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K-1131 FEED PLANT

B. H. Thompson

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Union Carbide Nuclear Company, Oak Ridge Gaseous Diffusion Plant, Operating Contractor for the U.S. Atomic Energy Commission.

J. Preston for ASQ vist 1/24/96

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INTRODUCTION ON K-1131

The feed plant facility in K-1131 was started up in 1950 with three lines of equipment for converting UO_2 to UF_4 and UF_4 to UF_6. Both steps were accomplished with vibrating tray reactors. Development of a tower reactor for fluorination of UF_4 had been started during actual construction of K-1131. By the time K-1131 was completed the tower reactor had been advanced to a stage suitable for consideration as a production unit. When the fluorination tray reactor presented rather serious operational problems during the startup period a tower reactor was installed for trial purposes. This tower reactor performed so well that it was decided to convert the three fluorination trays to hydrofluorination units in series with the hydrofluorination trays already in existence and, at the same time, to install a fluorination tower reactor at the end of each hydrofluorination line. This system functioned well enough to meet production requirements for some time. However, with continued usage at the vibration frequencies necessary for efficient operation, these trays became progressively more subject to structural failures of fatigue origin. At the same time the tower system presented insurmountable problems of contamination control because of both equipment design and arrangement.

Realizing the foregoing situation and in the face of the steadily rising schedule for UF_6 commitments, it was decided to proceed with a wall-to-wall replacement of the hydrofluorination and fluorination systems. In view of favorable operating experience at both Mallinkrodt and Fernald, it was decided to install screw reactors. At the same time, applying knowledge that had been gained at both K-1131 and Paducah, an entirely new tower system was proposed. It would retain all the operational advantages of previous systems but would, by means of overall improved design and a plan of mass flow type of powder conveyors offered a unit operation that, with reasonable care, could be kept radiation-clean. Cleanup cold traps of an altogether new design were to replace the fragile traps that had been salvaged from gaseous diffusion plant operation. New powder handling and vacuum cleaning facilities, and positions for ten fluorine cells were also incorporated in the final project.

The present plant now has a capacity of 12 metal tons per day of UF_6. It has, furthermore, entirely fulfilled expectations with regard to contamination control.

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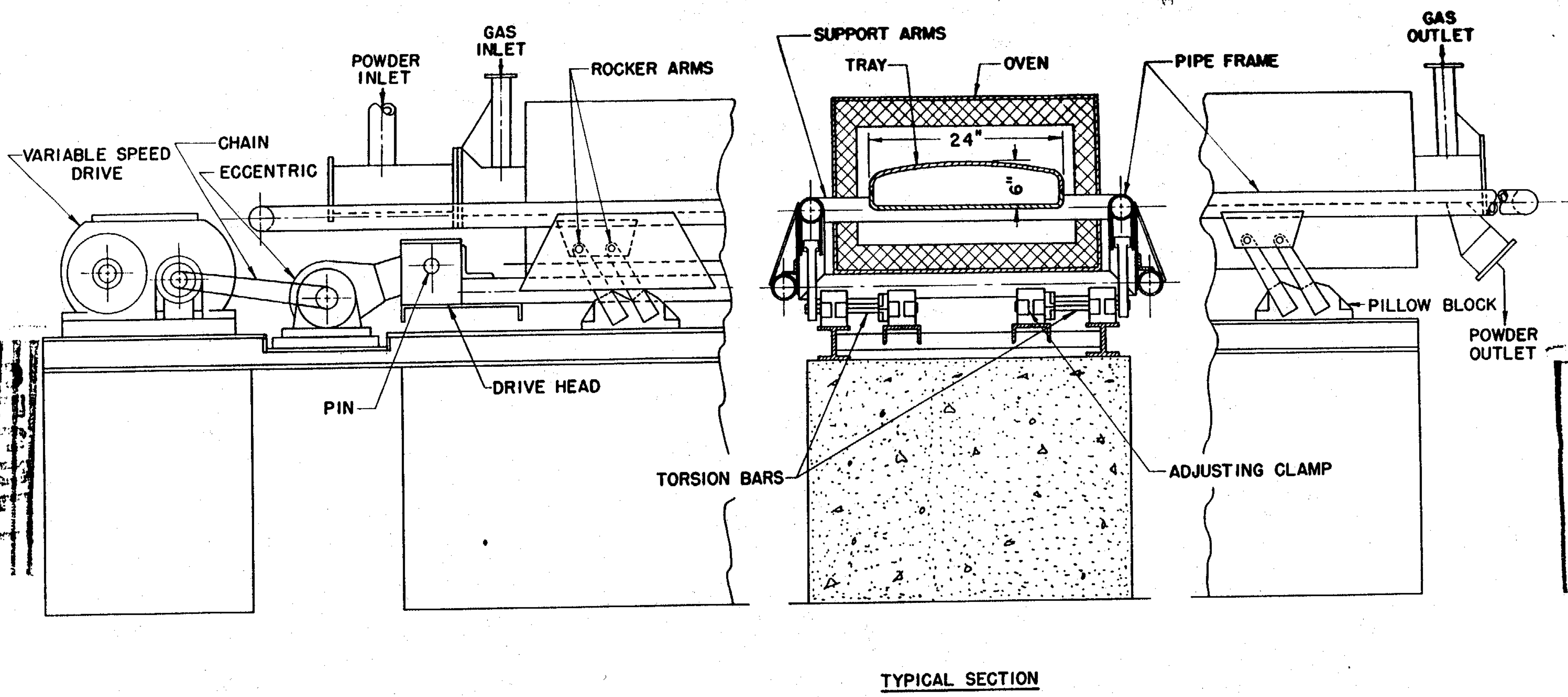
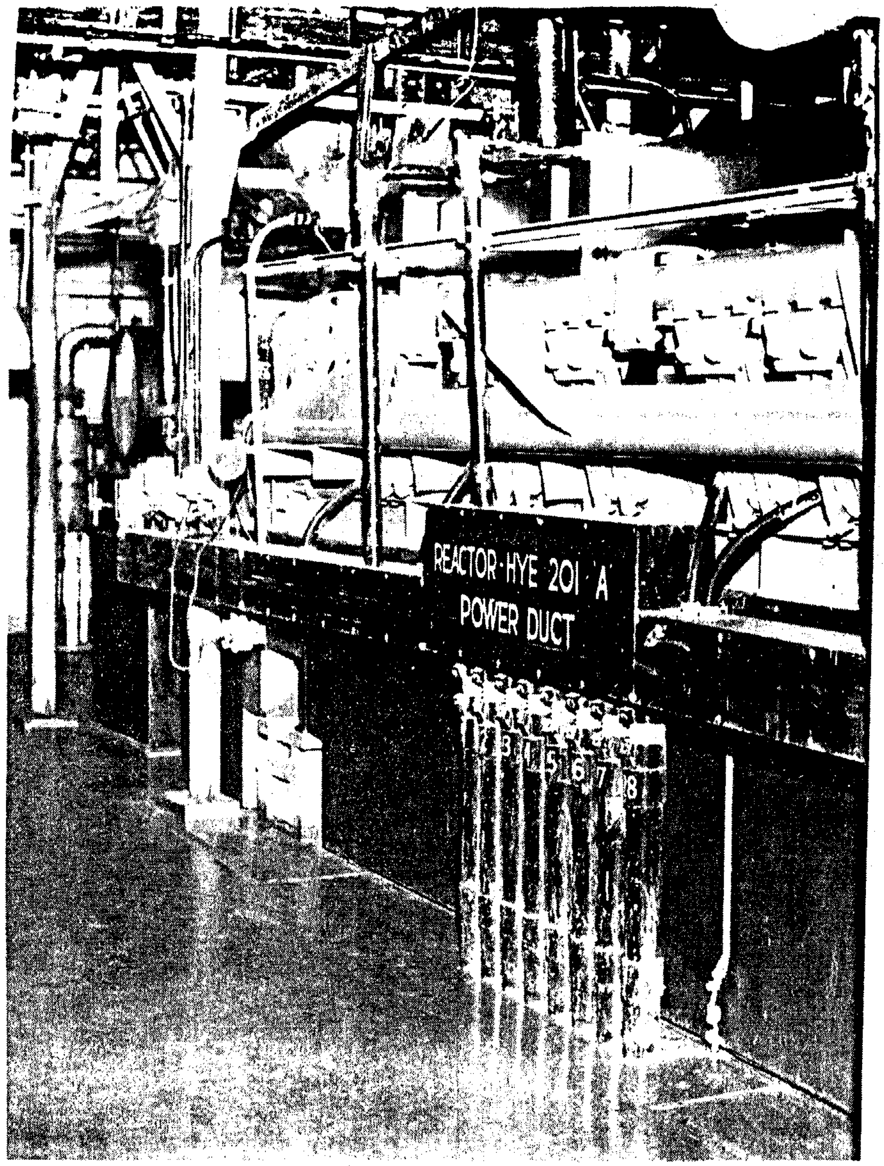
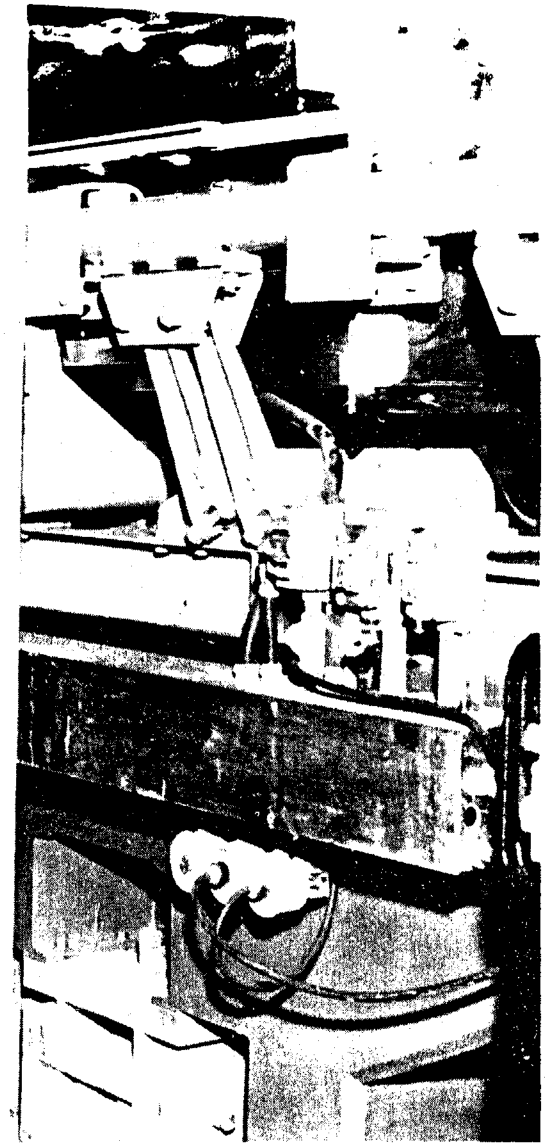
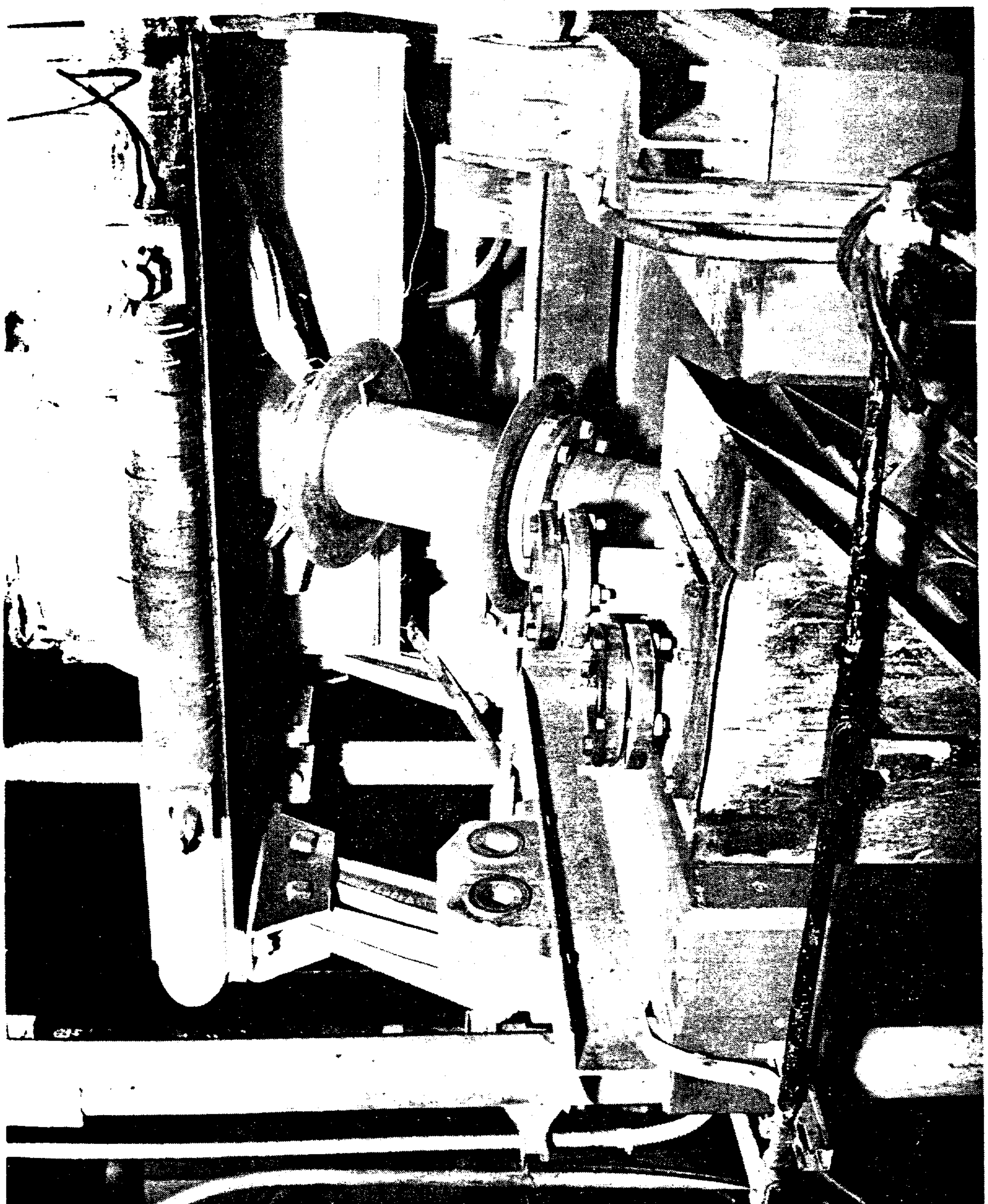


15' REACTOR TRAY


REACTOR-HYE 201 A
POWER DUCT





REDUCTION SYSTEM

K-1131

EQUIPMENT

Three vibrating tray reactors, electrically heated, with dimensions, 15' x 2' x 5".
Recirculating pumps are of the centrifugal displacement type, using water as a liquid.
Fifteen caustic H_2 cells.
H_2 is also supplied as by-product from F_2 plant.

OPERATING CONDITIONS

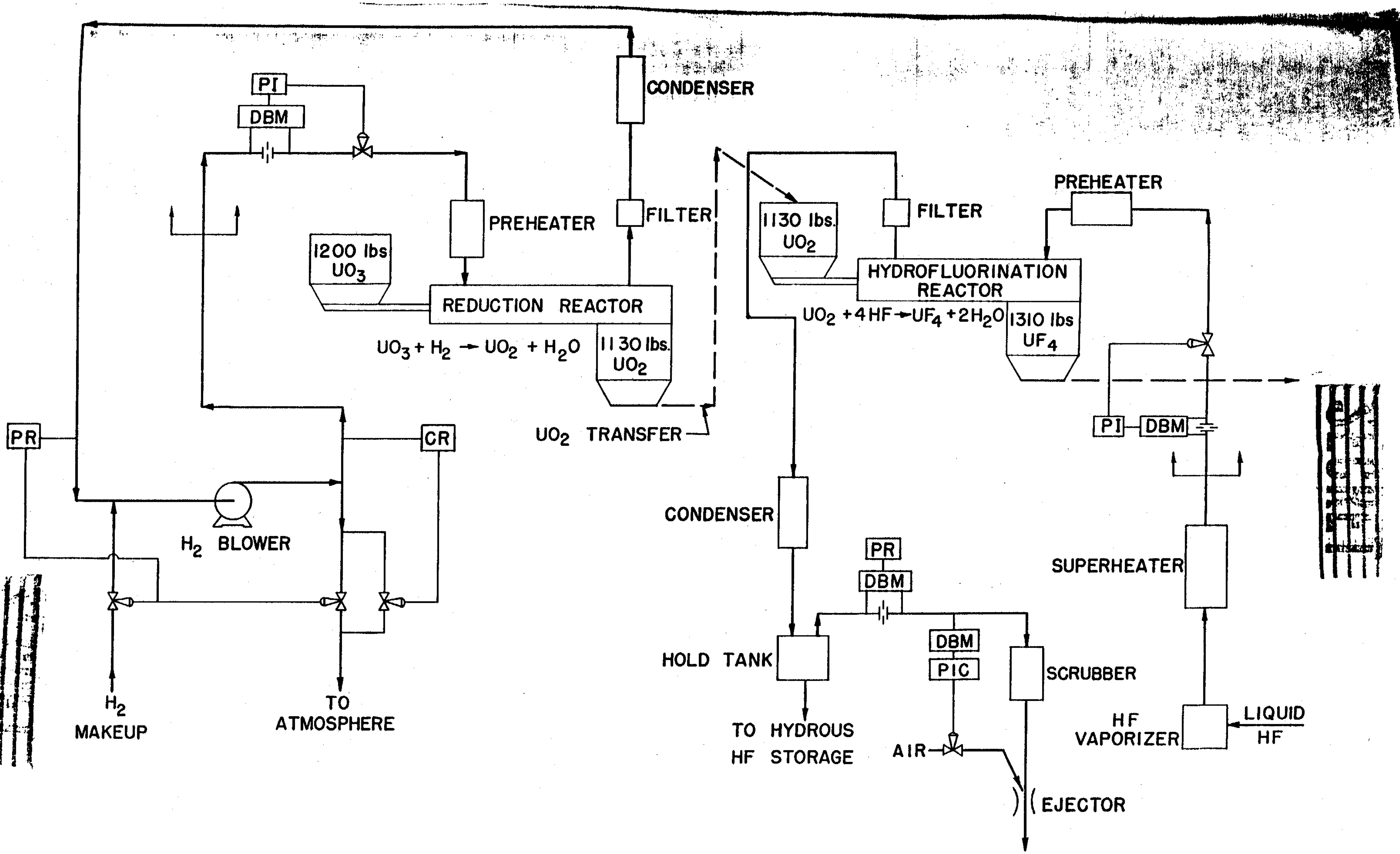
H_2 comes from H_2 cells at rate of 5 lb. mols/hr, or 10.2 lb. H_2/hr, at 8,200 amps for 15 H_2 cells.
H_2 from F_2 cell at rate of .3 lb. H_2/cell at 3500 amps.
H_2 concentration: 87-100%.
Inlet H_2 temperature: 1000°F.
H_2 usage: 7.93 lb. H_2/hr. (125% of stoichimetric)
H_2 flow concurrent with powder movement.
Tray reactor temperature: 1100°F. - 1200°F.
Conversion UO_3 to UO_2: 94-97%.
Tray frequency: 1000 cycles/min.
Tray stroke: 1/8"

Tray cycles:	Feed screw on time	12 sec.
	Tray shake time	19.5 sec.
	Tray off time	10 min.

Retention time: 1 to 1-1/2 hrs.
UO_3 feed rate is 4 TU/day/line or 405 lb. UO_3/hr.
UO_2 product rate is 4 TU/day/line or 382 lb. UO_2/hr.

MAINTENANCE EXPERIENCE

No tray failures to date.



SCHEMATIC FLOW DIAGRAM
UF_4 PRODUCTION

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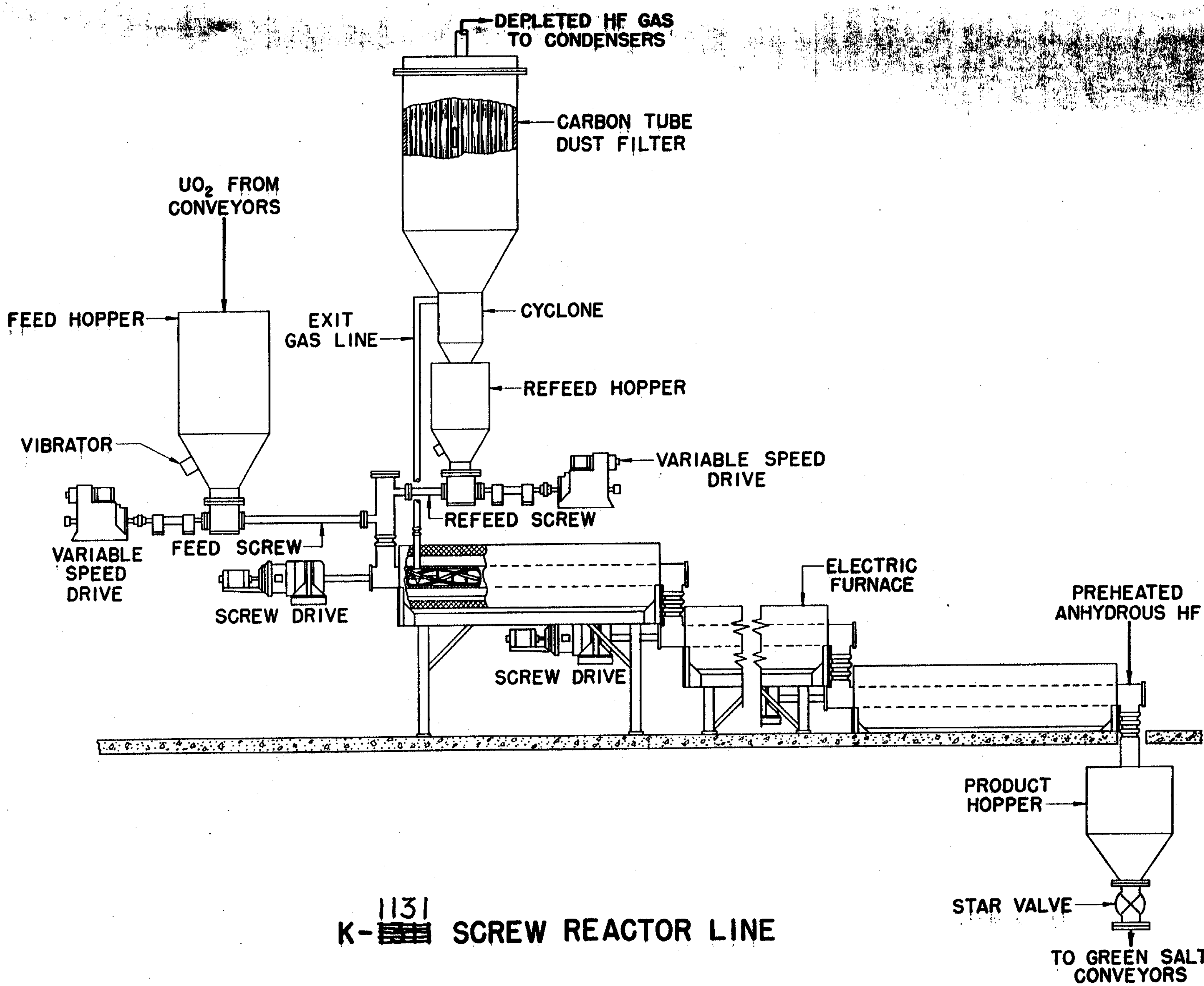

K-1131 SCREW REACTOR LINE

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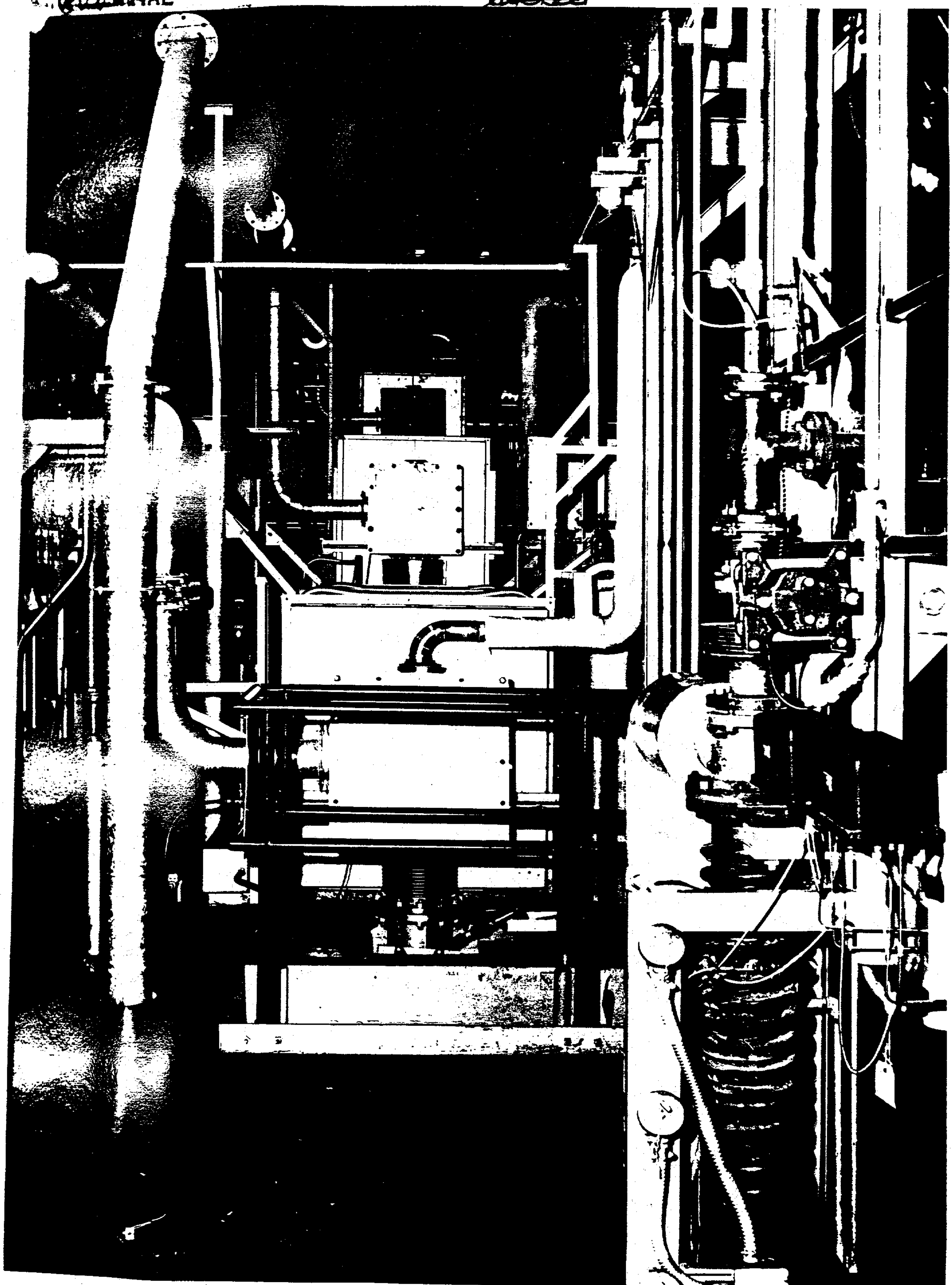

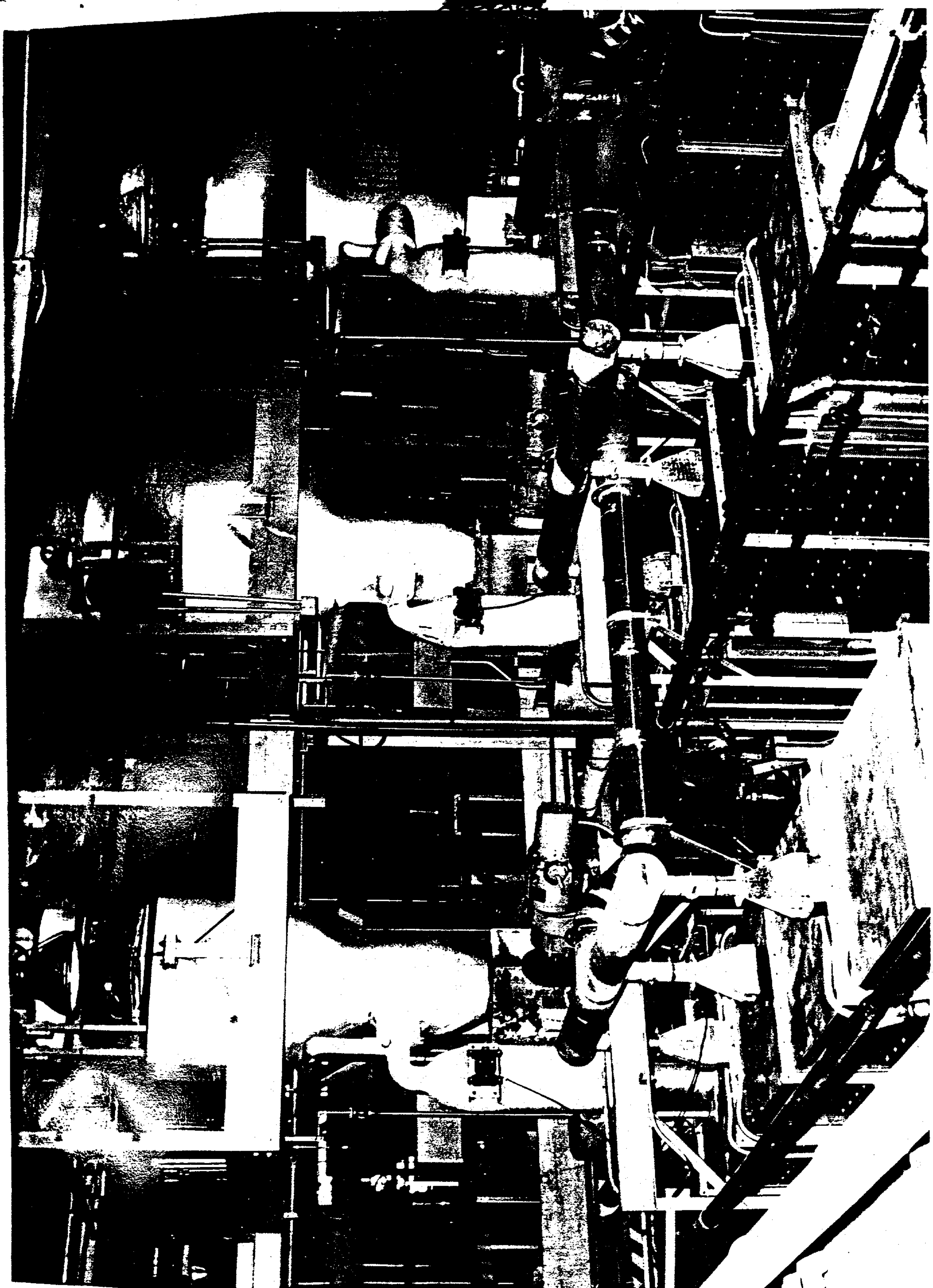

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HYDROFLUORINATION SYSTEM

K-1131

EQUIPMENT

Three process lines.
Each line has three electrically heated screw reactors, 20' x 16", with HF preheated and carbon filter with associated re-feed hopper.
Screws rotated by direct mechanical drives with variable voltage speed control.

OPERATING CONDITIONS

Temperature Gradients		Reactor Speeds
1st reactor:	600-700°F.	10 r.p.m.
2nd reactor:	800-1000°F.	11 r.p.m.
3rd reactor:	1000-1100°F.	15 r.p.m.

Retention time: 5-6 hours
HF flow is counter current to powder travel.
HF flow rate is 100% excess of stoichimetric.

Powder conversion analysis:		
	UF_4	89-93%
	UO_2F_2	4-5%
	UO_2	3-6%

Production: 1307 lbs./hr. or 12 tons U as UF_4/day.

MAINTENANCE EXPERIENCE

Only one screw failure since startup.

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HYDROFLUORINATION SCREW REACTORS

K-1131

K-1131 has three lines of screw reactors that are in general quite similar to those installed in the green salt plants at Mallinckrodt and Fernald. There are three 20' screws in each line, staggered above each other with sufficient room for convenient screw removal. This arrangement is in contrast with Fernald and Mallinckrodt installations which have their individual reactors on separate floors with reversed direction of powder flow at each succeeding reactor. The K-1131 units have direct mechanical drives with speed control accomplished with a variable voltage output.

Electrical rod elements are used for heating purposes. Forced air cooling is installed on all sections of the first reactor. Depending upon the characteristics of powder and the production rate desired, temperature gradients for all three reactors may range from 600 to 1100°F.

The HF flow is adjusted to a rate of 100% excess of stoichimetric. This rate supplies optimum excess required for conversion and at the same time allows the recovery of 70% acid.

The HF flow rate for screw reactors is the same as that for tray reactors. Also like tray reactors, the HF flow direction is counter current to the movement of the powder. From the standpoints of capacity and product conversion, the screw reactors appear to be superior to the tray reactors. The exact difference between these two systems has never been firmly established because of varying production requirements between Paducah and Oak Ridge. In addition, the two plants have, for the most part, been using powders of different reactivity and physical characteristics. The most important reason for improvement of capacity of screw reactors would be the factor of mixing and the feasibility of higher temperatures. It has been shown that in a tray reactor material moves in what amounts to essentially a solid sheet of material. In the case of the screw reactor, the open flight screws effect continuous stirring of the powder bed and also promote a considerable dusting condition, both of which improve surface exposure.

One distinct advantage of screw reactors is the fact that in the event of powder leakage at any location, the powder does not have the opportunity of scattering as it does with a vibrating system.

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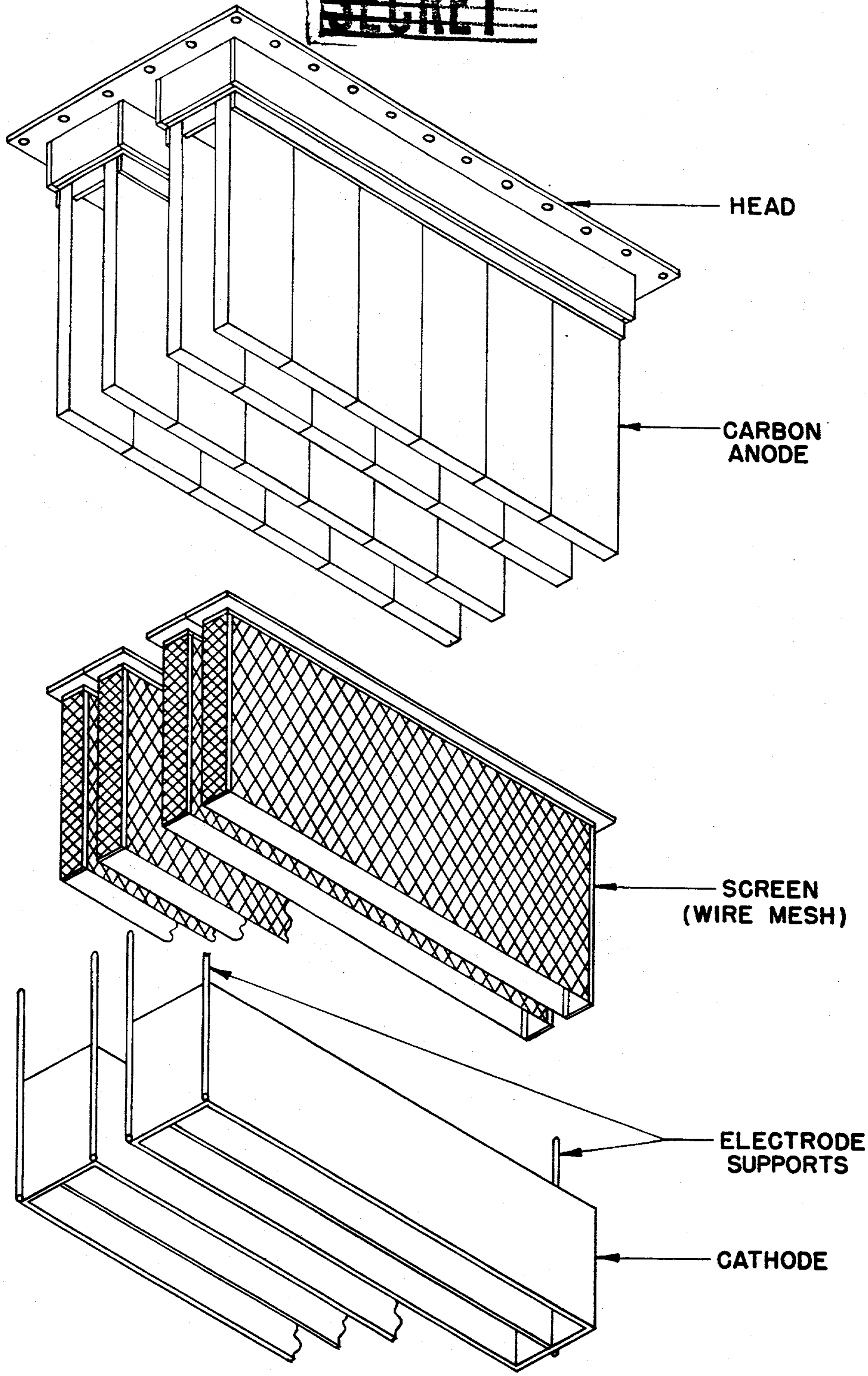


Fig. 4 - FLUORINE CELL HEAD ASSEMBLY
(Fluorine Cell - Dykstra et al.) [redacted]

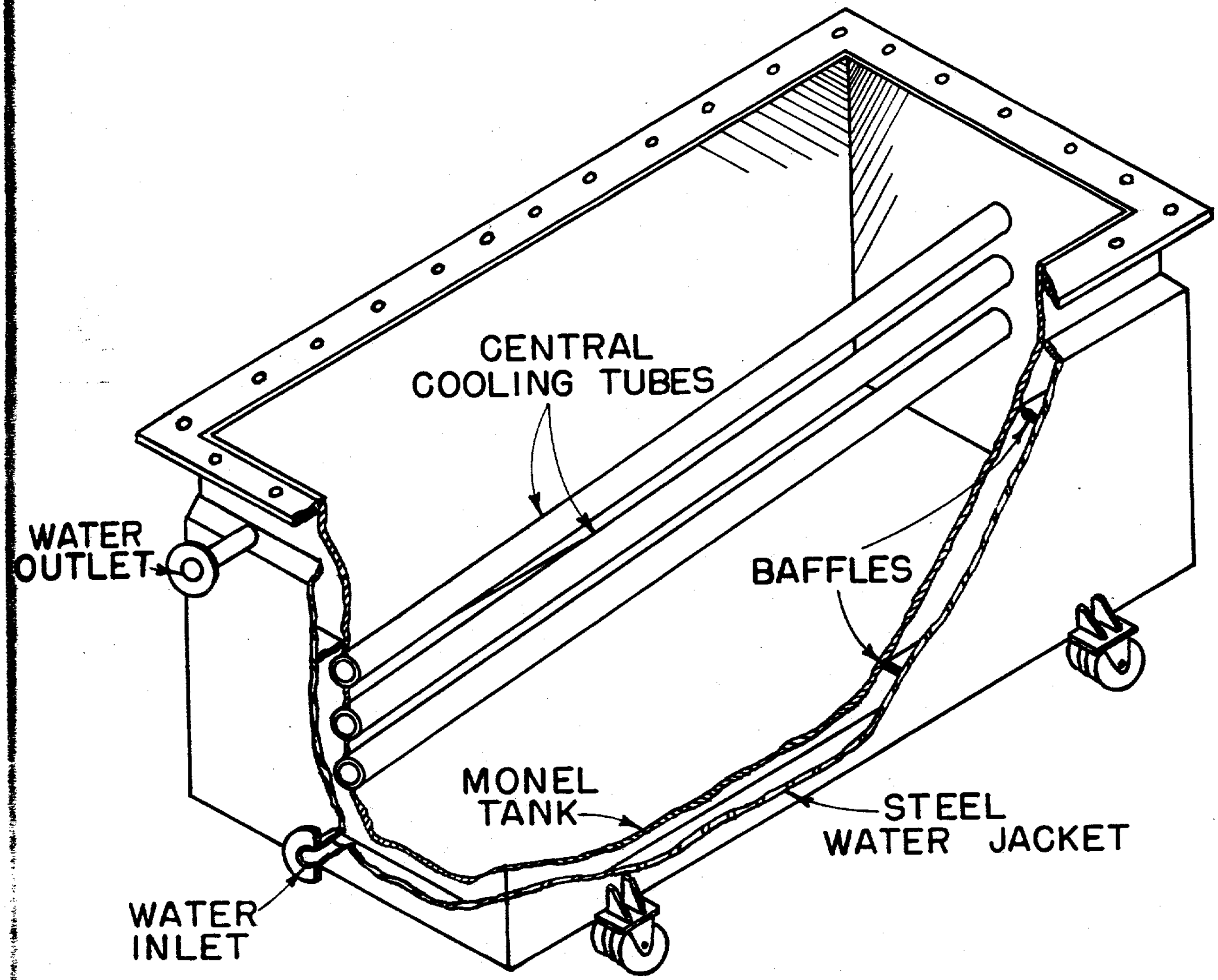
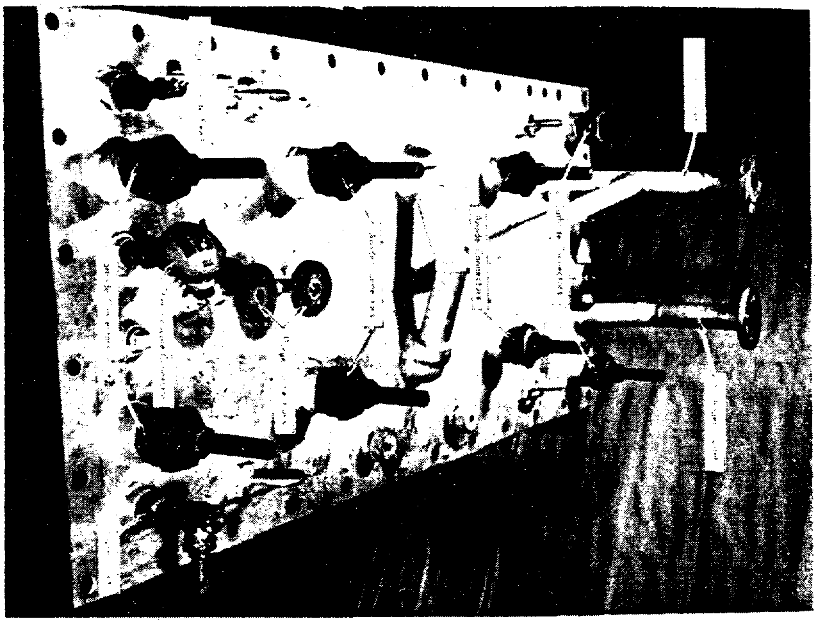
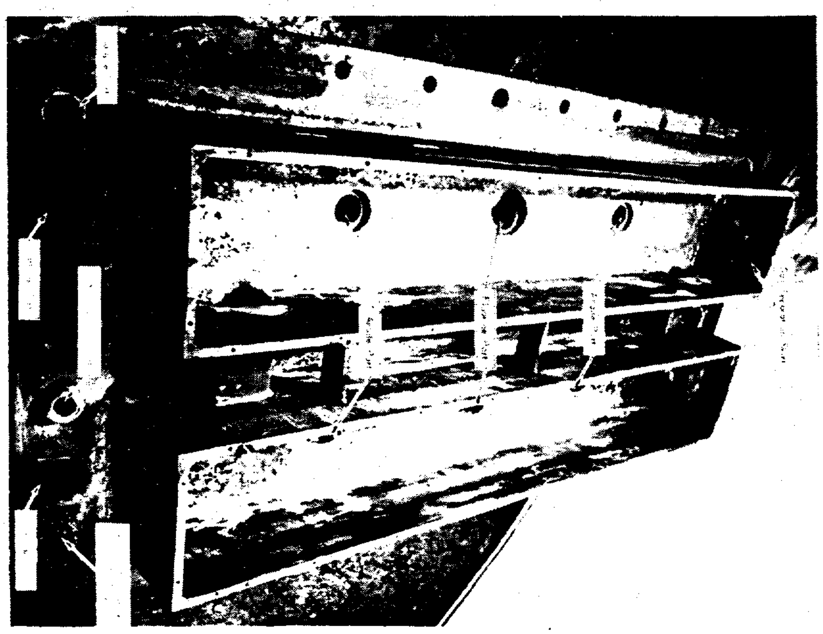


Fig. 1 – CELL BODY
(Fluorine Cell – Dykstra et al.)





FLUORINE PLANT

K-1131

EQUIPMENT

Thirty-five small F_2 cell positions. Twenty-four anodes, 18" x 8" x 1-1/4".
Ten large F_2 cell positions. Thirty-two anodes, 26" x 8" x 2".
Thirty-two small cells in electrical series.
Ten large cells in electrical series.
Three single cells in parallel circuits.
Cell electrolyte: KF·2HF, with 41-43% HF.

OPERATING CONDITIONS

Amperage:

32 small cells -	3400-4000 amps
3 small cells -	3000 amps
10 large cells -	5000 amps

Cell voltage: 8-12 volts.
Electrolyte temperature: 200-220°F.
Cooling water temperature: Inlet 140-150°F.
Outlet 160-165°F.
Cell level: 4-1/2 to 5".
Cell Press: 0-2" water (alarm at 2").
Fluurine pump suction: 0-1" H_2O.
Pumps cut off at ± 2" H_2O, or at P of 2" H_2O between H_2 anf F_2.
Cell efficiency: 88%.
Cells produce: 1.375 lbs. F_2/1000 amps.
Product analysis: 88% F_2
11% HF
1% inerts
Average lift of cells: 5.0 x 10^6 for small. Not enough data for large.
F_2 passes through condenser at -115°F. to remove HF.
Analysis of F_2 to tower: 95% H_2
4% HF
1% inerts

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IMPROVEMENT OF FLUORINE CELL LIFE

K-1131 has thirty-five positions for the standard small fluorine cells and ten positions for the large, or modified, cells. Several basic improvements were made in the modified cells which so far can be credited with very significantly increasing service life over that of the small cells. The three most important changes were the following:

1. An increase in blade thicknesses from 1-1/4" to 2".

2. An increase in effective anode area from 32 sq. ft. to 42 sq. ft.

3. Much more efficient and uniform electrolyte cooling.

During the past several months a number of steps have been taken to promote longer operating life for both types of cells. These improvements may be divided into two headings.

Cell Assembly

1. Tighter specifications for cleaning and degreasing of cell component parts.

2. Matching of anodes by resonant frequency testing.

3. Holding all component parts, particularly anode assemblies, to the closest possible tolerances. This policy requires the contact surfaces of anodes to be smooth and free of chips or deep scratches; pressure plates and anode hangers to be smooth and of a high degree of parallelness; anode bolts to have shoulders which are flat and smooth at the point of contact with pressure plates.

4. Resistance between each anode and the hanger is measured to be sure of the best contact and closest uniformity among all anodes.

5. Making sure of the cleanliness of all assemblies and component parts prior to the time of final assembly.

6. Closer control of spacing and alignment between anodes and cathodes.

Operation

1. Closer control of HF concentration and cell level.

2. Reduction of pressure surges by improvement of instrumentation.

3. Refinement of techniques for depolarization.

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Small Cell Life

July	2.0×10^6
August	2.6×10^6
September	3.5×10^6
October	4.4×10^6
November	5.3×10^6
December	5.7×10^6

In the case of the modified cells, K-1131 has experienced only one failure. This failure can be attributed to a defect in skirt fabrication which eventually allowed cross-mixing.

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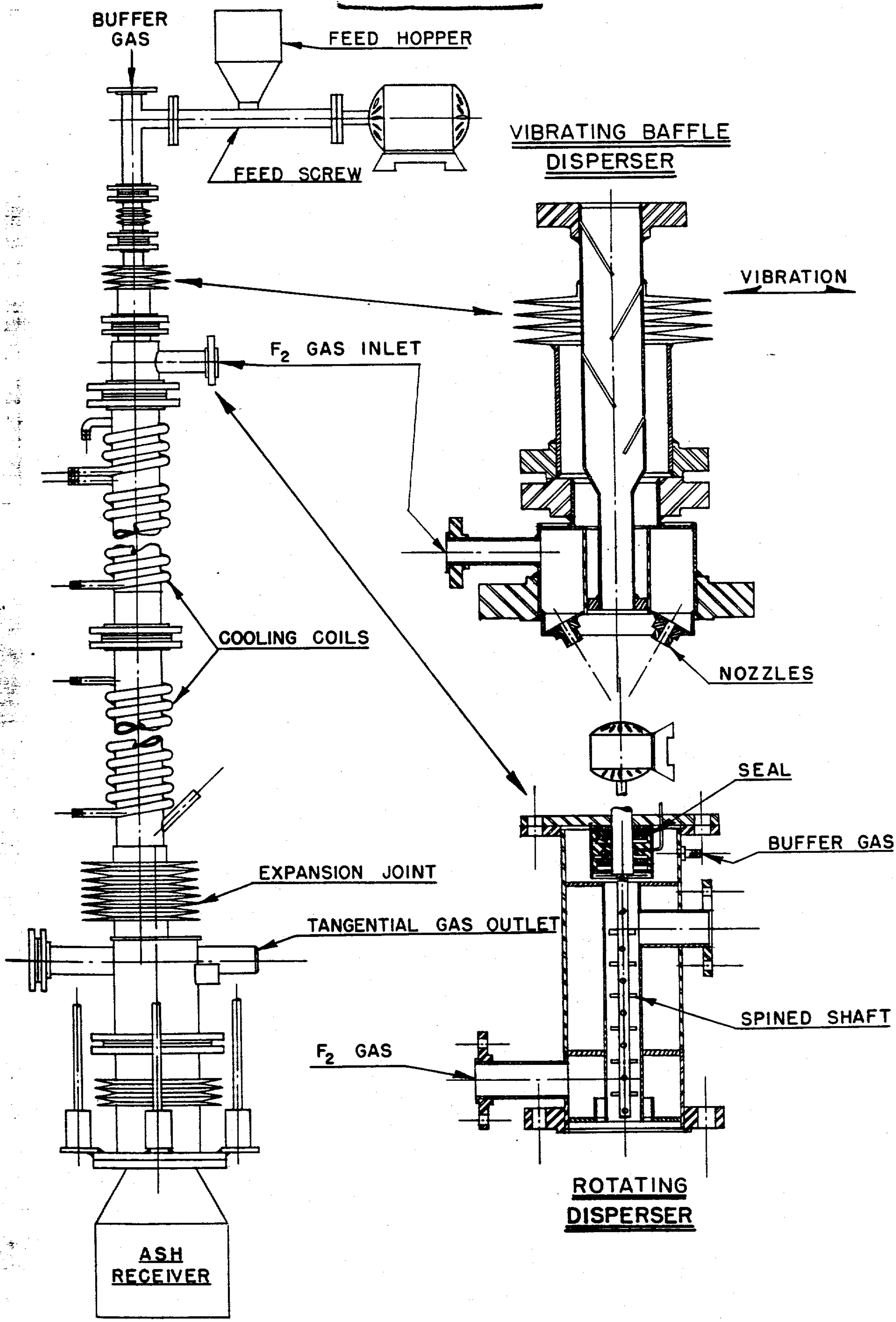

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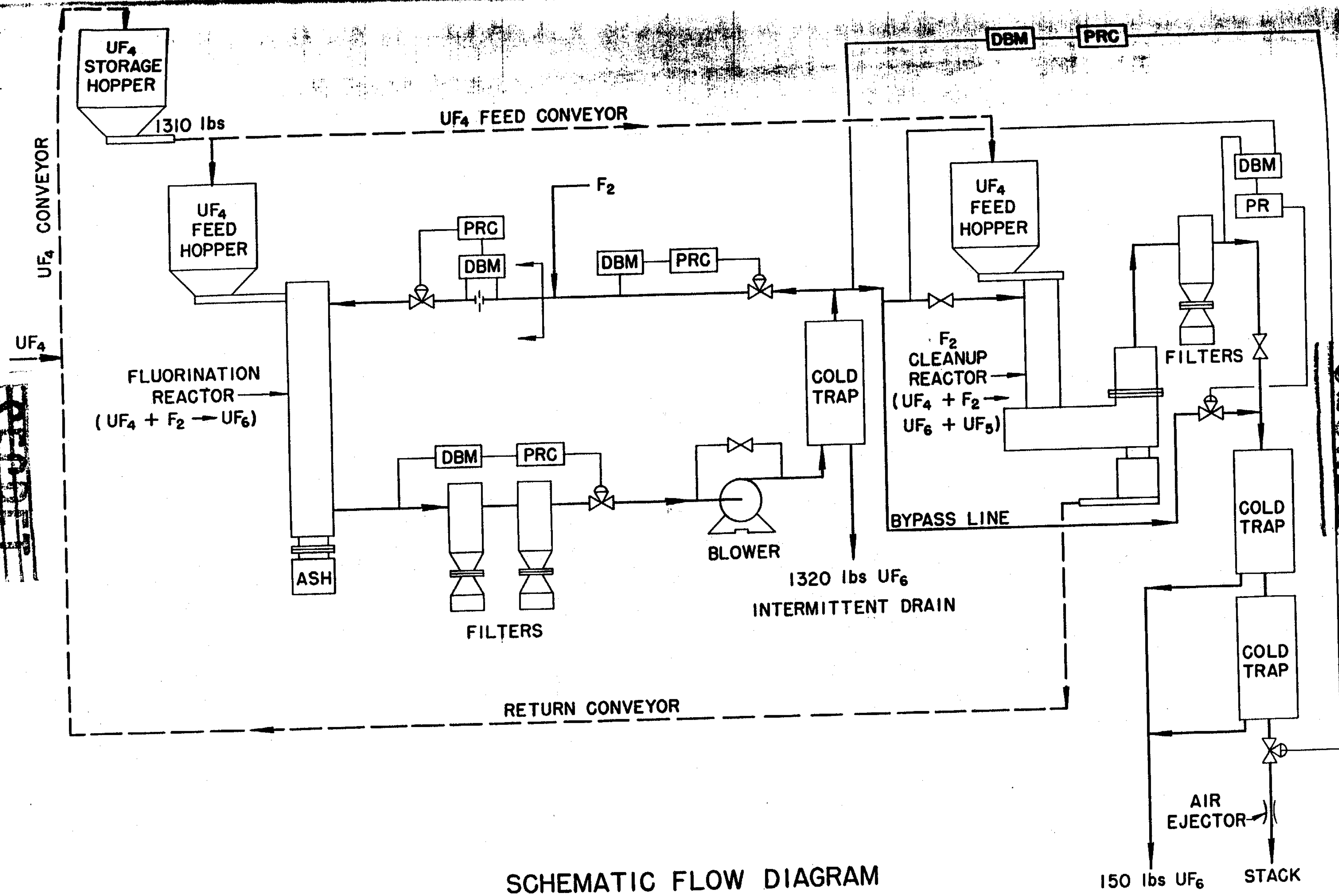
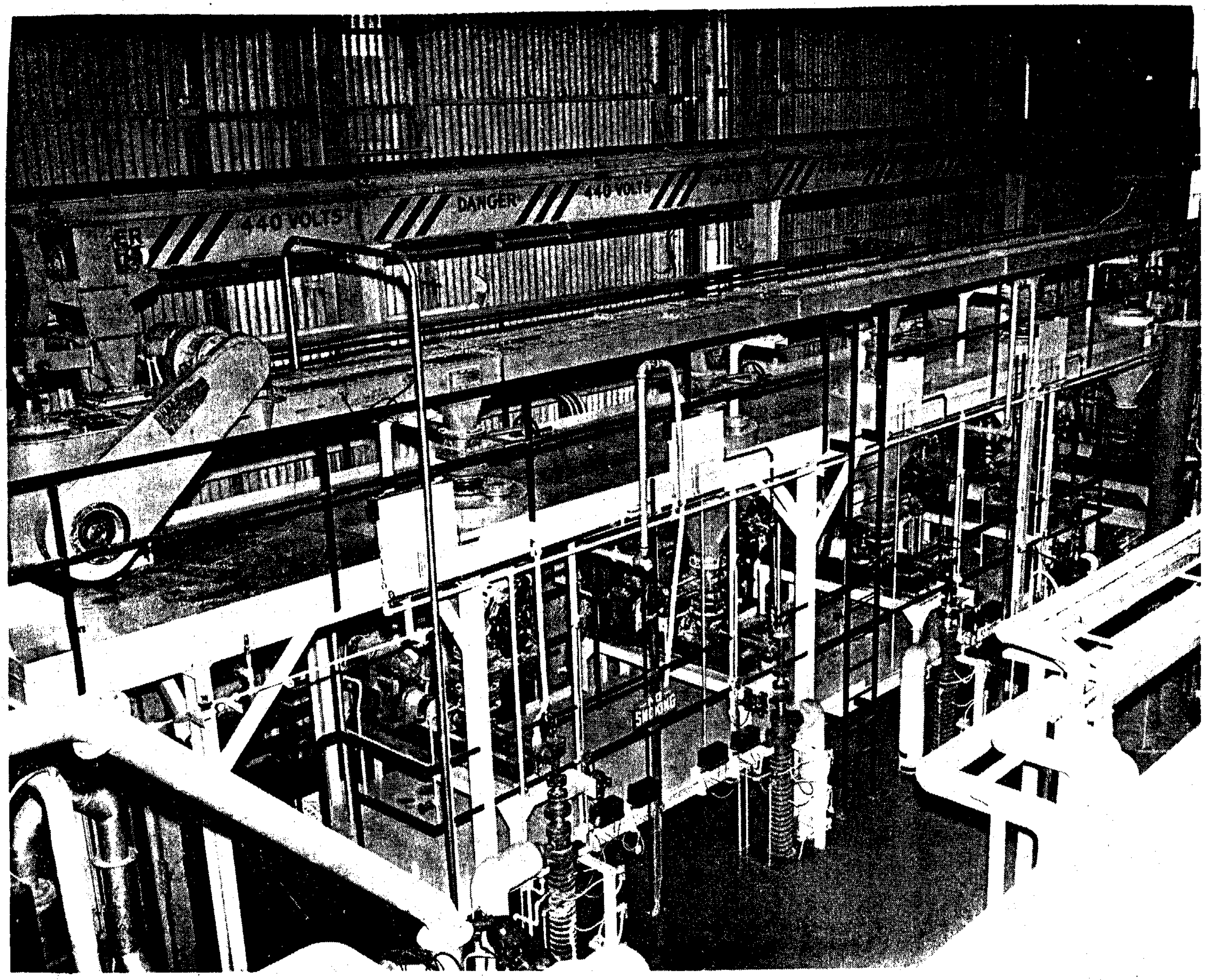
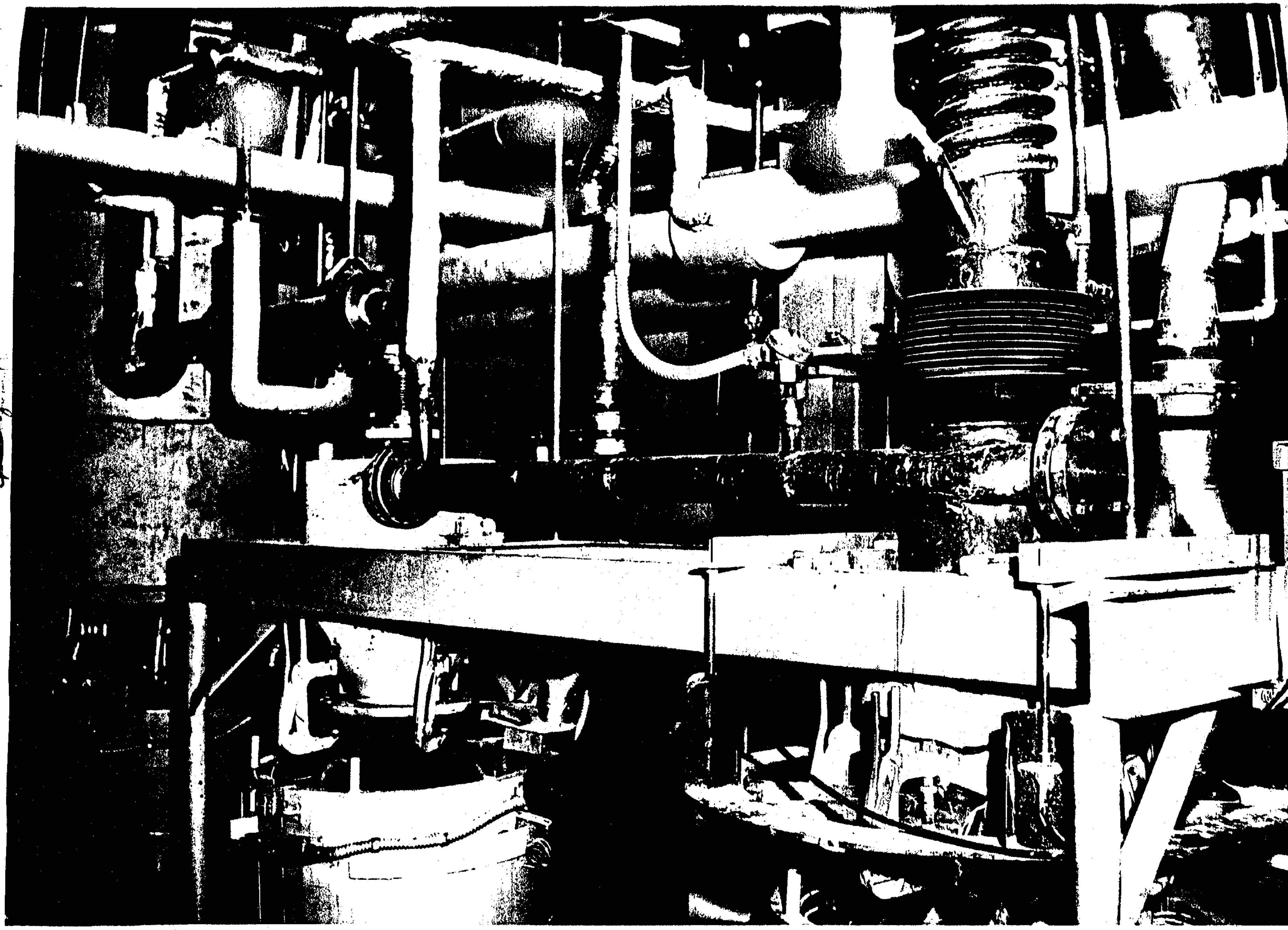


SCHEMATIC FLOW DIAGRAM
UF_6 PRODUCTION


440 VOLTS
DANGER



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FLUORINATION

K-1131

EQUIPMENT

Each line has 10' x 6" water-cooled tower reactor with fluorine preheater, vibrating powder dispenser, F_2 jet assembly, cyclone, and combined cyclone and barrier filter unit.

Fluorine cleanup reactor consists of insulated 8' x 6" water cooled tower reactor with calcining type cooling screw.

OPERATING CONDITIONS

Total gas flow to towers: 8-10 mols/hr or 48-60 scfm.
F_2 preheat: 300-500°F
Tower skin temperature: 750-900°F.
F_2 usage: 192 lbs/hr or 4600 lbs/day at 12 T/day rate.

Primary Towers

	Without Cleanup Reactor	With Cleanup Reactor
Inlet:	50-65% F_2	50-65% F_2
	2-6% UF_6	2-6% UF_6
	30-48% inerts	30-48% inerts
Outlet:	6-10% F_2	16-20% F_2
	30-50% UF_6	20-40% UF_6
	40-64% inerts	40-64% inerts

Cleanup Reactor

Inlet	Outlet
20-35% F_2	1% F_2
8-12% UF_6	20-35% UF_6
53-72% inerts	65-79% inerts

Tower exit gas pumped to Modine cold traps. Major portion of exit gas from Modine trap goes to tower recycle. Over-pressure is sent to cleanup reactor.

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K-1131 TOWER LAYOUT

Primary towers in K-1131 are arranged to allow removal of jet and baffle assemblies at a convenient working height from floor level. This is a matter of considerable advantage both in the efficiency of the maintenance job itself and the control of contamination. All else being equal, the more elevated the point of spill the more widely spread will be the resultant contamination.

Real merit exists in locating ash receivers and barrier filters in a single enclosure completely isolated, ventilation-wise, from the rest of the building. There is always the possibility that the removal of an ash receiver will be the occasion of a UF_6 release. Furthermore, it is impossible to remove a tower plug and to change out an ash receiver or barrier filter without producing some degree of scattered contamination. Confining these operations to a single separated area greatly reduces the problem of containing a release or spill.

The location of the four primary towers and the cleanup reactor in one compact straight line system has permitted the use of shorter and straighter lengths of lines than have previously been feasible in a tower system. Process lines also prove to be much more accessable for maintenance or clean out.

The UF_4 storage silo, with a capacity of 30,000 pounds of green salt, provides a stockpile of immediately available powder without the expense of contamination problem to be associated with any type of drum transfer. The screener unit, which removes all objects which could possibly obstruct conveyor screws, has undoubtedly prevented a number of costly and untidy shutdowns.

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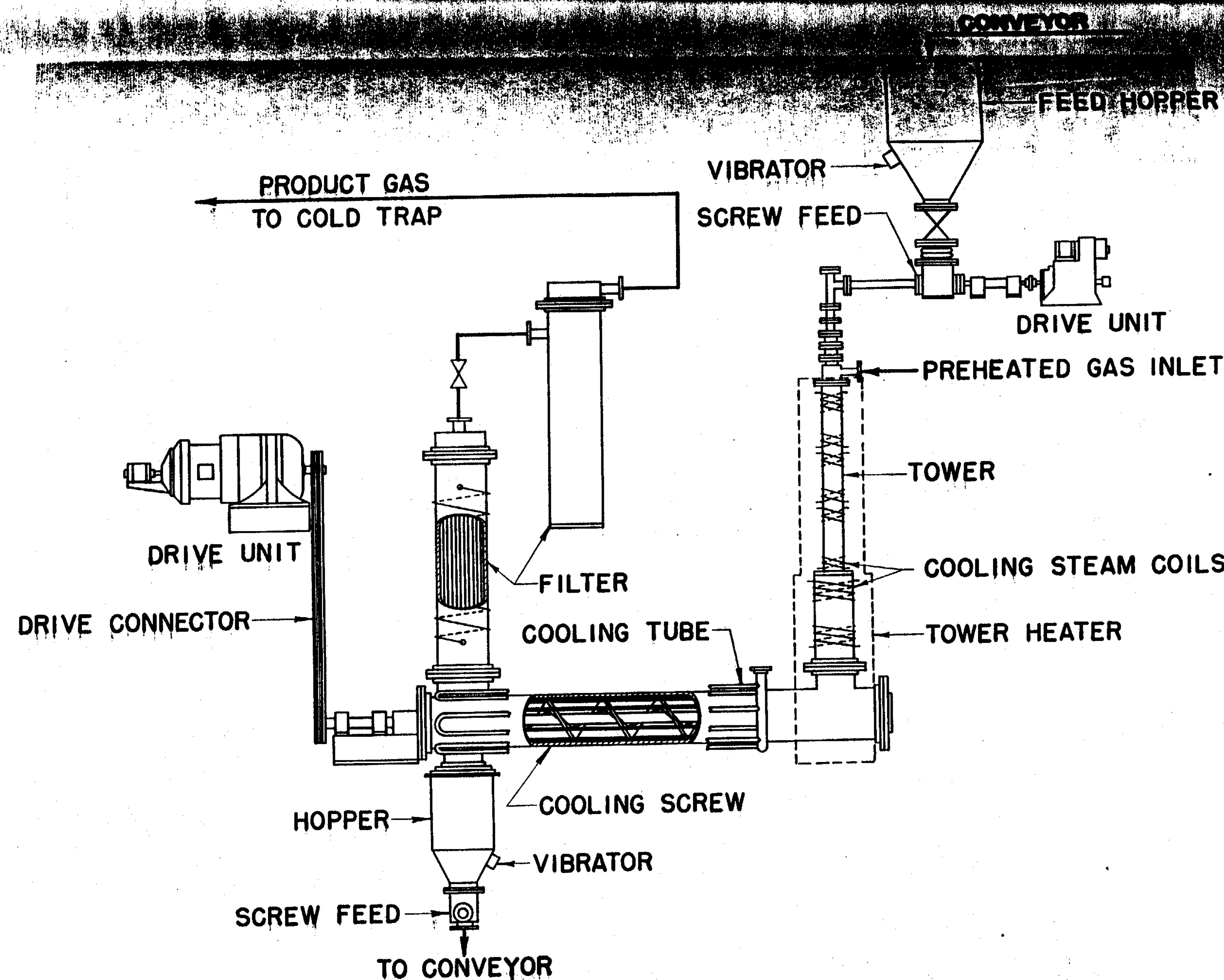

CLEAN-UP REACTOR SYSTEM

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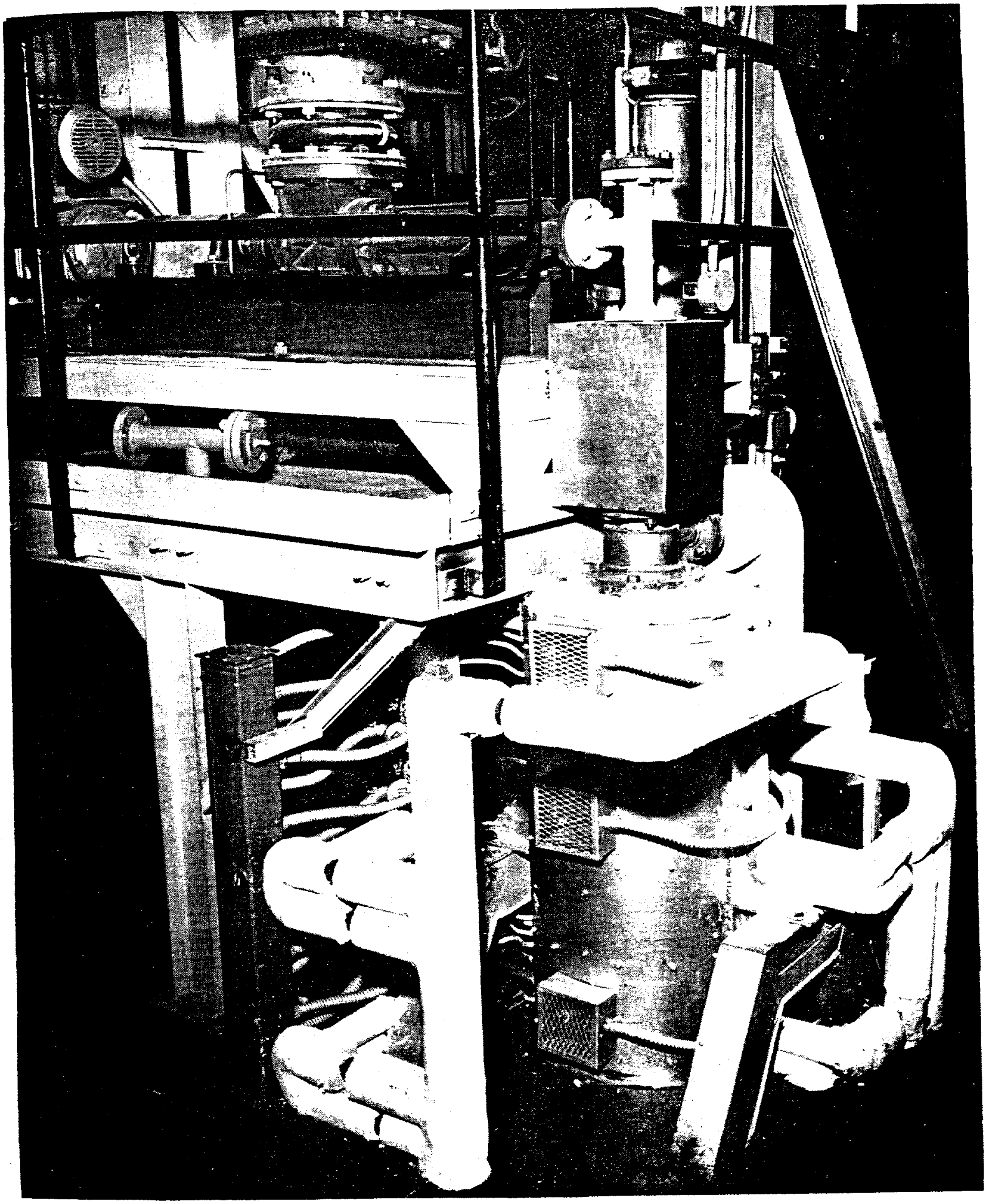

FLUORINE CLEAN-UP REACTOR

K-1131

EQUIPMENT

Standard 6" primary tower reactor shortened to 8'. Insulated, and with heating elements to assure a temperature of 800°F.

Cooling screw is 10' x 16". Has cooling coil for water and/or steam.

OPERATING CONDITIONS

Utilizes approximately 10% of fluorine production.
UF_4 excess is about 40%.
Exit gas from cooling screw <350°F.

Gas Composition

Inlet	Outlet
20-35% F_2	1% F_2
8-12% UF_6	20-35% UF_6
53-72% inerts	65-79% inerts

MAINTENANCE EXPERIENCE

One tower has been replaced. Cooling coils failed for reason yet to be determined.

FLUORINE CLEAN-UP REACTOR

To assure satisfactory efficiency of the primary fluorination towers, they must be operated with a constant excess of fluorine. Allowing the fluorine rate to come within 5% excess of stoichimetric may appreciably increase the ash rate; operating with a deficiency of fluorine will cause tower plugging. The action of clearing a tower plug requires extensive effort and will always be responsible for conditions somewhat hazardous because of both penetrating and non-penetrating radiation.

A clean-up reactor is required to salvage the high fluorine vent resulting from an excess of fluorine to primary towers.

The K-1131 clean-up reactor functions on the principle that a large excess of powder dropping through a tower reactor of standard design will scrub out virtually the last traces of fluorine. Formation of a cake of intermediate uranium compound on the walls of the tower is prevented by maintaining a surface temperature above 600°F. Sufficient unreacted powder falls out to shield the UX_1 and UX_2 resulting from the powder which has been reacted. Thus the relatively large quantity of ash may be immediately blended with regular primary tower feed.

A cooling screw similar to a hydrofluorination screw reactor serves to reduce the temperature of the tower exit gas to less than 350°F so that it may pass through a barrier filter without danger of burning the component tubes. The cooled gas, with a content of approximately 25% UF_6, flows through two cold traps which are in series and chilled to -50°F.

Aside from the usual difficulties of startup, the clean-up reactor has had relatively few interruptions. It appears on the basis of two months experience that there are no basic design weaknesses in the unit.

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OAK RIDGE FEED PLANT

Production and Cost

	F_2		UF_4		UF_6	
1955	Production Pounds	Unit Cost	Production Pounds	Unit Cost	Production Pounds	Unit Cost
July	33,744	1.202	723,050	.151	222,190	.416
August	80,425	.774	571,914	.171	647,848	.302
September	85,665	.677	597,728	.139	559,215	.295
October	103,569	.952	636,634	.164	730,185	.313
November	133,456	.778	810,860	.136	924,897	.265
December	140,219	.790	889,650	.149	1,023,119	.271
1956						
January	114,623	.643	635,506	.142	792,140	.249
February	104,560	.667	586,415	.144	684,412	.280

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