RFP-2600
June 1, 1977

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FLUID BED DIRECT DENITRATION PROCESS FOR PLUTONIUM NITRATE TO OXIDE CONVERSION

Kenneth R. Souply

David H. Neal

Chemistry Research and Development
PROCESS CHEMISTRY AND ENGINEERING GROUP

Work performed under 189 No. F-AL-10-001
for the
Savannah River Operations Office
U.S. Energy Research and Development Administration

Rockwell International

Atomics International Division
Rocky Flats Plant
P.O. Box 464
Golden, Colorado 80401

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CONTRACT EY-76-C-04-3533

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Available from the
National Technical Information Service
U. S. Department of Commerce
Springfield, Virginia 22161
Price: Printed Copy $4.50 Microfiche $3.00
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Printed
June 1, 1977

RFP-2600
UC-78 LIGHT WATER
REACTOR TECHNOLOGY
TID-4500-R65

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SUBJECT DESCRIPTORS

Plutonium Processing
Plutonium Nitrates
Plutonium Oxides

ROCKWELL INTERNATIONAL
ATOMICS INTERNATIONAL DIVISION
ROCKY FLATS PLANT
P.O. BOX 464
GOLDEN, COLORADO 80401

Prepared under Contract EY-76-C-04-3533
for the
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U. S. Energy Research and Development Administration

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CONTENTS

ACKNOWLEDGMENTS

Appreciation is expressed, for the preparation of this report, to the following members of the PNO Project Team: Rosamond M. Greinetz, George D. Lehemkuhl, and Walter E. Sperry.

FLUID BED DIRECT DENITRATION PROCESS FOR PLUTONIUM NITRATE TO OXIDE CONVERSION

Kenneth R. Souply and David H. Neal

Abstract. The fluid bed direct-denitration process appears feasible for reprocessing Light Water Reactor fuel. Considerable experience with the fluid bed process exists in the denitration of uranyl nitrate and it shows promise for use in the denitration of plutonium nitrate. The process will require some development work before it can be used in a production-size facility. This report describes a fluid bed direct-denitration process for converting plutonium nitrate to plutonium oxide, and the information should be used when making comparisons of alternative processes or as a basis for further detailed studies.

INTRODUCTION

This report contains information which may be used as a basis when comparing fluid bed direct-denitration to other plutonium nitrate-to-oxide (PNO) conversion processes. The information should also be used when initiating development of a prototype or plant-scale facility.

Reprocessing of Light Water Reactor (LWR) fuel elements includes separation of plutonium (Pu) from the uranium (U) and from unwanted fission products. The PUREX solvent-extraction process separates Pu as plutonium nitrate [$Pu(NO_3)_X$] in an aqueous nitric acid (HNO_3) stream. Shipping regulations[1] require that the Pu be in a solid form. Since plutonium oxide (PuO_2) powder is used in the fabrication of mixed uranium-plutonium oxide reactor fuels, PuO_2 is a logical choice of form of the Pu product from a fuel reprocessing plant. Therefore, it is necessary to choose a process for converting the plutonium nitrate to plutonium oxide.

Each time an industrial or government organization considers building a plutonium nitrate-to-oxide conversion facility, various candidate processes are compared before making a final process selection. The final selection of a process depends on the criteria developed by that organization, and on the knowledge that organization has about the processes. Such a comparison is being made as part of the Rocky Flats PNO Conversion Project. A report will be issued presenting an evaluation of the processes, and discussing them as they relate to the evaluation criteria.

The following processes are being considered: Plutonium(IV) oxalate-precipitation and calcination, plutonium(III) oxalate-precipitation and calcination, plutonium peroxide-precipitation and calcination, fluid bed direct-denitration, screw-calciner mechanical direct-denitration, batch direct-denitration, and Sol Gel.

The intent of this report, and others in this series, is to provide information to be used in comparing the above processes. The report includes the relative advantages and disadvantages, the history, and a detailed description of the process, complete with a block flow diagram, Figure 1, and equipment flow sheet, Figure 3.

DISCUSSION

History

Development of a fluidized bed for application to the denitration of uranyl nitrate [$UO_2(NO_3)_2$] and aluminum nitrate [$Al(NO_3)_3$] solutions was undertaken in 1953 by the Argonne National Laboratory.[2] This work was done in an attempt to replace the batch technique then in use.

Two sizes of equipment were used in the development work. The first was a 3-inch diameter bench-scale unit used for exploratory runs to determine

the feasibility of the process and to establish the approximate operating conditions. The second was a 6-inch reactor made from Type 304 stainless steel and consisted of the following three sections: a gas dispersion chamber, a reaction chamber, and a disengaging section.. The overall height of the unit was 64 inches. The reaction chamber was heated by thirty 1000-watt tubular heaters set into grooves in the chamber wall.

Thirty runs, each lasting about 8 hours, were made. These runs produced about 5,000 pounds of uranium trioxide (UO_3). Particle growth was a problem but was controlled by careful manipulation of temperature and feed concentration.

The spray nozzle was a type in which atomization occurred externally. This type nozzle produced less caking. Mounting the nozzle horizontally, with the tip flush with the inner wall, helped to prevent caking around the nozzle. No corrosion, which could cause impurities in the product, was experienced.

In the early 1950's, the Australian Atomic Energy Commission established a pilot-scale plant for the denitration of $UO_2(NO_3)_2$.[3] The pilot unit was 9 inches in diameter, with a 3-foot operating bed depth. Power input to the bed was approximately 20 kilowatts (kW).

Considerable trouble was experienced by partially decomposed nitrate collecting on the nozzle. Experience showed that the nozzle should be 2 to 3 inches from the vessel wall and at least a foot beneath the surface of the solids. Eventually, 1000 operating hours were achieved without cleaning the nozzle.

On the basis of Argonne National Laboratory's work, Mallinckrodt Chemical Works placed a similar fluid-bed denitrator in operation in September 1957.[4] Development of the process was initiated with the installation of a pilot-plant denitrator at the Destrehan Street Plant in Weldon Spring, Missouri. After 21 experimental runs, a new and somewhat modified pilot denitrator was installed at the newly-constructed Weldon Spring Plant.

The major physical difference between the two reactors was the greater height-to-diameter ratio of the Weldon Spring unit. Major operating differences at Weldon Spring were the use of fluidizing velocities considerably in excess of those employed at Destrehan Street, and of higher concentrations of $UO_2(NO_3)_2$. A total of 142 experimental runs were made at the Weldon Spring Plant.

The early development work at Mallinckrodt led to two obvious conclusions:

1. Sustained operation of continuous fluid-bed denitrator at rates equal to or greater than 350 pounds per hour per square foot of reactor cross section is practical with uranyl nitrate concentrations of up to 11.8 pounds of U per gallon.

2. Although a strict statistical experiment to completely determine the effects and interactions of all known variables was never carried out, it is obvious that the physical characteristics of the product can be varied within limits by minor variations in the operating conditions. Experimental results indicated that an increase in the bed temperature, feed concentration, sulfate content, or production rate would generally tend to increase the mean particle size. Also, changes in the fluidizing velocity generally lead to changes in the particle size distribution.

A plant-scale fluid-bed denitration system was installed at the Weldon Spring refinery in May 1964.[5] Subsequent development was aimed at trying to obtain a more reactive oxide for subsequent hydrofluorination. Although this could not be done in the reactor, it was found that soaking the UO_3 in uranyl nitrate hexahydrate [$UO_2(NO_3)_2 \cdot 6H_2O$] would provide the necessary reactivity.

Three major problems were noted in the operation of the plant-scale reactor:

1. Severe salt leakage developed at the middle and bottom denitrator flange sets. Thermal shock on startup apparently distorted the flanges, and the problem was never completely resolved.

2. Plugging of the nozzles from improper flushing of the nozzles and recycle lines or over-concentration of the uranyl nitrate hexahydrate could be decreased by reducing the number of startups and shutdowns. Cake formation on the nozzle tips appeared to occur gradually from an accumulation of UO_3 from spray back-flow. Reduction of nozzle protrusion into the denitrator to a minimum may have reduced the amount of cake formation and make nozzle maintenance easier, but complete elimination of the caking was doubtful.
3. A problem of filter tubes backing out of their threads and falling into the bed was overcome by welding a connecting rod to each filter tube.

The overall on-stream-factor for the plant-scale fluid bed reactor was about 70 percent. Approximately 9 percent downtime was associated with startup and shutdown, 15 percent with periodic acid cleaning, and 6 percent with general maintenance. Maintenance downtime would have been greater if maintenance work could not have been done during the other downtime periods.

For reasons not completely disclosed, the Mallinckrodt plant was closed on April 28, 1966.

The Idaho Chemical Processing Plant (ICPP) installed a fluid bed reactor in 1970 to convert $UO_2(NO_3)_2$ solution to UO_3.[6] The conversion of the plant inventory of $UO_2(NO_3)_2$ solution was successfully completed in January 1971. This plant-scale compaign was accomplished after a lengthy cold startup of the process, during which time many mechanical problems were identified and resolved.

Approximately 800 kilograms (kg) of highly enriched uranium in a solution averaging 365 grams of U per litre of solution were processed in fourteen days of plant operation.

One major difference between ICPP's process and those used at Argonne and Mallinckrodt was that the feed concentration at ICPP was 350 grams of U per litre of solution in a 0.1*M* HNO_3 solution, whereas, the other processes used molten $UO_2(NO_3)_2$ at a concentration of about 650 grams of U per litre of solution.[7]

Initial testing of the ICPP plant unit revealed the following problems:

1. Poor feed control
2. Excessive generation of fines
3. Bed caking
4. Heater problems
5. Nozzle plugging
6. Plugging of pressure probes
7. Restrictions in the product overflow line
8. Restrictions in the bed removal line

The following conclusions were reached from the production experience at ICPP:

1. Chunks of UO_3 will probably be formed during every run. Some mechanical means are needed to keep the overflow line open.
2. Plugging of the feed nozzles and pressure probes can be a serious problem in a UO_3 bed having a filter blowback system. Elimination of all air traps in the feed line will minimize nozzle plugging. Use of check valves on pressure probes that extend downward into the bed for some distance will minimize plugging.
3. General conclusions drawn about particle growth:
   a. High temperature promotes growth. Low temperature may allow an equilibrium to be established.
   b. Thermal shocking can be effectively used to reduce particle size.
   c. High sulfate promotes growth. Low sulfate may allow an equilibrium to be established.
   d. Jet grinding can be used to reduce particle size.
4. Proper assembly of the nozzle is very important. The nozzles should be visually tested before installation.

Most of the operation of the fluid bed at ICPP was done in the temperature range of 300 to 400 °C. When the equipment required cleaning, as in the case of severe plugging, it was flushed with 3*M* HNO_3 followed by a water rinse, repeated several times.

Work cited in a paper by P. G. Alfredson in 1972, shows that the Australian Atomic Energy Commission was using a single fluidized bed to both denitrate and reduce ammonium diuranate (ADU) to obtain UO_2.[8] This work first involved using the fluid bed as a batch operation in which a single charge of material was both calcined and reduced in the fluid bed reactor. Then a batch-continuous operation was tried in which ADU was fed continuously to the top, the bed allowed to build up to a maximum level, and the feed subsequently turned off to allow the contents to calcine and reduce.

Finally, a continuous operation was tried in which the feed was left on with the calcining and reduction occurring simultaneously. Apparently, the processes worked well, as approximately 1500 kg of yellow cake was processed to UO_2 powder. It was reported that all of the UO_2 powder produced in the fluid bed was more readily pelletized and has shown a lower incidence of cracking and pellet defects than powder produced by batch-tray calcination-reduction.

The first fluid-bed denitration of solution containing plutonium was done at Argonne National Laboratory, Chicago, Illinois. The early experimental work was with a uranyl nitrate-plutonium nitrate solution.[9]

The first denitration runs with U/Pu feed were aimed at continuing the displacement of the original UO_3 bed with $UO_3 - PuO_2$ to achieve steady state with respect to product composition. The product at that time contained about 2 percent plutonium. This was in the range of interest for plutonium recycle fuel. The pilot plant possessed a feed makeup system of limited capacity and the runs were limited to approximately 10 to 15 hours each. Several runs were necessary to provide the number of bed displacements needed to achieve a steady-state composition.

The particle size could be controlled by the use of a jet grinder, although in the later runs, the jet grinder was not needed.

All of the U/Pu studies were conducted in a 4-inch diameter pilot plant reactor.[10] The process appeared to be applicable over the entire concentration range of U/Pu materials, as well as for Pu alone.

Only two runs were made using plutonium nitrate as the feed solution. These runs were relatively short (46 min, 3.25 hr) and produced PuO_2 at a rate of 750 grams per hour. No difficulty was experienced and Pu seemed more easily processed than U.

Process Description

The fluid bed direct-denitration process converts $Pu(NO_3)_x$ solutions to a PuO_2 solid suitable for blending with uranium oxide (UO_2), and fabrication into fuel pellets for LWR fuel.

The main process stream and the waste streams are shown in Figure 1, appearing at the end of the text. The main stream starts with the storage of the feed solution. It is then evaporated, with the bottoms stream from the evaporator being sent to storage tanks. The more concentrated solution is then fed to the calciner where it emerges as the PuO_2 solid. This is then screened and packaged as the finished product.

A detailed description of the process is given below. A description of the equipment and a material balance are shown in Figure 3.

Evaporation

The denitration-unit feed from the separations unit is assumed to be 250 grams of Pu per litre (ℓ) of solution with a HNO_3 concentration of $3M$. This feed is concentrated to 417 grams of Pu per ℓ of solution for feed to the denitration reactor. The evaporator overhead, at $0.5M$ HNO_3, is sent to distillate storage. The distillate is sampled for Pu and, if acceptable, is then sent to the Waste Treatment unit. If not acceptable, it is sent to the feed evaporator.

Denitration

The concentrated feed from evaporation is fed to three denitration reactors in parallel. The reactors contain beds of PuO_2 which are fluidized with air. The plutonium nitrate solution is atomized with air and sprayed into the bed where evaporation of

the water and HNO_3 takes place. The plutonium nitrate calcines on the PuO_2 particles to PuO_2. As the bed increases in size, it overflows to a product accumulator. The air, vapors, and off-gas pass through a set of sintered metal filters to a condenser. The overall calcination reaction is believed to be:

$$Pu(NO_3)_4 \xrightarrow{\Delta} PuO_2 + 3.4\ NO_2 + 0.6\ NO + 1.3\ O_2$$

Product Handling

The PuO_2 product from the product accumulator is ground, screened, and packaged for shipment or storage.

Off-Gas System

The reactor off-gas stream goes to a condenser where water and HNO_3 are condensed. The condensate then goes to storage. The condenser off-gas is sent to a venturi scrubber where it is scrubbed with water. Very fine PuO_2 which may have remained in the condenser off-gas and residual HNO_3 are removed from the off-gas stream. Some oxides of nitrogen (NO_x) and oxygen (O_2) will also be removed, but to be conservative, the flow sheet assumes there will be no removal of these components. The scrubber off-gas then goes to the plant filter plenum. The scrubber bottoms stream joins the condenser condensate in storage and the bottoms are then evaporated in a waste evaporator. The evaporator distillate is sampled and, if the Pu concentration is low enough, joins the feed evaporator distillate and is sent to waste treatment. The evaporator bottoms stream, assumed to contain some very small level of PuO_2, is sent to contaminated waste disposal.

Advantages and Disadvantages

The following advantages and disadvantages of the fluid bed process were compiled from literature research and from conversations with individuals having operating experience with the process. A separate report will be published at a later date which will compare various denitration processes as to the advantages and disadvantages as they exist in present technology.

Advantages

1. Excellent mass transfer between solid and gas.
2. Excellent heat transfer and ease of temperature control.
3. High mobility of solids, permitting simplicity of handling.
4. Simplicity of equipment design with an absence of moving parts.
5. A large capacity per unit volume of equipment.
6. Easily adapted to remote operation.
7. Minimum maintenance requirements.
8. The process should not be hazardous to operate because no dangerous materials are involved other than the plutonium being processed.
9. The process does not require any feed preparation other than an evaporation step.
10. No significant recycle streams are involved in the fluid bed process.
11. Compared with most other processes, fewer inventory problems exist. An excessive amount of plutonium will not be in the production stream at any one time.

Disadvantages

1. The fluid bed process produces large volumes of waste gases that have to be treated.
2. The process has limited experience with plutonium and has no remote operating experience. Therefore, it will require extensive development to determine the operating parameters.
3. The fluid bed process does not purify the product. A feed solution of sufficient purity will be needed to obtain an oxide that will meet specifications.

4. The process is relatively energy intensive. Possibly, a significant amount of power would be needed for proper operation.

Research and Development

As defined from the results of a literature search and from discussions with those who have experience with fluid bed denitrators, the following development work should be completed prior to the building of a production facility:

1. A glass prototype should be used to develop information concerning the behavior of a PuO_2 bed. The ability to see bed action under various conditions of fluidizing air velocity and jet grinder velocity should provide considerable insight in developing a metal operating denitrator.

2. More research should be done on the selection of the optimum bed temperature. Literature has indicated that particle size and other characteristics of the oxide will vary with the temperature, but too little research has been done to insure a workable production unit.

3. The proper nozzle design and location are apparently critical factors for the successful operation of the fluid bed. Nozzles tend to erode with time, and become loose in the shell due to contraction and expansion. Also, there is a problem of nozzle-caking which had been a major problem in the production of UO_3 in a fluid bed. The location of the nozzle with respect to the bed also seems to be important Especially important is the development of a nozzle which can easily be changed remotely.

4. Although some development work has been done on the jet grinder,[11] more should be done to determine the optimum operating conditions. The optimum length of the tube inside the denitrator must be determined, as well as the optimum air flow for particle size control. Also, a control system should be developed which automatically determines particle size distribution and reports it for either automatic adjustment of particle size reduction or manual adjustment from a remote control board. It could be determined from the development work that the jet grinder may not be needed.

5. Most of the uranyl nitrate fluid bed units have exhibited the problem of clogging of the overflow tube and other various parts in addition to the nozzle. The solutions to this problem have traditionally been to vibrate the various parts or to tap with a hammer. It may be that some vibratory feature will have to be designed into the unit.

6. Relatively long runs should be made to determine the problems that would be encountered in a production unit. Also, long runs would provide a better understanding of the design problems in remoting.

7. Some research should be done to determine what the effects of certain process parameters, such as residual nitrate, will have on product quality.

CONCLUSIONS

The fluid bed direct-denitration process appears feasible for reprocessing Light Water Reactor fuel. It offers numerous advantages, mainly that of simplicity, over other processes; however, several disadvantages, such as the production of large volumes of waste gases, a lack of purification capability, a relatively large energy requirement, and the fact that it has little experience with Pu, exist in the process. Further development work will be required before the process can be used in a production facility.

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ILLUSTRATIONS

Figures 1 through 3

DIRECT DENITRATION (FLUID BED)

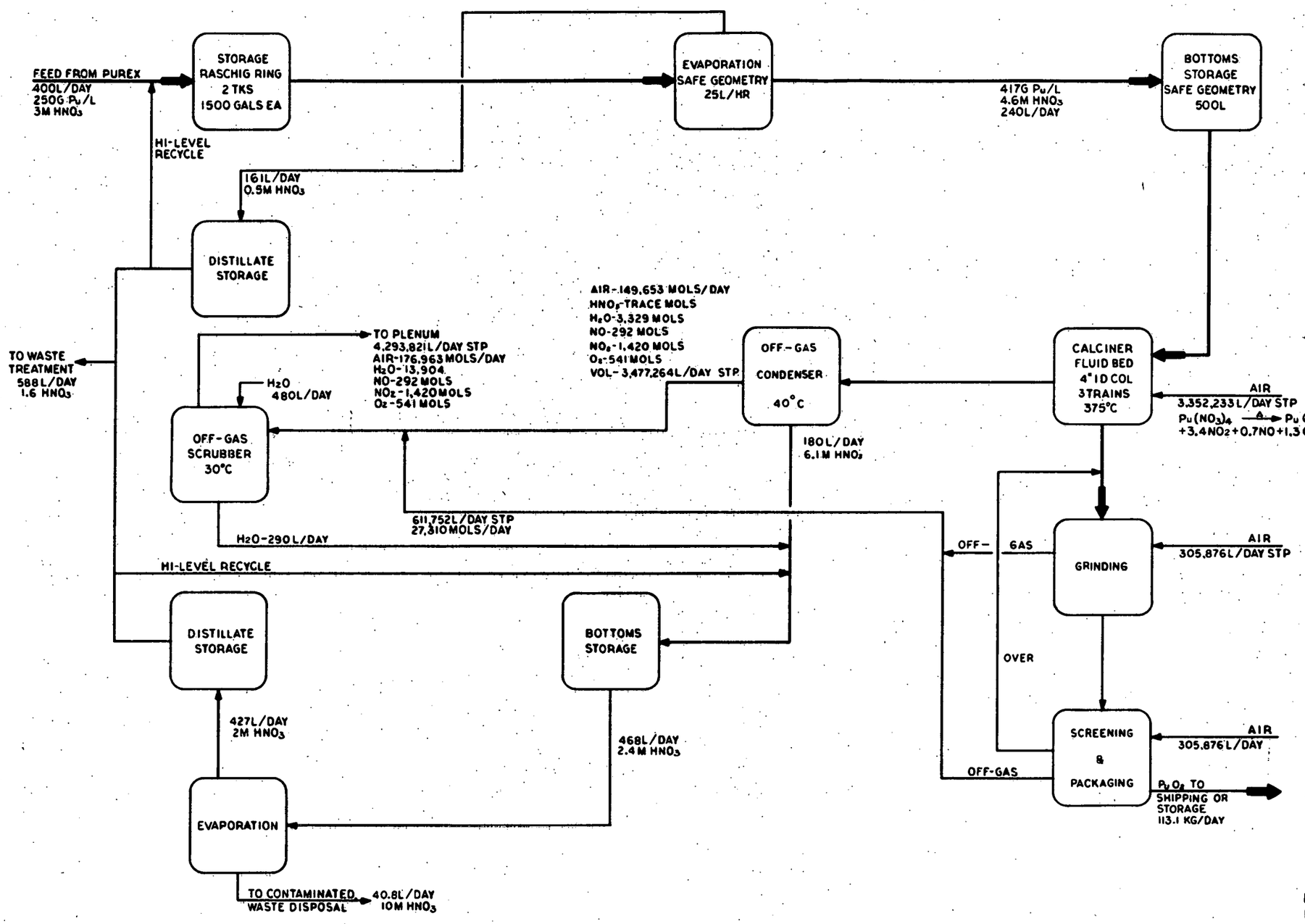
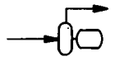
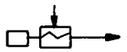
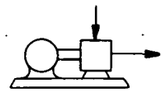
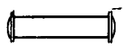
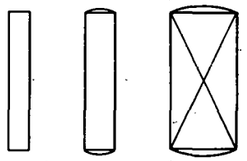
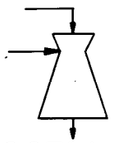


FIGURE 1. BLOCK FLOW DIAGRAM, FLUID BED DIRECT-DENITRATION PROCESS

LEGEND SHEET FOR "PNO" FLOW SHEETS

EQUIP. SYMBOL	LETTER SYMBOL	DESCRIPTION
	—	LINE IDENTIFICATION
	P	CENTRIFUAL PUMP
	P	GEAR PUMP
	P	DIAPHRAGM PUMP
	B	BLOWER
	C	COMPRESSOR
	E	HEAT EXCHANGER
	D,R	VESSEL , REACTOR
	J	JET, EDUCTOR

MISCELLANEOUS

A	AGITATOR
CV	CONVEYOR
CY	CYCLONE
F	FURANCE
FL	FILTER
H	HOPPER
ME	MISCELLANCEOUS MECHANICAL EQUIP.
W	DRYER
Z	VIBRATOR
STM	STEAM
COND	CONDENSATE
PW	PROCESS WATER
CWS	COOLING WATER SUPPLY
CWR	COOLING WATER RETURN
CHWS	CHILLED WATER SUPPLY
CHWR	CHILLED WATER RETURN

FIGURE 2.

A	ORIGINAL ISSUE			2-3-77					
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TOLERANCES FRACT. ± UNLESS NOTED OTHERWISE		BY	DATE	U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION					
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	DRAWN	S. MATCH	2-3-77						
	CHECKED								
	APPROVED			"PNO" CONVERSATION PROJECT FLOW SHEET LEDGEND					
REMOVE BURRS AND SHARP EDGES									
NEXT ASSEMBLY									
	SUBMITTED			SIZE	DRAWING NUMBER		ISSUE	SHEET	
SCALE	APPROVED A1			D			A	1 OF 1	
	APPROVED ERDA								

PART	QUAN.	DESCRIPTION	MATERIAL

D-1 FEED STORAGE — SLAB TANKS, SST, 3,000 GAL. CAPACITY

P-1 EVAPORATOR FEED PUMP — SST, CAP = 0.1 gpm

D-2 EVAPORATOR — SST, 5" ID, 25 L/HR CAP., DEMISTER EQUIPPED

D-3 CONDENSATE DRUM — SST, 5" ID, 10L CAP.

E-1 REBOILER — TANTALUM TUBES IN SST SHELL, DUTY = 25,000 BTU/HR

P-2 BOTTOMS PUMP — SST, TANTALUM INTERNALS, CAP = 0.3 gpm

E-2 CONDENSER — SHELL & TUBE, SST, DUTY = 20,000 BTU/HR

P-3 CONDENSATE PUMP — SST, CAP = 0.1 gpm

R-1A,B&C REACTOR — 4" ID, 36" HIGH, TANTALUM, DUTY = 24 KW

FL-1A,B&C FINES FILTER — SINTERED METAL FILTER ELEMENTS IN SST, VESSEL, 4" ID, 45" HIGH

D-6A,B&C COLLECTION VESSEL — SST, 4" ID, 95" HIGH

E-4A,B&C CONDENSER — SHELL & TUBE, SST, DUTY = 30,000 BTU/HR

E-3 BOTTOMS COOLER — SST, DOUBLE-PIPE HEAT EXCHANGER, DUTY = 3,500 BTU/HR.

D-4 BOTTOMS STORAGE — SLAB TANKS, SST, 1000 L CAPACITY

P-4 FEED PUMP — SST, CAP = 0.1 gpm

D-5A,B&C CONSTANT HEAD TANK — SST, 5" ID, CAP = 10L

D-7A,B&C CONDENSATE DRUM — SST, 5" ID, 10L CAP

P-5A,B&C PUMP — SST, CAP = 0.1 gpm

ME-1 BED LOADING POT — SST

ME-2A,B&C SCREENER

ME-3 CANNER

ME-4 BALANCE

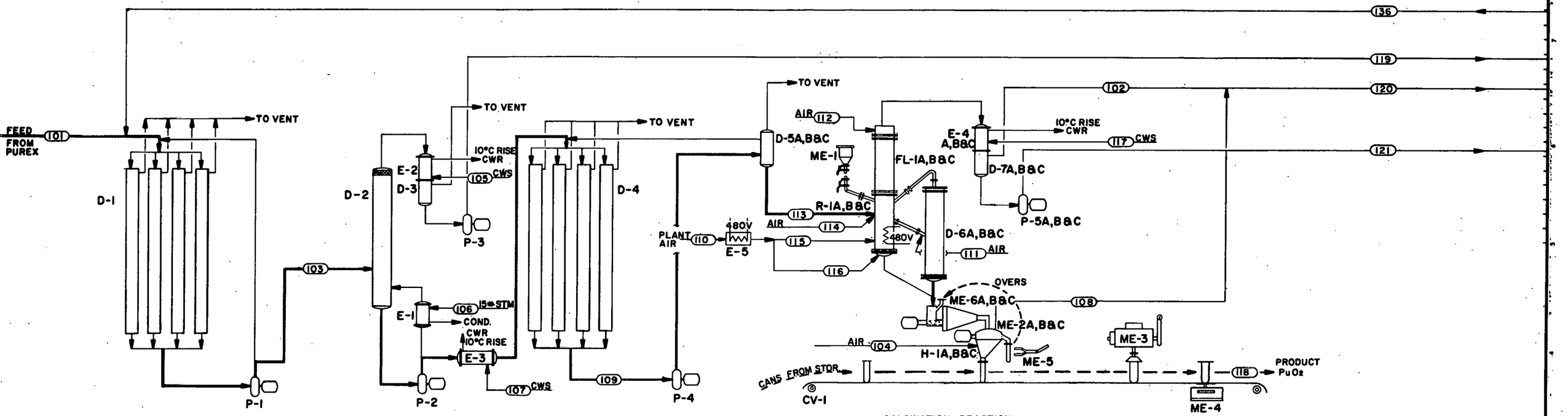
ME-5 MANIPULATOR

CV-1 CONVEYOR

E-5 AIR HEATER — SST, DUTY = 10KW

H-1A,B&C HOPPER — SST,

ME-6A,B&C BALL MILL



CALCINATION REACTION

$$Pu(NO_3)_4 \xrightarrow{\Delta} PuO_2 + 3.4\,NO_2 + 0.7\,NO + 1.3\,O_2$$

STREAM / GMS/HR / COMPONENT	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	136	
$Pu(NO_3)_4$	8,471		8,471						8,471				8,471						TRACE				
PuO_2		TRACE						TRACE										113,100		TRACE	TRACE		
H_2O	15,186.	2,497	15,186		900#/HR		183#/HR		8,651			FILTER BLOWBACK AIR	8,651	ATOMIZING AIR	JET GRINDER AIR	FLUIDIZING AIR	4,900#/HR		6,535	2,497	6,053		
HNO_3	3,151	TRACE	3,151						2,879				2,879						272	TRACE	2,848		
NO_2		2,722																		2,722			
NO		365																		365			
O_2 (FROM REACTION)		721																		721			
AIR		180,831		33,000				33,000		139,918	1,150	1,150		38,613	23,502	116,416				213,831			
METAL IONS	169		169						169				169					169				HI-LEVEL RECYCLE	
SULFUR	8		8						8				8					8					
HALOGENS (F&Cl)	1		1						1				1					1					
STEAM						22#/HR																	
TOTAL GMS/HR.	26,986	187,136.	26,986	33,000	900#/HR	22#/HR	183#/HR	33,000	20,179	139,918	1,150	1,150	20,179	38,613	23,502	116,416	4,900#/HR	113,278	6,807	220,136	8,901		
Pu, GMS/L	250		250						417				417						10^{-4}		10^{-4}		
FLOW, L/HR	16.7	165,725	16.7	27,822	1.8 GPM		0.4 GPM	27,908	10	16,516	950	136	10	32,034	5,336	184,962	9.8 GPM		6.7	194,950	7.5		
PRESS, PSIA		15		ROOM				SYSTEM		105	15	105		15	105	15			PUMP	SYSTEM	PUMP		
TEMP. °C		40		ROOM				50		25	25	25		25	300	300			40	40	40		
MOLARITY	3M HNO_3		3M HNO_3						4.6MHNO_3				4.6MHNO_3						0.5MHNO_3		6.1MHNO_3		
PHASE	LIQUID	VAPOR	LIQUID	GAS	LIQUID	VAPOR	LIQUID	GAS	LIQUID	GAS	GAS	GAS	LIQUID	GAS	GAS	GAS	LIQUID	SOLID	LIQUID	GAS	LIQUID	LIQUID	

NOTES:

1. IN THE CASE OF MULTIPLE TRAINS THE FLOWS SHOWN ARE TOTALS.

FIGURE 3.

A	ORIGINAL ISSUE							1-11-77	
MARK	DESCRIPTION							DATE	APP.

TOLERANCES: FRACT. ±; ANGLE ±; DEC. ±; MACHINE SURFACE FINISH; BREAK EDGES AND CHAMF. 0.005; HEAT ASSEMBLY

	BY	DATE
DESIGNED	D. NEAL	12-15-76
DRAWN	S. HATCH	1-11-77
CHECKED		
APPROVED		
SUBMITTED		
APPROVED AT		
APPROVED ERDA		

SCALE

U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
ROCKY FLATS AREA OFFICE, GOLDEN, COLORADO

EQUIPMENT FLOW SHEET & MATERIAL BALANCE
FLUIDIZED BED DIRECT DENITRATION

SIZE D — DRAWING NUMBER — SHEET 1-2

D-8 SCRUBBER BOTTOMS STORAGE — SST, 1000 gal. CAPACITY, PACKED WITH BORON-GLASS RASCHIG RINGS

P-6 PUMP — SST, 0.1 GPM

D-9 EVAPORATOR — SST, 5" ID, 25 L/HR CAPACITY

E-6 CONDENSER — SST, SHELL & TUBE, DUTY = 45,000 BTU/HR.

E-7 REBOILER — SST, SHELL & TUBE, DUTY = 50,000 BTU/HR.

P-7 PUMP — SST, 1 GPM

P-8 PUMP — SST, 0.1 GPM

D-10 CONDENSATE DRUM — SST, 5" ID, 10L CAPACITY

E-8 BOTTOMS COOLER — SST, DOUBLE-PIPE HEAT EXCHANGER DUTY = 500 BTU/HR

D-11 DISTILLATE STORAGE — SST, 1000 gal CAPACITY PACKED W/BORON-GLASS RASCHIG RINGS

P-9 PUMP — SST, 0.1 GPM

D-12 DISTILLATE STORAGE — SST, 1000 gal CAPACITY PACKED W/BORON-GLASS RASCHIG RINGS

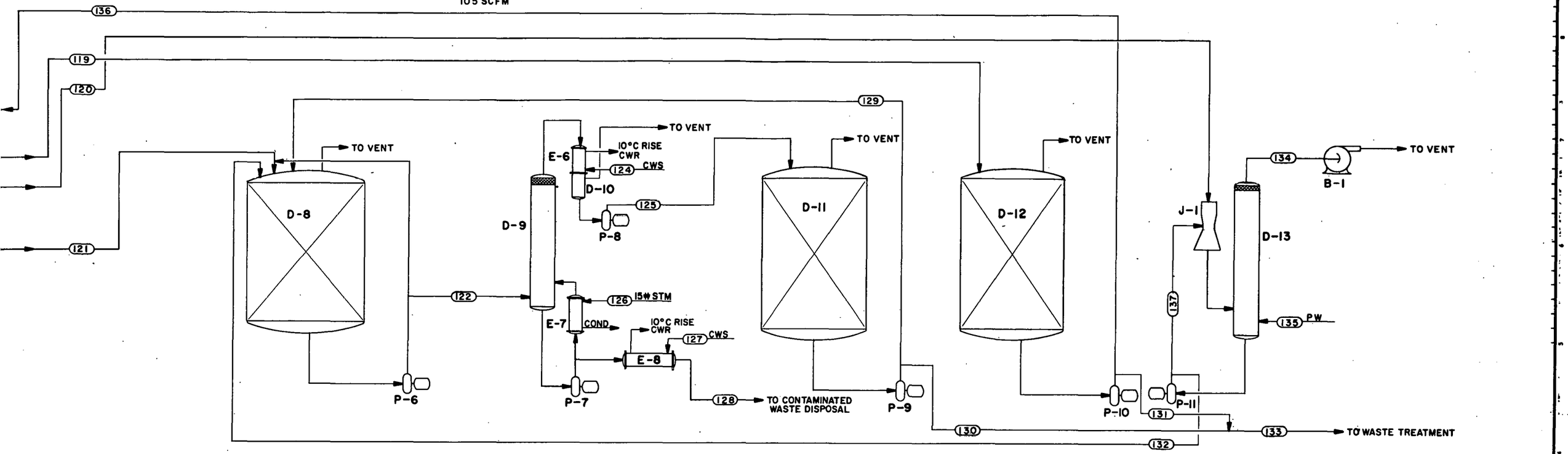
P-10 PUMP — SST, 0.1 GPM

P-11 PUMP — SST, 1 GPM

J-1 VENTURI SCRUBBER — SST

D-13 SEPARATOR — SST, 5" ID

B-1 BLOWER — SST & FRP, 105 SCFM



CONT. FROM SHT. 1

STREAM / GMS/HR COMPONENT	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	
$Pu(NO_3)_4$	TRACE												TRACE	TRACE	TRACE					
PuO_2		TRACE	TRACE	TRACE						TRACE										
H_2O	6,535	2,497	6,053	18,068		2,340#/HR	16,783		20#/HR	1,285		16,783	6,535	12,015	23,318	10,428	19,946			
HNO_3	272	TRACE	2,848	2,848			2,041			807		2,041	272	TRACE	2,313					
NO_2		2,722														2,722				
NO		365														365				
O_2(FROM REACTION)		721														721				
AIR		213,831														213,831				
METAL IONS																				
SULFUR																				
HALOGENS (F&Cl)																				
STEAM								46.8#/HR												
											HIGH-LEVEL RECYCLE							HIGH-LEVEL RECYCLE	CIRCULATION	
TOTAL GMS/HR.	6,807	220,136	8,901	20,916		2,340#/HR	18,824	46.8#/HR	20#/HR	2,092		18,824	6,807	12,015	25,631	228,067	19,946			
Pu, GMS/L	10^{-4}		10^{-4}	10^{-4}									10^{-4}	10^{-4}	10^{-4}	$< 10^{-4}$				
FLOW, L/HR	6.7	194,950	7.5	19.5		4.7 GPM	17.8		0.04 GPM	1.7		17.8	6.7	12.1	24.5	205,123	20		119.2	
PRESS, PSIA	PUMP	SYSTEM	PUMP	PUMP			PUMP					PUMP	PUMP	PUMP	PUMP	SYSTEM	SYSTEM		PUMP	
TEMP, °C	40	40	40	< 40			40			50		AMBIENT	AMBIENT	~ 40	AMBIENT	40	27		~ 40	
MOLARITY	0.5M HNO_3		6.1M HNO_3	2.4			2M HNO_3			10M HNO_3		2M HNO_3	0.5M HNO_3		1.6M HNO_3					
PHASE	LIQUID	GAS	LIQUID	LIQUID		LIQUID	LIQUID	VAPOR	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	VAPOR	LIQUID	LIQUID	LIQUID	

FIGURE 3 (continued)

A	ORIGINAL ISSUE		1-7-77
ISSUE	DESCRIPTION	BY	DATE
	DESIGNED	D. NEAL	12-15-76
	DRAWN	S. HATCH	1-7-77
	CHECKED		
	APPROVED		

U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
ROCKY FLATS AREA OFFICE GOLDEN, COLORADO

EQUIPMENT FLOW SHEET & MATERIAL BALANCE
FLUIDIZED BED DIRECT DENITRATION

SIZE D — DRAWING NUMBER — ISSUE A — SHEET 2 of 2