WMCO, HISTORICAL PROCESS DESCRIPTIONS - (USED AS A REFERENCE IN OU 5 RI REPORT)

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C. A. HILL   T. R. CLARK
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MEMO
From: C. A. Hill (6554)
Date: March 8, 1989
Subject: HISTORICAL PROCESS DESCRIPTIONS
Ref: See Attached
To: T. R. Clark

The attached document has been prepared to provide a basis from which to estimate historical process emissions at the FMPC. The information presented is the result of exhaustive file searches and a large number of personnel interviews with employees (both former and current) and represents the most complete work available on the subject to the author's knowledge.

C. A. Hill
Engineer II
TRC/1ar

Att:

c: Central Files
PT Files - Process History
HISTORICAL PROCESS DESCRIPTIONS

In order to quantify airborne emissions from unmonitored sources, it was first necessary to identify the processes that operated during the FMPC's history. Many current operations have existed in some form since the FMPC initiated production in 1953. However, several production operations were only used for short periods of time and were then discontinued and the equipment dismantled. Because many of the production records were discarded under the regular disposition schedules of the AEC, a significant effort was made to re-create production flows and to determine sources of emissions. This section discusses the uranium and thorium operations which have operated throughout the history of the plant and have a probability of emitting radionuclides.

Production Process

The uranium production process (Figure 2) at FMPC begins with the purification of uranium contained in materials that are recycled from production and are received from other DOE sites. Scrap metals generated on-site or received from other sources are also refined for production. Heating the materials in a furnace is often the first step used to prepare the material for further chemical processing.

Initially, uranium oxides and uranium metal pieces are dissolved in nitric acid to produce a crude uranyl nitrate solution (UNH) for solvent extraction purification in Plant 2/3. Purified UNH is concentrated by evaporation and is thermally denitrated to uranium trioxide (UO₃). Uranium trioxide is then converted in Plant 4 to uranium tetrafluoride (UF₄) for reduction to metal. Uranium tetrafluoride is also produced in the Pilot Plant from uranium hexafluoride (UF₆) received from other DOE sites.

To begin metal production in Plant 5, UF₄ is blended with magnesium granules and placed in a closed reduction pot. The reduction pot is heated in a furnace until the contents react to produce crude uranium metal (derbies), weighing 136 to 168 kg. Some derbies are sent directly to other DOE sites; most, however, are cast into ingots at FMPC in Plants 5 or 9.
Ingots are formed by melting derbies, along with metallic scrap and briquettes recycled from earlier production and fabrications, in a graphite crucible in an induction furnace under vacuum. When the molten metal reaches the proper temperature, it is bottom poured into a graphite mold to form ingots.

Ingots vary in weight, size, and shape according to how they will be used. Since the late 1960s, all cylindrical ingots have been center drilled at FMPC and sent offsite for extrusion (the process of forming metal into tubes). Most of these extruded tubes are returned to FMPC for heat treatment and final machining in Plant 6 before they are shipped to other DOE facilities.

Current Processes

The following processes are used to produce uranium and to process waste materials. Most of them have been in operation since the beginning of production operations in the early 1950’s.

UO₃ Gulping, Conveying, and Packaging: Plant 2/3.¹ When denitration of a pot charge has been completed, the operator inserts a vacuum gulping tool into the pot and opens the slide valve (Figure 3). UO₃ is carried through the vacuum header to cyclone separators where the bulk of solids will drop out. Solids not separated in the cyclones are removed by scrubber acid fed into a blower and then to a final venturi-jet scrubber before being exhausted to the atmosphere.

Nitric Acid Recovery System: Plant 2/3.² The nitric acid recovery system collects nitrogen oxide fumes from the uranium metal dissolver, ore concentrates and recycle residue digestors, and denitration pots located in Plant 2/3.

In the normal mode of operation, these fumes together with ventilation air in-leakage are drawn by a blower (Figure 4) into the bottom of and through absorber tower D3-12 (east), and then into the bottom of and through absorber tower D3-13 (west). The gases flow upward through 27 bubble-cap trays in each absorber tower where they are contacted by a downward flow of recirculated water (west tower) and weak nitric acid (east tower). A major portion of the...
Figure 3. Plant 2/3 UO₃ Gulping - Packaging System
nitrogen oxide is absorbed in the liquid phase, and the final tail gas from the west absorber is mixed in a ventilation stack with a large volume of air which is discharged into the atmosphere. A nitrogen oxide analyzer samples and analyzes the gas stream at the following points:

1. Upstream from the blower (east absorber feed gas)
2. East absorber tail gas (west absorber feed gas)
3. West absorber tail gas
4. Diluted gases in the ventilation stack (to atmosphere).

UF₆-UF₄: Pilot Plant.³ The reduction of UF₆ to UF₄ (6-4) is brought about by mixing UF₆ with hydrogen in the form of dissociated ammonia in the top of a tubular reactor (Figure 5). A UF₆ cylinder is heated in an autoclave (which is an ASME approved pressure vessel) so that the UF₆ sublimes to a gas to react with hydrogen. The UF₆ gas is introduced to the process by a connection called a pigtail inside the autoclave. The UF₆ to UF₄ reaction vessel heats the reactant gases to induce ignition, and then proceeds with the evolution of a large quantity of heat. The reactor itself consists of a vertical tube approximately 20 feet long. At the bottom of the tube, the product falls into a water-jacketed cooling screw conveyor with a water-cooled shaft. From here the offgas is disengaged and the product travels through a series of transport screws, mills, and valves to be packaged in drums. The offgas, consisting of excess hydrogen, nitrogen, hydrogen fluoride, small quantity of UF₄ particulates, and possible trace quantities of unreacted UF₆, passes through two cyclones in tandem and two sintered metal filters in series to remove UF₄ particulates, a carbon trap to remove any unreacted UF₆, a two-stage refrigerated condenser system to collect anhydrous hydrofluoric acid, and a water scrubber to further remove traces of HF as dilute (aqueous) hydrofluoric acid prior to being vented to atmosphere.

Scrap Pickling: Plant 6 (1953-Present).⁴ Uranium metal, such as scraps, rejected cores and rod ends, are pickled in nitric acid to remove oxide contamination and uranium-daughter products that have accumulated on the surface. The scrap is cycled through a degreasing tank, a nitric acid tank and two water rinse tanks. After being pickled, the scrap metal is returned
to the production stream via the remelt processes, which are monitored emissions sources located in Plants 5 and 9 (Figure 6).

The scrap pickling process is operated three shifts per day, five days per week. Typical current production is 5,318 kilograms per shift.

The scrap pickling process has one emission source—the exhaust stack that ventilates the pickling tank and the two wash tanks. Exhaust from the stack was sampled and an emission factor developed as part of the study conducted in July 1988.3

Briquetting: Plant 6 (1953-Present).5 Scrap uranium chips and turnings (from machining) are degreased in detergent, pickled in nitric acid, then dried and pressed into briquettes which are recycled into the remelt process (Figure 7).

Typical production from the Plant 6 briquetting process was 6,818 kilograms of uranium per eight hour day in 1987. In a typical week, briquetting is operated one shift per day, one day per week.

Three emission sources exist in the briquetting process: the exhauster from the crusher area and chip washing (minimal emissions), the dryer centrifuge exhaust (minimal exhaust), and the HNO₃ pickling tank exhaust (these emissions have been sampled and an emission factor has been developed).

Recovery Plant: Plant 8. Scrap metal and residues are generated in each of the production plants at the FMPC. The pure uranium-metal pieces are generally recycled in the casting plants, but the impure metal and residues are sent to the Recovery Plant for processing. Figure 8 shows the origin of the recycle metal and the residues at the FMPC.6

High grade residues such as machining chips and turnings are processed in automatically rabbled furnaces. There the metallic uranium particles are burned to U₃O₈. A vibrating screening operation separates the +8 mesh (U.S. standard) fraction which contains most of the unoxidized metal to be recycled for further oxidation. The -8 mesh fraction is drummed as product and sent to
Plant 2/3. The furnaces are vented to caustic scrubbers and the screening operation is vented to a monitored dust collector. Figure 9 shows the flow diagram of this system. The scrubber stack emissions have recently been sampled using a modified EPA Method 5 sampling train to develop an emissions database for individual feed materials.

Low-grade residues, such as sump cakes, floor sweepings and dust collector residues are also processed through automatically rabbled furnaces which vent to Venturi-type scrubbers. Figure 10 shows the flow diagram of this system.

Emissions from the oxidation furnaces, the box furnace, the rotary kiln and the primary calciner were reported in FMPC-2082 and in the Annual Environmental Monitoring Reports based on factors developed during stack sampling tests for years after 1980. Prior to 1980 the emissions were estimated based on scrubber liquor sample results and an assumed 83 percent efficiency.

Oxidation Furnace No. 1. The Oxidation No. 1 furnace is a six-hearth, automatically rabbled furnace with a total hearth area of 85 square feet. It is used to oxidize high grade scrap such as uranium metal fines and "sawdust" from metal machining operations to U₃O₈. The U₃O₈ is feed for the Plant 2/3 digestion system.

Typical annual production from Oxidation No. 1 is 12 metric tons of uranium per month. This is a current production rate; no historical production records are available.

Offgas from the furnace passes through a venturi-type water scrubber before being discharged to the atmosphere. (See Figure 11 for flow diagram.) A monitored dust collector provides ventilation for the feed tray and packaging station.
The Oxidation No. 2 furnace is a six-hearth furnace most recently used to convert uranium tetrafluoride to calcium uranate and calcium fluoride using calcium hydroxide (lime). Originally, it was used to oxidize dust collector residues and to reoxidize scrap or impure $U_3O_8$ to $U_3O_8$ which could be used as refinery feed.

No production records are available.

Combustion gases from the furnace passes through a cyclone separator and a water scrubber before being exhausted to the atmosphere. A monitored dust collector provides ventilation for the bucket elevator, cyclone separator, and product packaging station.

The Primary Calciner is an eight-hearth automatically rabbled furnace used to process low grade residues.

No production records are available.

Offgas from this furnace passes through a venturi-type scrubber before being exhausted to the atmosphere. A monitored dust collector ventilates the packaging station.

The Rotary Kiln consists of a 45 foot steel cylinder lined with refractory bricks which are backed by insulating blocks (Figure 12). The kiln was used to process low-grade residues such as nonbriquettable turnings and pyrophoric finely-sized residues. Currently the kiln is used to dry waste materials before they are shipped offsite for burial.

Wet materials are fed to the kiln from a feed tray into a chute equipped with a valve operated by a foot lever, whereas dry materials are fed by means of a drum dumper and feed screw. The rotation and incline of the kiln causes the material to move from the feed end to the exit end, where it is discharged into a water-cooled screw conveyor which conveys the material to a packaging station. Materials passing through the kiln are dried, roasted, or oxidized depending upon the characteristics of the feed materials and the desired product.
Typical current feed to the rotary kiln is 77.3 metric tons of uranium per month.

Exhausts containing entrained dust, water vapor, and other volatiles are passed through a cyclone separator to remove the dust and then through a venturi-type scrubber with a 10% caustic solution. A monitored dust collector ventilates the drum dumper, feed tray, breach chamber packaging station, and the product packaging station. Dusts from the cyclone and dust collector are discharged into the dry feed dumping station for recycle.

**Box Furnace.** The Box Furnace is of a refractory-lined steel fire-box, and is fed in batches and rabbled (furnace contents are agitated to ensure complete combustion) manually until the charge is completely oxidized. After oxidation is complete, the furnace charge is manually transferred into a product drum. The Box Furnace is used to oxidize gloves, filters, rags, and other contaminated burnables to recover their uranium content, as well as to oxidize miscellaneous metallic scrap to $U_3O_8$.

Currently, the Box Furnace produces one kilogram of uranium per month due to the low uranium content of the feed material.

A venturi-type water scrubber provides exhaust ventilation for the furnace charging port, the furnace off-gases, and the product drumming station (Figure 13).

**Drum Washer.** Drums which are in good condition are washed so that they can be reused in the production process. The drum washing unit is a turntable which indexes over rinsing and washing stations inside a metal enclosure. Rinse and wash waters are directed through jets by two pumps to supply the cleaning action. A sodium hydroxide solution or equivalent is used in the wash cycle.

Typical throughput for the drum washer is 1,250 drums per month.

The enclosure is exhausted directly to the atmosphere.
Figure 13. Equipment Diagram Plant 8 Box Furnace
The Zirnlo process is used to remove zirconium, copper, nickel or aluminum cladding from the surface of rejected cores by digesting the cladding in hydrofluoric acid, nitric acid or caustic. This process was also used to dissolve uranium metal. Currently, it is used to pickle derbies to remove salt residues, potassium carbonate and lithium carbonate, left by the salt cleaning process (Figure 14).

Typical production rates are available only for current derby pickling. Sixty-four derbies are pickled during an average shift. Zirnlo is operated two shifts per day, five days per week.

Each of the acid tanks used in the Zirnlo process has an exhaust stack with a blower. Recent EPA Method 5 sampling tests have been performed on the exhaust from the nitric acid tank and an emission factor has been developed.

Decontamination and Decommissioning: (1958-Present). Process equipment and other miscellaneous material which are to be decontaminated are dipped into either a hydrochloric acid, nitric acid or caustic bath to remove radioactive surface contamination (Figure 15).

Typical production is twelve batches per week with a batch defined as an item or group of items which are placed into the bath together.

Two emission sources exist in decontamination and decommissioning: the stack that vents the two hydrochloric acid tanks, and the stack which vents the nitric acid and caustic tanks.

Historical Processes

This section describes processes which are no longer in operation at the FMPC and in many cases the processing equipment has been removed. Included in this section are descriptions of thorium processes and uranium processes which have been replaced by newer equipment or whose product is no longer required.
Thorium Processes

Thorium was processed at the FMPC throughout much of the history of the site. The demand for various thorium materials fluctuated greatly and the FMPC developed or modified processes to meet these varying requirements. During different periods, thorium was processed through Plants 2/3, 4, 8, 9, and the Pilot Plant.

Thorium Metal: Plant 9 (1954-1955). Thorium metal was produced in Plant 9 from 1954 through 1955. The process began with the dissolution of solid thorium nitrate tetrahydrate in nitric acid. Hydrofluoric acid was then added to the solution to precipitate a wet thorium tetrafluoride (ThF₄). The ThF₄ was dried in a predryer, a retort dryer and then was pulverized. The pulverized ThF₄ was blended with calcium metal and zinc chloride and placed in a refractory lined furnace pot. Thorium tetrafluoride was co-reduced by the calcium to form a zinc-thorium derby which was then dezinced and remelted in a vacuum furnace. The resulting 500 kilogram thorium metal ingot was machined to produce the final thorium metal product.¹⁵

The thorium chips and turnings produced by the machining process were washed in a nitric acid wash and dried. The cleaned chips were pressed into briquettes which were returned to the production process via the remelting process.

Production quantities are not available for thorium metal production or thorium briquetting in Plant 9. A process flow diagram (Figure 16) has been prepared to illustrate locations of possible emissions from the process. A total of 380 metric tons of thorium are estimated to have been produced by this process.

Three likely locations for unmonitored thorium emissions were the dissolution of thorium nitrate tetrahydrate, the precipitation of ThF₄, and the acid wash of the thorium metal chips. Records indicate that the dissolving tank vented directly to the atmosphere, the precipitation tank vented to an absorber of some type and the acid wash of the chips vented through a dust collector.
Thorium Tetrafluoride: Plant 4 (1954). This process began with the dissolution of solid thorium nitrate tetrahydrate in Plant 9 and then precipitation of thorium oxalate with oxalic acid. The thorium oxalate was filtered, dried and calcined to thorium oxide (ThO_2) in Plant 9. The dried ThO_2 was transported to Plant 4 and hydrofluorinated to produce dry ThF_4 in hydrofluorination Bank 7. The ThF_4 was returned to Plant 9 and used to produce thorium metal. This process took place during 1954 and was a short duration process due to mechanical difficulties in Bank 7.

Production quantities are not available for ThF_4 production in Plant 4. Because of the problems encountered, it is believed that this process was only operated for a short period and hence the potential for emissions was very slight. A flow diagram has been prepared to illustrate locations of possible emissions from the process (Figure 17).

The likely sources of emissions are the dissolution and precipitation tanks and the calciner in Plant 9. It was assumed that the calciner vented through a wet scrubber as all current-day calciners at the FMPC do.

Thorium Digestion and Extraction: Pilot Plant (1964-1980). Thorium ores, crushed thoria pellets, thorium oxalate and other thorium materials were processed through the Pilot Plant thorium digestion and/or extraction system from approximately 1964 through 1980. These systems were used to produce a purified thorium nitrate solution that could be used as feed for other thorium production streams. Purified thorium nitrate solution was also shipped as product. The digestion and extraction systems were not used continuously during the time period they were in service. Some years, the systems achieved throughput rates as high as one ton per day of purified thorium nitrate solution; other years they operated periodically or not at all.

Available production records indicate that 790.4 metric tons of thorium in the form of purified thorium nitrate solution were produced from 1966 to 1973. No production records have been located for other years of operation. No production data is available for the digestion system.
Figure 17. Plant 9/Plant 4 Thorium Tetrafluoride Process Flow Diagram

- Catcher
- Drier
- Filtration
- Cooling
- Dissolution & Precipitation Tank
- Solid Thorium Nitrate
- Tetrahydrate [(Th(NO₃)₄·4H₂O)]
- ThO₂ to Plant 4
- Bank 7 Hydofluorination
- ThF₄

Oxalic H₂O HNO₃ Acid

Plant 9 1954

Suspected Unmonitored Emission Source
The extraction system did not contain any sources of significant thorium emissions. The digestion system, however, consisted of a large tank into which the material to be digested was dumped. No feed tray or other feed system was used. Emissions produced during the digestion were either vented through a packed tower scrubber or vented directly to the atmosphere. Information obtained during interviews with long-time employees did not definitely establish whether a scrubber was used.

Thorium Gel Preparation: Pilot Plant (1964-1970). Purified thorium nitrate solution was the feed material for the thoria gel process (Figure 18). Carbon dioxide and aqueous ammonia were added to the thorium nitrate tetrahydrate solution to cause thorium hydroxide to precipitate from the solution. The thorium hydroxide was then slurried with water and aqueous ammonia, filtered on a plate and frame filter, and dried in a shelf dryer. The dried thoria gel (thorium hydroxide) was packaged and shipped to another location for calcining and the final thorium oxide product was shipped to the customer.

Production records indicate that 492 metric tons thorium as thoria gel were produced from 1966 to 1970.\textsuperscript{16} Production for 1964 and 1965 was estimated based on a linear extrapolation of the quantity produced in 1966 through 1970.\textsuperscript{6} The estimated total production from this process is 686 metric tons assuming linear production from 1964-1970.

The thoria gel production process contained three sources of potentially significant emissions. The precipitation tank was vented either through a water scrubber or directly to the atmosphere; the records are unclear. The shelf dryer was vented to a venturi-type water scrubber. The plate and frame filter was a dusty operation and produced thorium emissions inside the building.

Thorium Nitrate Tetrahydrate Crystal Production: Pilot Plant (1966). Thorium nitrate tetrahydrate crystals were produced during a short-term test by use of a Sandvik Water Bed Conveyor. Purified thorium nitrate tetrahydrate solution was boiled in a tank to a defined concentration. The molten salt was
fed onto a water cooled conveyer where it crystalized, and product was drummed at the end of the conveyer.

A total of 425 kilograms of thorium as thorium nitrate tetrahydrate crystals was produced during the test of the Sandvik Water Bed Conveyor.\textsuperscript{17}

The only potential source of emissions from this process was the boildown tank. However, the short duration of this campaign would limit the amount of emissions produced.

\textbf{Thorium Metal Production: Pilot Plant (1969-1971).} Thorium metal was produced in the Pilot Plant using a modification of the process used in Plant 9 in the 1950's. The precipitation process for production of dense crystalline thorium tetrafluoride was altered to produce a ThF\textsubscript{4} that would filter more easily and wash more efficiently. Zinc fluoride was used instead of zinc chloride in the reduction of ThF\textsubscript{4} to thorium metal. The by-product of the reaction was calcium fluoride which was used to line the furnace pot instead of using a refractory liner. The metal quality was significantly improved by this change.\textsuperscript{18}

Thorium tetrafluoride was precipitated by adding hydrofluoric acid to the thorium nitrate tetrahydrate solution. The ThF\textsubscript{4} was filtered on a pan filter, dried in a shelf predryer, and redried in a retort vessel in a furnace. The dried ThF\textsubscript{4} was milled and blended with calcium metal and zinc fluoride. An argon gas purge was maintained on the blender to prevent the buildup of hydrogen gas due to the reaction of calcium metal with moisture in the ThF\textsubscript{4}. The blended charge was placed in a furnace to reduce ThF\textsubscript{4} to thorium metal. The resulting zinc-thorium derby was placed in a dezincing furnace in which the zinc was boiled off. The thorium derby was cleaned and sawed to produce a final thorium metal product.

Production records indicated that 809 thorium derbies were produced by this process weighing approximately 51 metric tons of thorium metal.\textsuperscript{19}

The possible significant sources of thorium emissions from this process are the precipitation tank and the shelf predryer. The precipitation tank vented
to packed tower water scrubber. The shelf dryer consisted of a drying oven with several shelves onto which trays of wet thorium tetrafluoride were placed and dried for twenty-four hours. Emissions from the shelf dryer were vented to a caustic wet scrubber. The 1969 temporary operating procedure located for the shelf dryers stated that the wet scrubber was not to be used; the blower was turned on, but the caustic recirculation system was not used. However, a later report issued described the use of the scrubber during operation of the shelf dryer. For the purpose of calculating emissions, a scrubber was assumed to have been used.

Thorium Oxalate: Pilot Plant: (1971-1976). Thorium oxalate was produced by a precipitation process. Oxalic acid was added to purified thorium nitrate tetrahydrate solution to form a wet thorium oxalate precipitate which was filtered on a plate and frame filter. After filtering, the thorium oxalate was packaged and shipped to another location for calcining to thorium oxide.

Production records for this process were located for the duration of the operation. A total of 153 metric tons of thorium as thorium oxalate were produced.²⁰

Two possible significant thorium emission sources existed on the thorium oxalate system. The make-up and the precipitation tanks used in the production of thorium oxalate were vented to a packed tower water scrubber. The plate and frame filter had an exhaust hood to minimize dust emissions produced during filtering. Despite the exhaust hood to ventilate the plate and frame filter, it was a reported source of thorium emissions to the building.

Thorium Gel: Pilot Plant (1977-1979). When the need for thorium materials decreased to a level at which no further production was required, a means of stabilizing the remaining thorium nitrate was developed. The process (Figure 20) was similar to that used earlier to produce thoria gel. Carbon dioxide and aqueous ammonia were added to thorium nitrate solution to cause thorium hydroxide to precipitate from the solution. The thorium hydroxide was slurried with water and aqueous ammonia, filtered on a plate and
frame filter and dried in a shelf dryer. The dried thoria gel (thorium hydroxide) was packaged into drums for storage.

Production records indicate that 350 metric tons of thorium as thoria gel were produced by this process for storage.21

The thoria gel production process contained three potential sources of emissions: the precipitation tank vented to a water scrubber, the shelf dryer vented to a venturi-type wet scrubber, and the plate and frame filter.

Thorium Production Plant Test: Plant 2/3 (1968). Few details are available regarding this process (Figure 19). Thorium nitrate crystals were produced in a denitrination pot in Plant 2/3. Interviews with long-time employees indicated that this was a short-term operation, probably one pot of crystals was produced. Other records discuss the production of thorium oxide in Plant 2/3 by a process of denitration, redigestion and drying.

This plant test is of interest because the gulping system was used to remove thorium nitrate tetrahydrate crystals and thorium oxide from the denitrination pot. The gulping system is a major contributor of emissions for the uranium stream. However, due to the short duration of the test, thorium emissions from Plant 2/3 are considered negligible.

Thorium Hydroxide Production: Plant 8. Thorium hydroxide was produced in Plant 8 for six months during 1966 in the reversion system. Thorium tetrafluoride was reverted to thorium hydroxide by heating it in a reverter tube with hydrofluoric acid. The offgas from the reverter was neutralized in a caustic scrubber.

Approximately 59 metric tons of thorium in the form of thorium hydroxide were produced by this system.17

The offgas scrubber was assumed to be the only possible source of thorium emissions.
Figure 19. Thorium Production Plant Test Flow Diagram - Plant 2/3
Figure 20. Pilot Plant Thoria Gel Process Flow Diagram
Thorium Residue Recovery: Plant 8 (1969-1971). Various thorium residues were processed to thorium hydroxide in order to return them to the production stream (Figure 21). Residues were digested in hydrochloric acid and the solution was filtered on a rotary vacuum filter. The filtrate was pumped to a precipitation tank and mixed with oxalic acid. Thorium oxalate precipitated out of solution. The thorium oxalate precipitate was filtered, slurried, and reverted with sodium hydroxide solution to thorium hydroxide. The thorium hydroxide was filtered on a rotary vacuum filter and the solution was recycled back to the precipitation tank. The filter cake was calcined in a multiple hearth furnace called the uranium ammonium phosphate (UAP) furnace. The dried thorium hydroxide was digested in the Pilot Plant digestion system.

Approximately 310 metric tons of thorium as thorium hydroxide were produced through the Plant 8 oxalate system.\(^{17}\)

Possible sources of emissions from the oxalate system are the digestion tanks which vented to the atmosphere, the oxalate precipitation tanks which vented to a packed tower water scrubber, the pan filter which vented to a packed tower water scrubber, and the UAP furnace which vented to a venturi-type scrubber.

Uranium Processes

Residue Recovery Operations: (Plant 8). Construction of the Recovery Plant (Plant 8) was completed in July 1953 with production beginning in November of the same year. The main purpose of the Recovery Plant was the quick return of uranium to the production stream where it was urgently needed. In about 1963, when the supply of uranium became adequate, low-grade residues were processed to reduce the amount stored in drums.

The individual processes in the Recovery Plant for converting the impure metal scrap and low-grade residues included hydrometallurgical and miscellaneous operations.\(^{17}\)

Emissions from the oxidation furnaces, the box furnace, the rotary kiln and the primary calciner were reported in FMPC-2082 based on factors developed.
during stack sampling tests. These factors were applied to historical operations by linear extrapolation based on production rates.
Figure 21. Thorium Residue Recovery Process Flow Diagram
Ammonium Diuranate and Uranium Ammonium Phosphate Processes. These systems were used for recovering uranium from low-grade residues. The two main components of the system were feed preparation and processing and calcining to ammonium diuranate (ADU) and uranium ammonium phosphate (UAP) product. There were three venturi-type caustic scrubbers on these systems. The ADU process operated from 1955 to 1957 and from 1967 to 1971. The UAP process operated from 1958 to 1967. Figure 22 shows that the flow sheet of the UAP process differed from the ADU process only in that phosphoric acid was also fed into the precipitator tank in the UAP process; the soda salt conversion step was by-passed, and product handling equipment was installed so that the wet UAP product could be packaged into drums.

Production of UF₄ by Aqueous Precipitation (WINLO). The WINLO Process (Figure 23) was started in August 1962 and operated until April 1964. This process was used as a means of returning relatively pure, high assay enriched materials to the production stream without refining. Due to mechanical problems, which caused the WINLO process to be in operation only 50 percent of scheduled operating hours, the process was shut down.

The precipitator vented to a venturi-type caustic scrubber while the Holoflite dryer and filter vented to a packed-tower water scrubber.

Muffle Furnace. The muffle furnace was a single hearth rabbled-type furnace. Two monitored dust collectors were used for ventilation of the furnace system. Off-gasses from the furnace passed through a cyclone separator and then to a caustic scrubber before being exhausted to the atmosphere.

Metal Dissolver. From about 1955 until 1959, massive metal pieces in batches of about 2,500 pounds were dissolved in a hydrochloric acid solution. The equipment consisted of two 2,500 gallon wooden dissolver tanks which
Figure 22. Recovery of Uranium from MgF₂ Slag by Uranyl Ammonium Phosphate Process Plus the Soda Salt Process - Plant 8
operated in the Plant 8 Metal Dissolver. The acid solution was heated to approximately 180°F. The tanks were open and vented to the atmosphere.

**UF₆-UF₄: Plant 7 (1954-1956).** Uranium hexafluoride was reduced to uranium tetrafluoride with dissociated ammonia in a process similar to current Pilot Plant UF₆-UF₄ operations.

The UF₆ to UF₄ process in Plant 7 was similar to the current Pilot Plant process described in the section on current processes except that steam chests, rather than autoclaves were used to vaporize the UF₆. Because the steam chests were not pressure vessels, it is possible that they were a potential source of emissions. The probability that this steam was contaminated with UF₆ is extremely low since the UF₆ cylinders are pressurized. There are no reported incidents of a cylinder rupture in a steam chest; therefore, the only potential source for uranium contamination is a pigtail leak. Typically such leaks do not release significant amounts of UF₆ (less than 0.5 lb.). Most of the material released in this manner would react with the steam to form UO₂F₂ and would only be released to the atmosphere via steam in trace quantities. This type of incident is considered in the discussion of building exhausts.

**Core Pickling: Plant 9 (1961-1963).** This process is assumed to have been analogous to current pickling operations. The cores were pickled in a nitric acid bath and rinsed with water.

Production records are unavailable for the core pickling process. In order to estimate the emissions from this operation, production quantities were estimated based on known quantities of metal produced in Plant 9 and the ratio of material pickled to material produced during those years for which data was available.

Assumed emission sources were the exhaust stacks from the acid tank.

**Briquetting Uranium and Thorium: Plant 9 (1953-1963).** Thorium and uranium metal chips and turnings were processed in the Plant 9 Briquetting process. Chips and turnings were washed in an acid bath, assumed to be nitric...
acid, rinsed in two water baths and pressed into briquettes. Briquettes were returned to the process stream via the remelt cycle.

No production data is available for this process. In order to estimate the emissions from this operation production quantities were estimated based on known quantities of metal produced in Plant 9 and the ratio of material briquetted to material produced during those years for which data was available.

Two assumed sources of emissions from this process were the vent from the acid bath and the exhaust air from the dryer.

**Box Furnace: Pilot Plant (1956-1961).** A box furnace was installed at the Pilot Plant in 1956 to process U₃O₈, enriched uranium turnings, "sawdust" and other residues generated in the production of enriched cores.⁶

No production data is available for this process.

The exhaust air from the furnace is a probable source of radionuclide emissions.
References

7. Oxidation Furnace No. 1, SOP 8-C-207, FMPC, September 12, 1983.