions of Table I.
- (3) Runs made with larger evaporator holdup gave results which were more reproducible and therefore probably more accurate.
- (4) Determined with a Brookfield Synchro-Lectric Viscometer, Multi-Speed Model RVF. Points 4 and 8 were determined at 100°C., point 11 at 120°C., and point 15 at 125°C.
- (5) The per cent UO_3 is based on the UNH analysis, and the per cent HNO_3 is based on the total nitrate analysis. Comparable HNO_3 acid are obtained by calculation from the UNH and free HNO_3 analysed. The per cent water was calculated by difference.
- (6) Calculated from the acid-base compositions and the density.
- (7) Since a total nitrate analysis was not available on this sample, this value was calculated from the UNH and free HNO_3 analysis.
- (8) The per cent UN and the per cent HNO_3 were determined on different samples.

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DILING POINT RUN (1)

Composition	Acid Base Composition			Composition in gram-moles/l. (8)			Mole Ratio	
	Free HNO ₃ (%)	UO ₃ (%)	HNO ₃ (%)	Uranium (as UN and UO ₃)	Total NO ₃	Total H ₂ O	NO ₃ /U	H ₂ O/U
14.97		36.8	32.1	31.1	2.79	11.1	40.2	3.98
(4.86)		44.9	25.5	29.6	3.25	8.365	37.35	2.57
8.18		46.5	28.5	25.0	3.53	9.81	33.7	2.78
5.19		50.4	26.6	23.0	3.98	9.555	32.8	2.40
5.69		53.2	28.8	18.0	4.07	10.0	26.0	2.46
4.93		(52.4)	31.7	15.9	3.98	11.0	23.2	2.76
2.31		58.0	27.6	14.4	5.08	11.0	25.0	2.17
(-0.37)		58.7	26.3	14.9	5.23	10.7	26.4	2.04
1.64		(61.5)	26.9	11.6	5.46	10.85	21.9	1.99
1.71		(59.0)	29.6	11.4	5.71	13.0	23.2	(2.27)
0.48		62.4	26.4	11.2	6.37	12.2	24.6	1.92
-0.10		62.8	26.9	10.3	6.83	13.3	24.6	1.95
0.36		62.8	31.3	(5.90)	6.24	14.1	15.6	2.27
0.23		62.9	23.9	13.1	6.42	11.1	27.7	1.73
0.58		(60.8)	25.3	14.0	7.09	13.4	33.0	1.89
0.36		64.2	28.6(7)	7.20	6.62	13.2	18.4	2.00
-0.58(8)		64.5	26.2	9.30	7.15	13.2	23.6	1.85
								3.29

es for the per cent

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TABLE III

TBP BEHAVIOR IN RCU CONCENTRATION

Table II run number	6	7	8
Boiling point (°C)	137.	146.	140.
TBP in still pot at start (g.)	---	.481	.035
TBP added to still via feed	0.043	.043	.023
Total TBP in pot (g.)	----	.524	.058
Total in still pot at end (g.)	.481	.035	.126
TBP in still sple.	.032	.005	.025
TBP in distillate (g.)	.020	.012	.016
Total TBP output (g.)	.533	.052	.167
PO ₄ in still at start (g.)	--	.030	.031
PO ₄ in still at end (g.)	.030	.031	.025
PO ₄ in distillate (g.)	.000025	.00049	.0019

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TABLE IVEquilibration Studies

<u>Point</u>	<u>Solution</u>	<u>UNH, g. /l.</u>	<u>E⁰/A for UNH</u>
Concentrator Feed No. 2, Table I	Diluted feed solution	3.21	0.00532
	Equilibrated aqueous	3.01	
	Equilibrated organic	0.016	
Run 6, Table II	Diluted still sample	3.51	0.00189
	Equilibrated aqueous	3.44	
	Equilibrated organic	0.0065	
Run 7, Table II	Diluted still sample	3.46	0.00216
	Equilibrated aqueous	3.06	
	Equilibrated organic	0.0066	
Run 10 Table II	Diluted still sample	3.62	0.00201
	Equilibrated aqueous	3.23	
	Equilibrated organic	0.0065	

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FIGURE 4
 $\text{UO}_2(\text{NO}_3)_2 - \text{HNO}_3 - \text{H}_2\text{O}$ SYSTEM
 FREEZING POINT
 VS.
 BOILING POINT

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FIGURE 5
 $UO_2(NO_3)_2 - HNO_3 - H_2O$ SYSTEM
FREEZING POINT
VS.
 $UO_2(NO_3)_2$ CONCENTRATION

Numbers by points refer to runs summarized in Table II.

URANYL NITRATE - WEIGHT PER CENT

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FIGURE 6

$UO_2(NO_3)_2 - HNO_3 - H_2O$ SYSTEM
FREE NITRIC ACID
VS.
BOILING POINT

FREE NITRIC ACID - WEIGHT PER CENT

Numbers by points refer to runs summarized in Table II.

Boiling points observed at atmospheric pressure.

Boiling point for point 3 taken from boiling point-freezing point curve, Figure 4.

BOILING POINT - °C.

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FIGURE 8

$UO_2(NO_3)_2 - HNO_3 - H_2O$ SYSTEM
VISCOSITY VS. BOILING POINT

Numbers by points refer to runs summarized in Table II. Boiling points observed at atmospheric pressure.

VISCOSITY - CENTIPOISES

BOILING POINT - °C.

Viscosities determined with a Brookfield Model RVF Viscometer, No. 2 Spindle. Viscosities of points 4 and 8 at 100°C., point 11 at 120°C., and point 15 at 125°C.

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Figure 11
URANYL NITRATE CONCENTRATOR

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