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PROCESS ENGINEERING REPORT

on

REVISED PROCESS DESIGN TRANSMITTAL

GREEN SALT PLANT

JOB #3004

of the

FEED MATERIALS PRODUCTION CENTER - FERNALD, OHIO

for the

UNITED STATES ATOMIC ENERGY COMMISSION

NEW YORK OPERATIONS OFFICE

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SPECIFICATION - CONTRACT #3000

PART XXV

SECTION 4

ENGINEERING DEPARTMENT
OF
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INTRODUCTION

This report constitutes a revised transmittal which contains all process information that has been transmitted to project engineering through May 21, 1952. This information served as a basis for detailed mechanical design of the green salt plant. Because of the advanced state of project engineering and detailed mechanical design, it is possible to discuss the plant on essentially an "as built" basis. Furthermore, it is possible, in the discussion of operations, to be specific as to number, arrangement, and design of production components.

The process design information concerning equipment and operation of the green salt plant, which is transmitted herewith includes the following:

1. Process Flow Diagrams
 - A. Process Flow Diagram, Dwg. No. 3004-H-27-F
 - B. Dust Control, Process Heating & Ventilating,
Dwg. No. 3004-H-28-F
 - C. Vent Gas Gathering & Neutralizing,
Dwg. No. 3004-H-26-F
2. Equipment List
3. Estimated Utilities

The following section of this transmittal will describe the processing equipment and operation of the green salt plant.

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FUNCTION

The function of the Green Salt Plant is to convert the product of the Ore Refinery (UO_3), commonly called orange oxide, into green salt (UF_4) which is later reduced to uranium massive metal in the metals plant.

DESCRIPTION OF PROCESS

The orange oxide from the Ore Refinery is reduced to brown oxide with hydrogen prepared by dissociating ammonia. The reaction is:

The reaction is carried out in a hydrogen-nitrogen atmosphere formed by dissociated ammonia. A temperature of 1200°F to 1500°F is used, depending upon the type of oxide desired. Oxide produced at 1500°F is more stable than that prepared at 1200°F, but the latter is more reactive in the hydrofluorination reaction. An excess of hydrogen is necessary to carry the reduction to completion. Ammonia dissociators are provided to supply hydrogen at a maximum mole ratio of hydrogen to UO_3 of 4 to 1.

The brown oxide is hydrofluorinated to green salt with anhydrous hydrogen fluoride. The reaction is:

Provision has been made to carry out the reaction at progressively increasing temperature, starting at 700°F and finishing at 1150°F. The reaction is exothermic. The temperatures and reaction times are based upon conditions determined by Mallinckrodt Chemical Works (MCW), Plant 7 at St. Louis.

An excess of hydrogen fluoride is necessary to complete the reaction. Provision has been made to supply three times the stoichiometric equivalent

of HF required for the reaction. Approximately half of the excess HF is recovered as 70% aqueous HF and is sold back to the vendor. The other half is recovered as anhydrous acid and recycled in the process.

PROCESS EQUIPMENT AND OPERATION

The Reactors:-

The reduction and hydrofluorination reactions are carried out in a bank of four horizontal cylindrical reaction-tubes mounted in a vertical bank for series flow of the solid phase by gravity from one reaction-tube to the next lower one in the series. The solid phase is moved through the reaction tube from inlet to outlet by a form of stirring or "screw" mechanism still undergoing development by MCW at Plant 7 in St. Louis. The reaction tubes have an inside diameter of 16" and a reaction zone of 16'. Overall length of the tubes is 21 to 22 ft.

The reduction and hydrofluorination reactions are exothermic, however, it is necessary to encase the reaction-tubes in individual electric furnaces to supply heat losses and to preheat the reactants to reaction temperature.

The heating elements are located on the side walls of the electric furnaces. A Leeds and Northrup DAT relay control is used to maintain the reaction-tube wall at a predetermined temperature. Thermocouples mounted in blocks which are welded on the reaction tubes actuate the control mechanisms.

The reaction-tubes used in the reduction step are fabricated from 309 stainless steel. The stirring mechanisms are made of Illium R and the central supporting shafts are Inconel. The reaction-tubes for the hydrofluorination

step are fabricated from Inconel. The stirring mechanisms are made of Illium R, Inconel and Hastelloy C. The stirring mechanisms are driven by individual electric motors through reduction gears. Rotation may be varied from 2.3 to 12 rpm.

To simplify the description of the reactor operation, the sources and methods of handling the solid and gaseous phases are outlined briefly:

The solid phase (UO_3) feed to the reactor system is transported in stainless steel hoppers from the Ore Refinery to "in process" storage in the Green Salt Plant. These hoppers contain about 13,500 pounds of orange oxide each. When needed, they are lifted by an elevator to the top floor and placed on a scale over the feed hoppers serving the upper or reduction reactor-tube. The rate of feed is controlled through the speed of the feed screw, hopper level and weight.

REDUCTION

Orange oxide is reduced to brown oxide as it is moved through the reaction-tube counter-current to a stream of dissociated ammonia. Ammonia is moved in the liquid phase under its vapor pressure to the dissociators from the tank farm.

Hydrogen is passed in excess of stiochiometric requirements through the reaction-tubes, the excess is burned and the combustion gases passed to the dust collecting system. Should the dust collecting system be shut down, these gases would go temporarily to the atmosphere. Suitable precautions have been taken to ensure proper functioning of the hydrogen burners.

The brown oxide drops from the reduction tube into the surge and feed hopper between the reduction reaction-tube and hydrofluorination reaction-tubes below it. Care must be used to provide an adequate seal between the reduction and hydrofluorination reaction-tubes. A star valve and an adequate depth of brown oxide must be carried in this feed hopper to prevent leakage of hydrogen fluoride and steam from the hydrofluorination to the reduction step. Hydrofluoric acid attacks the protective coating formed on the stainless steel wall of the reaction tube and increases metal contamination. Brown oxide is hygroscopic and condensation of steam in the feed hopper would cause material hang-up and irregularities in the feed rate to the following step. The brown oxide is fed to the first hydrofluorination reactor by a variable rate screw feeder.

HYDROFLUORINATION

The AHF gaseous reactant is transferred to the process area from the tank farm in the liquid phase. Dry compressed air will be provided to move it when the vapor pressure is insufficient.

The liquid AHF is vaporized in a copy of the MCW type of vaporizer and passed through a steam heated superheater. The gaseous reactant is metered in the vapor phase and therefore, complete dissociation is essential for accurate measurement.

A pressure relief valve on the vapor feed line to the reactors maintains a pressure below the break-point of the seal in the hopper between the reduction and hydrofluorination systems.

The brown oxide is converted to green salt as it moves through the reaction-

tubes counter-current to the gaseous reactant. The green salt discharges through a hopper to a water cooled screw conveyor. Occluded hydrofluoric acid gas is purged from the salt in the cooling conveyor with a counter-current stream of nitrogen. The cooling screw delivers into a weigh hopper which is discharged intermittently to the packaging section.

After the conversion to green salt has been completed, the major process problem remaining is the recovery of hydrogen fluoride from the gaseous reaction products.

PACKAGING SYSTEM

The green salt is packaged in five gallon containers for transfer to the Metals Plant. Provisions have been made for conversion to accomodate 10 gallon containers. Each container holds a charge for a reduction bomb and the scales furnished are accurate to within $\pm 1/10$ of a percent.

Two packaging units are provided, one for each battery of six reactors. Two conveyors transfer the green salt from the weigh bins below each reactor line to an elevator which feeds the packaging line. The green salt may be passed either through a Mikro-Pulverizer or directly to the weigh hopper, then to a Sturtevant dustless blender which discharges through a continuous sampler to the packaging hopper. The five gallon containers are automatically filled, weighed and the weight printed on a tape which is glued to the container.

A secondary packaging system is provided for loading green salt into 30 gallon drums for outside shipment. This line takes product from below the blender from the main packaging line.

HF RECOVERY SYSTEM

Recovery of hydrogen fluoride from the reactor effluent is an economic necessity. The large quantity of nitrogen gas used as a buffer, purging and sealing medium makes total condensation of the hydrogen fluoride necessary so the inert gases may be vented and the HF recycled. The water vapor formed in the reaction is removed by differential condensation. A controlled temperature coolant is used in the partial condenser and the gaseous effluent leaves the condenser at the equilibrium temperature of the 70% liquid hydrofluoric acid (70% HF - 30% H₂O) removed at this point. The gas-vapor phase passes to the final condenser. The steep vapor pressure curve of anhydrous hydrofluoric acid requires a low temperature for the the final condensation to minimize the quantity of HF carried out with the non-condensibles vented from the condenser. A Freon 22 refrigeration system is provided and final condensation is carried on at -30°F. At -30°F, about one pound of HF will be vented with every three pounds of nitrogen. The use of the nitrogen as a buffer gas has been estimated at fifty pounds per hour.

The corrosion rate of HF varies with concentration, and reaches a maximum at about 52 wt.%. This concentration corresponds with the first drop condensation in the system employed for the removal of water as 70% acid. To produce a saleable 70% acid and to minimize the effects of corrosion, it has been found necessary to condense on a fine silver surface. Those surfaces of the partial condenser which are exposed to the acid are therefore, fabricated of fine silver.

VENT GAS GATHERING AND NEUTRALIZING SYSTEM

Hydrogen fluoride gas from vents and relief valves in the storage and process areas is gathered and neutralized by contacting with potassium hydroxide solution.

The system is divided into high and low pressure systems and serves two purposes:

The high pressure system gathers hydrogen fluoride gases from storage tanks, the anhydrous hydrofluoric acid reactant system and all points where the vapors or gases are not contaminated with uranium bearing dust. These gases are scrubbed and neutralized with potassium hydroxide in a spray tower. The spent solution is discharged directly to the contaminated sewer system. The low pressure system gathers hydrogen fluoride vapors from the cooling screws at the reactors, from low pressure vents and points where the gases may be contaminated with uranium bearing solids. These vapors are drawn through a pair of ejectors with potassium hydroxide solution and discharged into a recirculating caustic tank. The spent solution from this system is passed through an Ensinger filter. The filter cake is washed, repulped and wrung dry in a basket centrifuge of the Bird type. The solids are packaged and sent to scrap recovery.

The design of this section is based upon the installation of the Mallinckrodt Chemical Works at St. Louis.

DUST COLLECTION SYSTEM:

Dust from the packaging equipment and enclosures is gathered and discharged into dust collectors. Contaminated dust is packaged and sent to

the scrap plant. Uncontaminated dust is recycled.

Vacuum outlet connections are provided for clean-out of the reaction tubes and for clean-up purposes in the reaction area. All uranium bearing contaminated dust is packaged and sent to the scrap plant for rework.

The total amount of air handled by the six dust collection systems used to collect uncontaminated dust is 20,325 cfm. The two units that collect contaminated dust handle 7,500 cfm.

The design of this system is based upon the installation of the Mallinckrodt Chemical Works at St. Louis.

HYDROGEN AND NITROGEN GENERATING SYSTEMS

The hydrogen required for the reduction of the orange oxide (UO_3) to the brown oxide (UO_2) is as noted, cracked ammonia. Ammonia is disassociated in commercial packaged units. Nitrogen is not removed, but is carried with the hydrogen without adverse affect to the reaction. The excess hydrogen (2 to 3 times theoretical amounts are used) is burned and the combustion gases are discharged to the atmosphere after passing through dust collectors. Anhydrous ammonia is the source material. It is stored in pressure tanks in the tank farm.

Hydrogen leak detectors are incorporated in the design of the disassociating area. The detector is set to sound alarms when hydrogen is detected in the atmosphere, and to cut off power to any electrical equipment which is not explosion proof when the hydrogen level approaches explosive limits.

Nitrogen required for sealing is generated in a commercial generating unit. This unit takes a side stream of the disassociated ammonia and burns

out the hydrogen and removes water formed, leaving relatively pure nitrogen. This nitrogen is stored in tanks outside the building at 50 psig. Nitrogen required by the metals plant will be supplied by this source.

OFF-GRADE PRODUCT PROCESSING SYSTEMS

Two types of off grade product will occasionally be produced. Product which has not been completely converted to the tetrafluoride is directed from the normal stream and sent to the re-run unit. The re-run unit is a bank of reactors, identical to those described except that the first tube is inconel rather than S.S. 309, in which product of low conversion is reacted further to satisfactory product.

The degree of conversion may be determined rapidly enough so that diversion of the stream will not interrupt normal operations.

The second type of off-grade material will be that which is contaminated with foreign material such as iron, nickle, copper, etc. Due to the difficulty of determining this type of off-grade, reprocessing will depend on final analysis of the packaged product.

Grossly contaminated material will be sent to the scrap plant for conversion to black oxide, U_3O_8 , and reprocessed as a feed to the refinery. Material which is not grossly contaminated will be blended into the production stream as permitted by current production, through a blending system provided.

ESTIMATED UTILITY REQUIREMENTSMAXIMUM DEMAND RATE

Cooling Water	366 GPM
Process Water	80 GPM
Steam	4920 lbs/hr.
Natural Gas	16 CFM
Compressed Air	18 CFM
Electricity	3500 KVA

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EQUIPMENT LIST

<u>Item No.</u>	<u>Title and Description</u>	<u>No. of Units</u>
D4-1 to 9	Ammonia Dissociators	9
D4-10 to 19, 52 & 53	Brown Oxide Furnace (electric)	12
D4-20 to 49, 54 to 59	Green Salt Furnaces (electric)	36
D4-51	Scrubbing Tower	1
E4-6 and 7	AHF Superheater	2
E4-8	Silver Lined Partial Condenser	1
E4-9	Tempered Water Cooler for E4-8	1
E4-10	Final Condenser, AHF, -30°F	1
F4-2 and 3	Nitrogen Storage Tanks, 1500 std. ft. ³ @ 50 psig.	2
F4-6	Low Pressure Scrubber Tail Tank	1
F4-13 and 14	70% HF Rundown Tanks, Monel @ 625 gal.	2
F4-15 and 16	AHF Rundown Tanks, Steel @ 625 gal.	2
F4-17	AHF Makeup Tank, adj. 70% HF	1
F4-18	Water Make-up Tank, adj. 70% HF	1
F4-19	Tempered Water Makeup Tank	1
F4-20	KOH Recirculating Tank, High Pressure	1
F4-21	KOH Makeup Tank	1
F4-22	Low Pressure Scrubber Tail Tank	1
F4-23	Sump Tank	1
F4-24	Filtrate Holdup Tank	1
F4-26	Slug Tank, Centrifuge Feed	1

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EQUIPMENT LIST (Cont'd.)

<u>Item No.</u>	<u>Title and Description</u>	<u>No. of Units</u>
F4-39 to 48	Furnace Feed Hopper, Orange Oxide	10
F4-49 to 58, 107 & 108	Cooling Screw Feed Hopper	12
F4-59 to 68, 109 & 110	Green Salt Weigh Bins	12
F4-69	Bad Lot Storage Hopper, Low Conversion UF ₄	1
F4-70 and 71	Nitrogen Bump Tanks for Adams Blowdown	2
F4-74 and 95	Green Salt Weigh Hopper	2
F4-75 and 97	Green Salt Packaging Hopper	2
F4-76 and 77	Syntron Feed Hopper #1	2
F4-78 to 80	AHF Vaporizers Tanks	3
F4-81	HF Separator	1
F4-82	KOH Rec. Tank, Low Pressure	1
F4-83	Slurry Tank	1
F4-84 to 93, 105 & 106	Seal Hopper, Brown to Green	12
F4-98 and 99	Syntron Feeder Hopper #2	2
F4-101	Green Salt Packaging Hopper - Large	1
F4-102	Reject Dust Storage Hopper	1
F4-111	Blow Back Tank, Safety HF or AHF (liq.) collector	1
F4-103 and 104	Hopper, Brown Oxide	2
F4-112	Condensate Flash Tank	1
F4-120 and 121	Monel Hair Filters & Pads	2

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EQUIPMENT LIST (Cont'd.)

<u>Item No.</u>	<u>Title and Description</u>	<u>No. of Units</u>
G4-2	Collector for Contaminated Dust	1
G4-3	Collector for Uncontaminated Dust	1
G4-4	Collector #1 for Green Salt Packaging	1
G4-5	Collector #2 for Green Salt Packaging	1
G4-7 and 8	Collector for Unfinished-uncontaminated Green Salt Dust	1
G4-9	Green Salt Vacuum Collector	1
G4-10	Brown Oxide Vacuum Collector	1
G4-11	Hoffman Vacuum Collector, Contaminated Dust	1
G4-13	Low Pressure Scrubber	1
G4-14	Nitrogen Generator	1
G4-15	Nitrogen Compressor	1
G4-16	Nitrogen Drier	1
G4-19	Freon 22 Refrigeration Unit	1
G4-23 and 24	Tempered Water Circulating Pumps	2
G4-25	KOH Recirculating Pump, High Pressure Scrubber	1
G4-26 and 27	KOH Recirculating Pump, Low Pressure "	2
G4-30 and 31	Ball Checks for AHF Vaporizers	2
G4-32	KOH Makeup Pump	1
G4-33	L. P. Scrubber	1
G4-35	Agitator for KOH Rec. Tank, L. P. Scrubber	1
G4-36	Agitator for KOH Rec. Tank, H. P. Scrubber	1
G4-37	Recirculating Pump for L. P. Scrubber	1
G4-38	Sump Slurry Pump	1

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EQUIPMENT LIST (Cont'd.)

<u>Item No.</u>	<u>Title and Description</u>	<u>No. of Units</u>
G4-39	Pressure Filter, Enxinger Union	1
G4-40	Sluice Water Pump	1
G4-41	Slurry Pump for Filter	1
G4-42	Filtrate Effluent Pump	1
G4-44	Batch Centrifuge	1
G4-45	Packaging Centrifuge Cake	1
G4-51 to 62	Driver & Suffing Box for Furnaces, Brown Oxide	12
G4-74 to 85	Orange Oxide Hopper Discharge Screws	12
G4-104 to 115, 310 to 319, 378 & 379	2" Furnace Feed Screws	24
G4-320-355	Reactor Driver & Stuffing Box, Green Salt	36
G4-380	Gasket Tube, for Removal of Screws	1
G4-381 to 392	3" Feed Screw, for Cooling Hopper	12
G4-400 to 411	Cooling Screw, Tube, Screw & Speed Reducer	12
G4-516 to 527	Adams Filters, Filters HF from Reactors	12
G4-567 and 568	Green Salt Pulverizers	2
G4-569 and 570	Blenders, Green Salt	2
G4-589 and 590	Packaging Units, 5 & 10 gallons	2
G4-597	Agitator for KOH Makeup Tank, H. P. Scrubber	1
G4-599	Water Eductors for Sumps	5
G4-602 and 603	Roller Conveyor, Packaging Lines	2
G4-604 and 605	Electric Chain Hoists, Packaging Line	2
G4-606 and 607	Samplers, Green Salt from Blenders	2
G4-608	Agitator for Sump Tank	1

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EQUIPMENT LIST (Cont'd.)

<u>Item No.</u>	<u>Title and Description</u>	<u>No. of Units</u>
G4-609	Agitator for Slurry Tank	1
G4-652	Condensate Return Pump and Receiver	1
G4-653	Mikro Air Lock and Drive	1
G4-657	Roller Conveyor, 30 gallon packaging	1
G4-659	30 Gallon Packaging Unit	1
G4-663	Dirty Dust Blower	1
G4-664	Green Salt and Brown Oxide Blower	1
G4-672 and 673	Horizontal Rerun Conveyors	2
G4-674	Vertical Rerun Conveyor to Hopper	1
G4-675 and 676	Horizontal Conveyors, Green Salt	2
G4-677 and 678	Vertical Conveyors, Green Salt	2
G4-682 and 683	Agitators for 70% HF Rundown Tanks	2
G4-705 and 706	Blower for Leak Gases to Atmosphere	2
G4-803 and 804	Polishing Adams Filters	2
G4-711	Crane	1
G4-712 and 713	Trolley Hoists	2
G4-720	Air Driver	1
G4-731 and 732	Furnace Cooling Fans	2
G4-733	Reject Dust Drum Feeders	1
G4-734	Electric Hoist for KOH Drums and Dumper	1
G4-735	Reject Dust Packaging Unit	1
G4-736	Electric Chain Hoist for Reject Dust Pkg,	1

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EQUIPMENT LIST (Cont'd.)

<u>Item No.</u>	<u>Title and Description</u>	<u>No. of Units</u>
G4-750 to 796 & 802, 807 to 809 (exclusive of 752, 754, 757, 758, & 778 to 785)	Heating and Ventilating Equipment	
G4-800	Main Screw Extractor	1
G4-805	Blending off Grade Dust Hood	1
G4-806	Blending off Grade Chain Hoist	1
N4-1 to 4	Power Centers	4

AMF VAPORIZERS
F4-78 25FT³ EACH
F4-79 2 OPERATE
F4-80 1 SPARE

OFF GRADE MATERIAL TRANSFERRED TO RERUN UNIT BY TWO HORIZONTAL CONVEYORS RUNNING PARALLEL TO PRODUCT CONVEYORS AND DISCHARGING INTO VERTICAL CONVEYOR TO RERUN HOPPER

PACKAGING UNIT FOR GREEN SALT FROM CONVEYOR G4-676 (A BATTERY)

DUPLICATE UNIT HANDLES GREEN SALT FROM CONVEYOR G4-675 (B BATTERY)

PULVERIZER G4-568

WEIGH HOPPER F4-74

BLENDER G4-570

SAMPLER G4-606

F4-75 PACKAGING HOPPER

PACKAGING UNIT

PARTIAL CONDENSER F4-8 860 FT³

HF SEPARATOR F4-81 4'-0" X 3'-0"

AMF MAKEUP F4-17 3'-0" X 3'-0"

H₂O MAKEUP F4-18 3'-0" X 3'-0"

TO KOH SCRUBBING

TO KOH SCRUBBING

TO 1/2 HF RUNDOWN TANKS 4'-0" X 6'-0"

TO TANK FARM BLOWN BY AIR

TEMPERED H₂O MAKEUP TANK F4-19 4'-0" X 6'-6"

TEMPERED H₂O COOLER F4-9 416 FT³

FINAL CONDENSER F4-10 154 FT³

VENT INERTS TO KOH SCRUBBING

TO TANK FARM BLOWN BY AIR

TO TANK FARM BLOWN BY AIR

TO TANK FARM BLOWN BY AIR

TO TANK FARM BLOWN BY AIR

TO TANK FARM BLOWN BY AIR

TO TANK FARM BLOWN BY AIR

TO TANK FARM BLOWN BY AIR

DRAWING NO. 3004-H-27-F

PROCESS FLOW DIAGRAM GREEN SALT PLANT

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