

PA. 25
FAC #2 10051
FOLDER #1
PA. 25-11

KENNECOTT COPPER CORPORATION

161 EAST 42ND STREET
NEW YORK 17, N. Y.

AND

KOPPERS COMPANY, INC.

GENERAL OFFICES
PITTSBURGH 19, PA.

JOINT PROPOSAL GROUP
KOPPERS BUILDING
PITTSBURGH 19, PA.

CONFIDENTIAL

CLASSIFICATION CANCELLED
DATE 8-18-59
For The Atomic Energy Commission

A. R. Michener
Classification Officer, ORO

October 30, 1956

Mr. S. R. Sapirie, Manager
Oak Ridge Operations Office
U. S. Atomic Energy Commission
P. O. Box E
Oak Ridge, Tennessee

Attention: Mr. John R. Moore, Director
Contract Division

Subject: Addendum (A) to Proposal for a Feed Materials Processing Plant,
dated September 27, 1956

Dear Mr. Moore:

In the proposal for a feed materials processing plant for the production of uranium hexafluoride that was submitted jointly by Koppers Company, Inc. and Kennecott Copper Corporation under date of September 27, 1956, we described a research and development program that we had initiated in support of the proposal. We also stated that we would keep the USAEC advised of our progress in this work. This is the first such interim report.

Very promising results are being obtained in the laboratory on improved, low-cost methods for producing UF₄ and UF₆. Pilot-plant units for larger-scale testing of the processes have been constructed and are now undergoing "shake-down" runs.

The results obtained to date further substantiate our Alternate Proposals No. 1 and No. 2 and indicate the probability that designs can be still further simplified to reduce the "possible prices for UF₆" that were quoted in the proposal.

We would like to take this opportunity to invite you and/or your representatives to visit us in Pittsburgh so we can show you the work in progress and review it in more detail.

INTERNATIONAL CORPORATION
MARK I

Sincerely yours,

E. B. Gungou

E. B. Gungou, Manager
Nuclear Products Section

EBC:swc

**CONFIDENTIAL
RESTRICTED DATA**

This document contains restricted data as defined in the Atomic Energy Act of 1954. Its transmittal or the disclosure of its contents in any manner to an unauthorized person is prohibited.

CONFIDENTIAL

INTERIM REPORT ON URANIUM FEED MATERIALS RESEARCH AND DEVELOPMENT PROGRAM as of October 30, 1956

1.0 Summary

This is an interim report on the results from the research and development program that is being conducted by the Company in connection with its Proposal for a Feed Materials Production Plant. The objective of these studies is to obtain data that will further substantiate and improve the Company's Alternate Proposals No. 1 and No. 2.

Very promising results have been obtained in bench-scale studies of new low-cost techniques for producing UF_4 and UF_6 . Pilot-plant units for larger-scale testing of the new processes have been constructed and are now undergoing "shakedown" runs.

In studying the production of UF_4 , it has been discovered that UO_3 , U_3O_8 , UO_2F_2 , and $(NH_4)_2 U_2O_7$ can be converted to fairly high-grade UF_4 (suitable for UF_6 production) by calcining a mixture containing these compounds, plus starch and ammonium fluoride. Up to 91% UF_4 has been produced from ammonium diuranate in less than 10 minutes, with only the stoichiometric amount of fluoride in the original mixture and with no addition of fluoride during calcination. This process provides a means for completely utilizing the HF, which could be supplied from a low-cost source such as by-product 70% acid from the existing feed plants. The pilot plant equipment is designed to study the reactions with or without the addition of HF during residence times as low as 2 seconds.

In studying the production of UF_6 by reacting UF_4 powder and O_2 , it has been found that very rapid reaction rates can be obtained. In shake-down runs with the bench-scale equipment, UF_6 was produced during a reaction time

CONFIDENTIAL

~~CONFIDENTIAL~~

of only 3 seconds. In these tests, much of the UF_4 was completely oxidized to UF_6 and UO_2F_2 . The pilot-scale equipment is now ready for testing the process under conditions that are applicable to the full-scale plant.

The results obtained to date further substantiate the original designs for Alternate Proposals Nos. 1 and 2 and show that these designs may be further simplified to reduce the "possible average price for UF_6 " originally quoted for each of the Alternates (see Table I, Part I, of the Proposal).

In a longer-range program, conversion of impure ore concentrate to UF_4 and UF_6 and subsequent purification of the UF_6 by distillation are being investigated. Promising preliminary results on the one-step method in producing UF_4 from ore concentrates have been obtained in the laboratory.

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

2.0 Introduction

The Company is devoting a concerted effort on a high-priority research and development program in order to substantiate and improve its Proposal for a Feed Materials Production Plant, which was submitted to the U. S. AEC on September 27, 1956. As emphasized in the Proposal (see Part III, Volume 2 of the Proposal), such a program is justified by the large cost savings potentially available from new processes, the more advanced of which were selected for Alternate Proposals No. 1 and 2. The Company's program includes bench-scale and pilot-scale studies of new and improved techniques for producing UF_4 and UF_6 . This interim report contains the results of the program to the present time. The work is continuing at an accelerated rate.

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

3.0 UF₄ Production

A new, economical method for producing UF₄ and recovering waste HF solutions has been developed in the Company's laboratories. In this process, UO₃, UO₂F₂, U₃O₈, (NH₄)₂U₂O₇, and impure ore concentrate are converted directly to UF₄ by simultaneous reaction with starch, ammonium fluoride recovered as an aqueous solution, and hydrogen fluoride.

The new process takes advantage of two factors that were known previously: (1) starch reduces compounds such as UO₃, U₃O₈, UO₂F₂, and (NH₄)₂U₂O₇ at a temperature of 450°C. or below, and (2) the double salts of NH₄F and UO₂F₂ or UF₄ are stable up to 450°C. or higher. By heating a dried mixture of the uranium compound, starch, and an ammonium fluoride solution, the uranium is reduced to the tetravalent state and converted to UF₄ as the fluoride is released from the double salts. A fairly high-grade UF₄ has been made in this manner, without the addition of fluoride during calcination. Very high reaction rates have been experienced in the bench-scale tests. Equipment for pilot-scale testing of the process with and without added HF gas has been constructed and is now ready for use.

3.1 Bench-scale UF₄ Production

A relatively simple technique was developed for bench-scale testing the new process for UF₄ production and HF recovery. In these tests, the reactants were pre-mixed, dried, calcined, and then analyzed. All of the reactants were incorporated in the feed mixture; no fluoride was added during the drying and calcination steps.

3.1.1 Experimental Procedure

The uranium compound, in powder form, was mixed with dry corn starch, and then a solution of fluoride salts was added. This mixture reacted while wet to form UO₂F₂, UO₂F₂·xNH₄F, and

~~CONFIDENTIAL~~

CONFIDENTIAL

UF₄ (from U₃O₈). The mixture was then formed into an extrudable paste or dough and pelletized. The pellets were dried in air at 150°C. About 10 grams of dry 3/16 inch pellets were placed in a 5 inch length of 1/2 inch monel pipe, which was tightly plugged at one end and loosely plugged at the other. The tube was placed in an open-end muffle furnace and heated. After the calcination step was completed, the tube was removed from the furnace and allowed to cool in air. The material was then removed from the tube, pulverized, sampled, and analyzed.

3.1.2 Results

The operating conditions and results of the experiments are summarized in Table I and presented graphically in Figures I and II.

The following observations concerning the conversion of refined compounds to UF₄ were made (see Figure I):

- a. The best conversion to UF₄ occurred with ammonium diuranate. Up to 91%* conversion was experienced with the stoichiometric amount of fluoride in the mixture. This UF₄ exceeds the requirements for the Alternate No. 2 design (see the Material Balance Sheet, Part III, Volume 3, Section III, of the Proposal). Mixtures containing 10 to 25% excess fluoride are now being tested in an effort to obtain even greater conversion. Also, since the tests were performed by heating the mixture to 800°C. in less than 10 minutes, and since there is some indication that more gradual heating results in higher yields, lower heating rates are being tried.

* The conversion was calculated by dividing the fluoride content of the product by the ~~fluoride content of UF₄~~ (24.2%).

CONFIDENTIAL

~~CONFIDENTIAL~~

- b. Hard, stable pellets were made with each of the uranium compounds. None of the mixtures fused or became sticky during the calcination step. Therefore the mixtures should be suitable for use in the moving-bed reactor and in other types of reactors.
- c. When mixtures containing UO_3 were heated slowly, somewhat higher conversions (up to 82% UF_4) were obtained than when rapid (less than 10 minutes) heating was employed.
- d. The product from a mixture containing UO_3 that was heated for only two minutes in a 1000°C . furnace contained 68% UF_4 and only 0.54% NH_3 . (A pneumatic-conveyor reactor has been constructed for testing reaction periods as low as 2 seconds).
- e. Little benefit was obtained in the batch tests by incorporating more than about 50% excess fluoride in the mixtures. This probably was due to the larger excesses being evolved at low temperature.
- f. U_3O_8 gave about the same yields as UO_3 .
- g. Low conversion (less than 50%) to UF_4 was experienced when starch was omitted from the mixture containing UO_3 .
- h. When less than the stoichiometric amount of fluoride was used in the mixtures fluoride utilization was high.
- i. Reduction of the U(VI) to U(IV) averaged over 99% for the 8 samples that were analyzed for UO_2F_2 .

The following observations were made concerning the conversion of impure ore concentrates to impure UF_4 (see Figure II):

- a. The presence of starch is required for high conversion.

~~CONFIDENTIAL~~

CONFIDENTIAL

- b. Since the maximum fluoride content of the product exceeded 24.2% (that for pure UF_4), part of the impurities must have been retained in the product as fluorides. Additional analytical data on the products are being obtained. The analysis of the untreated Durango ore that was used is given in Table II. It is estimated that the impurities in the product accounted for about 6% of the fluoride content of the product.
- c. Assuming that 6 or 7% of the fluoride in the product was combined with impurities, the conversion of Durango ore concentrate to UF_4 was equal to or greater than that for the refined compounds.
- d. The fluoride content of the product from a composite of six ore concentrates, Durango, Anaconda (acid), Anaconda (carbonate), Monticello (acid), Rifle and Vitro, was appreciably less than that from Durango ore alone. This may have been due to a difference in impurity content. More complete analyses of these materials are being obtained.

3.2 Pilot-scale UF_4 Production

The bench-scale tests of the new UF_4 production technique, coupled with previous experience with the ORNL pilot-plant moving-bed reduction-hydrofluorination reactor under similar operating conditions, provide sufficient data to anticipate successful utilization of the process in production-scale moving-bed reactors. The designs for Alternate Proposals No. 1 and 2 already include the equipment required for employing these new techniques. Therefore, additional pilot-scale tests of UF_4 production in moving-bed reactors are not considered mandatory at this

~~CONFIDENTIAL~~

time. Instead, two pilot-scale reactors of new design have been fabricated for use in testing the new process at high reaction rates. One is a pneumatic-conveyor reactor and the other is a falling-particle unit. In these reactors, HF gas will be employed to force the reaction more nearly to completion.

The pneumatic-conveyor reactor (see Figures III and IV) consists of a 1/4 inch tube 50 ft. long, coiled around a cyclone separator 2-3/4 inches I.D. and 25 inches long. The assembly is inserted in a tube furnace. Dry, pulverized mixtures of the uranium compounds, starch, and ammonium fluorides will be pre-mixed with HF gas, which will convey the material through the unit. The HF concentration will be kept high enough to favor conversion to UF_4 at the contemplated maximum operating temperature (500 to 600°C). It is planned to test the unit at a product rate of up to 10 lbs./hr. The residence time will be about 3 seconds. The gaseous and solid products will be separated in the cyclone while at maximum temperature to prevent contaminating the product with the double salt, $UF_4 \cdot NH_4F$. The UF_4 will be withdrawn from the bottom of the unit and the off gases will be scrubbed to recover the HF, NH_3 and entrained dust. The scrub liquor will be recycled to the mixing step.

The falling-particle reactor (see Section 4.2.4) that has been constructed for UF_6 production studies has been made adaptable for studying the UF_4 -production technique. In this unit, counter-current flows of the solids and HF gas can be employed to provide more favorable conditions for complete conversion. A somewhat greater residence time can be obtained in this unit, if needed.

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

4.0 UF₆ Production

The Company's major feed materials research and development effort is concentrated on the low-cost production of UF₆ by reaction between UF₄ and oxygen, according to the following reaction: $2UF_4 + O_2 \rightarrow UF_6 + UO_2F_2$. The design for Alternate Proposal No. 2 utilizes moving bed reactors for this step and for producing the required UF₄ from UO₃ and recycled by-product UO₂F₂. This design, which was based on experimental data obtained at the Oak Ridge National Laboratory, is the most economical large-scale method for producing UF₆ that is known. However, more experience with the oxidation step is required before trouble-free operation of a plant of this design can be assured. The company is attempting to obtain this information quickly by high-priority work on a bench-scale and in two pilot plants. Very encouraging results have been obtained in the bench-scale equipment, and the pilot plants are now undergoing shake-down tests.

4.1 Bench-Scale UF₆ Production

Since the moving-bed tests at ORNL and laboratory tests in England⁽¹⁾ indicated that the oxidation reaction is rapid at temperatures of 800 to 900°C., a bench-scale facility, containing a pneumatic-conveyor reactor plus auxiliaries, was constructed to study the reaction kinetics. The primary objective of the study is to determine the optimum conditions for testing the falling-particle reactor. In the equipment (see Figures V and VI), O₂ metered from a cylinder picks up a metered stream of UF₄ and conveys it through a heated 1/4 inch diameter x 50 ft. long Inconel tube, where the mixture is heated to the desired temperature; the solid and gaseous products are separated in two settling chambers; the UF₆ is cold trapped; and the gases are then passed through two water scrubbers and to the stack.

⁽¹⁾ Mandleberg, C. J. and Davies, P. "Kinetics of the Reaction Between UF₄ and O₂", ~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

CONFIDENTIAL

Two exploratory runs have been made in the inconel tube reactor. In these tests, UF_4 containing 23.5% fluoride was conveyed through the reactor by a large excess of oxygen. The residence time for preheating and reacting the UF_4 and O_2 was approximately 3 seconds. The products were then passed through two settling chambers and two water scrubbers, connected in series, from which the off-gases were vented to the stack. The UF_6 was not cold-trapped in these preliminary tests.

In the first test, unscreened Mallinckrodt UF_4 powder was used. Mechanical difficulties caused the UF_4 to be fed somewhat erratically. The average maximum reactor temperature was $820^{\circ}C$. The solid product that settled in the first entrainment separator was mostly green, with some yellow-white particles, and contained 21.5% fluoride; that which settled in the second chamber was grey-white, with no green color evident, and contained 15.5% fluoride.

In the second run, the minus 325-mesh fraction from Mallinckrodt UF_4 powder was fed. The powder was well dispersed into the O_2 , and was fed at a fairly uniform rate. The average maximum reactor temperature was $850^{\circ}C$. The evolution of UF_6 from the reactor began 3 seconds after the feeding was started. Since only 5% of the weight of the powder fed was collected as solid product in the two settling chambers, the scrub water is also being analyzed for uranium and fluoride content. With complete conversion and recovery, the solid UO_2F_2 product would weigh 49% as much as the UF_4 feed. The first settling chamber contained 85% of the solid product that was collected. This material was light-green in color and contained 16.9% fluoride. That collected in the second chamber was white and contained 14.1% fluoride. The calculated oxidation of the UF_4 , based on fluoride content of the solids and assuming

CONFIDENTIAL

~~CONFIDENTIAL~~

that one mole of UF_6 was evolved for each mole of UO_2F_2 collected, was 78% for the material from the first settling chamber and 92% for that from the second.

These runs showed that the reaction between UF_4 and O_2 is rapid enough that considerable conversion should be obtained in the pilot-scale falling-particle reactor. Additional runs are required to complete the kinetic study and to obtain material-balance data, and these runs are being made. Two additional runs have already been made, and the reaction products are now being analyzed. Preparations are being made to continue these studies in the falling-particle reactor, in which a UO_2F_2 liner should minimize errors in the data due to corrosion.

4.2 Pilot-Scale UF_6 Production

Two pilot plants are being made ready for obtaining the additional data that are required in connection with Alternate Proposal No. 2. The moving-bed oxidation reactor at ORNL is now being tested (under contract with Union Carbide Nuclear Company), and a falling-particle reactor has been constructed at the Koppers Research Center. Both reactors are equipped with protective refractory liners of UO_2F_2 or U_3O_8 and employ carbon or CO as a supplemental source of heat in order to avoid exposing the Inconel shells to the high-temperature corrosive conditions. An attempt will be made to obtain accurate material-balance data in these reactors since this has been a difficulty with smaller reactors in which corrosion caused inaccurate results.

~~CONFIDENTIAL~~

4.2.1 Moving-Bed Reactor Tests

The ORNL moving-bed reactor (see Figure VII), which has been rehabilitated and is now undergoing shake-down runs, will be used to test more extensively the moving-bed techniques that were developed previously in the same reactor. The Alternate No. 2 design is presently based on successful tests in this reactor. In the current tests, it is planned to reproduce as closely as possible the following conditions, which were employed to obtain 90% oxidation of the UF_4 :

Solid Feed	minus 4 + 8 mesh UF_4 pellets containing 0.4% carbon.
Temperature of Solid Feed	625°C.
Gaseous Feed (cocurrent)	100% excess O_2
Temperature of Oxygen	approximately 400°C.
Solids Residence Time	1-1/2 hours

4.2.2 Falling-Particle Reactor Tests

The falling-particle reactor is designed to take advantage of the high reaction rate between UF_4 powder and O_2 that was experienced in the bench-scale tests. The unit (see Figures VIII through XIII) consists of metering devices for UF_4 , O_2 , N_2 , and carbon, a UO_2F_2 -lined reaction zone 2" I.D. x 9 ft. long, tube furnaces for heating the reactor walls, suitable means for withdrawing the solid product, a cold trap to remove the UF_6 , and scrubbers for the off-gas.

The contemplated operating procedure for initial tests in the unit is as follows: The Inconel reactor walls and UO_2F_2 lining will be preheated by the wall heaters to about 700°C. Then O_2 and carbon will be fed to the top of the reactor to

~~CONFIDENTIAL~~

raise the reaction zone temperature to 800 to 900°C. The wall heaters will be adjusted to keep the Inconel shell below 700°C. When the proper temperatures have been reached, UF_4 powder will be metered into the O_2 stream, which will convey and disperse the powder into the reaction zone. The UF_4 , O_2 , N_2 , CO_2 and products will fall or flow downward through the reaction zone to the gas-solids separator at the bottom. The solid product will be collected, weighed, sampled, and analyzed. The UF_6 will be cold trapped and weighed or sent to the two scrubbers, along with the other off-gases.

It is planned to operate the falling-bed unit initially at a rate of approximately 10 lbs. of UF_4 per hour and with about 100% excess O_2 . The calculated residence time for the UF_4 powder is 3 to 10 seconds, depending upon its particle size.

The system is adaptable for testing countercurrent flow of the gases and solids, if this appears desirable. Cocurrent flows have been selected for the initial tests, however, to avoid the possibility of reaction between the UF_6 product and the incoming UF_4 and carbon.

~~CONFIDENTIAL~~

5.0 Long-Range Program

The Company has started a long-range program to develop one or more of several highly economical potential processes for producing UF_6 from impure ore concentrates (See Part III, Volume 2, of the Proposal). Initial results in producing UF_4 from ore concentrates are encouraging (See Section 3.0). It is planned to continue studies with the impure materials under the best conditions that are found for producing UF_4 and UF_6 from refined oxides. The UF_6 so produced will be purified by distillation, if required. In order to expedite the UF_6 -distillation studies, approximately 85 lbs. of impure UF_6 , especially prepared from ore concentrates, is being obtained through the USAEC. A pilot-scale facility for distilling this material is now being designed.

6.0 Conclusions

The feed materials research and development program to date has provided additional data to support the Company's Alternate Proposals No. 1 and 2 and to show that it may be possible to simplify the original designs to reduce the cost of UF₆, as follows:

- a. The two dry gas scrubbers and their auxiliaries (10 major equipment units) can be eliminated from the design in each of the Alternate Proposals. The reduction-hydrofluorination reactors and remaining equipment for recovering and recycling HF and NH₃ have now been shown to be adequate for essentially complete HF utilization.
- b. The high reduction-hydrofluorination rates that have been found show that the 4-hour residence time now provided for in the designs for Alternates No. 1 and 2 is much greater than necessary, therefore, the reduction-hydrofluorination reactors undoubtedly could be made smaller and simpler.
- c. Calculations indicate that the use of a pre-mixed charge containing recovered ammonium fluoride solution could eliminate the need for cooling the reduction-hydrofluorination reactors by injecting HF gas into the reactors at intermediate points. The reactors could, therefore, be further simplified in design and operation.
- d. Ammonium diuranate should be given further consideration as an intermediate compound, since high conversion was obtained with this material in the new UF₄ process and since this material could be cheaper than UO₃ to produce, under certain circumstances (See Appendix A, Part III, Volume 2, of the Proposal).

~~CONFIDENTIAL~~

- e. The high reaction rates obtained in the production of UF_6 by reaction between UF_4 and O_2 further substantiate the Alternate No. 2 Proposal and show that the design is conservative. The kinetic studies indicate that a falling-particle reactor probably can be developed, which may have advantages over the other types of reactors that have been considered.

~~CONFIDENTIAL~~

CONFIDENTIAL

TABLE I

**Conversion of Uranium Compounds to UF₄
in Batch Tests by Calcination of Pellets of
Pre-Mixed, Dried Mixtures**

Run No.	Uranium Source		Composition of Feed Mixture				Reaction Conditions ⁽¹⁾				Product Analysis, %				
	Compound	Wt. gms.	Starch, gms.	Na ₂ F ₂ HF, gms.	Na ₂ F ₂ , gms.	HF, gms.	F/U atom ratio	Time, (Min.)	Max. Temp. °C.	Sample ⁽²⁾ Designation	U	HFU	U ⁴	UF ₄	UF ₃
15-1	U ₃	100	-	45	39	-	6.3	10	800	C	11.2	0.01	79.64		
15-2	U ₃	100	-	45	39	-	6.3	10	800	C	10.8	0.01	80.02		
72-1	U ₃	100	0.5	-	-	8.1	1.2	10	800	C	6.8	none			
72-2	U ₃	100	0.5	-	-	8.1	1.2	240	150	C	7.2	0.02			
73-1	U ₃	100	0.0	0	0	14.1	2.0	10	800	C	12.0				
73-2	U ₃	100	0.0	0	0	14.1	2.0	240	150	C	13.2				
15-3	U ₃	100	9.0	45	-	-	4.0	120	600	C	16.1	0.07	79.83		
15-4	U ₃	100	9.0	45	-	-	4.0	120	500	C	16.8	0.07	71.36		
15-5	U ₃	100	9.0	45	-	-	4.0	45	800	F	17.3	0.01	78.20	0.8	
15-6	U ₃	100	9.0	45	-	-	4.0	45	800	F	16.4	0.01	78.19	0.3	
15-7	U ₃	100	9.0	45	-	-	4.0	45	800	F	17.3	0.01	78.30	0.5	26.2
15-8	U ₃	100	9.0	45	-	-	4.0	45	800	F	17.5	0.01	77.97	0.5	
15-9	U ₃	100	9.0	45	-	-	4.0	45	800	F	16.8	0.01	78.17	1.0	
15-10	U ₃	100	9.0	45	-	-	4.0	10	800	C	15.8	0.01	78.19	1.7	29.96
15-11	U ₃	100	9.0	45	-	-	6.0	120	600	C	17.9	0.13	73.02		
15-12	U ₃	100	9.0	45	-	-	6.0	220	600	C	20.3	0.76			
15-13	U ₃	100	9.0	45	-	-	6.0	60	600	C	19.8	none			
15-14	U ₃	100	8.0	45	-	-	6.8	10	800	C	18.1	0.10			
15-15	U ₃	100	8.0	45	-	-	6.8	10	800	C	16.9	0.08			
15-16	U ₃	100	8.0	45	-	-	6.8	4	900	C	16.7	0.02			
15-17	U ₃	100	8.0	45	-	-	6.8	4	900	C	17.3	0.10			
15-18	U ₃	100	8.0	45	-	-	6.8	4	900	C	16.5	2.05			
15-19	U ₃	100	8.0	45	-	-	6.8	2	900	C	19.5	1.15			
15-20	U ₃	100	8.0	45	-	-	6.8	2	1000	C	15.7	0.23			
15-21	U ₃	100	8.0	45	-	-	6.8	2	1000	C	16.5	0.24			
15-22	U ₃	100	8.0	45	-	-	7.0	10	800	C	18.0	0.01			
15-23	U ₃	100	8.0	45	-	-	7.0	10	800	C	18.4	0.04			
15-24	U ₃	100	8.0	45	-	-	7.0	10	800	C	19.6	0.06			
15-25	U ₃	100	8.0	45	-	-	7.0	10	800	C	18.2	0.01			
15-26	U ₃	100	8.0	45	-	-	8.1	10	800	C	17.7	0.04			
15-27	U ₃	100	8.0	45	-	-	8.1	10	800	C	18.5	0.02			
15-28	U ₃	100	5.3	50	-	-	8.0	10	800	C	19.1	0.01			
15-29	U ₃	100	5.3	50	-	-	8.0	10	800	C	19.0	trace			
73-3	(NH ₄) ₂ U ₂ O ₇	100	8.0	13	-	7.5	2.6	10	800	C	15.3	0.05			
17-1	(NH ₄) ₂ U ₂ O ₇	100	8.3	37	-	-	4.0	10	800	C	21.0	0.01	75.83	1.4	
17-2	(NH ₄) ₂ U ₂ O ₇	100	8.3	37	-	-	4.0	10	800	C	21.0	0.01	75.07	1.0	11.03
15-30	(NH ₄) ₂ U ₂ O ₇	100	8.3	37	-	-	4.0	10	800	C	22.2	0.19			
15-31	(NH ₄) ₂ U ₂ O ₇	100	8.3	37	-	-	4.0	10	800	C	22.1	0.13			
27-1	D.O.C. (3)	100	-	50	-	-	5.75	10	800	C	16.8	0.01			
27-2	D.O.C.	100	-	50	-	-	5.75	10	800	C	16.9	0.01			
25-1	D.O.C.	100	10	50	-	-	5.75	10	800	C	21.7	0.05			
25-2	D.O.C.	100	10	50	-	-	5.75	10	800	C	21.9	0.05			
29-1	D.O.C.	100	6	50	-	-	5.75	10	800	C	23.0	0.02			
29-2	D.O.C.	100	6	50	-	-	5.75	10	800	C	22.2	0.01			
35-1	D.O.C.	100	6	70	-	-	8.1	10	800	C	25.4	0.11			
35-2	D.O.C.	100	6	70	-	-	8.1	10	800	C	25.6	0.01			
35-3	D.O.C.	100	10	50	30	-	8.4	10	800	C	25.0	0.10			
35-4	D.O.C.	100	10	50	30	-	8.4	10	800	C	24.8	0.10			
37-1	D.O.C.	100	6	80	-	-	9.2	10	800	C	26.3	0.01			
37-2	D.O.C.	100	6	80	-	-	9.2	10	800	C	26.1	0.01			
37-3	D.O.C. (4)	100	8	-	100	-	8.9	10	800	C	21.8	0.13			
37-4	D.O.C. (4)	100	8	-	100	-	8.9	10	800	C	21.9	0.26			
45-1	C.O.C.	100	8	80	-	-	9.1	10	800	C	21.0	0.17			
45-2	C.O.C.	100	8	80	-	-	9.1	10	800	C	20.7	0.22			
50-1	C.O.C.	100	8	80	40	-	9.2	10	800	C	23.3	0.19			
50-2	C.O.C.	100	8	80	40	-	9.2	10	800	C	23.4	0.29			

Notes: 1. The temperature of the mixture was gradually raised to the indicated temperature during time shown.
 2. Sample designations: C (composite), F (gas outlet end of reaction tube), and R (stoppered end of tube).
 3. D.O.C.: Durango Ore Concentrate.
 4. C.O.C.: Composite containing equal portions of the following ore concentrates: Durango, Anaconda (acid), Anaconda (carbonate), Monticello (acid), Rifle and Vitro.

~~CONFIDENTIAL~~

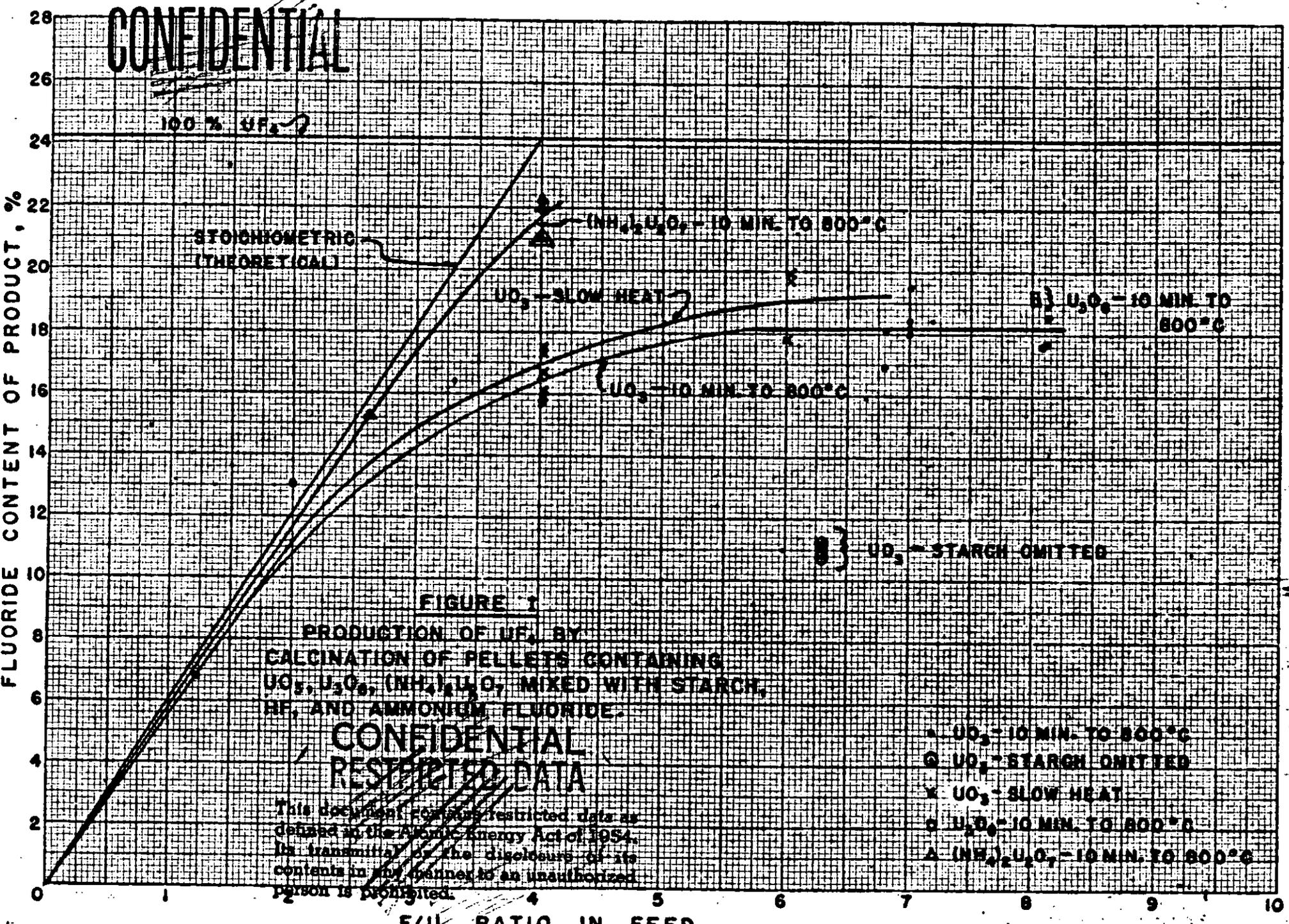
TABLE II

Analysis of Durango Ore Concentrate
Used in One-Step UF₄ Production

	<u>Spectrographic</u>	<u>Chemical</u>
Silver	2 - 10 ppm	-
Al ₂ O ₃		0.8%
As	5 - 20 ppm	
Boron	0.10 - 0.5 ppm	
Bi	not detected	
Ca		0.32%
Cd	not detected	
Co	1 - 5 ppm	
Cr	less than 50 ppm	
Cu	0.1 - 0.5%	
Fe ₂ O ₃		0.23%
Mg	0.05 - 0.2%	
Mn	.1 - .5%	
Mo	not detected	
Na		5.9%
Ni	less than 50 ppm	
P	200 - 1000 ppm	
Pb	100 - 500 ppm	
SiO ₂		1.4%
Sn	2 - 10 ppm	
V		0.15%
Zn	0.1 - 0.5%	
SO ₄		1.4%
Cl		.08%
U ₃ O ₈		85.58%
Loss @ 110°C.		1.2%

~~CONFIDENTIAL~~

CONFIDENTIAL



~~CONFIDENTIAL~~

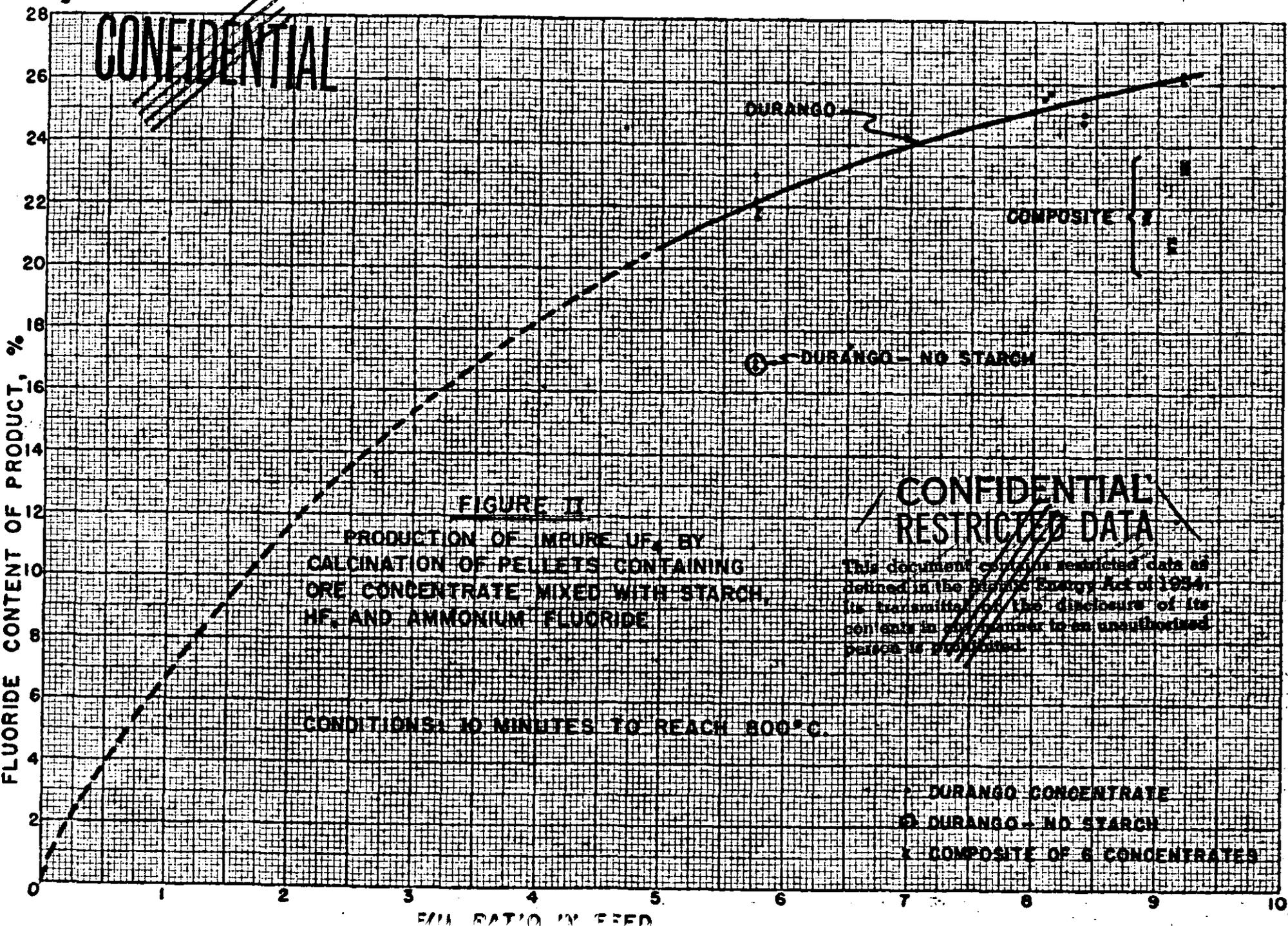


FIGURE II

PRODUCTION OF IMPURE UF₄ BY
CALCINATION OF PELLETS CONTAINING
ORE CONCENTRATE MIXED WITH STARCH,
HF, AND AMMONIUM FLUORIDE

CONDITIONS: 10 MINUTES TO REACH 800°C.

~~CONFIDENTIAL
RESTRICTED DATA~~

This document contains restricted data as defined in the Atomic Energy Act of 1954. Its transmission or the disclosure of its contents in any manner to an unauthorized person is prohibited.

- DURANGO CONCENTRATE
- ⊙ DURANGO - NO STARCH
- × COMPOSITE OF 6 CONCENTRATES



KOPERS COMPANY, INC.

RESEARCH DEPARTMENT
VERONA, PA.

THIS DRAWING AND ALL INFORMATION THEREON IS THE PROPERTY OF KOPERS COMPANY, INC. RESEARCH DEPARTMENT AND IS CONFIDENTIAL AND MUST NOT BE MADE PUBLIC OR COPIED UNLESS AUTHORIZED BY IT AND IS SUBJECT TO RETURN UPON DEMAND.

SKETCH SHEET

NAME

DATE

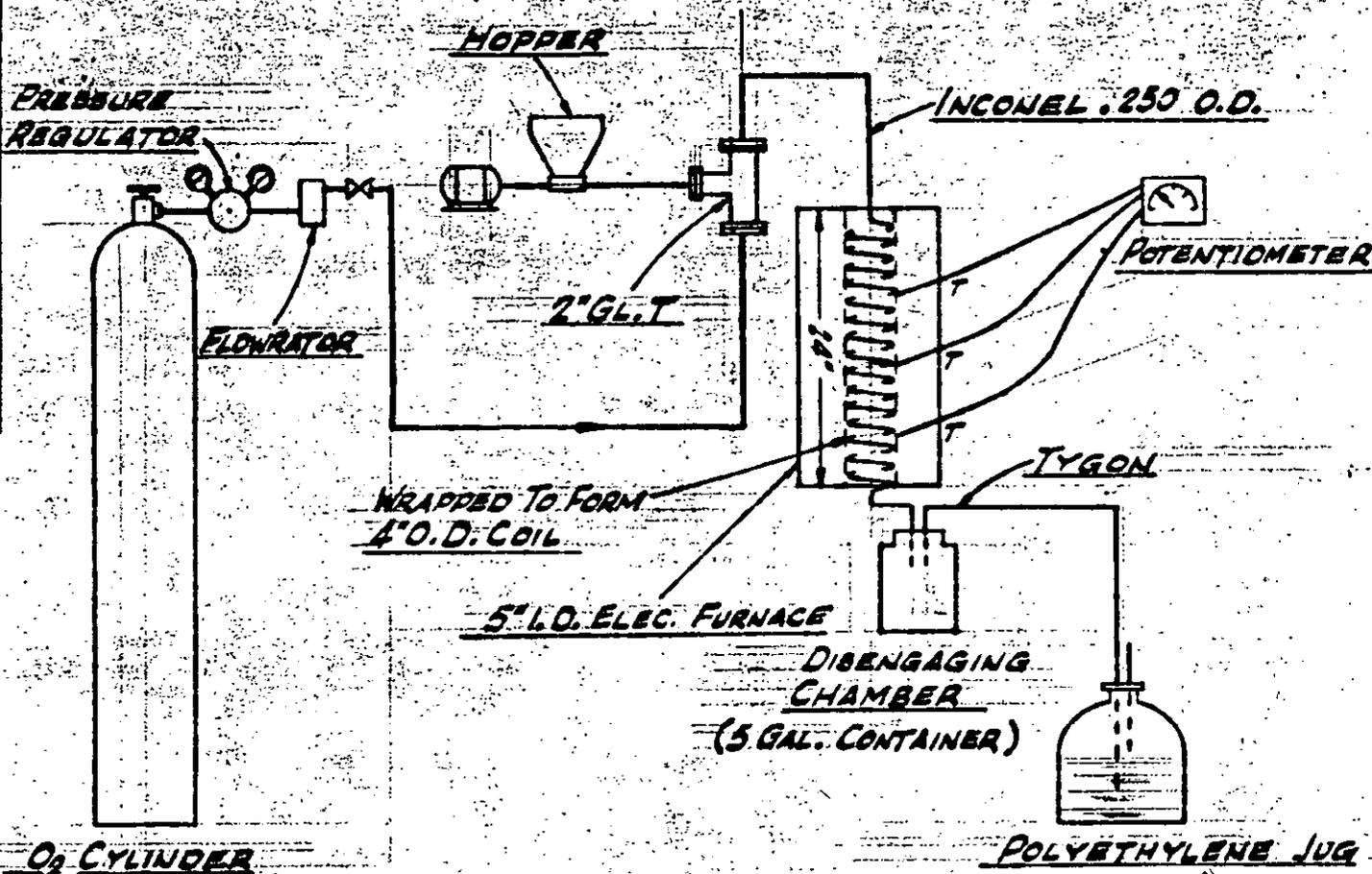
DRAWN BY: *W. KURVACH*

10-3-56

CHECKED

J. LAGAKINS 10-3-56

~~CONFIDENTIAL~~



~~CONFIDENTIAL
RESTRICTED DATA~~

This document contains restricted data as defined in the Atomic Energy Act of 1954. Its transmittal or the disclosure of its contents in any manner to an unauthorized person is prohibited.

REV.	DESCRIPTION	CHKD BY	DATE

KINETIC STUDY FLOW SHEET

FIGURE V

F-22119

PROJECT NO.	
-------------	--

~~CONFIDENTIAL~~



Figure VI

Pneumatic conveyor reactor system for Kinetic Study of the
reaction $2\text{UF}_4 + \text{O}_2 \rightarrow \text{UF}_6 + \text{UO}_2\text{F}_2$

~~CONFIDENTIAL~~



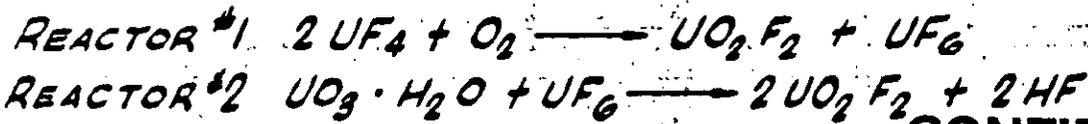
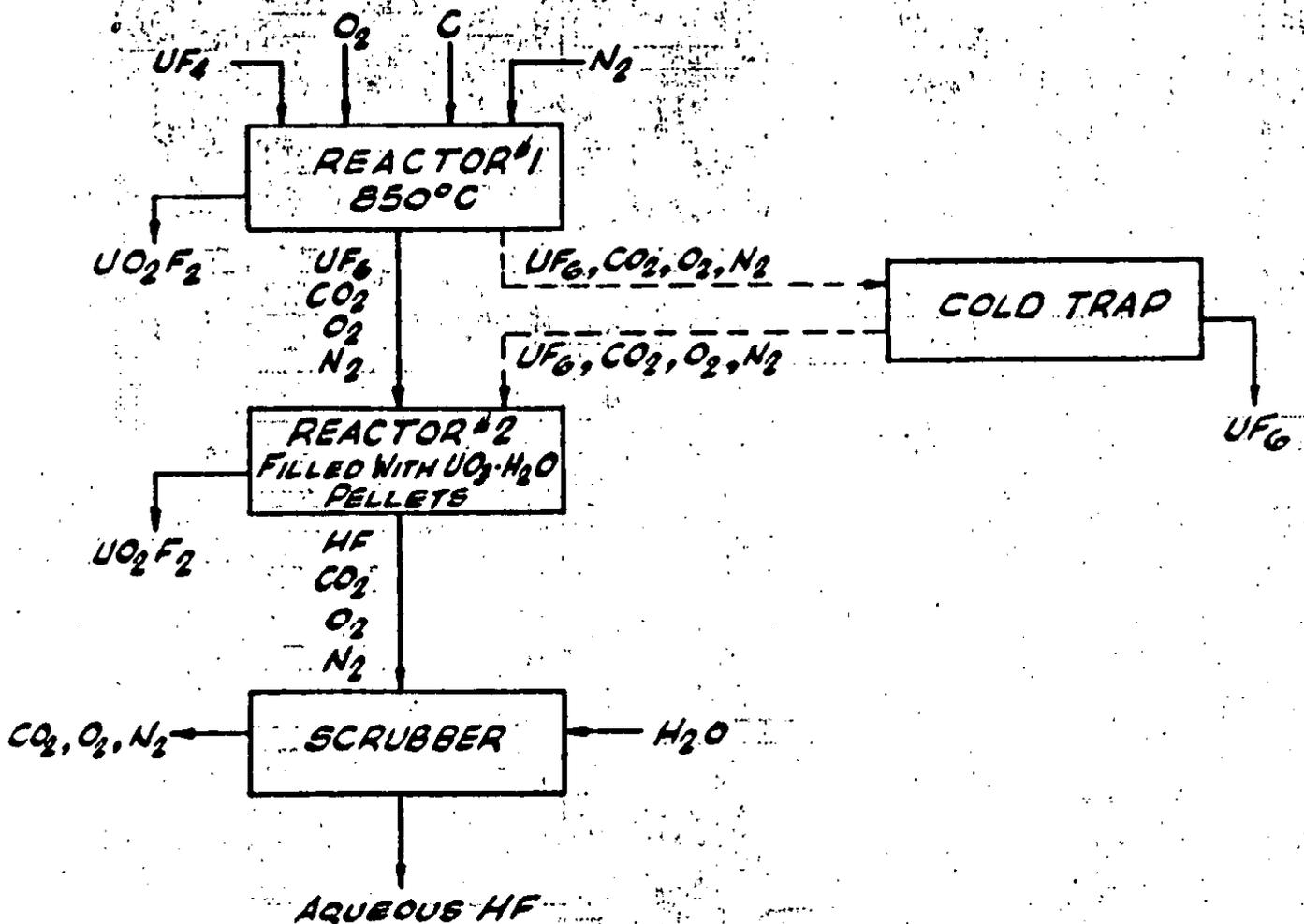
KOPPERS COMPANY, INC.
RESEARCH DEPARTMENT
VERONA, PA.

THIS DRAWING AND ALL INFORMATION THEREON IS THE PROPERTY OF KOPPERS COMPANY, INC. RESEARCH DEPARTMENT AND IS CONFIDENTIAL AND MUST NOT BE MADE PUBLIC OR COPIED UNLESS AUTHORIZED BY IT AND IS SUBJECT TO RETURN UPON DEMAND.

SKETCH SHEET

NAME _____ DATE _____
DRAWN *W. KURVACH* 10-26-56
CHECKED *R. White* 10-26-58
WSK 10-26-56

CONFIDENTIAL



CONFIDENTIAL
RESTRICTED DATA

This document contains restricted data as defined in the Atomic Energy Act of 1954. Its ~~transmission or the~~ disclosure of its contents in any manner to an unauthorized person is prohibited.

REV.	DESCRIPTION	CHKD. BY	DATE

FIGURE IX

D-672
PROJECT NO.

TITLE PROCESS FLOW DIAGRAM OF NUCLEAR PILOT PLANT F-22132

~~CONFIDENTIAL~~

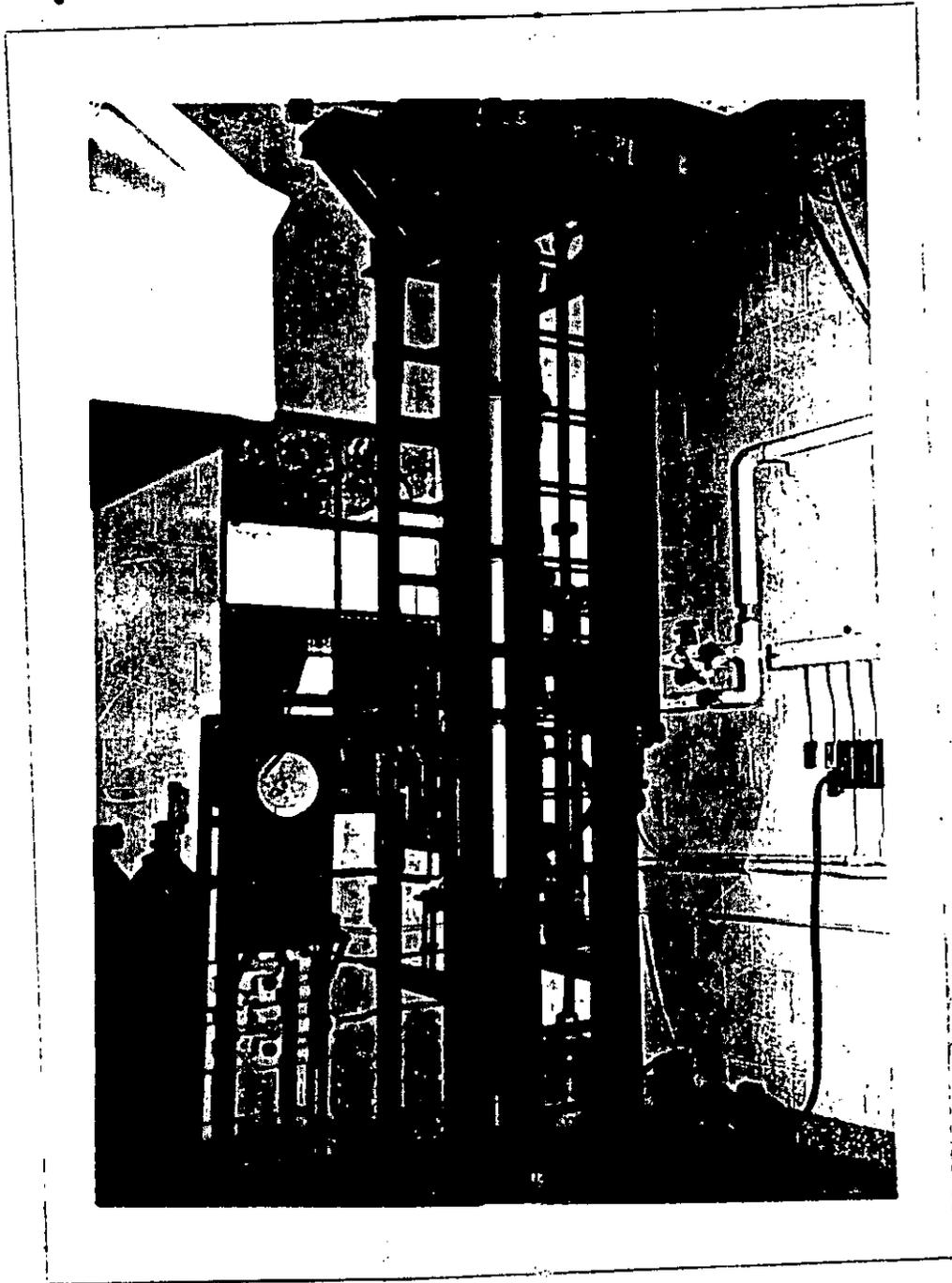
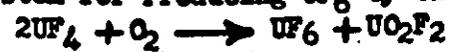


Figure X

Pilot Plant System for Producing UF_6 by the following reaction:



View showing assembled system.

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

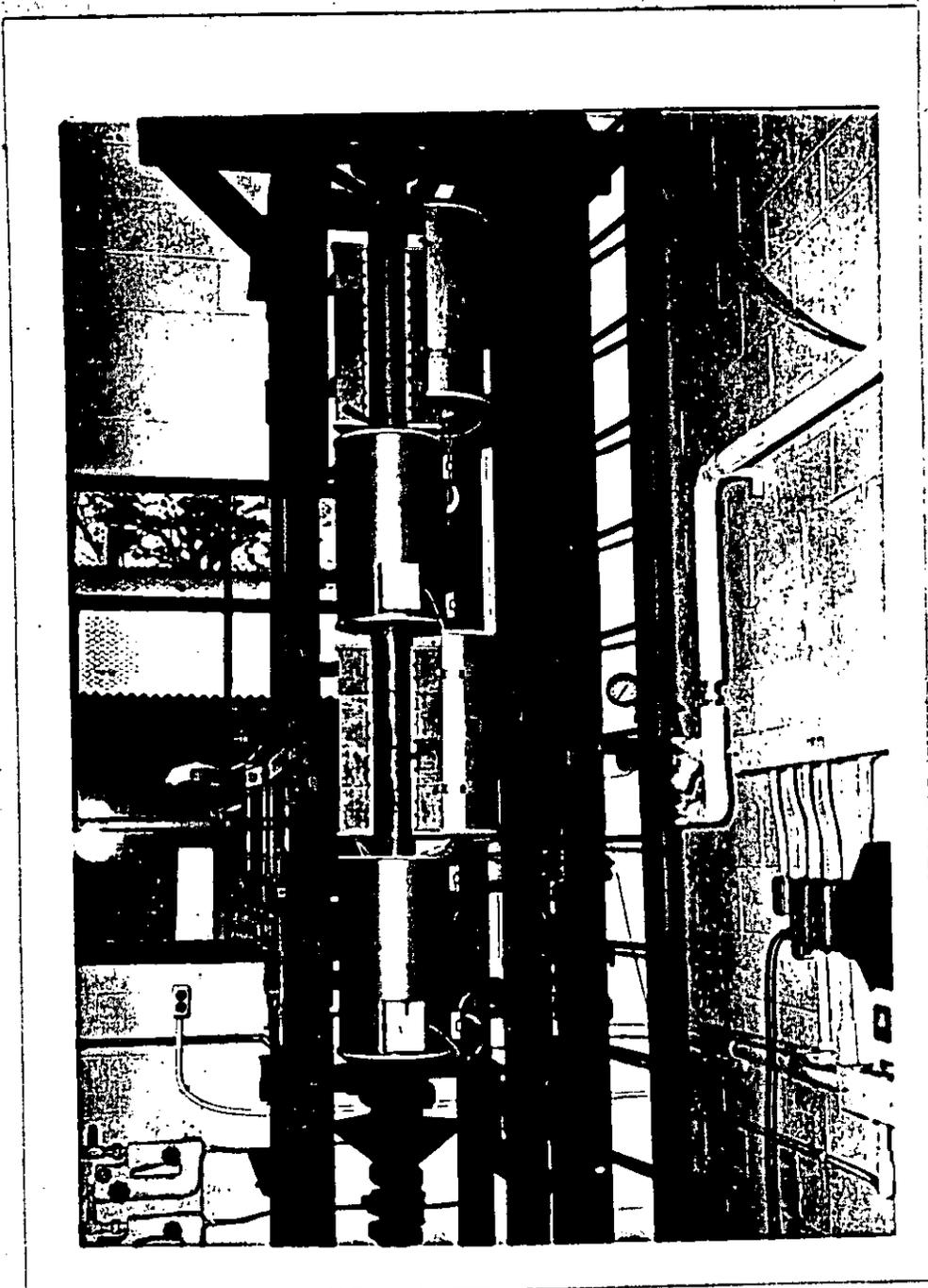


Figure XI

Pilot Plant System for Producing UF_6 by the following reactions:
 $2UF_4 + O_2 \rightarrow UF_6 + UO_2F_2$

View showing reactor inserted in tube furnaces.

~~CONFIDENTIAL~~

CONFIDENTIAL

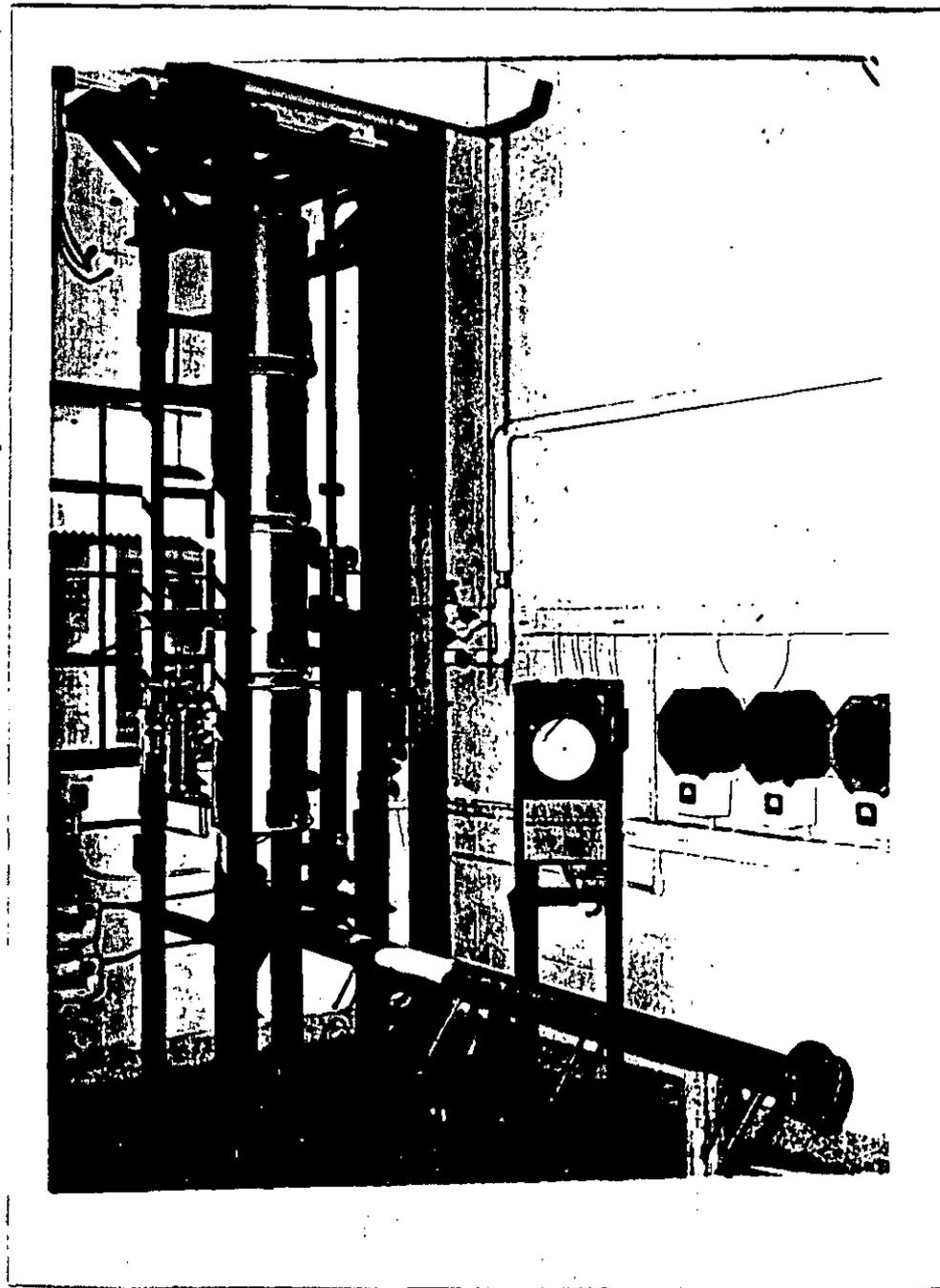
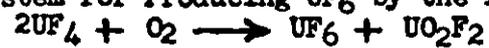


Figure XII

Pilot Plant System for Producing UF_6 by the following reaction:



View showing reactor removed from furnaces.

CONFIDENTIAL

~~CONFIDENTIAL~~

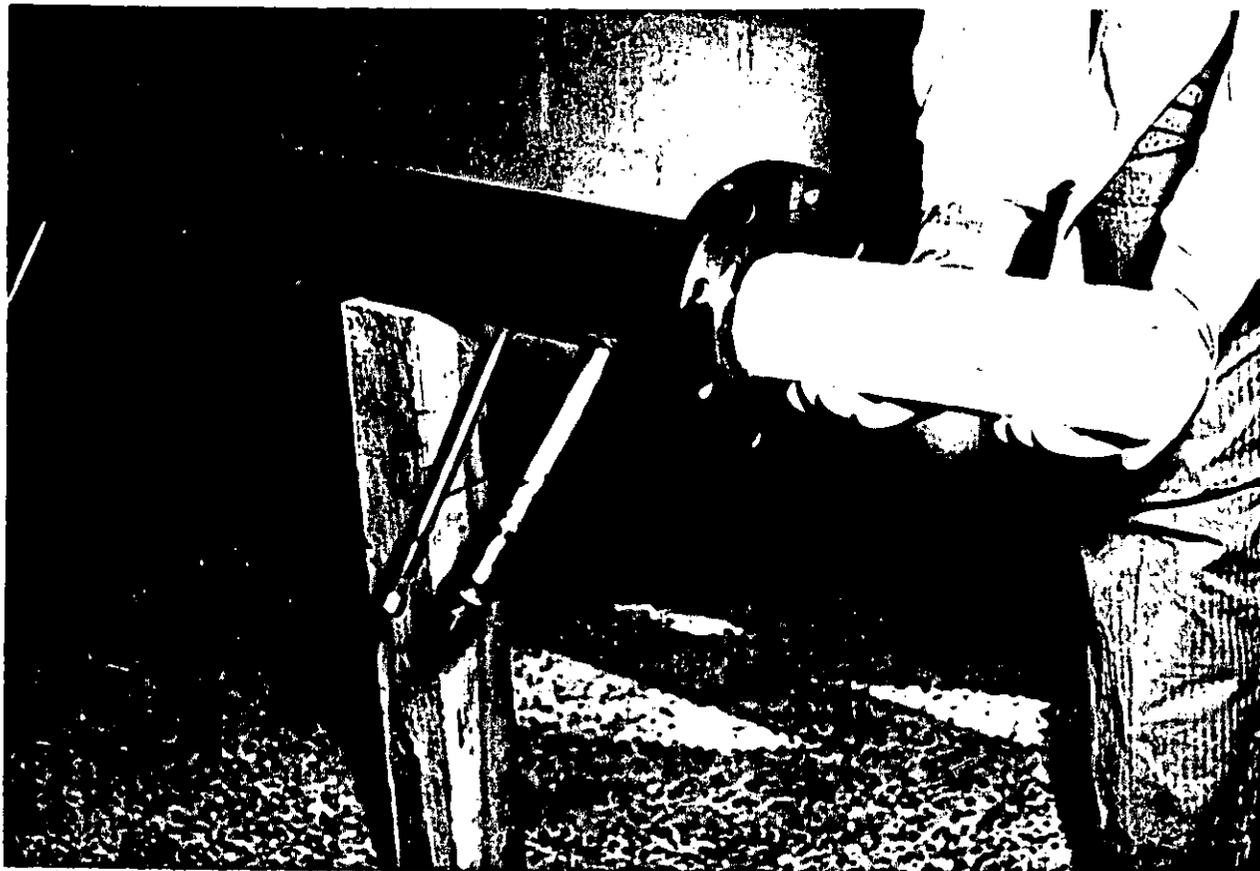


Figure XIII

Refractory liner being inserted into UF_4 oxidation reactor.

~~CONFIDENTIAL~~