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CHEMICAL TECHNOLOGY DIVISION
Unit Operations Section

SOLUTION OF EXPERIMENTAL BREEDER REACTOR SLUGS

E. M. Sampson, Jr.

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1.0 Abstract

A full-scale, always-safe, metal dissolver for Experimental Breeder Reactor fuel was designed, built, and installed for test operation. It was found that the dissolver operated satisfactorily, and feasible operating procedures were established for the dissolution of bare, or jacketed, EBR slugs.

Minor modifications of the dissolver design have been required to accomodate a modified EBR slug, but it is believed that this will not significantly affect its operating characteristics.

2.0 Introduction

An always-safe dissolver was designed for the dissolution of enriched Experimental Breeder Reactor slugs at the Idaho Chemical Processing Plant. Because there was no previous operating information on this equipment, a prototype full-scale dissolver was installed to demonstrate the feasibility of the suggested design and to develop practical operating procedures. The uranium when in the EBR is in a stainless steel jacket with sodium metal as the jacket to uranium bonding agent. After withdrawal from the reactor, the stainless steel and sodium are removed and the uranium slug is placed in an aluminum can to aid in its storage and handling. At the time of this work, a firm decision of the use of the aluminimum can had not been made; therefore, the dissolving of bare and aluminum canned slugs was studied. The aluminum canned slugs will probably be used.

In the course of this study, the effect of the following dependent variables were evalutated:

1. Dissolution of aluminum-jacketed slugs vs. bare slugs.
2. The length of dissolving time on final solution composition.

In addition, data were obtained on the following:

1. Acid-to-metal dissolved ratio.
2. The relation of vapor temperature in the dissolver to the time of dissolution completion.
3. The volume of water to be added to the dissolver at the completion of dissolution to give the desired solution composition.
4. The off-gas volumes, rates, and compositions.

The object of this study was to dissolve 9 EBR slugs (Dimensions: 1.771-1.773" long, 0.362-0365" diameter; weights: 525 gms. of uranium, 35.0 gms. of aluminum) to a final composition and volume as follows:

$UO_2(NO_3)_2$	1.28M
$Al(NO_3)_3$	0.72M
Acid Deficiency	0.20N
Volume	1750 ml

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2.0 Introduction (continued)

With bare slugs the composition and volume become:

$UO_2(NO_3)_2$	2.0M
Acid Deficiency	0.2N
Volume	1130 ml

The bases for these compositions were solubility and available storage volume. It was found that a total molarity of 2.0 was consistent with the tankage available for storage and would insure non-freezing of the final solution. Both solutions are acceptable as feed to the "25" Process.

The size of the charge to be placed in the dissolver was determined on criticality grounds even though the dissolver was to be of sub-critical design, i.e., 4 inches inside diameter. Also, because a 0.2N acid deficient final solution and a short dissolving time were desirable, a 200 per cent metal heel was adopted. The maximum uranium-235 was taken as 8 kg. (assumed criticality limit based on present data available).* However, a factor of safety of 5 reduces the amount of uranium to 1.6 kg. With the 200 per cent heel, the charge becomes about 530 grams, approximately equal to the weight of nine slugs.

3.0 Summary

1. It was demonstrated that the sub-critical dissolver operated satisfactorily when dissolving either aluminum-jacketed, or bare, EBR slugs. The time required for dissolving nine jacketed slugs was 3.5 hours, while 4 hours was necessary for the bare slugs. The increase in the dissolution time for bare slugs was essentially due to the longer time required for the

*ORNL-725, Page 12

3.0 Summary (continued)

solution to go acid-deficient.

2. The nitric acid to metal dissolved ratios were 3.9 and 4.1 for the jacketed and bare slug dissolutions, respectively, to obtain an acid deficiency of 0.20N.

3. Observations of the vapor temperature in the dissolver disclosed that it decreased slowly to a minimum and then remained constant. The constant temperature was reached 45 minutes before the end of the dissolution of the jacketed slugs and 1.5 hours before the end of bare slug dissolving.

4. Experience indicated the addition of about 475 ml. of water to the hot solution at the end of a regular dissolution run was necessary to give the desired concentrations in both types of dissolutions.

5. The total volumes of gas evolved during the dissolution of bare and jacketed slugs were 110 and 130 liters, respectively, while the maximum gas rates were 1.0 and 1.7 liters/minute, respectively.

4.0 Recommended Operating Procedures

The dissolving of jacketed slugs involves three types of runs, viz, one jacket, numerous regular, and two heel dissolutions. The dissolving of bare slugs involves two types of runs, viz, numerous regular and two heel dissolutions. The operating conditions can be found in Table 4.0 on Page 10. The general operating procedure for all dissolutions is as follows:

1. Add required number of slugs to dissolver (See Column A).

TABLE 4.0

RECOMMENDED OPERATING CONDITIONS FOR

DISSOLUTION OF JACKETED AND BARE EBR SLUGS

		A	B	C	D			
Type of Dissolution	Type of Run	Slugs Charged	Nitric Acid to Metal Dissolved Ratio	Time of Run	Volume of Water to be Added at End of Run	Composition of Final Solution		
						Uranium	Aluminum	Acid Deficiency
		No.	Mole/Mole	Hours	Ml.	M	M	N
Jacketed Slugs	Jacket Removal	18	3.5	1.5	150	0.25	1.95	0.6
	Regular Dissolution	9	3.8	3.5	475	1.32	0.78	0.3
	Heel Diss. #1*	0	4.4	4.5	600	2.10	0.00	0.0
Bare Slugs	Regular Diss. #1	27	3.9	4.5	475	2.10	--	0.3
	Regular Diss.	9	3.9	4.0	475	2.10	--	0.3
	Heel Diss. #1*	0	4.4	4.5	600	2.10	--	0.0

*Add enough acid to dissolve the equivalent of 11 slugs.

2. Add volume of water necessary to dilute the 70% HNO_3 required (See Column B) to 55%, or to 40% (jacket dissolution). In all jacketed slug dissolutions 1% of the aluminum weight as $Hg(NO_3)_2$ is added to this water.
3. Heat dissolver contents to boiling with 25 psig steam.
4. With dissolver contents refluxing, add the required volume of 70% HNO_3 over a period of 5-10 minutes maintaining the system pressure at atmospheric.
5. Dissolve for the required time (See Column C).
6. Add dilution required (See Column D) to give desired final solution composition, and cool dissolver contents.
7. Transfer dissolver solution to intermediate tank.

The second heel dissolution run is made like all others, except that the same amount of acid used in the first heel dissolution run is charged and the run continues until all metal is dissolved.

5.0 Equipment Description

The dissolver system consisted of a full-scale sub-critical dissolver, a down-draft single-pass condenser, nitric acid storage and feed tanks, and a gas collecting tank. For a picture of the system see Figure 1 on Page 12. All process equipment and piping were of 347 (18-8Cb) stainless steel.

The dissolver was a cylindrical vessel 4.03 inches in diameter and 16 inches high equipped with a flanged top, a slightly sloping flat bottom, and a flanged 2 inch slug chute. The bottom half is jacketed for steam heating, or water cooling. A perforated crash plate with a perforated

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Photo 8754

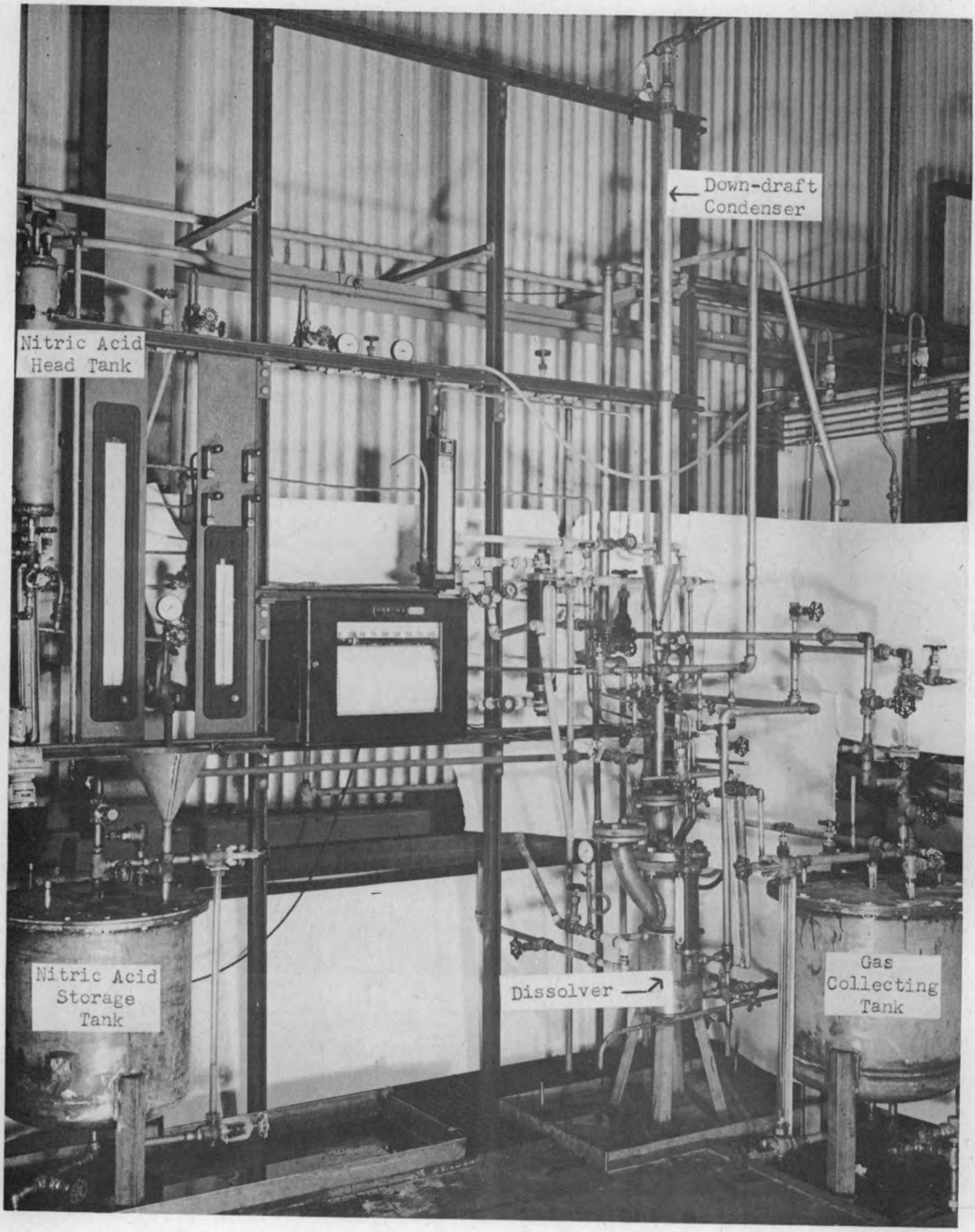

FIGURE 1
Experimental EBR Slug Dissolution Equipment - General View

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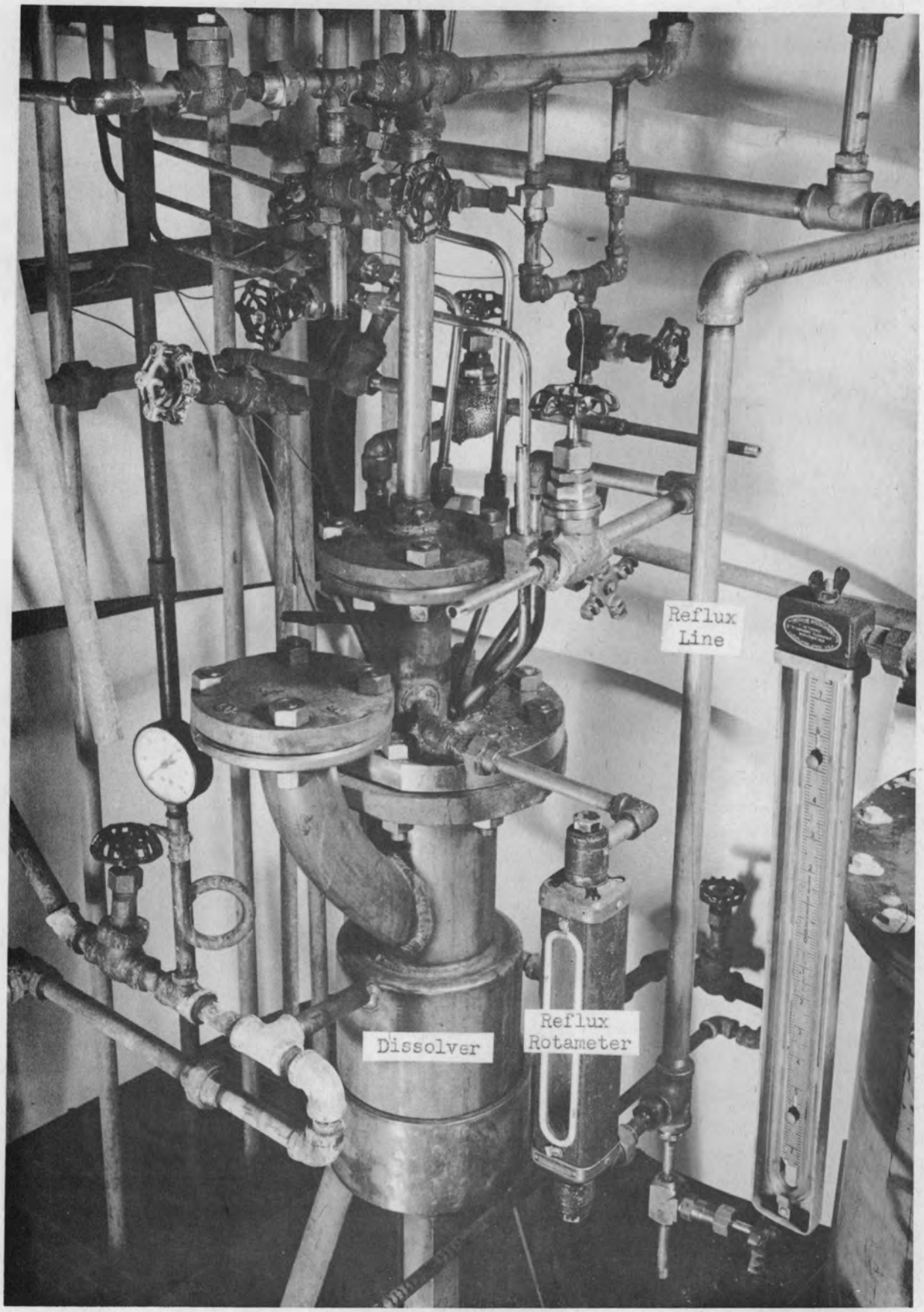
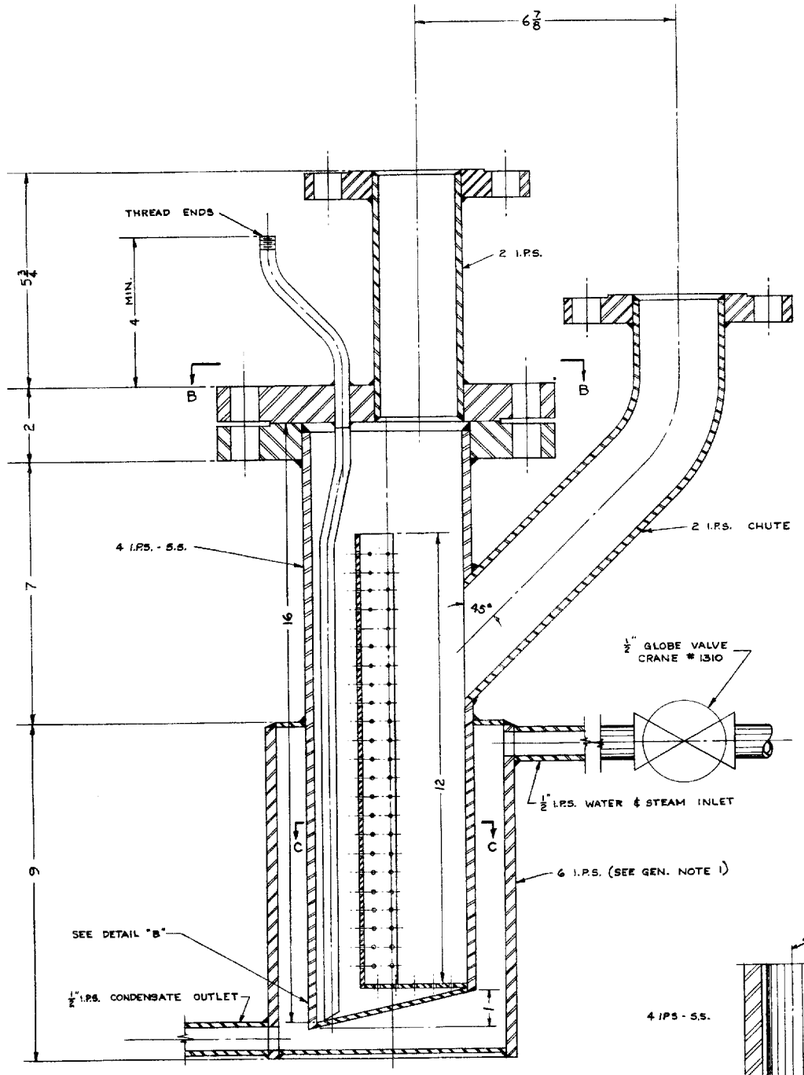


FIGURE 2

Experimental EBR Slug Dissolver

MATERIALS LIST					
ITEM NO.	DWG. NO.	QTY.	NAME	SIZE	MATERIAL

DIP TUBE SCHEDULE				
TUBE	SIZE	SERVICE	DISTANCE DOWN	DISTANCE ABOVE 4" FLR.
A	1/8 IPS	SAMPLER	TO BOTTOM	4 MIN.
B	3/8 IPS	JET SUCTION	TO BOTTOM	4 MIN.
C	1/8 IPS	INSTRUMENT	TO BOTTOM	4 MIN.
D	1/8 IPS	INSTRUMENT	JUST PENETRATES TANK WALL	4 MIN.
E	1/8 IPS	INSTRUMENT	2 1/2 FROM BOTTOM	4 MIN.
F	3/8 IPS	AIR SPARGER	TO BOTTOM	4 MIN.
G	1/8 IPS	THERMOWELL	TO BOTTOM (SEAL END)	4 MIN.



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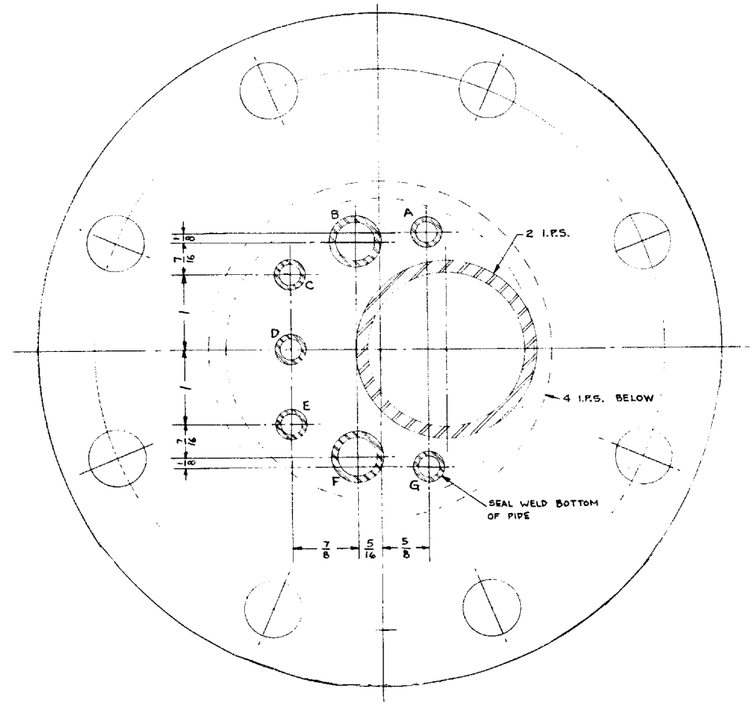
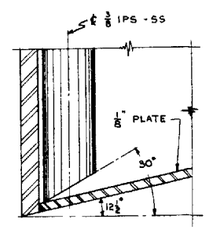


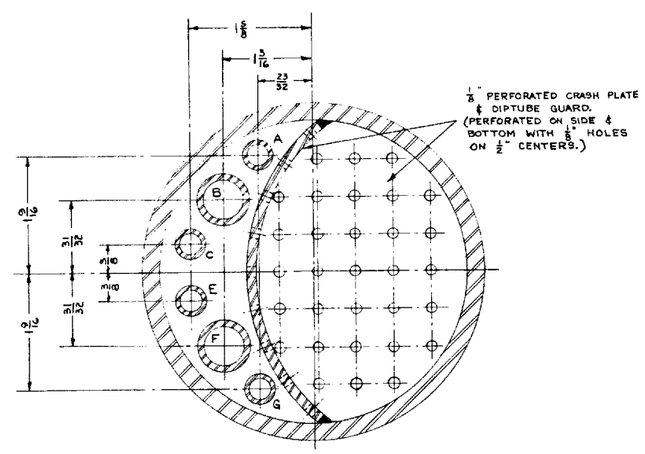
SECTION B-B

FULL SIZE



DETAIL "B"

FULL SIZE



SECTION C-C

FULL SIZE

GENERAL NOTES

1. ALL MATERIAL SHALL BE TYPE 347 S.S. UNLESS OTHERWISE NOTED. JACKET SHALL BE STAINLESS STEEL IF AVAILABLE IN SURPLUS STOCK, IF NOT AVAILABLE, MAKE FROM BLACK IRON.
2. ALL WELDS SHALL BE FREE OF LOOSELY DEPOSITED METAL AND FREE FROM PITS & CRACKS.
3. ALL WELDS SHALL BE AS SHOWN AND SHALL BE GROUND SMOOTH.
4. ALL GASKET FACES SHALL BE MACHINED SMOOTH.
5. TANK SHALL BE TESTED AS FOLLOWS:

JACKET -	WORKING	PRESSURE - 50 PSI
	TESTING	PRESSURE - 125 PSI
TANK -	WORKING	PRESSURE - ATMOSPHERIC
	TESTING	PRESSURE - 15 PSI

NO.	REVISIONS	DATE	APPR.	APPR.

DRAWING NO. D-

DRAWN BERRY	DATE 10/3/51	CHECKED	DATE	APPROVED	DATE
DESIGNED	DATE	SUBMITTED	DATE	APPROVED	DATE

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CHEMICAL PROCESSING PLANT

FIG. 3 - BLDG 3503

EXPERIMENTAL EBR DISSOLVER

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OPERATED BY

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A DIVISION OF UNION CARBIDE AND CARBON CORPORATION

OAK RIDGE, TENNESSEE

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5.0 Equipment Description (continued)

bottom protects the various probes held by the flanged top and extending to the bottom of the dissolver. These probes permit the removal, the sparging, the measurement of temperature, the measurement of specific gravity and liquid level, and the sampling of the dissolver contents. For a close-up picture of the dissolver, see Figure 2 on Page 13. For detailed drawing of dissolver, see Drawing D-10157 on Page 14.

A 3/4-inch line connects the dissolver to the condenser which sits vertically and consists of a 1-inch pipe inside a jacket of $1\frac{1}{2}$-inch pipe. Water flows through the jacket. The unit was about 6 feet long and had 1.30 sq. ft. of condensing surface.

The feed tank was constructed from a 2-foot length of 4-inch pipe and was equipped with a sight glass. The calibration was 7.52 cc/mm. and held about 4 liters of 70% HNO_3. It had a top into which three lines came. One was a vent, a second was connected to vacuum and a third to the storage tank. The single outlet line ran to the vapor line, meeting it about 1 foot above the dissolver. Valves in this line were located just below the feed tank and just before the vapor line. A drain was located upstream from the latter valve.

The gas holder and nitric acid storage tanks were identical. Their capacities were 73.5 liters each and had a straight side calibration of 160 cc/mm. They were 18 inches in diameter and 18 inches on the straight side, and were equipped with flanged tops and dished-head bottoms. The tops held three $\frac{1}{2}$-inch nipples and two $\frac{1}{4}$-inch nipples, with the middle

$\frac{1}{2}$-inch nipple on the HNO_3 storage tank being the only one to extend to the bottom. This one was connected to the feed tank. Another $\frac{1}{2}$-inch nipple was equipped with a valve and funnel for venting and filling purposes. The bottom was equipped with two $\frac{1}{2}$-inch nipples. One was connected to a drain and the other to the sight glass, the other end of which led to the middle $\frac{1}{2}$-inch nipple on the top. The middle nipple on the gas collector acted as the gas inlet and the top anchor of the sight glass. Another $\frac{1}{2}$-inch nipple acted as the city water inlet. One $\frac{1}{4}$-inch nipple was used as a combination sampling port and impulse line for Hg manometer. The third $\frac{1}{2}$-inch nipple was equipped with a valve for venting purposes. The bottom outlets were connected to the sight glass and to a drain line which ran to the first floor and a can.

The gas and condensate flowed co-currently through a 1-inch line for a short distance to a tee where the gas line narrowed down to $\frac{1}{2}$-inch as did the reflux line. The gas line flowed upward through a loop which held a vent line and a sight glass. A large line connecting to the roof vent joined the loop just above the gas collector and a valve in the line. This connection allowed venting toxic NO_2 to the roof when necessary. The reflux line continues on the same level until it is almost above the reflux rotameter. A loop is then formed, one side of which is $\frac{1}{2}$-inch and the other $\frac{1}{4}$-inch holding a rotameter. A $\frac{1}{4}$-inch line ran from the rotameter to the 2-inch nipple just above the dissolver.

Thermowells were installed to allow the measurement of the dissolver contents, the vapors at the dissolver, the vapors at the condenser, the

5.0 Equipment Description (continued)

liquid leaving the condenser and the cooling water temperatures in and out.

Sampling ports were located on the dissolver, on the vapor line above the dissolver (liquid sampling), on the gas holder, and in the reflux line at the rotameter.

Instrumentation consisted of a specific gravity manometer, liquid level manometer and Brown potentiometeric multipoint temperature recorder, and mercury manometers on the feed tank and gas collector.

6.0 Chemistry of Dissolution

Any discussion of data obtained during the experimental program must be withheld until there is an understanding of the chemistry involved. Available information shows that uranium dissolves by the following oxidation-reduction reactions:

$$U + 6\ NO_3^- + 4\ H_2O \longrightarrow UO_2^{++} + 6\ NO_2 + 8\ OH^- \qquad (1)$$

$$U + 2\ NO_3^- + 2\ H_2O \longrightarrow UO_2^{++} + 2\ NO + 4\ OH^- \qquad (2)$$

$$8\ U + 12\ NO_3^- + 14\ H_2O \longrightarrow 8\ UO_2^{++} + 6\ N_2O + 28\ OH^- \qquad (3)$$

As well, aluminum with mercuric ion as a catalyst dissolves by the following oxidation-reduction reactions:

$$Al + 3\ NO_3^- + 3\ H_2O \longrightarrow Al^{+++} + 3\ NO_2 + 6\ OH^- \qquad (4)$$

$$Al + NO_3^- + 2\ H_2O \longrightarrow Al^{+++} + NO + 4\ OH^- \qquad (5)$$

$$8\ Al + 6\ NO_3^- + 15\ H_2O \longrightarrow 8\ Al^{+++} + 3\ N_2O + 30\ OH^- \qquad (6)$$

$$10\ Al + 6\ NO_3^- + 18\ H_2O \longrightarrow 10\ Al^{+++} + 3\ N_2 + 36\ OH^- \qquad (7)$$

These reactions will take place provided there is a source of hydrogen ions

6.0 Chemistry of Dissolution (continued)

present to neutralize the hydroxyl ions. This is done by the addition of nitric acid. The dissolution process can continue after the hydrogen ions present in the original nitric acid are used up. This is accomplished by an additional supply of hydrogen ions obtained as follows:

$$\left[UO_2\ (H_2O)_x\right]^{++} \rightleftharpoons \left[UO_2\ (OH)\ (H_2O)_{x-1}\right]^{+} + H^{+} \qquad (8)$$

$$\left[Al\ (H_2O)_x\right]^{+++} \rightleftharpoons \left[Al\ (OH)\ (H_2O)_{x-1}\right]^{+} + H^{+} \qquad (9a)$$

$$\left[Al\ (H_2O)_{x-1}\ (OH)\right]^{++} \rightleftharpoons \left[Al\ (OH)_2\ (H_2O)_{x-2}\right]^{+} + H^{+} \qquad (9b)$$

The presence of a down-draft condenser in the system allows the absorption of NO_2 in the reflux which is returned to the dissolver. Its reaction with water which promotes further absorption is as follows:

$$2\ NO_2 + H_2O \longrightarrow HNO_3 + HNO_2 \qquad (10)$$

Heat in the dissolver will decompose the nitrous acid as follows:

$$3\ HNO_2 \longrightarrow HNO_3 + 2\ NO + H_2O \qquad (11)$$

7.0 Time of Dissolution for Jacketed and Bare EBR Slugs

The times of dissolution for jacketed and bare EBR slugs were 3.5 and 4.0 hours, respectively, to obtain a final solution 0.30N acid deficient, with a 200 per cent uranium heel. The difference in dissolving times is attributed to the fact that the hydrated aluminum ion hydrolyzes more rapidly than the hydrated uranyl ion (See Section 6.0). This comparatively short dissolving time is the result of these factors:

(1) The high ratio of surface area to weight.

(2) The 150 per cent freeboard in the dissolver.

7.0 Time of Dissolution for Jacketed and Bare EBR Slugs (continued)

Of these, the surface area to weight ratio was the most effective since the dissolving reactions are very surface dependent. The large freeboard in the dissolver allowed boiling of the dissolver contents despite the violent foaming which occurs.

The dissolution times for both types of dissolution could not be predetermined. As a result, the dissolving program involved using many dissolution times until the proper lengths of dissolutions were found. Their determinations were complicated by the fact that it was difficult to maintain a 200 per cent uranium heel. With a higher heel the dissolution time is reduced, and with a lower uranium heel, the effect is opposite. For dissolution times used and metal heels present in the individual runs, see Tables 13.1.2 through 13.1.6 on pages 30 through 34.

The reported dissolution times are averages. The first runs proceed less rapidly than later runs because the surface area increases slowly with each succeeding run until it reaches an equilibrium value. (Assume uranium heel remains constant). Not enough runs were ever made during any one series to determine the equilibrium time of dissolution. However, the reported average time was reasonably close.

The length of the jacket dissolution run in the dissolving of jacketed EBR slugs was only 1.5 hours which was much shorter than that for the regular dissolution runs. This is indicative of the fact that the rate of reaction of nitric acid and aluminum is more rapid than that for nitric acid and uranium.

8.0 Nitric Acid to Metal Dissolved Ratio for Jacketed and Bare EBR Slugs

The individual nitric acid to metal dissolved ratios for Series II through V (jacketed EBR slug dissolution) and for Series VI (bare EBR slug dissolution), can be found in Tables 13.1.2 through 13.1.6 on pages 30 through 34. The average nitric acid to metal dissolved ratios for Series III through VI are shown in Table 13.1.1 on page 29. These ratios are dependent on two factors:

(1) Acid deficiency of the final solution.

(2) Efficiency of the down-draft condenser.

The effect of the acid deficiency of the final solution on the nitric acid to metal dissolved ratio is shown in Table 13.1.3 on page 31. The decrease in this ratio with increasing acid deficiency is the result of an additional amount of uranium which can be dissolved through the acid deficient process [See reactions (8), (9a), and (9b) in Section 6.0] with no additional nitric acid charged. In order to put the average nitric acid to metal dissolved ratios given in Table 13.1.1 on a comparable basis, the following table is presented:

TABLE 8.0

Type of Dissolution	Series No.	Average Nitric Acid to Metal Dissolved Ratio, Mole/Mole, at Acid Deficiencies of: 0.0N	0.2N	0.3N
Jacketed Slug	III	4.26	3.92	3.77
Jacketed Slug	IV	4.41	4.06	3.90
Jacketed Slug	V	4.20	3.86	3.71
Bare Slug	VI	4.40	4.05	3.89

8.0 Nitric Acid to Metal Dissolved Ratio for Jacketed and Bare EBR Slugs (continued)

Even though the solution to be stored and later fed to the "25" Process will be 0.2N acid-deficient, the goal of the dissolving phase will be 0.3N acid deficient. As a result, an adjustment of the dissolver contents can be made in an intermediate tank before storage. This effectively reduces the nitric acid charged to the dissolver. The average nitric acid to metal dissolved ratio for all jacketed and bare EBR slug dissolutions was 3.79 and 3.89, respectively, at an acid deficiency of 0.3N.

The nitric acid to metal dissolved ratios presented in Table 8.0 at 0.0N acid deficiency show that the down-draft condenser was not 100 per cent efficient, for they are above the range of 3.5-4.0 predicted on the basis of reactions given in Section 6.0 and of 100 per cent NO_2 absorption. This fact is confirmed by results obtained on off-gas compositions (see Section 11.0).

The variation in the nitric acid to metal dissolved ratios for the individual runs was caused by the following factors:

(1) Varying acid deficiency of final solution.

(2) Errors in uranium determinations.

(3) Unaccounted for nitric acid losses.

9.0 Vapor Temperature Relation with Completeness of Dissolution of Jacketed and Bare EBR Slugs

The fact that the dissolution of jacketed, or bare, EBR slugs was divided into two phases was clearly shown by observing the vapor tempera-

9.0 Vapor Temperature Relation with Completeness of Dissolution of Jacketed and Bare EBR Slugs (continued)

ture at the top of the dissolver. The first phase was marked by the very slow decrease in the vapor temperature, an indication of the drop in the nitric acid concentration in the dissolver. Though the point at which the second phase, which was marked by a constant minimum vapor temperature, was difficult to determine exactly, it could be seen this temperature was essentially that of water and indicated the acid-deficient phase of the dissolving. (See Section 6.0, Equations 8, 9a and 9b). This phase lasted about 45 minutes for jacketed EBR slug dissolution and about 1.5 hours for bare EBR slug dissolution. The difference is attributed to the more rapid hydrolysis of the hydrated aluminum ion than that of the hydrated uranyl ion.

The vapor temperature was used as an operational aid during the experimental program. It is strongly recommended that it be used similarly at the Idaho Chemical Processing Plant.

10.0 Volume of Water to be Added at the End of Runs Made on the Dissolution of Jacketed and Bare EBR Slugs

The amount of water to be added to the hot solution in the dissolver at the end of a run was dependent on the type of run made. These volumes are summarized in Table 4.0 and are the result of trial and error determinations. The purpose of these water additions is to insure non-freezing of the solution upon cooling and to give the concentrations indicated in Table 4.0. In summarizing them, it is evident that for all runs except the heel dissolution

10.0 Volume of Water to be Added at the End of Runs Made on the Dissolution of Jacketed and Bare EBR Slugs (continued)

runs, a total molarity of 2.10 and an acid deficient normality of 0.30 is desired (Volume $\cong$ 1680 ml.). In this way the dissolver solution can be adjusted before storage in an intermediate tank to a total molarity of 2.00 and an acid deficient normality of 0.20 (Volume = 1750 ml.).

11.0 Volumes, Rates, and Compositions of Gases Evolved During the Dissolution of Jacketed and Bare EBR Slugs

For the individual runs made on the dissolution of jacketed and bare EBR slugs (excluding jacket removal and heel dissolution runs), the off-gas volumes, rates and compositions varied considerably for the following reasons:

(1) The amount of nitric acid addition varied resulting in changes in the amount of metal dissolved.

(2) Analyses of the gas samples were often in error.

(3) The absorption efficiency of the down-draft condenser varied.

To account for the variation due to these above factors, the following table presents on a comparable basis the results given in Tables 13.1.2 to 13.1.6 for Series II through V (jacketed EBR slug dissolution) and Series VI (bare EBR slug dissolution) and the gas compositions presented in Tables 13.1.8 through 13.1.12 for Series II through Series VI:

11.0 Volumes, Rates, and Compositions of Gases Evolved During the Dissolution of Jacketed and Bare EBR Slugs (continued)

TABLE 11.0

	Type of Dissolution	
	Jacketed Slug[a]	Bare Slug[b]
Al dissolved, moles	1.3	0.0
U dissolved, moles	2.2	2.2
Total volume, liters	130	110
Max. gas rate, liters/min.	1.7	1.0
Ave. gas composition, vol. %[c]		
NO	89	87
NO_2	6	10
N_2O	1.5	0
N_2[d]	1.5	0

[a]Excludes jacket removal and heel dissolution runs

[b]Includes all heel dissolution runs

[c]Corrected for inerts, mainly N_2 introduced into system

[d]Assumed nitrogen percentage resulting from dissolution of aluminum

The presence of additional metal as aluminum in the dissolution of jacketed EBR slugs causes the higher evolution rate and larger total volume than the rate and total volume obtained in the dissolution of bare EBR slugs. The presence of N_2O and N_2 in the gas evolved during jacketed EBR slug dissolutions was the result of reactions that aluminum underwent with nitric acid (See Section 6.0).

11.0 Volumes, Rates, and Compositions of Gases Evolved During the Dissolution of Jacketed and Bare EBR Slugs (continued)

The efficiency of the down-draft condenser is reflected in the NO_2 content of the off-gas. In general, one can say that the efficiency was reasonably good. The cause for the increased NO_2 content in the off-gas obtained in the jacketed EBR slug dissolution over that in the off-gas obtained during the bare EBR slug dissolution was possibly the fact that more NO_2 was formed per unit weight of metal dissolved.

In this study, gas analysis data were the only clues which gave any idea as to the mechanism by which aluminum and uranium dissolve. Jacket removal runs EBR 19, 31, and 43 involved mainly the dissolution of aluminum. The high content of N_2O and N_2 in the off-gas evolved during these runs indicated that reactions (4), (5), (6), and (7) in Section 6.0 all take place to an appreciable extent. The regular dissolution of bare EBR slugs (uranium only) was different because N_2O was notably absent in the off-gas. Therefore, reaction (3) in Section 6.0 does not take place to any appreciable extent.

In Section 7.0 the shortness of the jacket removal run (1.5 hours) in the dissolution of jacketed EBR slugs was pointed out. The rapid rate of aluminum dissolution was further confirmed by the fact that the first 77 liters of gas evolved during the jacketed EBR slug dissolution contained appreciable quantities of N_2O, while the remaining volume contained little, if any at all. The fact that the first gas portion (77 liters) was sampled about one hour after the start of the run indicated that practically all of the aluminum jacket had been dissolved by that time.

12.0 Heel Determinations in Jacketed and Bare EBR Slug Dissolutions

In order to check the amount of uranium heel in the dissolver, heel dissolution runs were made. The heel was calculated from the uranium charged and from the uranium analyses of the solutions formed in the EBR dissolver. In Series II and III the difference between the actual and calculated heel was appreciable, i.e., 10 per cent and 4.5 per cent, respectively, of the total uranium charged. For Series IV, V, and VI, the differences between actual and calculated heels were 0.57, 0.60, and 0.60 per cent, respectively, of the uranium charged. The improvement in the accuracy of the calculated heel was the result of more accurate uranium determinations, better sampling techniques, and more samples.

EMS:mh

E. M. Sampson, Jr.

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13.0 APPENDIX

13.1 TABULATED DATA

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TABLE 13.1.1

DISSOLUTION OF EBR SLUGS -

SUMMARY OF UNIT OPERATIONS TEST RUNS

Series No.	Number of Runs	HNO_3 Charged	Gram Atoms of Nitrogen					Metal Charged and Dissolved	HNO_3 Charged / Metal Dissolved	Total Nitrogen Out / Metal Dissolved	Final Solution Composition		
		Gram Atoms of Nitrogen	In NO_3^- in Solution	In Evolved Gases	In Gas Seal Water	In HNO_3 and HNO_2 in Solution	Total Leaving System				Uranium	Aluminum	Acid Deficiency
								Moles	Mole / Mole	Mole / Mole	M	M	N
III[a]	12	135.50	72.33	56.21	2.27	5.82	136.63	38.1	3.56	3.59	1.26	0.69	-.45
IV[a]	12	147.83	81.13	56.03	6.81	2.28	146.25	38.5	3.84	3.79	1.26	0.74	-.34
V[a]	4	39.15	23.11	15.33	0.75	0.00	39.19	10.5	3.73	3.73	1.39	0.74	-.29
VI[b]	8	70.42	33.71	35.56	1.01	0.26	69.54	17.4	4.04	4.00	2.06	--	-.21

[a]This series involved dissolution of jacketed EBR slugs.

[b]This series involved dissolution of bare EBR slugs.

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TABLE 13.1.2

JACKETED EBR SLUG DISSOLUTION

SERIES II RUNS

Full-scale sub-critical dissolver - 4" I.D. and 16" high
Down-draft single-pass condenser - 1.3 sq. ft. = surface area
Dissolver steam chest pressure = 25 psig.
Initial nitric acid concentration = 40% (jacket dissolution)
= 55% (regular & heel dissolution)
Reflux flow ≅ 30 cc/min.

Run No.	Uranium			Aluminum			Dissolving Time	Nitric Acid Used	Metal Dissolved		Final Solution Composition			Nitric Acid Used / Metal Dissolved	Nitrogen in Gas / Metal Dissolved
	Remaining from Previous Run	Charged	Total at Beginning of Run	Remaining from Previous Run	Charged	Total at Beginning of Run			Uranium	Aluminum	Uranium	Aluminum	H^+ a		
	Moles	Moles	Moles	Moles	Moles	Moles	Hrs.	Moles	Moles	Moles	M	M	N	Mole/Mole	Mole/Mole
6[b,c]	0.00	2.16	2.16	0.00	1.24	1.24	2-2/6	4.00	0.33	0.89	0.24	0.77	+0.65	3.39	1.30
7[c,d]	1.83	2.18	4.00	0.35	1.23	1.58	2-1/6	--	0.25	0.80	0.24	0.94	--	--	--
8[d]	3.76	2.18	5.94	0.78	1.19	1.97	1-2/6	7.93	1.03	1.15	0.48	0.53	+1.85	3.64	1.26
9[d]	4.90	2.18	7.08	0.84	1.17	2.01	4-5/6	12.50	2.09	2.01	1.12	1.08	+0.30	3.05	1.52
10[d,e]	4.66	2.17	6.83	0.00	1.24	1.24	6	11.70	1.87	1.24	1.02	0.68	-0.20	3.76	1.23
11[d,e]	5.30	2.18	7.48	0.00	1.22	1.22	6	11.00	2.75	1.22	1.55	0.69	-0.38	2.76	1.31
12	4.73	2.18	6.91	0.00	1.25	1.25	5-2/6	12.20	2.08	1.25	1.06	0.64	+0.50	3.68	1.29
13	4.82	2.18	7.00	0.00	1.27	1.27	5-3/6	13.00	2.43	1.27	1.29	0.67	+0.50	3.51	1.32
14	4.57	2.18	6.75	0.00	1.26	1.26	6	12.20	2.33	1.26	1.30	0.74	+0.88	3.41	1.81
15	4.42	2.18	6.60	0.00	1.24	1.24	7	12.30	2.41	1.24	1.39	0.73	+0.95	3.34	1.59
16	4.19	2.18	6.37	0.0	1.22	1.22	6-3/6	11.80	2.28	1.22	1.34	0.72	+0.74	3.38	1.56
17[f]	4.10 2.40	0.0	4.10	0.0	1.22	1.22	6	6.10	1.70	1.22	1.00	0.0	+3.00	3.59	1.90

[a](+), or (-), indicates excess H^+, or OH^- tied up in basic ion.
[b]Dissolver inspected and found empty at beginning of run.
[c]Jacket removal runs.
[d]Acid lost during run
[e]Design charge in reflux line made after this run.
[f]Dissolver inspected and found empty at end of run.

TABLE 13.1.3

JACKETED EBR SLUG DISSOLUTION

SERIES III RUNS

Full-scale sub-critical dissolver - 4" I.D. and 16" high
Down-draft single-pass condenser - 1.3 sq. ft. = surface area
Dissolver steam chest pressure = 25 psig.
Initial nitric acid concentration = 40% (jacket dissolution)
55% (regular & heel dissolution)

Reflux flow ≅ 30 cc/min.

Run No.	Uranium			Aluminum			Dissolving Time	Nitric Acid Used	Metal Dissolved		Final Solution Composition			Nitric Acid Used / Metal Dissolved	Nitrogen in Gas / Metal Dissolved
	Remaining from Previous Run	Charged	Total at Beginning of Run	Remaining from Previous Run	Charged	Total at Beginning of Run			Uranium	Aluminum	Uranium	Aluminum	H^+ a		
	Moles	Moles	Moles	Moles	Moles	Moles	Hrs.	Moles	Moles	Moles	M	M	N	Mole/Mole	Mole/Mole
19[b]	0.00	4.38	4.38	0.00	2.49	2.49	5-3/6	7.4	0.17	2.04	0.11	1.26	-1.30	3.31	0.97
20[c]	4.21	2.20	6.41	0.45	1.24	1.69	10-1/6	11.6	1.83	1.69	1.08	0.95	-1.15	3.39	1.47
21	4.57	2.20	6.77	0.00	1.22	1.22	10-1/6	11.8	2.57	1.22	1.45	0.69	-1.15	3.11	1.38
22	4.20	2.20	6.40	0.00	1.22	1.22	10-5/6	12.7	2.41	1.22	1.16	0.58	0.66	3.50	1.56
23	3.99	2.20	6.19	0.00	1.21	1.21	11	11.2	2.19	1.21	1.49	0.83	-1.47	3.28	1.60
24	4.00	2.70	6.70	0.00	1.22	1.22	7-5/6	11.2	2.19	1.22	1.35	0.75	-1.30	3.28	1.45
25	4.51	2.19	6.80	0.00	1.21	1.21	5	12.1	2.12	1.21	1.32	0.76	-0.86	3.64	1.46
26	4.58	2.19	6.77	0.00	1.24	1.24	4-2/6	12.4	2.32	1.24	1.47	0.78	-0.35	3.49	1.55
27	4.45	2.20	6.65	0.00	1.19	1.19	3-4/6	8.2	1.97	1.19	1.37	0.83	-0.95	2.59	1.32
28	4.69	2.20	6.89	0.00	1.16	1.16	3-3/6	12.1	1.94	1.16	1.09	0.66	-0.25	3.87	1.51
29	4.95	0.00	4.95	0.00	0.00	0.00	3-3/6	11.5	2.67	0.00	1.60	--	+0.25	4.31	2.19
30[d]	2.28	0.00	2.28	0.00	0.00	0.00	5-2/6	5.8	1.19	0.00	1.04	--	+5.06	4.89	2.12
	1.09														

[a] (+) or (-) indicates excess H^+ or OH^- tied up in basic ion

[b] Jacket removal run. Observed contents in dissolver--some aluminum present.

[c] Inspected dissolver--found all aluminum dissolved

[d] Second heel dissolution--inspected dissolver and found it empty.

[redacted]

[redacted]

TABLE 13.1.4

JACKETED EBR SLUG DISSOLUTION

SERIES IV RUNS

Full-scale sub-critical dissolver - 4" I.D. and 16" high
Down-draft single-pass condenser - 1.3 sq. ft. = surface area
Dissolver steam chest pressure = 25 psig.
Initial nitric acid concentration = 40% (jacket dissolution)
55% (regular & heel dissolution)

Reflux flow ≅ 30 cc/min.

Run No.	Uranium			Aluminum			Dissolving Time	Nitric Acid Used	Metal Dissolved		Final Solution Composition			Nitric Acid Used / Metal Dissolved	Nitrogen in Gas / Metal Dissolved
	Remaining from Previous Run	Charged	Total at Beginning of Run	Remaining from Previous Run	Charged	Total at Beginning of Run			Uranium	Aluminum	Uranium	Aluminum	H^+ [a]		
	Moles	Moles	Moles	Moles	Moles	Moles	Hrs.	Moles	Moles	Moles	M	M	N	Mole / Mole	Mole / Mole
31[b]	0.00	4.40	4.40	0.00	2.46	2.46	2-3/6	6.6	0.12	1.96	0.08	1.36	-1.20	3.18	0.71
32[c]	4.28	2.21	6.49	0.50	1.27	1.77	3-5/6	12.3	1.56	1.77	1.05	1.16	-0.17	3.72	1.42
33	4.93	2.22	7.15	0.00	1.30	1.30	3-3/6	12.2	2.01	1.30	1.18	0.76	-0.37	3.67	1.50
34	5.14	2.22	7.36	0.00	1.33	1.33	3-3/6	9.8	1.53	1.33	1.01	0.88	-0.80	3.42	1.28
35	5.83	2.22	8.05	0.00	1.27	1.27	3-3/6	12.7	2.25	1.27	1.13	0.64	-0.17	3.59	1.40
36	5.80	2.21	8.01	0.00	1.32	1.32	4	12.4	2.04	1.32	1.40	0.90	-0.85	3.69	1.38
37	5.97	2.20	8.17	0.00	1.31	1.31	3-3/6	13.5	2.19	1.31	1.38	0.82	-0.53	3.86	1.38
38	5.98	2.20	8.18	0.00	1.30	1.30	3-3/6	13.3	2.29	1.30	1.27	0.72	-0.45	3.70	1.56
39	5.89	2.20	8.19	0.00	1.32	1.32	3-3/6	13.3	2.57	1.32	1.60	0.82	-0.85	3.40	1.46
40	5.52	2.21	7.73	0.00	1.30	1.30	3-3/6	13.3	2.27	1.30	1.27	0.73	-0.65	3.72	1.50
41	5.46	0.00	5.46	0.00	0.00	0.00	6-5/6	11.6	3.04	0.00	2.08	0.00	+0.25	3.81	1.95
42[d]	2.42	0.00	2.42	0.00	0.00	0.00	9-5/6	9.8	2.28	0.00	1.70	0.00	+1.50	4.39	1.85
	0.14														

[a] (+) or (-) indicates excess H^+ or OH^- tied up in complex ion.

[b] Jacket removal run. Observed contents in dissolver--some aluminum present.

[c] Inspected dissolver--found all aluminum dissolved.

[d] Second heel dissolution run. Inspected dissolver and found it empty.

[redacted]

[redacted]

TABLE 13.1.5

JACKETED EBR SLUG DISSOLUTION

SERIES V RUNS

Full-scale sub-critical dissolver - 4" I.D. and 16" high
Down-draft single-pass condenser - 1.3 sq. ft. = surface area
Dissolver steam chest pressure = 25 psig.
Initial nitric acid concentration = 40% (jacket dissolution)
55% (regular & Heel dissolution)
Reflux flow ≅ 30 cc/min.

Run No.	Uranium			Aluminum			Dissolving Time	Nitric Acid Used	Metal Dissolved		Final Solution Composition			Nitric Acid Used / Metal Dissolved	Nitrogen in Gas / Metal Dissolved
	Remaining from Previous Run	Charged	Total at Beginning of Run	Remaining from Previous Run	Charged	Total at Beginning Of Run			Uranium	Aluminum	Uranium	Aluminum	Acid Deficiency		
	Moles	Moles	Moles	Moles	Moles	Moles	Hrs.	Moles	Moles	Moles	M	M	N	Mole / Mole	Mole / Mole
43[a]	0.00	4.43	4.43	0.00	2.58	2.58	1-4/6	8.93	0.18	2.35	0.18	2.42	-1.35	3.55	0.71
44[b]	4.25	2.21	6.46	0.23	1.29	1.52	3-5/6	12.30	2.11	1.52	1.18	0.86	-0.21	3.63	1.42
45	4.35	0.00	4.35	0.00	0.00	0.00	6-5/6	9.09	2.33	0.00	1.96	0.00	0.00	3.89	1.75
46[c]	2.02	0.00	2.02	0.00	0.00	0.00	9-5/6	8.87	1.98	0.00	2.22	0.00	0.00	4.48	2.17
	0.04														

[a] Jacket removal run. Observed contents in dissolver--small amount of aluminum present
[b] Observed contents in dissolver--no aluminum present
[c] Second heel dissolution run. Interior of dissolver inspected and found empty at end of this run.

[redacted]

[redacted]

TABLE 13.1.6

BARE EBR SLUG DISSOLUTION

SERIES VI RUNS

Full-scale sub-critical dissolver - 4" I.D. and 16" high
Down-draft single-pass condenser - 1.3 sq. ft. = surface area
Dissolver steam chest pressure = 25 psig.
Initial nitric acid concentration = 55% (regular and heel dissolution)
Reflux flow = 30 cc/min.

Run No.	Uranium			Dissolving Time	Nitric Acid Used	Uranium Dissolved	Final Solution Composition		Nitric Acid Used / Uranium Dissolved	Nitrogen in Gas / Uranium Dissolved
	Remaining from Previous Run	Charged	Total at Beginning of Run				Uranium	Hydrogen [a]		
	Moles	Moles	Moles	Hours	Moles	Moles	M	N	Mole / Mole	Mole / Mole
47	0.00	6.64	6.64	4-3/6	8.52	2.06	1.84	0.00	4.14	2.00
48	4.58	2.21	6.79	5-1/6	11.41	2.80	1.89	-0.44	4.07	1.96
49	3.99	2.21	6.20	4-2/6	8.52	2.32	2.25	-0.15	3.68	1.98
50	3.88	2.21	6.09	5	8.76	2.31	1.97	-0.55	3.79	1.98
51	3.78	2.21	5.99	4	6.58	1.64	1.98	-0.35	4.06	1.98
52	4.35	1.95	6.26	4	6.58	1.77	2.30	-0.76	3.72	1.87
53	4.49	0.00	4.49	4-2/6	10.48	2.54	2.10	+0.02	4.05	1.92
54[b]	1.95 0.08	0.00	1.95	11	9.31	2.03	2.02	+0.23	4.61	2.06

[a] (+) or (-) indicates excess H^+ or OH^- tied up in complex ion.
[b] Dissolver inspected and found empty at end of run.

TABLE 13.1.7

NITROGEN MATERIAL BALANCES FOR DISSOLUTION OF EBR SLUGS

Series Number	Run Number	In HNO_3 Charged	Gram Atoms of Nitrogen				
		Gram Atoms of Nitrogen	In NO_3^- In Solution	In Evolved Gases	In Gas Seal Water	In HNO_3 and HNO_2 in Solution	Total Leaving System
III[d]	19	7.35	5.01	2.14	0.12	--	7.27
	20	11.62	6.51	5.19	0.34	--	12.04
	21	11.79	6.77	5.22	0.15	--	12.14
	22	12.74	7.11	5.67	0.03	--	12.81
	23	11.19	5.88	5.46	0.03	--	11.37
	24	11.19	5.95	4.93	0.03	--	10.91
	25	12.12	6.49	4.88	0.32	--	11.69
	26	12.39	7.79	5.53	0.14	--	13.46
	27	9.96	6.18	4.16	0.93	--	11.27
	28	12.06	6.96	4.70	0.14	--	11.80
	29	11.50	5.35	5.81	0.03	--	11.19
	30	11.59	2.38	2.52	0.01	5.82	10.68
	Total	135.50	72.33	56.21	2.27	5.82	136.63
IV[d]	31	6.62	4.37	1.47	0.61	--	6.45
	32	12.29	8.06	4.73	0.26	--	13.05
	33	12.17	7.26	4.98	0.12	--	12.36
	34	12.42	5.86	3.66	2.73[a]	--	12.25
	35	13.42	8.02	4.92	0.89[b]	--	13.83
	36	13.54	6.78	4.65	1.31[c]	--	12.74
	37	13.50	7.46	4.83	0.25	--	12.54
	38	13.25	7.65	5.59	0.10	--	13.34
	39	13.25	7.74	5.69	0.17	--	13.60
	40	13.25	7.26	5.36	0.05	--	12.67
	41	12.00	6.11	5.93	0.02	--	12.06
	42	12.12	4.56	4.22	0.30	2.28	11.36
	Total	147.83	81.13	56.03	6.81	2.28	146.25
V[d]	43	8.93	6.08	1.80	0.09	--	7.97
	44	12.26	8.42	5.15	0.06	--	13.63
	45	9.09	4.66	4.08	0.34	--	9.08
	46	8.87	3.95	4.30	0.26	--	8.51
	Total	39.15	23.11	15.33	0.75	--	39.19
VI[e]	47	8.52	4.12	4.11	0.20	--	8.43
	48	11.41	5.59	5.48	0.10	--	11.17
	49	8.52	4.63	4.47	0.13	--	9.23
	50	8.76	4.61	3.89	0.12	--	8.62
	51	6.58	3.24	3.26	0.20	--	6.70
	52	6.58	3.54	3.30	0.05	--	6.89
	53	10.51	5.08	4.88	0.06	0.03	10.05
	54	9.54	3.90	4.17	0.15	0.26	8.48
	Total	70.42	33.71	35.56	1.01	0.29	69.57

[a] 2.60 mols HNO_3 lost during dissolver surge.
[b] 0.76 mols HNO_3 lost during dissolver surge.
[c] 1.19 mols HNO_3 lost during dissolver surge.
[d] This series involved dissolution of jacketed slugs.
[e] This series involved dissolution of bare slugs.

TABLE 13.1.8

JACKETED EBR SLUG DISSOLUTION

SUMMARY OF GAS ANALYSES - SERIES II

Sample No.	Gas Composition, Volume Per Cent							
	NO	NO_2	CO_2	O_2	N_2O	CO	H_2	N_2
EBR6	55.1	15.8	0.6	2.6	3.5	1.4	0.0	21.1
7	57.6	14.7	0.5	0.1	8.8	0.4	4.9	12.9
8	81.3	5.3	0.7	0.5	1.6	0.1	0.0	10.4
9A	83.6	3.7	0.4	0.5	1.2	0.0	0.0	10.6
9B	92.1	1.7	0.0	0.7	0.3	0.0	0.0	5.2
10A	58.7	31.7	0.7	0.3	0.0	1.2	0.0	7.3
10B	63.8	0.0	0.7	0.7	0.0	0.3	0.7	27.9
11A	69.1	10.1	1.0	0.6	1.4	0.6	0.0	17.2
11B	81.5	7.7	0.7	0.3	0.3	1.6	0.0	7.9
12A	87.4	0.0	0.6	0.3	3.3	0.1	0.3	8.0
12B	49.8	17.6	1.0	0.4	2.2	0.4	0.0	28.6
13A	92.0	1.0	0.5	0.4	1.8	0.0	0.0	4.3
13B	77.0	4.8	0.7	3.2	0.0	0.0	0.0	14.3
14A	89.8	4.2	0.5	0.3	1.4	0.1	0.0	3.7
14B	90.3	5.5	0.6	0.3	0.0	0.0	0.0	3.3
15A	78.7	12.9	0.5	0.5	1.5	0.4	0.0	5.5
15B	95.1	0.1	1.1	0.3	0.0	0.3	0.0	2.8
16A	89.1	0.0	0.5	0.5	0.8	0.3	0.0	8.8
16B	68.9	28.2	0.4	0.0	0.0	0.0	0.0	2.5
17A	84.5	11.7	-	-	-	-	-	3.8
17B	21.1	8.1	1.7	0.1	0.1	0.3	0.1	68.3

TABLE 13.1.9

JACKETED EBR SLUG DISSOLUTION

SUMMARY OF GAS COMPOSITIONS - SERIES III

Sample No.	Gas Composition, Volume Per Cent							
	NO	NO_2	CO_2	O_2	N_2O	CO	H_2	N_2
EBR19[a]	54.6	8.9	0.9	0.4	11.9	0.7	3.7	18.9
20	88.0	0.0	0.5	0.6	6.1	0.4	0.0	4.4
21A	89.0	0.0	1.2	0.4	3.8	0.4	1.7	3.4
21B	94.7	0.0	0.6	0.4	0.0	0.4	0.0	3.9
22	86.5	0.0	0.7	0.4	2.9	0.1	0.0	9.4
23A	76.0	13.8	0.1	0.1	2.6	0.0	0.0	7.4
23B	78.4	5.5	1.0	2.5	0.0	0.3	0.0	12.4
24A	89.0	0.0	0.1	1.2	2.6	0.3	0.1	6.4
24B	95.6	0.0	0.2	0.4	0.0	0.3	0.0	3.5
25A	82.0	12.4	0.8	0.5	1.1	0.3	0.0	2.9
25B	90.6	3.6	0.5	0.4	0.0	0.3	0.0	4.6
26A	93.7	1.2	0.6	0.4	1.3	0.1	0.0	2.7
26B	81.4	12.4	0.5	0.4	0.6	0.3	0.0	4.4
27A	85.7	8.2	0.6	0.3	0.3	0.1	0.0	4.8
27B	89.1	5.8	0.0	0.0	0.0	0.0	0.6	4.5
28A	82.0	9.4	0.5	0.0	2.0	0.0	0.7	5.4
28B	74.1	19.0	1.1	0.1	1.0	0.3	0.0	4.4
29A[b]	86.6	8.6	0.8	0.4	0.0	0.3	0.0	3.4
29B[b]	89.8	7.4	0.1	0.0	0.0	0.1	0.0	2.6
30[b]	76.7	14.2	1.1	0.3	0.0	0.1	0.0	7.6

[a]Jacket removal run

[b]Heel dissolution runs

TABLE 13.1.10

JACKETED EBR SLUG DISSOLUTION

SUMMARY OF GAS ANALYSES - SERIES IV

Sample No.	Gas Composition, Volume Per Cent							
	NO	NO_2	CO_2	O_2	N_2O	CO	H_2	N_2
EBR31	50.3	2.1	0.8	0.5	17.4	0.4	6.6	21.9
32A	81.4	5.8	2.3	0.4	0.3	0.6	0.2	9.0
32B	85.8	0.8	3.5	0.6	0.2	1.0	0.0	8.1
33A	93.5	0.0	0.7	0.2	1.0	0.1	0.0	4.5
33B	88.0	0.0	0.6	0.3	1.6	0.4	0.1	9.1
34A	87.4	0.0	0.1	1.0	4.5	0.1	0.7	6.2
34B	82.5	9.6	0.6	0.4	0.0	0.0	0.0	6.9
35A	74.6	13.9	0.7	0.7	3.0	0.4	0.4	6.2
35B	70.7	13.5	0.8	0.4	0.0	0.5	0.0	14.1
36A	75.6	10.8	0.8	0.3	4.6	0.1	0.6	7.2
36B	78.7	8.9	0.4	2.1	0.0	0.1	0.0	10.0
37A	90.3	1.4	0.9	0.3	2.9	0.0	0.5	3.7
38A	85.2	5.6	0.4	0.3	2.7	0.5	0.1	5.1
39A	85.9	4.7	0.0	0.4	0.0	4.4	0.0	4.7
39B	90.5	0.0	0.6	0.6	0.2	0.1	0.1	7.9
40A	93.0	0.0	0.7	0.3	1.4	0.0	0.0	4.6
40B	92.4	0.0	0.9	0.6	1.3	0.1	0.0	4.7
41A	98.0	0.0	-	-	-	-	-	2.0
41B	93.7	2.2	-	-	-	-	-	4.1
42A	92.0	4.1	-	-	-	-	-	3.9
42B	91.1	1.7	0.4	0.6	0.0	0.1	0.0	6.1

TABLE 13.1.11

JACKETED EBR SLUG DISSOLUTION

SUMMARY OF GAS ANALYSES - SERIES V

Sample No.	Gas Composition, Volume Per Cent							
	NO	NO_2	CO_2	O_2	N_2O	CO	H_2	N_2
EBR43A	55.9	0.4	0.8	0.3	19.4	0.0	7.6	15.6
44A	88.7	0.0	0.7	0.4	2.9	0.0	0.1	7.2
44B	85.8	4.1	0.7	0.7	0.3	0.3	0.0	8.1
45A	93.9	6.1	-	-	-	-	-	-
45B	31.3	15.2	0.8	0.3	0.0	0.5	0.0	51.9
46A	64.1	15.6	0.8	0.3	1.0	0.0	0.0	18.1
46B	82.5	13.0	1.8	-	-	-	-	2.7

TABLE 13.1.12

BARE EBR SLUG DISSOLUTION

SUMMARY OF GAS ANALYSES - SERIES VI

Sample No.	Gas Composition, Volume Per Cent							
	NO	NO_2	CO_2	O_2	N_2O	CO	H_2	N_2
EBR47A	76.5	22.2	-	-	-	-	-	1.3
47B	80.9	12.8	0.5	0.3	0.0	-	-	5.5
48A	96.0	-	0.3	0.5	-	-	-	3.2
48B	86.7	10.9	-	-	-	-	-	2.1
49A	96.7	2.3	-	-	-	-	-	0.9
49B	89.5	9.0	-	-	-	-	-	1.0
50A	57.5	18.8	0.7	4.3	0.2	0.4	0.0	18.1
50B	69.2	18.6	0.4	0.4	0.0	0.1	0.0	11.3
51A	67.7	22.9	0.5	0.3	0.0	0.0	0.1	8.5
51B	90.0	00.0	0.8	0.0	0.0	0.4	0.0	8.8
52A	84.7	12.6	-	-	-	-	-	2.7
52B	63.4	11.0	0.4	0.3	0.0	0.1	0.0	24.8
53A	81.7	13.7	-	-	-	-	-	4.6
53B	76.9	20.5	-	-	-	-	-	2.6
54A	75.0	15.6	1.5	0.5	-	-	-	7.4
54B	72.4	16.0	2.2	0.1	-	-	-	9.3

13.2 Sample Computation for

Jacketed EBR Slug Dissolution -

Run No. 37

Uranium

Uranium remaining from previous run	=	5.97 moles
Uranium charged to dissolver = 524.0 gms.	=	2.20 moles
Uranium in dissolver at beginning of run	=	8.17 moles

Aluminum

Aluminum remaining from previous run	=	0.00
Aluminum charged to dissolver = 35.4 gms.	=	1.31 moles
Aluminum in dissolver at beginning of run	=	1.31 moles

Nitric Acid Used

$$\text{Nitric acid charged} = \underbrace{118}_{\text{mm}} \times \underbrace{7.52}_{\text{cc/mm}} \times .690 \times \underbrace{1.39}_{\text{gm/cc}} \times \frac{1}{\underbrace{63.0}_{67\ \text{gm/mole}}}$$

$$= 13.5 \text{ moles}$$

Nitric acid used = nitric acid charged - nitric acid remainng
= 13.5 - 0
= 13.5 moles

Metal Dissolved

Uranium $= \frac{328}{238} \times 1.59 = 2.19$ moles

Aluminum* $\frac{35.4}{27.0} = 1.31$ moles

Nitric Acid Used to Metal Dissolved Ratio

$$\text{Ratio} = \frac{13.5}{2.19 + 1.31} = \frac{13.5}{3.50}$$

$$= 3.86 \text{ mole/mole}$$

*Assume that all aluminum goes into solution.

13.2 Sample Computation for

Jacketed EBR Slug Dissolution -

Run No. 37 (continued)

Nitrogen in Gas to Metal Dissolved Ratio

$$\text{Ratio} = \frac{4.83}{3.50} = 1.38 \text{ mole/mole}$$

NO_3^- in Dissolver Solution

Maximum NO_3^- as $UO_2(NO_3)_2$	= 1.38 x 1.59 x 2.00	= 4.39 moles
Maximum NO_3^- as Al $(NO_3)_3$	= .82 x 1.59 x 3.00	= 3.91 moles
		8.30 moles
Less OH^- equivalent to NO_3^-	= .53 x 1.59	.84 moles
		7.46 moles

Nitrogen in Gas

"A" 78.4 liters at 743 mm. Hg and 29°C
"B" 54.6 " " " " " " "

$$\text{"A" moles} = \frac{78.4}{22.4} \times \frac{743}{760} \times \frac{273}{302} = 3.09$$

$$\text{"B" moles} = \frac{54.6}{22.4} \times \frac{743}{760} \times \frac{273}{298} = 2.09$$

"A"

NO	= 3.09 x 1.00 x .903	= 2.79
NO_2	= 3.09 x 1.00 x .014	= .04
N_2O	= 3.09 x 2.00 x .029	= .18
N_2	= 3.09 x 2.00 x 0	= 0
		3.01 moles

"B"

Sample lost - assume NO + NO_2 = 90%

2.09 x 0.900 = 1.82 moles

Total Nitrogen in Gas = 3.01 + 1.82 = 4.83 moles of N_1

Nitrogen In Water

No samples. Estimated figure = .25 moles

13.3 Sample Computation and Table Showing the Effect of Acid Deficiency on Nitric Acid to Metal Dissolved Ratio

Assumptions:

(1) Reaction (2) given in Section 6.0 represented the net reaction during the acid deficient phase of dissolving (All NO_2 is absorbed with the evolution of NO).

(2) 2.20 moles of uranium and 1.30 moles of aluminum were dissolved to give a final volume of 1.75 liters.

Using a ratio of 4.30 for the nitric acid to metal dissolved at 0.0N acid deficiency, determine the ratio at 0.2N acid deficiency.

Acid Deficient (OH^-) Equivalents $= 1.75 \times 0.200 = 0.350$

Ratio of OH^- to uranium dissolved $= 4.00$ moles/mole

Uranium dissolved $= \frac{0.350}{4.00} = 0.0876$ moles

Ratio of HNO_3 to metal dissolved $= \frac{4.30}{1 + .0876} = \frac{4.30}{1.088} = 3.95$ moles/mole

This calculation was repeated to obtain the following table from which conversions can be made:

TABLE 13.3

Nitric Acid to Metal Dissolved Ratios, Mole/Mole, at Acid Deficiencies of:

0 N	0.1 N	0.2 N	0.3 N	0.4 N
4.60	4.41	4.23	4.07	3.92
4.50	4.31	4.14	3.98	3.83
4.40	4.22	4.05	3.89	3.74
4.30	4.12	3.95	3.80	3.66
4.20	4.02	3.86	3.71	3.57
4.10	3.93	3.77	3.62	3.49

13.4 Operating Instructions for Experimental EBR Slug Dissolver

START UP

1. If necessary, turn on nitrogen bleed.

2. Charge 9 jacketed slugs (or 18 for jacket dissolution run, or none for heel dissolution run) through slug chute.

3. Turn on multipoint temperature recorder and set chart so that a numbered line coincides with the quarter-hour.

4. Drain water from condenser shell. Then close the drain valve.

5. Open vent valve in gas line immediately above reflux line.

6. Fill gas holder full of water.

7. Put designated volume of water into the dissolver (volume will depend on type of dissolution run).

8. Shut off nitrogen by closing the two header valves, the two manometer by-pass valves, and the three lead valves at the dissolver, in that order.

9. If necessary, fill nitric acid head tank and record liquid level.

NOTE: Steps 10 and 11 are applicable only if aluminum is to be dissolved, i.e., in jacket removal and regular dissolution runs used in the dissolution of jacketed EBR slugs.

10. Weigh out about 0.3 gm. $Hg(NO_3)_2$ (or 0.6 gm. $Hg(NO_3)_2$ in case of jacket removal run), and place it in 44 ml. of H_2O held in a 50 cc graduated cylinder.

11. Add nitric acid to the $Hg(NO_3)_2$ and H_2O mixture and bring the volume to 50 cc by opening acid line drain valve.

12. Check all valves for proper positioning.

13. Make sure can is below water outlet of gas holder.

14. Making sure water is off the dissolver jacket, turn on steam and adjust its pressure to 25 psig.

15. When gas line at bottom of condenser begins to get hot, add the acid $Hg(NO_3)_2$ solution, immediately close the open vent valve, and crack the condenser water valve.

13.4 Operating Instructions for Experimental EBR Slug Dissolver (continued)

16. Charge slowly from the HNO_3 head tank a designated amount maintaining a slight vacuum on the system. Record final liquid level.

17. Adjust condenser water flow to a rotameter reading of 1.04(1.00 gpm).

18. Maintain a slight vacuum, or pressure on system by controlling water flow out of gas holder.

SHUT DOWN

1. Shut off steam to dissolver jacket. Turn on cooling water to dissolver jacket.

2. Isolate gas holder. Adjust gas holder pressure to zero. Record final liquid level.

3. Open vent valve to roof.

4. Sample gas in holder.

5. Open vent valve on top of holder.

6. Drain remaining water from holder. Sample water every time water fills can and record liquid level.

7. Close vent valve on top of holder. Open valve in gas line at holder.

8. Fill gas holder full of water.

9. Close valve in gas line at holder and open vent valve on gas holder.

10. Drain water entirely from holder.

11. Fill holder to 570 mm. mark with water.

12. Open valve on top of holder and close vent valve to roof.

13. Turn on nitrogen to manometers and record liquid level and specific gravity readings, when temperature of dissolver is 60°C.

14. Add a designated volume of H_2O to dissolver and heat dissolver to boiling.

15. Cool dissolver to 25° C.

13.4 Operating Instructions for Experimental EBR Slug Dissolver (continued)

16. Record liquid level and specific gravity readings.

17. Pull contents of dissolver out by evacuating a 4-liter suction flask connected to vacuum.

18. Pour the final solution into a graduated cylinder (at least 2-liter). Record the volume and sample after stirring effectively.

19. Pour this solution into 20-liter bottle, recording net weight before and after its addition.

20. Stir contents effectively and sample.

21. Shut off the temperature recorder.

22. Close valve in acid line at the vapor-gas line.