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Evaluation of Environmental Control Technologies for Commercial Uranium Nuclear Fuel Fabrication Facilities

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CONTENTS

EVALUATION OF ENVIRONMENTAL CONTROL TECHNOLOGIES FOR COMMERCIAL URANIUM NUCLEAR FUEL FABRICATION FACILITIES

by

B. L. Perkins

ABSTRACT

At present in the United States, there are seven commercial light-water reactor uranium fuel fabrication facilities. Effluent wastes from these facilities include uranium, nitrogen, fluorine, and organic-containing compounds. These effluents may be either discharged to the ambient environment, treated and recycled internally, stored or disposed of on-site, sent off-site for treatment and/or recovery, or sent off-site for disposal (including disposal in low-level waste burial sites). Quantities of wastes generated and treatment techniques vary greatly depending on the facility and circuits used internally at the facility, though in general all the fluorine entering the facility as UF_6 is discharged as waste. Further studies to determine techniques and procedures that might minimize dose (ALARA) and to give data on possible long-term effects of effluent discharge and waste disposal are needed.

CHAPTER I

INTRODUCTION

A. Report Objectives

As part of the evaluation of effluent/wastes relating to the nuclear fuel cycle, the objectives of this report are to determine the process discharge streams produced by uranium fuel fabrication facilities, to determine how these streams are presently treated, to collect any publicly available emission and monitoring data, to identify the final fate of these wastes, and to assess the adequacy of present waste treatment/disposal techniques and available data.

B. Background Information

1. Nuclear Fuel Cycle for Commercial Reactor Operations

Nuclear fuel fabrication facilities are a necessary component in the production of uranium fuel for commercial light water reactors.

Steps in the front end of the fuel cycle include

(a) Mining

Recovery of uranium from the host material by conventional mining, by *in situ* techniques, or as by-product recovery.

(b) Milling

Concentration of the uranium in the mined ore to a "concentrate" containing approximately 70-75% uranium.

(c) Conversion to UF_6

Removal of the uranium from the concentrate and chemical conversion of the uranium into the compound UF_6.

(d) Enrichment

Separation of the $^{235}UF_6$ and the $^{238}UF_6$ gases to produce a UF_6 product stream containing slightly more $^{235}UF_6$ than in the original feed stream.

(e) Fuel Fabrication

Chemical conversion of the slightly "enriched" UF_6 to UO_2 powder, production of pellets from the powder, and assembly of the pellets into fuel rod bundles.

2. Uranium Fuel Fabrication Facilities

As shown in Table I-1, there are presently seven commercial light-water reactor fuel fabrication facilities in the United States. Three of these facilities, Exxon's Richland, Washington, facility; General Electric's Wilmington, North Carolina, facility; and Westinghouse's Columbia, South Carolina, facility, complete the UF_6 conversion-fuel bundle assembly sequence. Four of the

TABLE I-1

CURRENT LWR FUEL FABRICATION INDUSTRY

Licensee and Plant Location	Plant Feed Material	Plant Product	Plant Capacity (MtU/yr) Current	Estimated 1985
Babcock & Wilcox Lynchburg, Virginia (2)[a]	UO_2 pellets (UF_6)	Fuel assemblies	230	830 [b]
Babcock & Wilcox Apollo, Pennsylvania (1)	UF_6	UO_2	c	
Combustion Engineering Hematite, Missouri (3)	UF_6	UO_2	d	
Combustion Engineering Windsor, Connecticut (1)	UO_2 powder	Fuel assemblies	150	150
Exxon Nuclear Richland, Washington (5)	UF_6	Fuel assemblies	665	1030 [e]
General Electric Wilmington, North Carolina (2)	UF_6	Fuel assemblies	1500	1500
Westinghouse Electric Columbia, South Carolina (2)	UF_6	Fuel assemblies	750	1600

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[a] NRC Region number.

[b] Babcock and Wilcox (B&W) plans to expand operations to increase capacity to 1200 MtU/yr in the early 1990s. The capacity listed in the table for 1985 is an interpolation of present and future capacity. In addition, a UF_6 to UO_2 conversion operation will be added as well as a UO_2 pelletizing operation.

[c] Currently, the B&W Apollo plant converts UF_6 to UO_2 powder and ships the UO_2 to its Lynchburg plant for fabrication into fuel assemblies.

[d] The Combustion Engineering (CE) Hematite plant produces UO2 (pellets or powder), which is then transferred to the CE Windsor plant for fabrication into fuel assemblies.

[e] Expanded to 1030 MtU/yr in 1980.

Source: NUREG-0782

facilities complete only a portion of the process steps: Combustion Engineering's Hematite, Missouri, facility converts UF_6 to both UO_2 powder and fuel pellets, which are then processed, in the several different operations necessary, into the final fuel bundle assemblies at Combustion Engineering's Windsor, Connecticut, facility; and Babcock and Wilcox's Apollo, Pennsylvania, facility converts UF_6 to UO_2 powder, with the production into fuel bundle assemblies being completed at Babcock and Wilcox's Lynchburg, Virginia, facility. These facilities may or may not have associated scrap recovery operations.

These facilities will be described briefly in the following section.

C. Fuel Fabrication Facilities

1. Babcock and Wilcox, Apollo, Pennsylvania

Babcock and Wilcox operate a facility at Apollo, Pennsylvania, to convert low-enriched (less than 5% ^{235}U) UF_6 into uranium oxide (UO_2) powder. The ammonium diuranate (ADU) "wet" process is used.

The uranium hexafluoride is received at the plant in cylinders containing approximately 1535 kg of uranium. These cylinders are placed in steam chests and heated to obtain the desired operating pressure. The gaseous UF_6 is metered to a hydrolysis column where it is contacted with water, forming a uranyl fluoride solution. This solution is metered to precipitation vessels. In these vessels, the UO_2F_2 is mixed with NH_4OH, forming the solid ADU. The ADU is separated from the ammoniacal liquor by filtration. The wet cake is dried, calcined to U_3O_8, reduced to UO_2, blended, packaged, and shipped to the customer.

Associated with the facility is a scrap recovery operation for recovering the uranium values from the various scrap forms. The process uses nitric acid as the primary process chemical, and the purified product is generally uranyl nitrate solution. The uranium is then converted to the oxide by the ADU process* (EDASMP, 1975, and EELECRPL, 1976).

The gaseous effluents are treated by filtration and/or scrubbing before discharge to the ambient air** (EDASMP, 1975).

Contaminants in the untreated liquid effluent/waste streams include nitrogen compounds (ammonia), organics, fluoride compounds, and uranium (EDASMP, 1975).

The barren liquid remaining after ADU filtration and the liquids from the scrubbers are combined and treated with 8-hydroxy-quinoline (8-OH) to precipitate the formerly soluble uranium remaining in the liquid solutions. After treatment, the liquids are filtered in a plate-and-frame filter to remove the uranium.***

The ADU system filter is a slurry filter belt and requires a vacuum. The vacuum is achieved by condensing steam. The steam condensate joins the 8-OH treated and filtered liquids, and the ammonia is removed using a steam strip.† The liquids (which will contain the fluorine that entered the plant in the UF_6 plus organics, including 8-OH, and nitrogen compounds) are then discharged to the river. In April 1980 a bioassay by EPA of the plant's liquid discharge into the Kiskiminetas River showed the effluent to be very toxic (EPA Memo 1980).

2. Babcock and Wilcox, Lynchburg, Virginia

Feed into the Babcock and Wilcox Commercial Nuclear Fuel Plant is in the form of low-enriched uranium (UO_2) powder from the Apollo facility. The powder is blended and pressed into fuel pellets, which are sintered in a reducing atmosphere and ground to the specified size. The pellets are loaded into fuel rods, which are then assembled into fuel bundles for delivery to light-water reactors (LWRs).

The plant occupies 25 acres of a 525-acre site located in a rural region of Campbell County near Lynchburg, Virginia. The 525-acre site also houses the Naval Nuclear Fuel Division and the Lynchburg Research Center.

All off-gases that might contain uranium particulate are passed through prefilters and HEPA filtration. Off-gases from the reduction (sintering) furnaces are flared in addition to undergoing filtration.

Liquid wastes from cleaning and etching operations (there are no plating operations) are sent to the Naval Nuclear Fuel facility for recycling. Zirconium machining chips are also sent to the Naval facility for recovery. In addition, sanitary wastes are sent to the Naval facility for treatment.

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*This information provided by M. A. Austin, Babcock and Wilcox, July 1981.

**This information provided by H. W. Crocker, NRC, June 1981.

***This information provided by Chris Del Signore, Babcock and Wilcox, July 1981.

†This information provided by H. W. Crocker, NRC, June 1981.

Liquid contaminated with uranium during the pellet grinding operation is centrifuged to remove the uranium, and the water is recycled. The recovered uranium is dried and recycled back into the process. Small acidic waste streams are neutralized before discharge to the James River. Mop water and other small effluent streams containing uranium are treated through pH adjustment to separate the solids before the decantate is discharged.

Clean (that is, nonchemically contaminated) scrap may be treated and recycled to the blender. Dried uranium-containing sludges, along with other chemically contaminated scrap, prefilters, and contaminated oils, are sent to Apollo for treatment and recycle or disposal. (It should be mentioned that HEPA filters are seldom replaced, as the prefilters are extremely effective in particulate removal from the off-gas streams.)

Contaminated solid wastes are disposed of by a licensed contractor. Uncontaminated solid wastes are sent to the Lynchburg sanitary landfill (EIA, BWCNFP).

3. Combustion Engineering, Inc., Hematite, Missouri

Combustion Engineering (CE) operates the facility at Hematite, Missouri, to convert low-enriched UF_6 into UO_2 powder and fuel pellets for shipment to the CE Windsor facility. This facility is discussed in detail in Chapter II.

4. Combustion Engineering, Inc., Windsor, Connecticut

The Combustion Engineering fuel fabrication facility is located on approximately 38 acres of a 556-acre tract in a rural region of woods and open fields near Windsor, Connecticut.

The facility receives UO_2 powder from the CE Hematite plant. Process operations in the Windsor plant include powder blending, pellet pressing, dewaxing, sintering, grinding, stacking and drying, fuel rod loading, and fuel bundle assembly (EIA, CE, 1974).

All off-gases that might contain uranium pass through filters.* The off-gases, which contain excess hydrogen, from the reduction furnaces are oxidized before filtration.**

Water containing uranium fines from the grinding operation is centrifuged to remove the uranium, and the water is recycled back for reuse.**

The spent HEPA filters are placed in glove boxes, and the uranium is removed by shaking and brushing. The uranium is sent to uranium recovery. The cleaned filters are sent to low-level waste (LLW) commercial burial.* Contaminated press oil is also sent to LLW commercial burial.**

Metal machining chips are sold for scrap. The acidic wastes from pickling the end caps are stored in tanks until picked up by a commercial spent acid disposal firm.**

Off-spec material is recycled back into the plant process.*** No plating or etching operations take place at the Windsor facility, and there is no wet scrap recovery.*** Scrap suitable for wet scrap recovery and combustible contaminated wastes are shipped to Hematite for processing.

5. Exxon Nuclear Co., Inc., lRichland, Washington

Since 1970, Exxon Nuclear has operated a fuel fabrication plant located on part of a 160-acre site at Richland, Washington. Process operations include chemical conversion of UF_6 to UO_2 using the wet ADU process, treatment and pressing of the UO_2 into fuel pellets, grinding the pellets to the required size specification, loading pellets into fuel rods, and final assembly of fuel rods into the fuel bundles. A wet scrap recovery operation is also conducted at the plant (ASER 1974).

All off-gases from the chemical conversion processes (Fig. I-1) are passed through scrubbers, dryers, and HEPA filters before discharge. Scrubber liquids are treated as necessary and recycled back into the process. Any necessary bleed is sent to liquid waste lagoons (ASER 1974). Spent HEPA filters are packed and sent to LLW burial.***

Spent resins from ion exchange (IX) (Fig. I-1) are currently being stored on-site.† The treated liquid from IX, containing most of the fluorine in the UF_6 received into the plant, is discharged to a lagoon (ASER 1974).

In the chemical conversion wet scrap recovery circuit, scrap for wet scrap reprocessing may first be oxidized to U_3O_8 if fluorine is present. Scrap is dissolved in a nitric

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*This information provided by H. W. Crocker, NRC, July 1981.

**This information provided by F. Pianki, Combustion Engineering, July 1981.

***This information provided by Don Raheinstein, Exxon Nuclear, July 1981.

†This information provided by Charles Malody, Exxon Nuclear, July 1981.

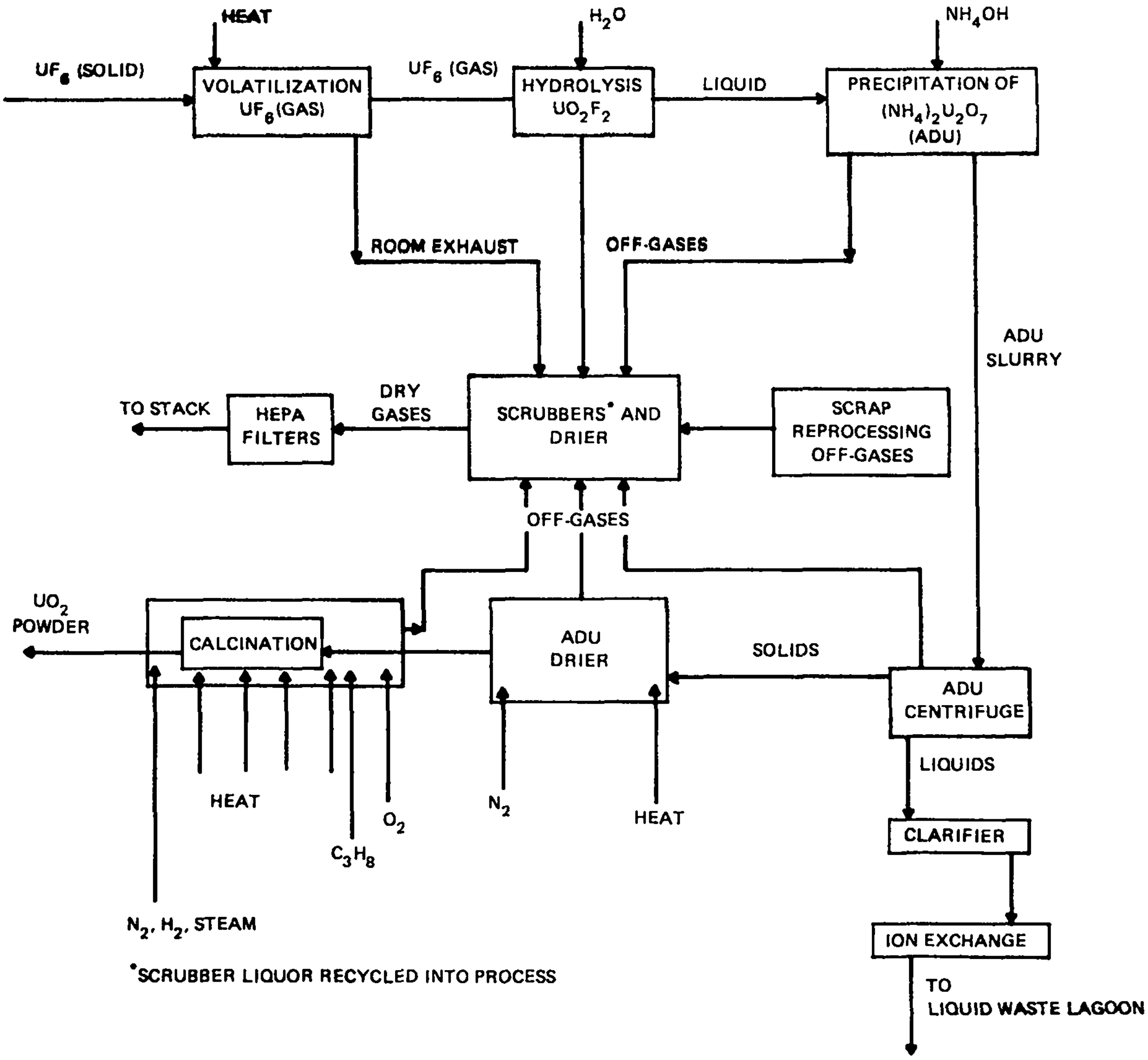

Fig. I-1. Schematic of UF_6-UO_2 conversion process for Exxon.

Source: ASER 1974.

acid leach, and, after dissolution, the liquor is centrifuged. Solids may be recycled or disposed of as solid waste. After recovering the uranium from the pregnant solution through solvent extraction-stripping-precipitation, the spent liquors containing nitrogen compounds, TBP and kerosene (used in solvent extraction), and a small amount of uranium are discharged to a lagoon. The uranium, precipitated as ADU, is separated from the slurry, dried, and calcined to UO_2 (ASER 1974).

In addition to chemical conversion processes, the plant manufactures pellets from UO_2 powder and assembles these into fuel bundles. Process steps include UO_2 powder preparation, pellet pressing, pellet sintering and grinding, fuel rod loading, fuel rod end closure, rod etch, fuel rod autoclaving, fuel rod testing, fuel element assembly, and storage.

Wastes are treated using the following techniques:

1. Process off-gases pass through HEPA filters. Off-gases from the sintering furnace are flared to oxidize excess hydrogen before these gases pass through filtration.* Spent HEPA filters are sent to LLW burial.

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*This information provided by Don Raheinstein, Exxon Nuclear, July 1981.

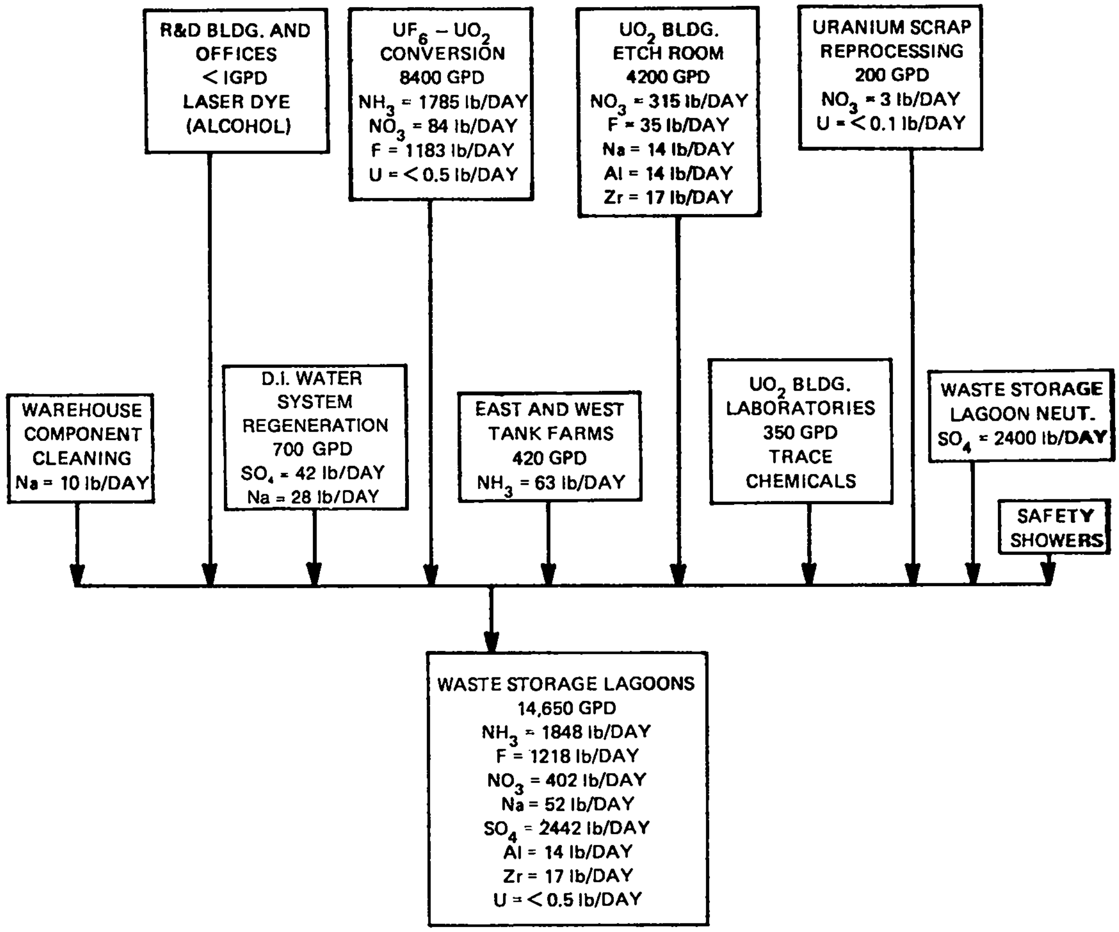

Fig. I-2. Exxon liquid effluent generation.

Source: ASER 1974.

2. The grinding water from pellet grinding is filtered, and the sludge is evaporated and calcined to U_3O_8 for recycling. The liquid waste is sent to the lagoons.*

3. Etching and stop bath solutions are discharged to the lagoons.**

4. Spent oils are put in an absorbent material and sent to LLW burial. Alternative disposal techniques are undergoing study.*

5. Cooling water and noncontaminated sanitary water is discharged to the sewer.**

6. Figure I-2 indicates the content and volume of liquid wastes discharged to lagoons for a plant throughput of 1.4 metric tons/day of UO_2 fuel. Lagoons presently in use are lined.*** Various alternatives for permanent disposal of the lagoon sludges, including dewatering and burial at a LLW site, are being considered.*

7. The plant's laundry uses a dry cleaning process, with the vapors being discharged to the atmosphere.

6. General Electric Company, Wilmington, North Carolina

Since April 1969, the General Electric Company (GE) has manufactured slightly enriched fuel bundles (up to 4% ^{235}U) at its fuel fabrication facility located on about

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*This information provided by Don Raheinstein, Exxon Nuclear, July 1981.

**This information provided by Charles Malody, Exxon Nuclear, July 1981.

***This information provided by Bill Cooley, NRC, July 1981.

0.61 km^2 of a 6.74-km^2 site in a rural area approximately 6 miles (9.65 km) north of Wilmington, North Carolina (Lyon et al. 1978).

Slightly enriched UF_6 is received into the plant and converted to UO_2 using both the wet ADU process and the "dry" direct conversion process. In the wet process, the UF_6, vaporized from the shipping cylinder, is hydrolyzed to UO_2F_2 and HF in a tank containing water. Ammonium diuranate is then precipitated from the solution by the addition of ammonium hydroxide. The solids are separated from the liquid by two centrifuges in series. The paste-like solids first enter a defluorinator-calciner furnace and are then reduced to UO_2 in a second furnace operated in a hydrogen atmosphere. The UO_2 is dried and packaged for transport to the UO_2 powder preparation area. Off-gases pass through a hydrogen oxidizer "flare", a scrubber, and a HEPA filter. (In general at GE, each section has its own discharge stack, resulting in many discharge points.) Liquid wastes are sent to waste treatment.

In the dry process, UF_6 is first oxidized to U_3O_8, which is collected in filter tubes. The off-gases pass through an absorber tower, where the HF is removed. (The dilute HF acid is sold.) The U_3O_8 is then formed into powder, reduced to UO_2, and dried. Hydrogen-containing off-gases are first oxidized to convert the H_2 to H_2O.* The dry process reduces the need for ammonia for the facility (EIA, GE 1975).

Besides the chemical conversions of UF_6 to UO_2, GE also operates a "wet" scrap recovery system. Scrap is dissolved in hot nitric acid to solubilize the uranium as $UO_2(NO_3)_2$. After filtration and cooling, the pregnant solution is reacted with H_2O_2 and NH_4OH to precipitate the uranium as $UO_4 \cdot 2H_2O$, which is separated by centrifugation, and calcined to UO_2. The off-gases from the dissolution tank have some of the nitrogen compounds recovered as weak nitric acid in an absorber (which is recycled), and the gases are then caustic scrubbed.*

Uranium-containing scrap mixed with foreign materials not meeting standards for processing on-site is shipped off-site to Nuclear Fuel Services for rework and recovery of uranium (Elder and Blahnik 1980).**

The liquid wastes from the chemical conversion facilities that contain high concentrations of fluoride compounds undergo further solids removal, and then lime is added to precipitate the fluorine as CaF_2. The freed ammonia is recovered using a proprietary process (Fig. I-3). At present, CaF_2 is being stored on-site. There are approximately two acres of stored sludge plus the sludge in the lagoons. The company is making pilot studies of techniques for removal of the uranium in the CaF_2 so that the CaF_2 can be sent outside the plant to landfills or processed to regenerate the fluorine (EIA, GE 1975).

The liquid wastes from the chemical conversion facilities that contain high concentrations of nitrogen compounds (primarily ammonium nitrate) are treated with $Ca(OH)_2$ to remove uranium. The nitrate waste is then dewatered, and the ammonium nitrate is shipped to the nearby Federal Paper Board plant for use in their biological waste treatment lake (EIA, GE 1975) (Fig. I-3).

Waste streams that contain laundry water or streams suspected of containing minor amounts of uranium are passed through high efficiency centrifuges to remove uranium, and the liquid is sampled to ensure low levels of uranium before discharge.

Treated liquids are discharged to outfalls that drain into the northeast Cape Fear River (EIA, GE 1975) (Fig. I-3).

In addition to chemical conversion processes used to produce UO_2, the facility completes the fuel fabrication process by manufacturing fuel bundles. The UO_2 powder is treated (pulverized, compacted, and granulated) and then pressed into fuel pellets, which are sintered in a hydrogen-reducing atmosphere, ground to a standard diameter, loaded into Zircaloy tubes, and further dried. After filling with helium and welding the final end cap, the tubes are assembled into fuel bundle assemblies that meet ^{235}U enrichment requirements. Fuel bundle assemblies are leak tested and inspected before shipment (EIA, GE 1975).

The liquid wastes from the UO_2 to fuel bundle manufacturing operations are handled as follows:

(1) After precipitation with $Ca(OH)_2$, plating waste sludge goes to a waste vendor.

(2) Used caustic is sold off-site.

(3) The liquid discharge from the chrome plate line undergoes ion exchange to remove the chrome.

(4) Waste coolants and used cutting oils undergo ultrafiltration. The concentrate goes to an off-site in-

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*This information provided by Gene Coryell, NRC, July 1981.

**This information provided by John Kahle, NRC, September 1981.

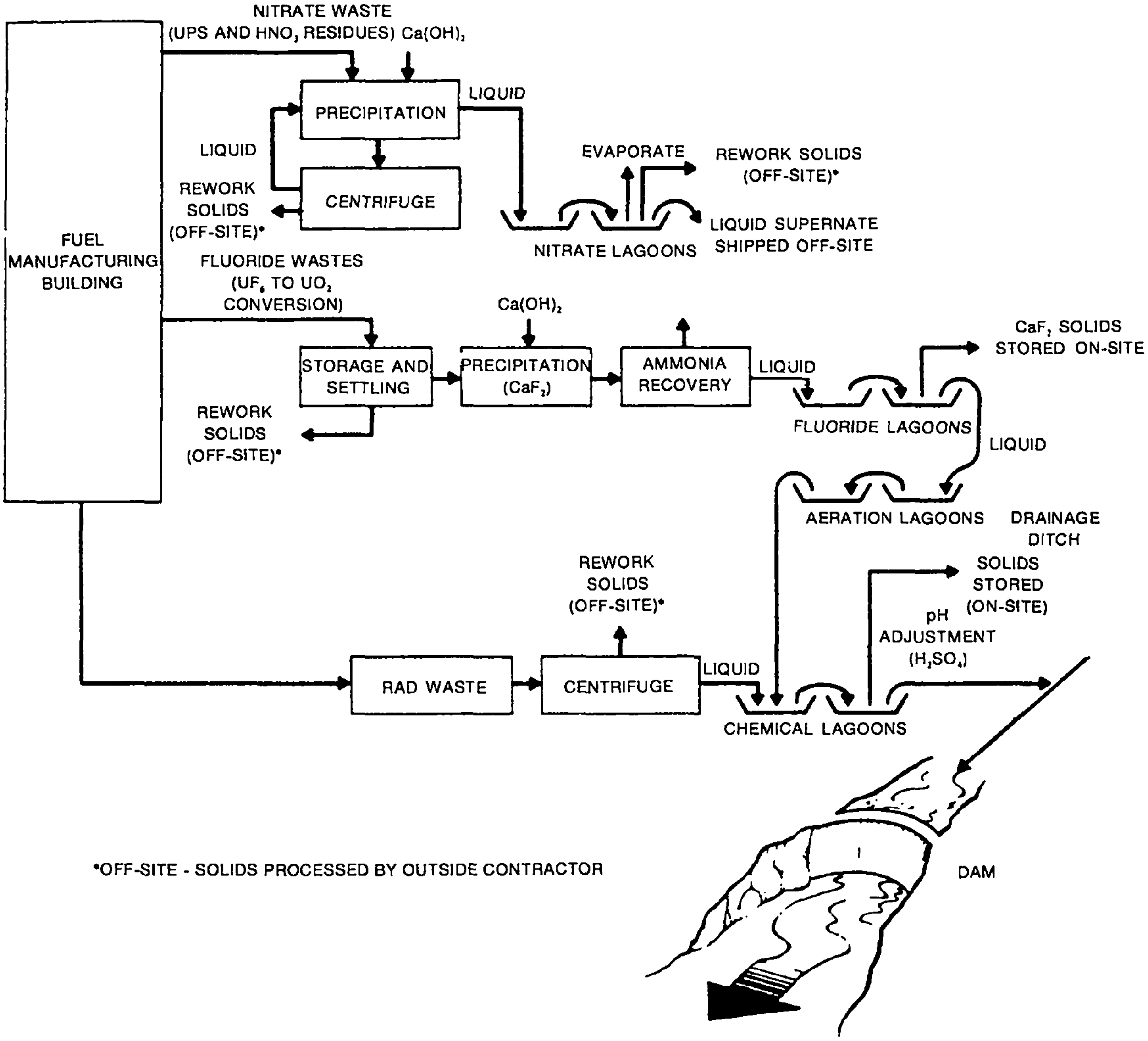

Fig. I-3. Process liquid waste treatment - General Electric.

Source: Elder, Blahnik 1980.

cinerator, and the liquid is discharged to the liquid treatment facility.

(5) The zirconium fines from machining, grinding, etc., are currently being stored on-site awaiting some suitable scheme of disposal.

Off-gases from pretreatment, pelletizing, sintering, grinding, and rod loading and welding pass through roughing and HEPA filters (EIA, GE 1975).

General Electric has previously incinerated uranium-containing combustible wastes. However, the feed was shredded before introduction into the furnace. The shredding arrangement proved unsatisfactory. (For more details on this incinerator and its problems, see Perkins 1976). At present, this incinerator has been removed, and a new batch-feed, two-stage combustion incinerator is being installed. This incinerator will also burn contaminated oils. Off-gases will be scrubbed. The scrubber liquid will be filtered, undergo pH adjustment, and reused, and any necessary bleed will go to the liquid waste treatment system. Combustible wastes, including filters, are currently being stored until the new incinerator begins operation.

Solid, noncombustible contaminated wastes in general are sent to a LLW burial site if the waste does not contain sufficient uranium to warrant recovery.

7. Westinghouse Electric Corporation, Columbia, South Carolina

Westinghouse Electric Corporation's Nuclear Fuel Columbia site receives low enriched UF_6 and converts this material into pressurized water reactor (PWR) commercial reactor fuel assemblies. The facility also includes scrap recovery operations. Uranium contaminated combustible materials are incinerated. This facility is discussed in detail in Chapter III.

D. Framework of Study

Each fuel fabrication facility is unique, and wastes/effluents are treated differently, depending not only on the processes used but also on the facility itself. However, to complete this study in the time frame required, only two facilities were chosen for in-depth analysis from the seven facilities described in the previous section. One facility was chosen that uses a dry conversion process from UF_6 to UO_2, and in addition does some pellet production, whereas the other facility chosen uses a wet conversion process from UF_6 to UO_2 and completes the process of fuel pellet fabrication, loading, and fuel bundle assembly.

For the two facilities chosen for in-depth study, a complete block flow diagram for each facility was constructed using material published in environmental reports and similar sources of information. These flow diagrams were then used to try to identify inputs and outputs and thus the origin and composition of each type of waste stream. Next, the treatment techniques for each stream were identified, and data on waste types, quantities, and types of disposal collected. Once a draft report of the description and waste data for each facility was complete, the report was sent to the company operating the facility for corrections. Each study was used as the basis for specific recommendations.

The two in-depth studies are covered in Chapters II and III. These studies and the brief material given in Section C of this chapter were then used to make the general conclusions and recommendations included in Chapter IV.

REFERENCES

"Applicant's Supplemental Environmental Report, Uranium Oxide Fuel Plant Expansion Phase II," Exxon Nuclear Co., Inc. (July 1974).

R. I. Cantor, EPA, memo to Joe Davis, EPA, on the subject of Babcock and Wilcox Apollo Plant, May 27, 1980.

"Draft Environmental Impact Statement on 10 CFR Part 61 'Licensing Requirements for Land Disposal of Radioactive Waste' Appendices A-F," US Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards report NUREG-0782, Vol. 3 (September 1981).

H. K. Elder and D. E. Blahnik, "Technology, Safety and Costs of Decommissioning a Reference Uranium Fuel Fabrication Plant, Vol. I, " Nuclear Regulatory Commission report NUREG/CR-1266, (Pacific Northwest Laboratory, Richland Washington, October 1980).

"Emission Evaluation of the Low Enrichment Conversion and Recovery Process Line for Babcock and Wilcox, Nuclear Materials Division, Apollo, Pennsylvania," (June 29, 1976).

"Environmental Data for the Apollo Site Materials Plants of the Nuclear Materials Division of the Babcock and Wilcox Corp.," (August 1, 1975) (no author).

"Environmental Impact Appraisal, Babcock and Wilcox Commercial Nuclear Fuel Plant, Lynchburg, Virginia," Division of Fuel Cycle and Material Safety, Nuclear Regulatory Commission, Washington, DC (no date).

"Environmental Impact Appraisal, General Electric Company Uranium Oxide Fabrication Facility, Wilmington, North Carolina," Docket No. 70-1113 Related to Renewal of Special Nuclear Materials License No. SNM-1097, Division of Materials and Fuel Cycle Facility Licensing, US Nuclear Regulatory Commission, Washington, DC (1975).

"Environmental Impact Information, Combustion Engineering, Inc., Windsor, Connecticut, Plant Site," US Atomic Energy Commission (October 1974).

R. J. Lyon, R. L. Shearin, and J. A. Broadway, "A Radiological Environs Study at a Fuel Fabrication Facility," US Environmental Protection Agency report EPA-520/5-77-004, Office of Radiation Programs, Washington, DC (October 1978).

B. L. Perkins, "Incineration Facilities for Treatment of Radioactive Wastes: A Review," Los Alamos Scientific Laboratory report LA-6252 (1976).

CHAPTER II

NUCLEAR FUEL MANUFACTURING HEMATITE, COMBUSTION ENGINEERING

A. Background Information

1. Plant Operation

Combustion Engineering's (CE) Nuclear Fuel Manufracturing—Hematite (NFM-H), Hematite, Missouri, plant converts low enriched (less than 4.1% ^{235}U) UF_6 to UO_2 powder using a dry conversion process. The powder is either shipped to CE's Windsor Plant for further processing or it can be fabricated into ceramic fuel pellets on-site and then shipped to Connecticut for fuel element fabrication (EII 1975, EIA 1977).

2. History

The Hematite facility (the first plant built in the US for commercial production of nuclear reactor fuel) was constructed in 1956 by Mallinckrodt Chemical Works to produce both high- and low-enriched uranium compounds from UF_6. In 1958, the plant was expanded to provide production capacity for low-enriched UO_2 fuel pellets and high-enriched uranium metal.

In 1961, plant ownership was transferred to United Nuclear Corporation, which in 1963 added naval reactor fuel production capability. In 1971, the plant was sold to Gulf Oil, and in 1973 Gulf Nuclear Fuel Corporation assumed ownership. In 1974, the facility was sold to Combustion Engineering Corporation, which decommissioned the operations involving highly enriched uranium. Start-up for the processing of low-enriched reactor fuel began in 1974 (EII 1975).

3. Site

The NFM-H plant is located in T40NR5E Sec. 9 of Jefferson County, near Hematite, Missouri, about 35 miles south of St. Louis (Authorization to Discharge, 1979). Jefferson County is predominantly rural, containing many sizeable woodland tracts (EII 1975).

The total plant acreage is 152 acres, containing a 16-acre grassy center tract. Approximately 5 acres of this center tract contain the major buildings, storage areas, parking lots, etc., associated with the Hematite facility. Figures II-1 and II-2 show the general location of the plant site, whereas Fig. II-3 indicates the layout of buildings in the 5-acre tract (EII 1975 and EIA 1977). Table II-1 identifies the buildings shown in the preceding figure (EII 1975).

Further information on land use, geology, hydrology, meteorology, etc., can be obtained from either the Environmental Impact Appraisal or the Environmental Impact Information document. These documents also discuss possibilities for floods, earthquakes, and man-caused accidents.

4. Resource Usage

Approximately 70 people are employed at the site.

Approximately 25 600 gpd (11.2×10^{-4} m^3/s) for process water, 45 000 gpd (19.7×10^{-4} m^3/s) for cooling

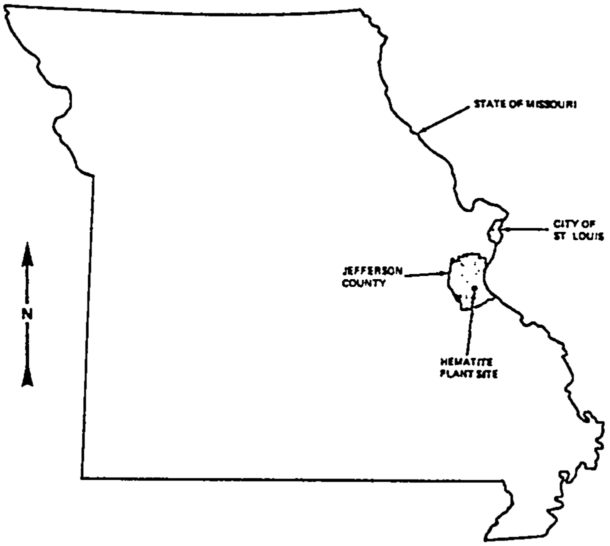

Fig. II-1. Hematite plant site location within the state of Missouri.

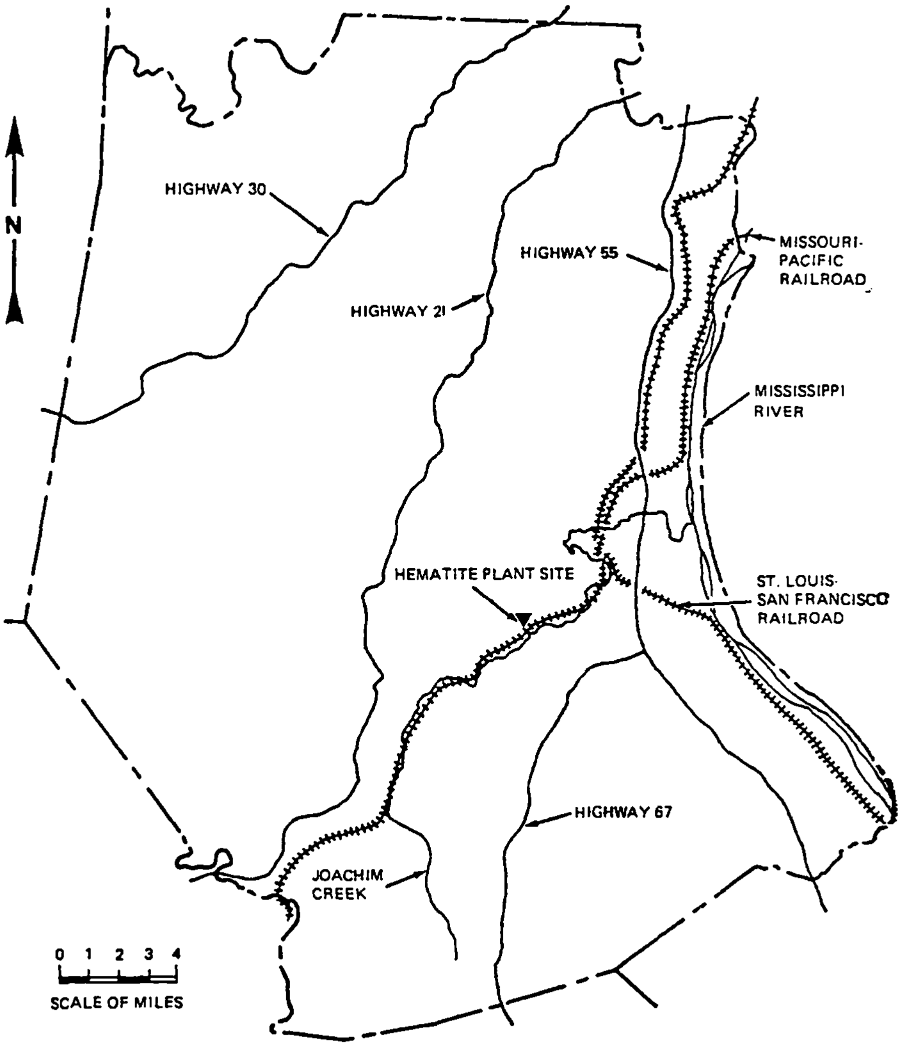

Fig. II-2. Hematite plant site location within Jefferson County and major transportation links.

water, and 1400 gpa (0.61 × 10^{-4} m^3/s) for sanitary use are required. This water is supplied by an artesian well located on the property (EII 1975 and EIA 1977).

Table II-2 indicates chemical usage. Natural gas is used to fire the boilers and some process vessels. In addition, electricity is required for pumps, various process equipment, etc. (EII 1975).

B. Processing, Effluent Treatment, and Waste Generation

1. Oxide Plant

The major chemical process at NFM-H is the conversion of UF_6 to UO_2. Solid UF_6, enriched to the desired level of ^{235}U, is received in 2.5-ton, 30-inch diameter cylinders. Each cylinder is placed within a steam chamber and heated to vaporize the UF_6, which initially under its own vapor pressure flows to the first fluidized bed reactor. When the cylinder has been drained, a vacuum condensation system is used to recover the remaining heel. In the initial reactor, the UF_6 reacts with the steam to form uranyl fluoride and hydrofluoric acid.

$$UF_6\ (gas) + 3H_2O\ (gas) \rightarrow UO_2F_2\ (solid) + 4HF\ (gas) + H_2O\ (gas).$$

The gaseous HF and H_2O exit the reactor through two sets of porous metal filters, where any entrained UO_2F_2

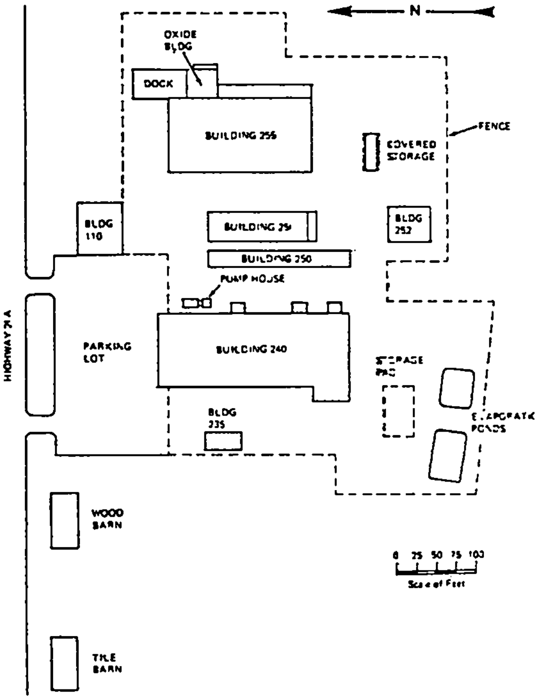

Fig. II-3. Location and identification of buildings and facilities on Combustion Engineering Hematite plant site.

Source: EIA 1977.

is removed, and are then routed to the central HF removal system. The UO_2F_2 particles pass to a second and third reactor in series, where the UO_2F_2 reacts with hydrogen (obtained from cracked ammonia) to form UO_2.

$$UO_2F_2 \text{ (solid)} + H_2 \text{ (gas)} \rightarrow UO_2 \text{ (solid)} + 2HF \text{ (gas)}.$$

The off-gases from the second and third reactor are also filtered through porous metal filters, after which the gases pass to the central HF removal system. The central HF removal system, reported to be 90-98% effective in removing fluorides, consists of a series of towers packed with pebbles of limestone in which the HF is removed by the reaction of F with Ca to form CaF_2 (EIA 1977). Excess H_2 in the off-gas stream is burned in an in-stack burner located after the limestone fluorine removal packed towers (EII 1975).

Product UO_2 is withdrawn from the reactors, cooled, and pneumatically transferred to storage silos. Figure II-4 indicates the process flow diagram for the oxide plant.

The particluate, containing uranium, obtained through cleaning of the porous metal filters, is sent to oxidation-reduction (dry scrap recovery), hence recycling this uranium back into the $U0_2$ production process.

TABLE II-1

BUILDING AND FACILITIES ON THE CE HEMATITE SITE

Building Number	Building Name	Present Use
101	Tile Barn	Emergency Center and Equipment Storage
–	Pump House	Site Water Supply
110	New Office Building	Guard Station and Offices
120	Wood Barn	Equipment Storage
–	Oxide Building and Dock	UF_6 to UO_2 Conversion
235	West Vault	Natural and Depleted Uranium Storage
240	240–1 240–2 and 3 240-4	Office and Cafeteria, Recycle and Recovery Areas, Laboratory and Maintenance Shop, and Laundry
250	Boiler Room/Warehouse	Steam Supply and Storage
252	South Vault	Radioactive Waste Storage
255	Pellet Plant	Fuel Pellet Fabrication, UO_2 Storage

Source: EIA 1977.

The spent limestone (the CaF_2 chemical reaction progress through the bed is monitored by noting the bed temperature) is removed from the tower, and after monitoring for uranium, is sent to disposal. The maximum activity of this spent material is reported not to exceed 50 dpm/g of activity, and usually, because of the effectiveness of the porous metal filter, the activity does not exceed background* (EIA 1977). If the limestone has no above-background surface contamination, it is generally disposed of outside the fenced area at the plant site.*

Current operations are reported to produce approximately 100 cubic yards (76.4 m^3) of spent limestone-CaF_2 per year. Approximately 35-50 drums of spent limestone containing levels of uranium too high for acceptable use as landfill have been shipped to a LLW burial site.***

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*This information provided by H. E. Eskridge, Combustion Engineering, July 1981.

**This information provided by Charles Peck, NRC, May 1981.

TABLE II-2

CHEMICAL USAGE FOR THE HEMATITE FACILITY PER YEAR[a]

Chemical	Pounds	Kilograms	Use	Fate
Ammonia	420 000	190 680	Reducing and producing ADU	Excess hydrogen burned in stack burner H_2O and N_2 to air; NH_3 from ADU section discharged
Nitrogen	500 000	227 000	Processing	Discharged to ambient air
Hydrogen	5500	2497	As a reductant in various operations	Excess burned to H_2O
UF_6	750 000	340 000	To convert U to UO_2	F^- at least 90% into limestone solid waste discharge
Potassium hydroxide	3500	1589	Scrubber	Forms KF_2 and KOH, which goes to regeneration and then burial
Trichloroethane	9500	4313	Powder preparation	Volatilized to ambient air
Cranko (organic compound)	9000	4086	Powder preparation	Volatilized during pellet dewaxing
Sodium hydroxide	4500	2043	Regeneration demineralizer resins	Discharged to creek after neutralization
Salt (NaCl)	7500	3405	Regeneration demineralizer resins	Discharged to creek after neutralization
Sulfuric acid	5000	2270	Regeneration demineralizer resins	Discharged to creek after neutralization
Hydrophobic starch	1500	681	Lubrication–pellet pressing	Volatilized during pellet dewaxing
Hydrochloric acid	850	386	Clean heat exchanger tubes	Discharged to creek
Boiler treatment chemicals	2600	1180	Boiler water treatment	Discharged to creek
Detergent	400	182	Laundry	Discharged to creek
Limestone	NA	NA	Remove fluorine	CaF_2 and excess limestone to landfill (on-site)

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[a] Does not include wet scrap recovery in which nitric acid, ammonium hydroxide, hydrogen peroxide, and potassium hydroxide are used, but includes operation when some pellet production is occurring.

Source: EII 1975

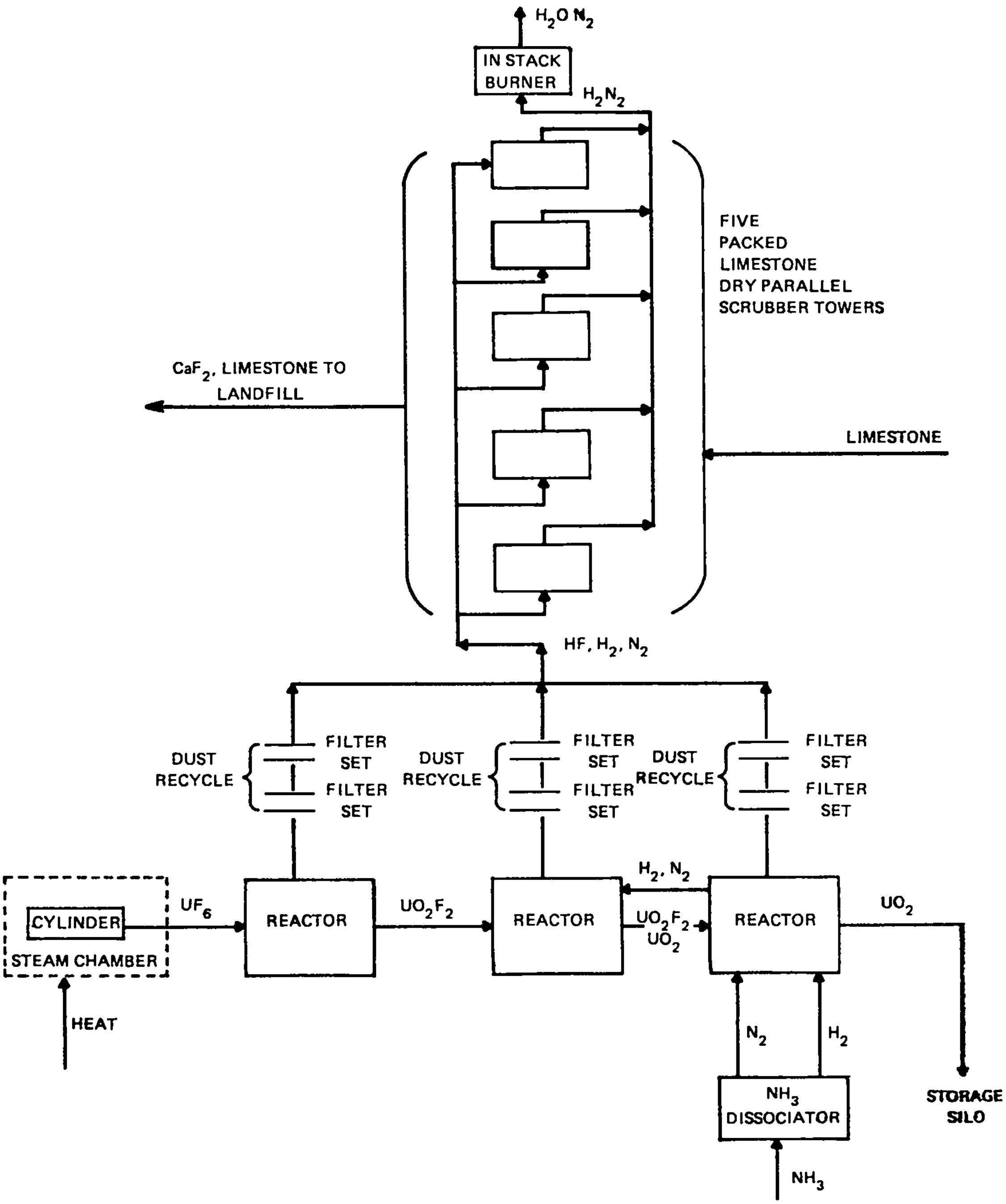

Fig. II-4. Oxide production.

All UO_2 contaminated mop and cleaning water from the Oxide Building and other process buildings is evaporated in the boil-down tanks, and the residue is recycled back into the plant processing (EIA 1977).

2. Powder Preparation and Blending

To prepare the UO_2 for fuel pellet fabrication, the powder is withdrawn from the storage silos and milled to a specific particle size range in a fluid energy mill (Fig. II-5). Recycle material, after meeting quality standards, is included in the milling process. The milled material is pneumatically transferred to the blenders (EIA 1975). From the blenders, the powder may either go for packaging and shipping or to pellet fabrication.

The off-gases from the powder preparation section will contain UO_2 fines and CH_3CCl_3 vapor. These process off-gases pass through single absolute filters before being vented to the ambient air. Filters are cleaned, and the residue is processed in the dry scrap recovery (EIA 1975).

3. Fuel Pellet Fabrication

For fuel pellet fabrication, the UO_2 powder is transferred from the blender to the agglomeration circuit. Here an organic binder and a solvent are mixed with the powder. The mixture is dried, granulated, a lubricant added, the mixture again blended, and then pressed to the desired shape (EIA 1977).

Off-gases from these operations contain organic vapors and UO_2 particulate. These off-gases are routed to the main pellet plant process ventilation air system where the gases pass through one of two manifold systems, each containing two banks of prefilters and two banks of absolute filters. These final filters are equipped with pressure differential measuring devices. If a significant increase in pressure differential occurs, the filters are replaced (EIA 1977).

The newly formed pellets discharged from the mechanical presses are sent to the dewaxing furnace where the binding and lubricating material is removed in a reducing atmosphere. Finally, the dewaxed pellets are introduced into a sintering furnace where, again in a reducing atmosphere, the desired final pellet density is obtained. Off-gases from these operations contain UO_2 fines, H_2, N_2, CO_2, H_2O, and hydrocarbons. These off-gases are also routed into the main Pellet Plant process ventilation air system for removal of the UO_2 fines (EII 1975).

The sintered pellets are ground to the required diameter (using a centerless grinder), dried, purity tested, and inspected. Pellets meeting requirements are packaged for shipment. Off-gases from pellet grinding will contain UO_2 fines and are also routed to the main Pellet Plant process ventilation air system (EII 1975). The water used in grinding is contaminated with finely divided UO_2. This water is centrifuged to remove UO_2, and the recovered material is recycled. The liquid is further treated by evaporation to recover any remaining uranium.

The reject pellets are recycled back into the system. This process is described in a later section.

4. UF_6 Cylinder Cleaning

Infrequently, to recover any UF_6 remaining in the shipping cylinder before the cylinders are pressure tested, a small amount of water is introduced into the cylinder to hydrolyze the UF_6.

$$UF_6 \text{ (liquid)} + H_2O \text{ (liquid)} \rightarrow$$
$$UO_2F_2 \text{ (solid)} + 4HF \text{ (liquid)} + H_2O.$$

The UO_2F_2 particles suspended in the dilute hydrofluoric acid are drained from the cylinders, and NH_3 is added to precipitate the uranium as ammonium diuranate (ADU). The slurry is pumped through a filter press to remove the particles of ADU. The ADU filter cake is sent to the oxidation circuit (dry scrap recovery).

The liquid filtrate contains ammonium fluoride, excess ammonia, and uranium daughter products from uranium decay in the cylinder.

The liquid is evaporated, solidified by adding cement, and shipped to licensed burial.*

The off-gases from the ADU precipitation section contain ADU particulate and NH_3 vapor. These gases are exhausted through a single absolute filter (EII 1975).

5. Dry Scrap Recovery

Reject pellets and other UO_2 scrap not contaminated with chemicals and the small amounts of ADU from cylinder heels recovery are prepared for recycle by heating in an air atmosphere to form U_3O_8, which is then heated in a reducing atmosphere to convert the U_3O_8 to UO_2 (EII 1975).

The off-gases from these operations containing UO_2 fines, HF, NH_3, N_2, hydrocarbons, H_2, and H_2O vapor pass through a KOH scrubber before discharge to the ambient air (EII CE 1976).* The scrubber liquor contains ammonium fluoride, potassium fluoride, potassium hydroxide, and ammonium nitrate. This spent liquor is treated to regenerate the KOH and precipitate the impurities.** The solids are filtered from the liquor, and the KOH is reused. The solids are solidified and sent to off-site burial.

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*This information was provided by H. E. Eskridge, Combustion Engineering, July 1981.

**This information was provided by Charles Peck, NRC, May 1981.

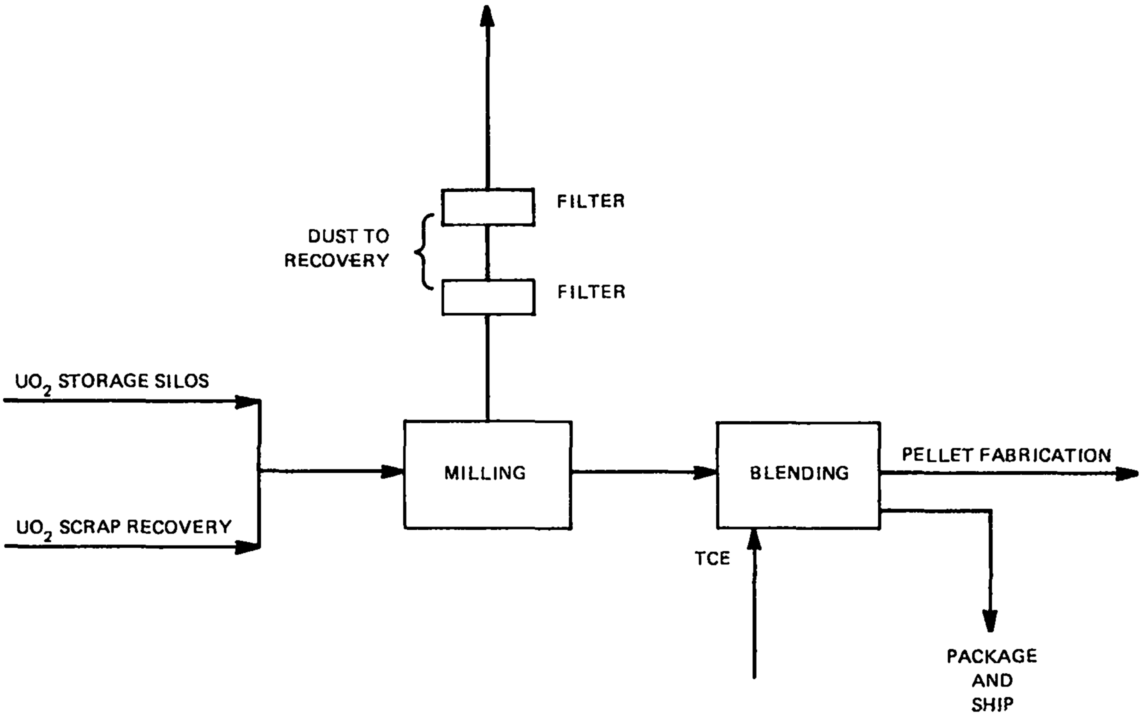

Fig. II-5. Powder preparation.

6. Wet Scrap Recovery

A wet scrap recovery operation was begun in 1977. About 1% of the total production (including materials returned from the Windsor Facility) requires wet recovery. However, because scrap had been stored before 1977, the following operations rates were proposed.

Year	MtU*
1977	2.4
1978	4.6
1979	2.1

*Metric tons of uranium

The maximum capacity of the wet recovery process under conditions of continuous operation could be as great as 255 lb uranium/day (115.8 kg/day); however, the operation has never been used continuously (SEII 1977).

The wet scrap recovery operation recovers uranium contained in chemically contaminated scrap materials and residues. Most of the scrap is first oxidized in the reaction boxes used for oxidation in the dry scrap recovery circuit. After any necessary preparation, a batch of approximately 9.6 kg uranium is mixed with water and introduced into the leach tank for 172 minutes, where nitric acid is added to solubilize the uranium as $UO_2(NO_3)_2$.

$$2U_3O_8 + 14HNO_3 \rightarrow$$
$$6UO_2(NO_3)_2 + 7H_2O + NO_2 + NO.$$

As indicated in the preceding equation, the off-gases during dissolution contain NO_2 and NO. These gases pass through a packed tower with a countercurrent flow of recirculating water as the absorption liquid. The scrubber liquid is recycled back to the system. The scrubber was designed to operate for maximum absorption efficiency by compression of gases using a water-sealed compressor. Scrubber efficiency is reported to be approximately 75%. During a pilot test with a dissolution batch of 9.6 kg of uranium, the total amount of NO_x released was approximately 102.5 g (ERALA 1977).

The solution from dissolution undergoes pH adjustment [$NH_4(OH)$ and H_2O_2 are added] to precipitate U as UO_4 and is sent to a hold tank. From the hold tank, the liquid moves into a mixer-settler/precipitation tank. The solution from this tank then undergoes further solid/liquid separation in a centrifuge. Additional solids removal occurs by treating the liquid from centrifuging in a filter press.

The barren solution from the final filter press (composed of an aqueous solution of ammonium nitrate plus acid-soluble impurities, mainly iron and nickel) is sent to a hold tank. The liquid is sampled, and if less than a gram per liter of uranium is present, the liquid is batch-processed in one of the three boil-down tanks described elsewhere in this report. The final sludge from boil-down is mixed with cement for solidification and sent to a commercial low-level waste burial site.*

During three pilot tests, the average concentration of uranium in the process liquors from the final filter was about 0.064 g/ℓ. Thus, about 0.25% of the uranium processed in the wet recovery operation is found in the discharge liquid waste evaporated in the boil-down tanks (SEII 1977 and EII, CE 1976).

The solid UO_4 separated during the solid/liquid separation steps is sent to a dryer and then converted back to UO_2 in the oxidation-reduction boxes also used for dry scrap recovery.

The off-gases from the UO_4 dryer are scrubbed in a spray tower type scrubber. The recirculating liquid is continuously filtered. Bleed is sent to the boil-down tanks for evaporation.

As mentioned previously in discussing the use of the oxidation-reduction boxes in the dry scrap recovery operation, off-gases from these boxes pass through a KOH scrubber where the scrubber solution is reused after treatment.

The off-gases from the various dry operations pass to the central dry gas treatment system (prefilters and double HEPA filters) before release.

Off-gases from the filter press, precipitation, and other wet operations pass to the wet side central gas treatment system where the gases pass through double HEPA filters before release (EII, CE 1976).

The complex flow diagram for the wet scrap recovery is given in Fig. II-6. It should be noted that this figure also indicates the dry recovery process, as the recycle/recovery furnaces (oxidation-reduction) are also used for the dry process.

7. Incineration

A small quantity of combustible waste, principally polyethylene bags, rags, and paper, becomes contaminated during plant operations. Recently, an incinerator having a capacity of 25 lb/h (11.3 kg/h) has been installed to incinerate these wastes.

The material is fed, packaged in plastic or paper bags, into the incinerator until 860 g of ^{235}U have been introduced into the system. The incinerator is designed with a primary combustion chamber and a secondary chamber with auxiliary natural gas burners in both chambers. The off-gases are first cooled by a heat exchanger and then pass through an ejector-venturi scrubber and then a packed tower scrubber before discharging to the ambient air.

The scrubber liquors include uranium-containing particulates and HCl and are recycled during each burn. After a burn, the complete scrubber and liquor sump system is drained and refilled with deionized water. The spent scrubber liquor is evaporated in one of the boil-down tanks.

Ash, removed from the incinerator by the vacuum collection hood, is analyzed for uranium and, depending on uranium content, is either packaged for burial at a commercial waste burial site or is sent to wet recovery. Off-gases from the ash vacuum system pass through a HEPA filter before discharge (C-EHI/SS).

8. Other Operations

a. Boil-Down Tanks. There are three boil-down tanks located outside that evaporate spent scrubber residue, contaminated mop and cleaning water, and other liquid residues. The sludge remaining after boil-down is either recycled or drummed for burial, depending on the uranium content.* The vapors from boil-down discharge directly to the air.

b. Laundry. An on-site laundry is operated to wash worker clothing. This discharge water and glassware cleaning water is discharged to the drains, which discharge to the site pond (EII 1975).

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*This information provided by Charles Peck, NRC, June 1981.

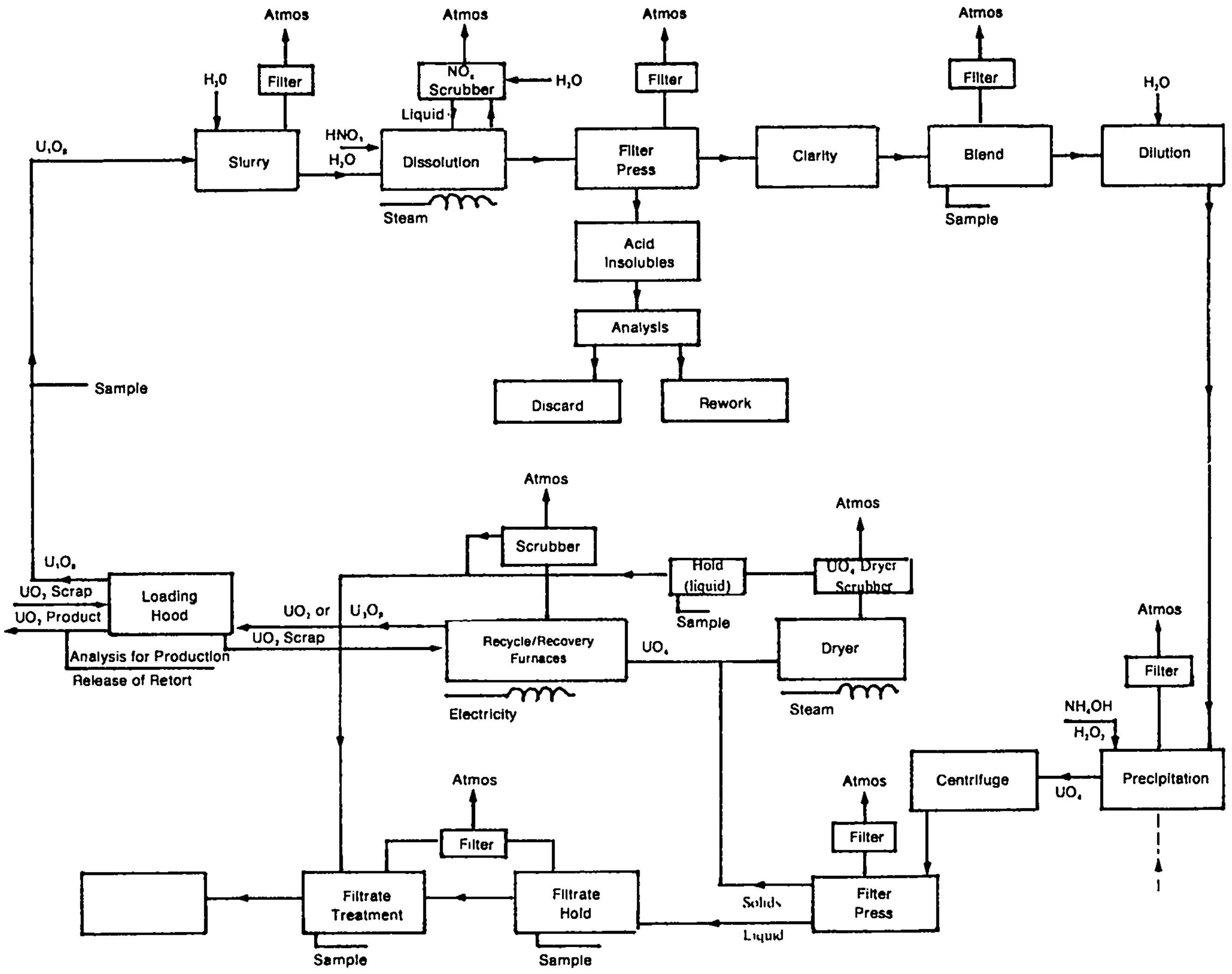

Fig. II-6. Wet scrap recovery flow diagram.

Source: ERALA 1977.

c. Cooling. Cooling water is also discharged to the site pond. Overflow from the site pond discharges to Joachim Creek, which flows into the Mississippi (EII 1975).

d. Sanitary Facilities. The sanitary waste water is discharged to a Sanitaire Mark I-R-4 extended aeration sewage treatment plant and an aerated sludge holding tank. After chlorine treatment, the water discharges to Joachim Creek (EII 1975).

e. Evaporation Pond Sludge

Until several years ago, approximately 100 gpd (4.38×10^{-6} m^3/s) of radiological waste water was discharged to retention ponds. This practice has been discontinued. Most of the pond sludges containing fluoride compounds, nitrogen compounds, potassium compounds, and small quantities of uranium have been removed and packaged in 55-gallon drums for burial.*

f. Solid Wastes Sent Off-Site. Solid wastes containing uranium compounds are generated at all process steps. Wastes are assayed, and wastes not suitable for recovery of uranium or for incineration are placed in 55-gallon steel drums and shipped to a low-level waste burial site. Bulky items having only low levels of surface contamination may be placed in plastic-lined wooden boxes for delivery to the burial site.

From September 1974 to May 1975, 1350 ft^3 (38.20 m^3) of solid wastes containing 15 760 g of uranium with 475 g of ^{235}U were shipped for disposal. (Depleted uranium wastes from start-up testing, which is not expected to occur again, were also shipped.) The amount of contaminated waste shipped to off-site burial has recently declined because of increased reprocessing.**

Wastes not contaminated with uranium are collected and disposed of by a commercial waste burial firm (EII 1975).

C. Discharge Data

1. Monitoring Summary 1975-1980

The tables included in the Appendix comprise a summary of the environmental monitoring data from 1975-1980. The pond well samples refer to monitoring wells placed around the now unused evaporation ponds. Further information on sampling sites is given in Figs. II-7 and II-8. For further information on sampling, the reader is referred to the Environmental Impact Information and the Environmental Impact Appraisal documents. The increase in beta counts on limited occasions was at least in part caused by contamination of UF_6 with ^{99}Tc at the enrichment facilities and the movement of this beta emitter through the plant into the sampled discharges.**

2. Other Data

Table II-3 indicates recent data (excluding sewer outfall) submitted by CE to the Environmental Protection Agency (EPA) for the National Pollutant Discharge Elimination System (NPDES), whereas Table II-4 summarizes recent radiological data (EMR 1980), including the sewer outfall.

In addition, it has been indicated that releases to the air are approximately 2.1 lb/day for NH_3 and 0.042 lb/day of NO_x (omitting NO_x discharges from combustion equipment) (EII, CE 1976).

3. Calculations

There appear to be no published data on the amount of CaF_2 going into the solid wastes. However, the monitoring data indicate that little fluorine is being discharged as a liquid effluent. In the impact information document, CE indicated that plant capacity was about 750 000 pounds of UF_6 per year. Using the monitoring data given for fluorine emissions, it appears that the scrubbers must remove about 95% of the fluorine if the plant has been running at the stated capacity. If it is assumed that (1) plant throughput is 750 000 pounds UF_6 per year, and that (2) 95% of the fluorine coming into the plant is converted to CaF_2, the total amount of CaF_2 waste each year is 213 799 kg. (This waste will be mixed with the unreacted limestone.) If the plant has been operating in this mode since 1958, then approximately 4922 metric tons of CaF_2 have been produced.

D. Conclusions

1. Monitoring

It would be helpful to have more data on the monitoring of the boil-down tank vapors and the de-

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*This information provided by H. E. Eskridge, July 1981.

**This information provided by Charles Peck, NRC, May 1981.

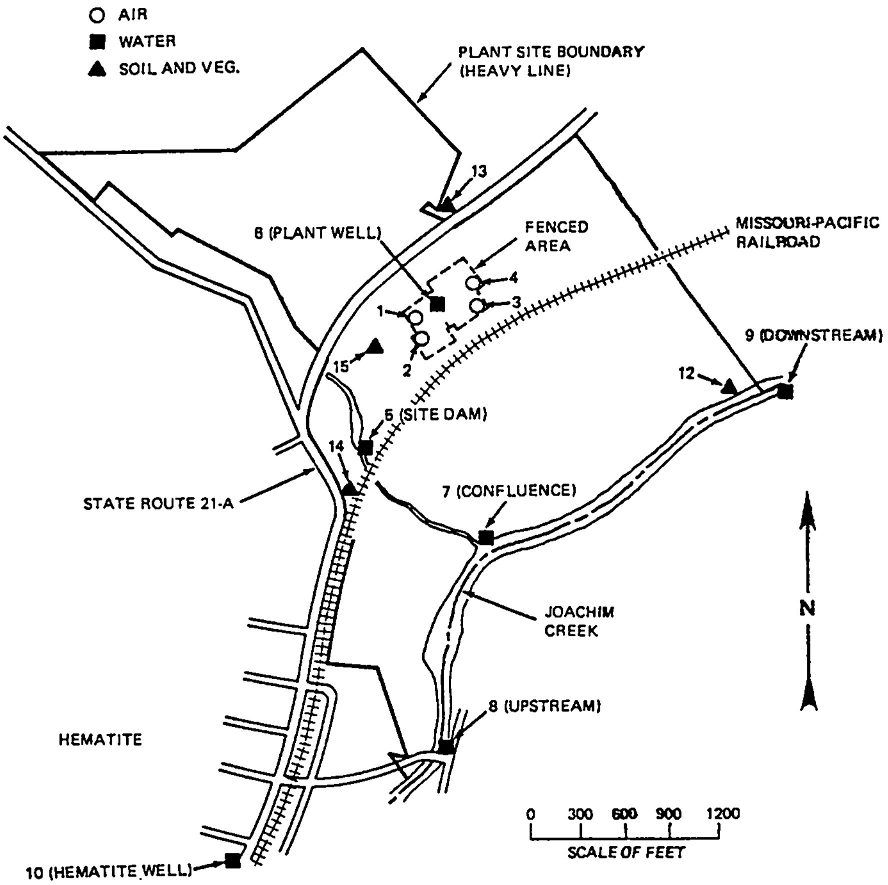

Fig. II-7. Location of air, water, soil, and vegetation sampling stations.

Source: EIA 1977.

termination of the efficiency of the limestone scrubbers. The effect of nitrates in the liquid discharge should be investigated. Splitting of samples and an independent monitoring program should be undertaken, with the data from all monitoring given in a publicly available yearly report. Data should include, at several locations, ambient air concentrations of uranium (including size fraction and solubility) and concentrations of uranium in nearby surface soils.

2. Solid Waste Disposal

A study of the disposal of the limestone containing CaF_2 wastes is needed to ensure that current disposal techniques will not result in mobilization of fluorine or uranium.

The quantity of uranium and the matrix composition of the waste going to LLW burial should be identified in detail and a determination made of the adequacy of this type of disposal.

3. Past Practices

No data were obtained on the decommissioning efforts made in 1974 for the highly enriched uranium processing circuits. It may be that further monitoring and investigations (such as looking for buried waste lines, sumps, contaminated soils, etc.) are needed to ensure that previous operations at the plant have been adequately decommissioned.

4. Inadvertent Discharges

No information was obtained as to quantity and types of inadvertent discharges as a result of clean-up equipment malfunction, line breaks, loss of power, etc. More data are needed on occasional inadvertent releases.

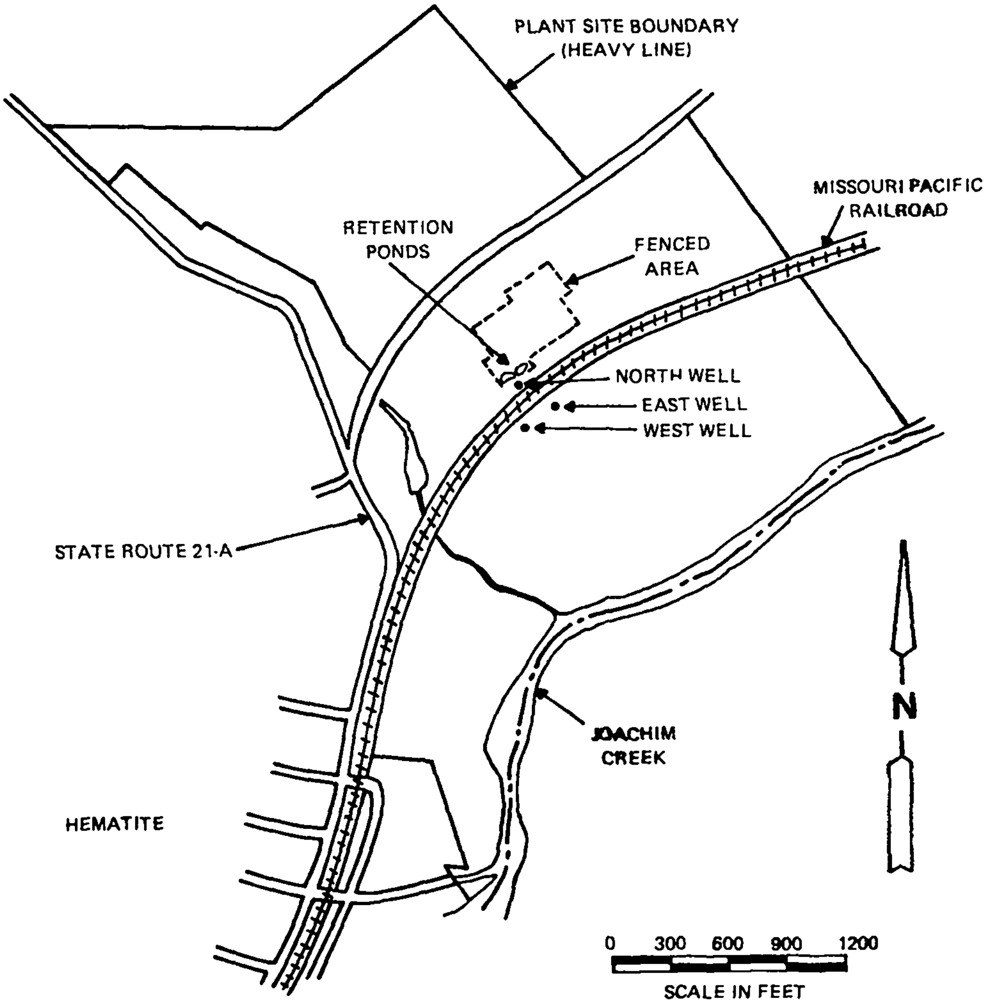

Fig. II-8. Location of retention ponds and sample wells.

Source: EII, CE 1976.

5. Fugitive Emissions

No information was obtained on fugitive emissions. Complete mass balances for all chemicals used in the plant should be obtained to indicate possible fugitive emissions.

REFERENCES

Combustion Engineering, Inc., "Environmental Monitoring Summary 1975-1980" (1981).

Combustion Engineering, Inc., "C-E Hematite Incinerator/Scrubber System" (1979).

Combustion Engineering, Inc., "Supplemental Environmental Impact Information Related to Installation and Operation of a Wet Scrap Recovery Process" (June 1977).

Combustion Engineering, Inc., "Environmental Impact Information Related to Installation and Operation of a Wet Scrap Recovery Process" (August 1976).

Combustion Engineering, Inc., "Environmental Impact Information, Combustion Engineering, Inc., Hematite Facility" (June 1975).

"Effluent Monitoring Report," submitted to the NRC by Combustion Engineering semiannually for the year 1980.

Environmental Impact Appraisal by the Division of Fuel Cycle and Material Safety Related to License Renewal for Material License No. SNM-33, Hematite Nuclear Fuel Manufacturing Facility, Jefferson County, Missouri, for Combustion Engineering, Inc., Docket No. 70-36, Nuclear Regulatory Commission report NR-FM-012 (March 1977).

Missouri Clean Water Commission Authorization to Discharge Under the National Pollutant Discharge Elimination System, Missouri Department of Natural Resources (September 1979).

"NPDES Monitoring Report for Non-Municipal Wastewater Discharges," submitted to the Missouri Department of Natural Resources, Division of Environmental Quality, by Combustion Engineering, quarterly for the years 1976-1981 (first quarter).

Nuclear Regulatory Commission staff, "Environmental Review of Applicant's License Amendment (SNM-33) to the Installation and Operation of a Wet Scrap Recovery Process" (1977).

TABLE II-3

NPDES MONITORING DATA (002 OUTFALL)

Date	Flow[a] (MGD)	Flow[a] ($m^3/s \times 10^{-2}$)	TSS (mg/ℓ)	pH	Temperature °C	Fluoride (mg/ℓ)	Oil & Grease (mg/ℓ)	Gross α (pCi/ℓ)	Grossβ (pCi/ℓ)
Jan 1977	0.05	0.22	15	7.8	5	2.5	3.7	59	50
Feb	0.13	0.57	1	7.0	12.2	<1.0	1.0	34	17
March	0.81	3.55	10	6.7	16.0	<1.0	6.7	14	14
April	0.5	2.19	6	6.9	20.0	<1.0	7.0	27	15
May	0.3	1.31	10	7.0	24.0	<1.0	8.0	28	25
June	0.6	2.63	9	6.9	24.0	<1.0	13.0	78	30
July	Pond down for repairs to site dam								
Aug	0.05	0.22	1.2	6.9	30.0	1.6	5.4	158	56
Sept	0.08	0.35	<1.0	6.8	24.5	<1.0	4.6	173	114
Oct	0.20	0.88	<1.0	6.9	17.7	<1.0	1.7	76	59
Nov	0.41	1.80	3.0	7.1	17.5	<1.0	2.7	31	16
Dec	0.88	3.85	0.3	6.9	14.7	<1.0	<1.0	16	18
Jan 1978	0.28	1.23	1.5	7.0	13.6	<1.0	<1.0	74	14
Feb	0.23	1.01	<1.0	6.9	13.8	<1.0	1.7	61	122
March	1.362	5.97	NA	6.9	12.3	NA	NA	16	13
April	0.56	2.45	3.6	6.8	15.0	<1.0	1.5	10	17
May	0.33	1.45	2.1	6.8	18.0	<1.0	1.6	10	13
June	0.63	2.76	3.6	6.9	20.0	<1.0	2.5	65	67
July	0.39	1.71	15.7	6.8	26.0	1.6	6.9	45	628
Aug	0.44	1.93	16.0	7.0	24.0	1.9	2.33	128	2374[b]
Sept	0.36	1.58	7.0	7.7	17.0	0.58	<1.0	93	654
Oct	0.10	0.44	7.0	7.7	17.0	<1.0	<1.0	220	429
Nov	0.13	0.57	6.0	8.5	12.0	2.0[b]	23.0[b]	138	276
Dec	0.60	2.63	4.5	7.2	9.0	<1.0	2.3	63	84
Jan 1979	NA								
Feb	NA								
March	NA								
April	1.8	7.88	2.8	6.8	16	<1.0	7.4	16	11
May	2.1	9.20	7.5	6.9	23	<1.0	7.7	16	20
June	2.0	8.75	<1.0	7.3	25	<1.0	5.4	60	66
July	0.05	0.22	6.0	8.1	28	<1.0	7.4	63	78.7
Aug	0.38	1.66	2.1	7.3	24	<1.0	6.9	38	36.0
Sept	0.06	0.26	4.8	7.5	18	<1.0	13.1	37.5	28.5
Oct	0.24	1.05	3.6	7.3	17	9[b]	4.8	71.0	96
Nov	0.33	1.45	1.2	7.4	4	<1.0	5.4	48	77
Dec	0.37	1.67	NA	NA	NA	NA	NA	NA	NA
Jan 1980	0.17	0.74	5.7	8.0	3	5[a]	1.7	c	c
Feb	0.42	1.84	4.5	7.9	11	1	4.9	c	c
March	1.3	5.69	18.0[b]	6.9	16	<1	6.9	c	c
April	0.63	2.76	1.8	7.3	18	2[b]	8.9	c	c
May	0.20	0.88	<0.1	7.2	22	8[b]	0.6	c	c
June	0.15	0.66	<0.1	7.8	28	17[b]	0	c	c
July	0.04	0.18	<1.0	7.1	32	<1	5.4	c	c
Aug	0.22	0.96	3.6	7.59	25	<1	2.6	c	c
Sept	0.15	0.66	1.8	7.8	23	<1	1.4	c	c
Oct	0.12	0.53	2.1	7.23	17	<1	<0.01	c	c
Nov	0.08	0.35	2.4	7.2	5	<1	<0.01	c	c
Dec	0.02	0.09	2.1	7.6	5	<1	<0.01	c	c

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[a] Includes spring flow of 60 gpm.
[b] Non-compliance.
[c] See Table II-4.
Source: Reports to EPA

TABLE II-4

SEMIANNUAL SUMMARY OF RADIOLOGICAL MONITORING
Combustion Engineering, Inc., Hematite, Missouri

	Monthly Average[a]		Highest Sample[a]	
1979	Alpha	Beta	Alpha	Beta
Discharge 001 (Sewer)				
July	66.0	33.0	66	32
Aug	76.2	75.2	113	132
Sept	39.7	29.0	59	31
Oct	53.0	35.0	92	61
Nov	78.0	84.0	114	148
Dec	50.0	33.0	58	49
Discharge 002 (Pond)				
July	63.0	78.7	77	113
Aug	38.0	36.0	56	65
Sept	37.5	28.5	55	50
Oct	71.0	96.0	101	148
Nov	48.0	77.0	62	95
Dec	29.0	16.0	56	26
Joachim Creek Upstream				
July	2.0	2.0		
Aug	8.0	9.0		
Sept	2.0	7.0		
Oct	4.0	8.0		
Nov	1.0	3.0		
Dec	2.0	5.0		
Joachim Creek Downstream				
July	2.0	2.0		
Aug	5.0	3.0		
Sept	2.0	6.0		
Oct	9.0	4.0		
Nov	5.0	5.0		
Dec	1.0	6.0		
Confluence				
July–Sept	3.0	3.0		
Oct–Dec	6.0	5.0		
Hematite Well				
July–Sept	7.0	3.0		
Oct–Dec	8.0	3.0		
Plant Well				
July–Sept	3.0	3.0		
Oct–Dec	3.0	3.0		

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[a] All values are picocuries per liter.
USNRC limits are alpha - 30 000
beta - 20 000

Source: EMR 1980.

TABLE II-4 (cont)

	Monthly Average		Highest Sample	
1980	Alpha	Beta	Alpha	Beta
Discharge 001 (Sewer)				
Jan	83	38	164	79
Feb	301	78	864	133
Mar	126	150	222	263
Apr	34	42	83	80
May	35	47	84	64
June	7	67	15	164
Discharge 002 (Pond)				
Jan	26	16	52	24
Feb	20	27	30	65
Mar	17	10	29	15
Apr	21	49	47	157
May	29	26	59	39
June	47	40	55	52
Joachim Creek Upstream				
Jan	4	5		
Feb	3	<3		
Mar	<2	6		
Apr	4	<3		
May	7	3		
June	3	3		
Joachim Creek Downstream				
Jan	5	3		
Feb	<2	<3		
Mar	<2	4		
Apr	7	5		
May	3	4		
June	3	4		
Confluence				
Jan–Mar	<2	3		
Apr–June	5	7		
Hematite Well				
Jan–Mar	5	5		
Apr–June	8	29		
Plant Well				
Jan	4	4		
Feb	2	<3		
Mar	32	8		
Apr	4	3		
May	<2	<3		
June	7	3		

TABLE II-4 (cont)

	Monthly Average		Highest Sample	
1980	Alpha	Beta	Alpha	Beta
Discharge 001 (Sewer)				
July	54	361	148	820
Aug	62	367	132	817
Sept	72	226	202	433
Oct	209	119	359	195
Nov	170	45	191	66
Dec	19	37	23	63
Discharge 002 (Pond)				
July	67	84	81	167
Aug	39	45	88	146
Sept	23	14	26	17
Oct	82	26	275	93
Nov	26	17	29	20
Dec	16	8	19	11
Joachim Creek Upstream				
July	<2	<3		
Aug	3	3		
Sept	<2	<3		
Oct	<2	<3		
Nov	<2	<3		
Dec	<2	<3		
Joachim Creek Downstream				
July	<2	<3		
Aug	6	3		
Sept	<2	<3		
Oct	<2	<3		
Nov	4	3		
Dec	<2	<3		
Confluence				
July–Sept	<2	<3		
Oct–Dec	<2	<3		
Hematite Well				
July–Sept	<2	<3		
Oct–Dec	<2	<3		
Plant Well				
July	<2	<3		
Aug	<2	<3		
Sept	<2	<3		
Oct	<2	<3		
Nov	<2	<3		
Dec	<2	<3		

APPENDIX

ENVIRONMENTAL MONITORING SUMMARY
1975-1980 (1981)

Combustion Engineering, Inc.

TABLE A-1

STACK MONITORING—RADIOACTIVITY[a]

(Microcuries released)

	1975	1976	1977	1978	1979	1980
January	94.9	39.4	26.9	5.9	2.0	12.9
February	27.7	100.7	23.7	28.4	2.2	3.2
March	2.9	43.8	9.3	22.0	0.8	4.9
April	5.8	102.7	6.2	17.6	0.7	1.6
May	17.5	27.4	20.6	63.2	0.8	3.4
June	7.3	80.0	7.4	10.3	0.1	2.3
July	4.4	140.2	6.3	16.7	0.3	7.6
August	2.9	2.9	6.3	16.7	0.1	3.7
September	1.5	43.8	4.7	8.8	0.1	1.7
October	62.8	33.6	20.5	5.6	2.0	6.1
November	16.1	24.8	14.2	2.2	8.4	2.4
December	16.1	36.5	4.6	1.1	2.3	3.9
Total	259.9	675.8	150.7	198.5	19.8	53.7
Site Boundary[b] Conc – μCi/mℓ	0.8×10^{-15}	2.1×10^{-15}	0.5×10^{-15}	0.6×10^{-15}	0.06×10^{-15}	0.2×10^{-15}
% MPC	0.020	0.052	0.012	0.015	0.002	0.005

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[a] Determined by gross alpha counting after allowing at least 8 h for decay of radon daughters.
[b] Calculated - does not take credit for site boundary expansion in 1979.

TABLE A-2

ENVIRONMENTAL AIR MONITORING—RADIOACTIVITY[a]

(10^{-15} microcuries per milliliter)

	1978		1979		1980	
	North Station	Southwest Station	North Station	Southwest Station	North Station	Southwest Station
January	5	<2	<2	<2	5	7
February	<2	<2	<2	2	5	<2
March	<2	<2	3	9	4	4
April	6	3	<2	4	7	<2
May	4	3	3	<2	3	6
June	2	<2	4	<2	3	2
July	2	3	10	2	5	<2
August	6	4	6	3	3	3
September	4	2	5	3	3	<2
October	5	7	2	<2	4	<2
November	6	6	3	3	7	4
December	2	<2	3	4	3	6
Average Concentration	3.8	2.8	3.2	2.5	3.9	2.7

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[a] Determined by gross alpha counting after allowing a 72-h period for decay of radon and thoron daughters.

TABLE A-3

SITE DAM OVERFLOW MONITORING—RADIOACTIVITY
(picocuries per liter)

	1975		1976		1977		1978		1979		1980	
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta
January	85	53	52	18	59	50	74	14	231	124	26	16
February	18	10	107	60	34	17	61	122	12	18	20	27
March	34	21	160	50	14	14	16	13	8	8	17	10
April	12	15	228	65	27	15	10	17	16	11	21	49
May	22	32	73	26	28	25	10	13	16	36	29	26
June	111	90	81	56	78	30	65	67	61	66	47	40
July	103	180	83	25	a	a	45	628	63	79	67	84
August	65	22	235	47	158	56	128	2374	38	31	39	45
September	28	16	187	45	173	114	93	654	38	29	23	14
October	89	36	153	45	76	59	220	429	71	96	82	26
November	102	32	82	39	31	16	138	276	48	77	26	17
December	a	a	144	74	16	18	63	84	29	17	16	8
Average Concentration	61	46	132	46	63	38	77	391	53	49	34	30
% MPC	0.2	0.2	0.4	0.2	0.2	0.1	0.3	2.0	0.2	0.2	0.1	0.2

---

[a] Data not available.

NOTE: Beta activity for Augut 1978 identified as ^{99}Tc, having MPC of 3 x 10^5 pCi/mℓ. Per cent MPC, however, is based on an MPC of 20 000 pCi/ℓ.

TABLE A-4

JOACHIM CREEK MONITORING—RADIOACTIVITY
(picocuries per liter)

	1975				1976				1977			
	Upstream		Downstream		Upstream		Downstream		Upstream		Downstream	
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta
January	<2	8	<2	<1	<2	4	8	4	b	b	b	b
February	a	a	a	a	<2	<1	6	<1	5	3	3	<3
March	a	a	a	a	<2	<1	<2	5	4	6	2	5
April	<2	<1	28	<1	6	<1	8	<1	2	3	3	9
May	a	a	a	a	<2	5	<2	<1	2	3	3	2
June	<2	<1	<2	5	<2	<1	<2	5	<2	5	4	4
July	6	12	<2	5	<2	<1	<2	<1	2	9	5	5
August	a	a	a	a	4	4	5	4	2	12	18	12
September	<2	<1	<2	<1	<2	2	6	3	6	11	7	7
October	<2	21	4	10	<2	4	5	8	2	60	2	5
November	<2	<1	<2	<1	7	5	10	9	<2	3	<2	3
December	a	a	a	a	<2	5	13	6	<2	4	2	4

	1978				1979				1980			
	Upstream		Downstream		Upstream		Downstream		Upstream		Downstream	
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta
January	b	b	b	b	b	b	b	b	4	5	5	3
February	2	3	3	3	<2	3	<2	6	3	<3	<2	<3
March	3	7	<2	2	<2	<3	<2	4	<2	6	<2	4
April	2	2	3	3	<2	3	<2	3	4	<3	7	5
May	2	4	<2	3	<2	4	3	5	7	3	3	4
June	2	3	5	5	<2	<3	<2	4	3	3	3	4
July	3	4	14	17	<2	4	2	3	<2	<3	<2	<3
August	<2	3	<2	23	8	9	5	3	3	3	6	3
September	<3	4	4	9	<2	7	2	6	<2	<3	<2	<3
October	<2	4	4	7	4	8	9	4	<2	3	<2	<3
November	6	<3	<2	<3	1	3	5	5	<2	<3	4	3
December	2	9	2	5	<2	5	1	6	<2	<3	<2	<3

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[a] Data not available.

[b] Stream frozen over - no sample collected.

TABLE A-5

QUARTERLY LIQUID ENVIRONMENTAL MONITORING—RADIOACTIVITY
(picocuries per liter)

	Site Well		Creek Confluence		Hematite Well	
	Alpha	Beta	Alpha	Beta	Alpha	Beta
April 1975	<2	<1	29	<1	<2	<1
September	<2	<1	a	a	<2	<1
November	<2	<1	a	a	<2	<1
February 1976	11	10	<2	<1	<2	<1
May	<2	6	<2	<1	<2	3
August	4	3	8	6	a	a
November	7	5	9	5	18	8
February 1977	3	3	11	15	5	<3
May	5	<3	6	6	<2	<3
September	6	3	48	29	2	4
October	<2	4	<2	234	7	4
March 1978	6	18	4	5	4	<3
June	3	4	2	6	7	4
September	<3	4	42	491	7	3
November	10	16	4	8	4	3
February 1979	16	56	<2	4	<2	<3
May	6	6	8	8	3	3
August	3	3	3	3	7	<3
November	4	2	6	5	8	3
March 1980	32	8	<2	3	5	5
June	7	3	5	7	8	29
September	<2	<3	<2	<3	<2	<3
November	<2	<3	<2	<3	<2	<3

---

[a] Data not available.

TABLE A-6

RETENTION POND SAMPLE WELL MONITORING—RADIOACTIVITY
(picocuries per liter)

	1977						1978					
	North		East		West		North		East		West	
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta
January	a	a	a	a	a	a	a	a	a	a	a	a
February	33	105	41	24	b	b	3	65	2	212	b	b
March	12	13	6	5	b	b	2	217	<2	3	b	b
April	<2	58	<2	<3	b	b	5	120	3	6	b	b
May	8	134	6	3	b	b	7	611	<2	<3	b	b
June	5	596	2	4	b	b	9	447	9	9	b	b
July	6	460	12	9	b	b	4	1550	<2	4	b	b
August	8	1510	5	18	b	b	54	4820	10	12	b	b
September	28	937	5	4	b	b	86	1030	6	9	b	b
October	3	8	2	5	b	b	57	581	4	4	13	12
November	2	107	<2	<3	b	b	69	1490	17	13	16	14
December	3	76	<2	3	b	b	8	337	4	7	13	14

	1979						1980					
	North		East		West		North		East		West	
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta
January	a	a	a	a	a	a	48	3	2	5	2	3
February	17	432	2	5	5	7	36	546	3	2	16	8
March	25	566	<2	<3	5	10	13	386	<2	7	2	2
April	12	363	2	<3	5	5	17	385	6	<3	6	4
May	26	316	<2	5	4	12	<2	<3	3	7	4	4
June	8	270	7	10	<2	3	7	12	5	4	3	<3
July	23	452	8	18	23	22	31	1696	2	<3	<2	5
August	22	520	5	5	9	9	<2	<3	6	3	7	9
September	30	317	8	9	3	7	<2	98	<2	<3	<2	3
October	40	27	3	4	11	7	<2	992	<2	<3	7	10
November	42	1125	<2	16	5	2	<2	377	18	6	4	3
December	25	447	<2	7	1	9	<2	6	2	3	<2	5

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[a] No sample because of heavy ice and snow cover.
[b] Well dry at this time.

Note: Beta activity in July 1978 north well sample identified as ^{99}Tc.

TABLE A-7

SITE WATER SUPPLY WELL MONITORING—RADIOACTIVITY
(picocuries per liter)

	1975		1976		1977		1978		1979		1980	
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta
January	a	a	a	a	a	a	3	10	4	3	4	4
February	a	a	11	10	3	3	12	66	16	56	2	<3
March	a	a	a	a	3	<3	6	18	<2	3	32	8
April	<2	<1	a	a	4	<3	2	3	<2	<3	4	3
May	a	a	<2	6	5	<3	2	7	6	6	<2	<3
June	a	a	a	a	6	3	3	4	<2	<3	7	3
July	a	a	a	a	a	a	2	5	<2	<3	<2	<3
August	a	a	4	3	6	3	<2	3	3	3	<2	<3
September	<2	<1	a	a	a	a	<3	4	7	7	<2	<3
October	a	a	a	a	<2	4	2	4	a	a	<2	<3
November	<2	<1	7	5	a	a	10	16	4	2	<2	<3
December	a	a	a	a	3	17	4	2	6	7	<2	<3

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[a] Data not available.

TABLE A-8

SEWAGE OUTFALL MONITORING—RADIOACTIVITY
(picocuries per liter)

	1977[a]		1978[b]		1979		1980	
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta
January			261	75	493	139	83	38
February	40	16	669	166	133	68	301	78
March			105	36	118	95	126	150
April			80	57	53	138	34	42
May	c	c	116	354	53	61	35	47
June			95	120	47	70	8	67
July			89	191	66	33	54	361
August	385	133	149	114	69	66	62	367
September			51	121	40	29	72	226
October			70	67	53	35	209	119
November	44	22	90	174	78	84	170	45
December			147	89	50	33	19	37

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[a] Quarterly sampling was conducted during 1977.
[b] New sewage treatment plant installed May 1978.
[c] No sample because of intermittent trickle discharge.

TABLE A-9

SOIL AND VEGETATION MONITORING—RADIOACTIVITY
(picocuries per gram[a])

	Station 12				Station 13				Station 14				Station 15			
	Soil		Vegetation		Soil		Vegetation		Soil		Vegetation		Soil		Vegetation	
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta
April 1975	6.5	2.2	<0.3	3.6	3.4	2.5	<0.3	3.6	1.3	1.0	<0.3	3.1	6.8	9.9	<0.3	4.3
September	5.0	3.0	1.0	3.0	14.0	3.0	<0.3	2.0	4.0	2.0	<0.3	2.0	8.0	3.0	2.0	3.0
November	6.0	4.0	2.0	5.6	7.0	7.0	3.0	6.0	5.0	2.0	2.0	5.0	26.0	5.0	2.0	14.0
February 1976	10.0	13.0	1.0	10.0	9.0	12.0	2.0	10.0	8,0	13.0	2.0	4.0	15.0	14.0	4.0	4.0
May	17.0	18.0	1.0	9.0	2.0	3.0	<0.3	11.0	8.0	2.0	1.0	8.0	26.0	5.0	1.0	10.0
August	7.5	18.0	0.6	9.5	5.5	2.4	5.5	7.6	4.3	2.8	0.5	5.8	9.7	3.4	1.8	6.5
November	70.8	3.6	3.0	9.0	72.0	25.0	3.0	7.0	9.0	5.0	1.0	6.0	31.0	14.0	2.0	10.0
March 1977	3.5	2.8	2.7	8.8	4.7	3.5	6.1	7.6	4.5	3.5	3.3	9.8	4.2	3.4	1.9	10.3
June	3.3	1.4	0.1	2.0	9.5	4.9	1.8	6.7	6.5	2.9	1.9	5.1	10.1	5.2	0.6	3.6
September	13.1	5.2	0.5	6.3	5.6	3.7	1.5	12.5	4.7	3.8	0.8	6.3	13.6	5.2	0.1	16.4
October	65.1	24.5	1.2	9.2	24.5	11.3	0.8	19.2	31.3	20.1	1.7	15.8	14.0	25.7	3.2	11.3
March 1978	8.0	5.0	4.6	10.1	8.7	2.5	4.9	14.7	6.1	3.3	5.0	9.8	5.9	3.1	3.3	12.1
June	8.7	5.0	0.9	12.5	8.9	4.4	4.6	10.7	7.9	5.0	0.9	8.5	3.2	1.6	0.9	7.0
September	8.7	6.0	1.0	9.1	8.0	2.1	0.9	10.2	5.7	2.7	0.5	7.9	6.6	3.5	0.5	8.8
November	10.8	7.2	2.7	8.9	63.7	8.1	1.1	4.0	9.7	5.0	1.9	6.9	12.7	6.0	5.8	5.7
March 1979	3.4	2.1	5.1	6.3	2.3	1.6	0.9	4.2	3.3	0.7	0.8	5.8	3.2	2.2	2.1	7.7
May	6.5	4.7	1.3	9.0	8.0	2.4	1.2	8.5	4.6	4.2	0.6	7.2	5.1	4.2	0.8	5.4
August	2.0	<3.0	1.8	8.0	2.0	<3.0	1.3	7.7	8.0	<3.0	1.0	5.3	3.0	<3.0	0.5	2.4
November	2.7	0.8	0.4	3.8	1.9	1.4	0.8	5.5	5.3	1.4	0.7	3.3	10.9	2.1	1.1	4.1
March 1980	7.8	4.4	b	b	2.2	2.2	b	b	16.2	5.1	8.9	21.3	13.8	4.7	b	b
June	9.3	4.4	b	b	2.7	2.2	b	b	15.5	5.3	b	b	15.5	6.7	0.0	26.6
September	7.3	2.5	0.6	2.5	1.0	1.1	0.4	3.0	6.4	2.0	0.4	3.1	8.5	2.1	0.0	2.5
November	18.3	3.7	0.0	95.4	5.2	2.7	0.0	69.8	5.2	2.7	0.0	90.5	5.3	2.0	20.6	86.2

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[a] Based on dry weight of sample.

[b] Data not available.

TABLE A-10

STACK MONITORING—FLUORIDE
(10^3 pounds F^- released)

	1977	1978	1979	1980
January	—	1.0	0.6	1.2
February	—	0.6	1.5	2.4
March	—	0.5	0.7	1.4
April	0.5	1.2	1.2	1.1
May	0.9	1.1	1.6	2.6
June	1.1	1.1	0.1	2.1
July	0.3	0.9	1.0	0.3
August	1.1	0.7	1.7	1.2
September	0.2	1.5	1.5	0.7
October	0.8	1.0	2.0	0.4
November	0.7	0.4	0.9	1.7
December	0.3	0.6	1.3	0.1
Total	5.9 (9 mo)	10.6	14.1	15.2

TABLE A-11

SITE DAM OVERFLOW MONITORING—FLUORIDE
(milligrams per liter)

	1975	1976	1977	1978	1979	1980
January	a	a	2.5	a	<1.0	5.0
February	a	<1.0	<1.0	<1.0	<1.0	1.0
March	a	a	<1.0	<1.0	<1.0	<1.0
April	<1.0	<1.0	<1.0	<1.0	<1.0	2.0
May	a	<1.0	<1.0	<1.0	<1.0	<8.0
June	a	<1.0	<1.0	<1.0	<1.0	17.0
July	a	<1.0	a	1.6	<1.0	<1.0
August	a	<1.0	1.6	1.9	<1.0	<1.0
September	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
October	a	<1.0	<1.0	<1.0	9.0	<1.0
November	3.0	2.4	<1.0	2.0	<1.0	<1.0
December	a	2.5	<1.0	<1.0	<1.0	<1.0

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[a] Not analyzed.

TABLE A-12

VEGETATION MONITORING—FLUORIDE[a]

(parts per million)

	Station 12	Station 13	Station 14	Station 15
July 1976	<2.0	<2.0	<2.0	2.0
November	b	b	b	b
March 1977	12.4	12.4	22.8	29.0
June	3.2	2.4	<2.0	<2.0
September	4.2	<2.0	3.4	<2.0
October	3.8	2.1	2.0	1.5
March 1978	92.0	22.0	17.0	15.0
June	28.4	16.0	11.7	25.2
September	4.6	6.4	3.0	7.4
November	4.0	8.2	<2.0	2.6
March 1979	66.0	23.0	16.0	25.0
May	21.0	8.0	7.0	19.0
August	9.0	8.0	9.0	9.0
November	11.0	56.0	10.0	18.0
March 1980	6.0	18.0	9.0	19.0
June	4.6	24.0	<4.0	7.6
September	26.0	8.6	9.2	15.2
November	<2.0	<2.0	<2.0	12.0

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[a] Total fluoride in sample as collected.
[b] Data not available.

CHAPTER III

WESTINGHOUSE ELECTRIC CORPORATION COMMERCIAL NUCLEAR FUEL FABRICATION PLANT COLUMBIA, SOUTH CAROLINA

A. Background Information

1. Plant Operation

Westinghouse Electric Corporation's Nuclear Fuel Columbia Site (NFCS) receives low-enriched UF_6 (less than 4.15% ^{235}U) from the enrichment facilities and converts this material into PWR commercial reactor fuel assemblies. Plant processes include (1) converting UF_6 to UO_2, (2) processing the UO_2 powder into pellets, (3) encapsulating the pellets into fuel rods, (4) fabricating fuel rods into final assemblies, and (5) packaging for shipment to the reactor site (EIA 1977).

2. History

The facility began operation in September 1969. Through 1974, plant capacity was approximately 400 MtU/yr (metric ton uranium throughput per year). Since that time, capacity has been increasing. Currently, the plant capacity is somewhat less than 1200 MtU/yr (RA, NRC).

3. Site

The facility is located in Richland County, South Carolina, approximately 8 miles southeast of Columbia (Fig. III-1). Westinghouse controls approximately 1158 acres, of which 60 acres are used for the plant and its associated facilities (Fig. III-2). The remaining acreage is composed of lake, woodland, swamp, and field (EIA 1977).

Further data on nearby population density, land use, geology, hydrology, meteorology, etc., may be obtained from the Environmental Impact Appraisal.

4. Resource Usage

In 1977, approximately 700 people were employed. Since that time, the employment has gradually increased as plant capacity has increased. It has been projected that 1850 people would be employed if the plant expanded to a capacity of 1600 MtU/yr (EIA 1977).

Chemicals used in the plant include ammonium hydroxide, nitrogen, nitric acid, sulfuric acid, hydrofluoric acid, sodium hydroxide, hydrochloric acid, nickel sulfate, sodium carbonate, organics (used in cleaning and in pellet production), anhydrous ammonia, hydrogen, argon, helium, and lime (EIA 1977).

Water is obtained from the Columbia Municipal Water System. Approximately 10.6×10^6 gal./month (37.8×10^3 m^3/month are estimated to be required for the plant for processing 1600 MtU. About 45% of the water coming into the plant is lost by evaporation. Approximately 2.85×10^6 gal./month (10.8×10^3 m^3/month) are estimated to be discharged as process wastes, and 2.85×10^6 gal./month (10.8×10^3 m^3/month) are estimated to be discharged as sanitary wastes at a throughput of 1600 MtU. At present, while operating at less than 1600 MtU, the water requirements and discharges are somewhat less*. The liquid wastes are transferred by pipeline to the Congaree River about 3.5 mi south of the facility, where they are discharged (EIA 1977).

Energy is required for processing operations, compressors, pumps, etc. Natural gas is used as the fuel in most of the equipment (EIA 1977).

B. Process Operations

1. Conversion—ADU Process

a. UF_6 Vaporization and Hydrolysis. The UF_6 is received into the facility in standard 2.5-ton cylinders and is placed in storage. When required, a cylinder is removed from storage and placed in a steam chamber (Fig. III-3). The UF_6 is vaporized in the steam chamber and moves into the desired ADU line. There are several ADU conversion lines so that different isotopic enrichments may be converted simultaneously. Each conversion line uses the same basic operation (EIA 1977).

Water is added to the gaseous UF_6, and the UF_6 is converted to an aqueous solution of uranyl fluoride and hydrofluoric acid:

$$UF_6 + 2H_2O \rightarrow UO_2F_2 + 4HF.$$

Any off-gases from vaporization and hydrolysis pass through a common scrubber and then through an absolute filter (EE 1975).

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*See Table III-5.

Fig. III-1. Westinghouse nuclear fuel site, Columbia, South Carolina.

Source: EIA 1977.

The solution of uranyl fluoride undergoes a pH adjustment and then moves into the precipitation circuit (EE 1975).

b. Precipitation. Ammonium hydroxide is added to the uranyl fluoride (Fig. III-3) to cause formation of solid precipitated particles of $(NH_4)_2U_2O_7$, often referred to as ADU:

$$2UO_2F_2 + 6NH_4OH \rightarrow (NH_4)_2U_2O_7 + 4NH_4F + 3H_2O.$$

Off-gases pass through a scrubber and filter (EE 1975).

c. Dewatering, Drying, Calcination. After formation of the ADU particles in the liquid, the particles are dewatered in a centrifuge and processed through a rotary dryer (Fig. III-3). The dewatered solids and some recycle material are loaded into a rotary calciner. In a reducing atmosphere, the ADU is reduced to uranium dioxide:

$$(NH_4)_2U_2O_7 + 2H_2 \rightarrow 2UO_2 + 2NH_3 + 3H_2O.$$

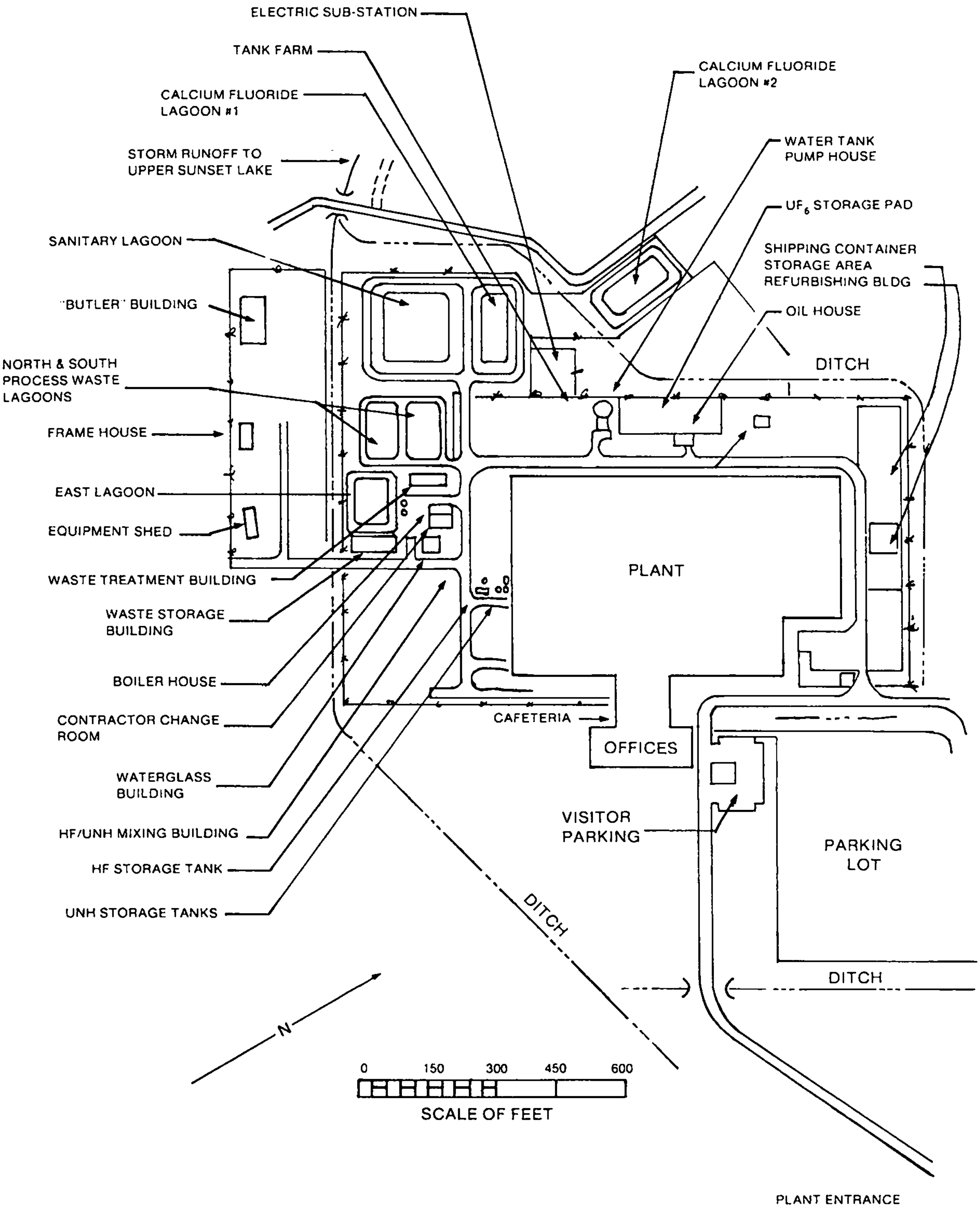
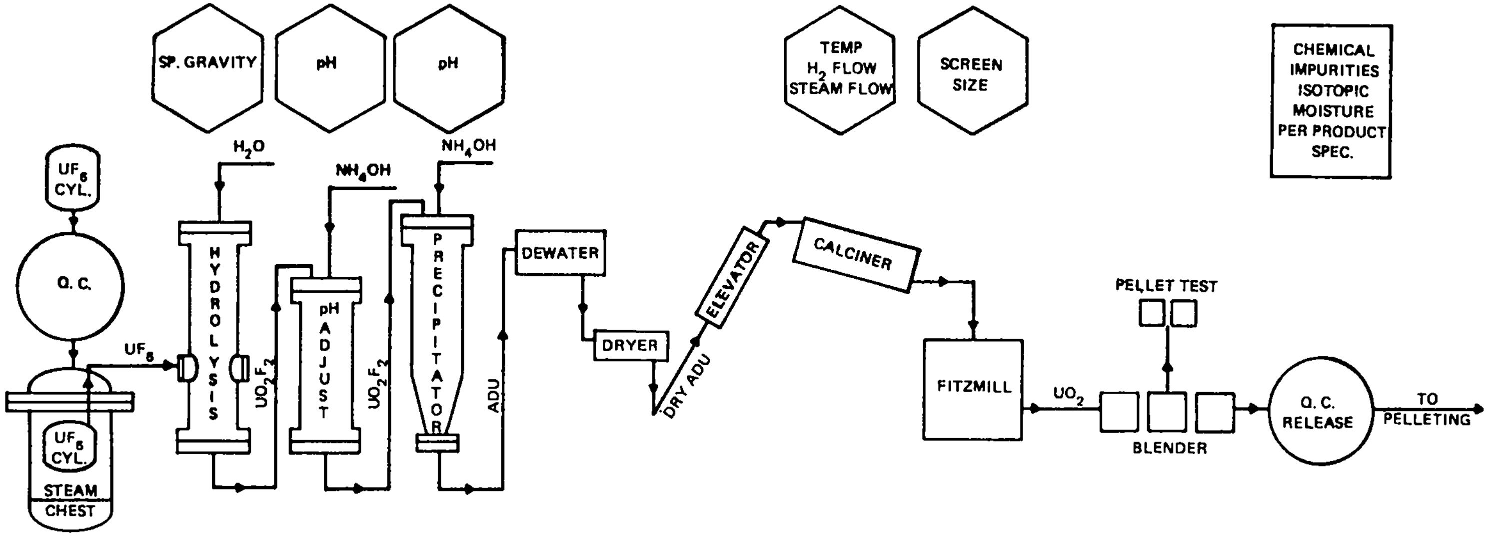


Fig. III-2. Detailed Columbia site plan.

Source: Westinghouse Electric Corporation.



VAPORIZATION	HYDROLYSIS	pH ADJUST	PRECIPITATOR	DE-WATER	DRYER	ELEVATOR	CALCINER	FITZMILL	BLENDER	Q. C. RELEASE
UF_6 FLOW UF_6 TEMP. STEAM PRESSURE	H_2O FLOW UF_6 FLOW TEMP. LEVEL CONTROL	LEVEL CONTROL NH_4OH FLOW	H_2O FLOW TEMP. LEVEL CONTROL NH_4OH FLOW NH_3 CONC.	% SOLIDS LEVEL H_2O ADD. PUMP SPEED	PRESSURE PRODUCT TEMP.	PRESSURE	TUBE SPEED PRESSURE N_2 FLOW	SCREEN SIZE RPM	PELLET TEST DENSITY INTEGRITY	PHYSICALS

Fig. III-3. Chemical conversion process.

Source: Westinghouse Electric Corporation.

The calciner off-gases pass through a scrubber, where the ammonia is absorbed. The scrubbed gases then pass to the central filter system. The dilute liquid ammonia coming from the scrubber is either reused in the first stage of dewatering or is sent to the waste treatment facility (EIA 1977).

The liquid discharge from the ADU dewatering is sent to a second stage of dewatering from which the "solids slurry" goes back to recycle and the liquids are sent to the uranium recovery waste liquid treatment facility (RAAOAWTP 1980 and EE 1975).

d. Liquid Treatment. In the advanced uranium recovery waste treatment facility (Fig. III-4), uranium-containing liquid waste streams from ADU precipitation, scrubber liquids, and uranium recovery operations are mixed together and treated with a flocculating agent and other chemicals to precipitate uranium compounds. (The complete process is proprietary.) The slurry, after chemical treatment, undergoes solid/liquid separation. The solid residues that contain uranium have the uranium recovered in the wet scrap recovery circuit.

In previous years, an ion exchange system was used to recover uranium. This new system is designed for better recovery. Although some start-up problems have been encountered for this treatment system, it is estimated that if the system works as designed, the liquid effluent will contain ≤ 0.5 ppm of uranium.*

The barren solution from the uranium recovery waste treatment contains NH_4F and other ammonia compounds. The liquid stream is first treated with slaked lime:

$$2NH_4F + Ca(OH)_2 \rightarrow 2NH_4OH + CaF_2,$$

and then pumped through a heat exchanger. Before distillation, further lime is added to adjust pH, and in addition, NaOH is added to convert most of the bound ammonia into free ammonia:

$$NH_4^+ + OH^- \rightarrow NH_3 + H_2O.$$

The treated liquid is then run through a still (Fig. III-4). The stripped ammonium hydroxide (30%) is stored for reuse in the ADU conversion process. Liquid (containing CaF_2) bottoms are dewatered by settling in lagoons. In most cases, the decant liquid is low enough in fluorides that it is discharged (Fig. III-4) (EIA 1977).

The solid CaF_2 sludge is solidified and shipped in bulk to Chem Nuclear's commercial burial site at Barnwell, South Carolina. The sludge is sent to a commercial site because it is difficult to determine the special nuclear material (SNM) content of these sludges, and it is possible that some sludges may contain sufficient quantities of SNM to require commercial burial.*

2. Direct-Conversion Fluidized-Bed (Dry) Process

The company has applied to the NRC for a license to use a direct dry conversion process. This is a proprietary process developed and used in England.* The process is not now in operation and hence is not included in Fig. III-3. When it is installed, it will be used in parallel with the ADU process.

3. Powder Preparation, Blending, and Packaging

a. Milling. To prepare the UO_2 for fuel pellet fabrication, the UO_2 produced in the conversion process is milled to a specific particle size range (Fig. III-3). Off-gases, which contain particles of UO_2, first pass through an absolute filter before discharge to the in-plant exhaust (EIA 1977).

b. Blending and Packaging. After milling, the material is transferred to blenders (Fig. III-3). Off-gases pass through an absolute filter.

After blending, the material is packaged and stored until needed in the pellet preparation circuit (EE 1975).

4. Pellet Production

a. Blending, Granulation, and Pressing. The UO_2 powder from chemical conversion or scrap recovery is removed from storage as necessary. The UO_2 is weighed, and the required amount is discharged into a blender (Fig. III-5). The blended powder is densified in a roll compaction operation and then processed in the granulation circuit. There, an organic binder and solvent are mixed with the powder, which is then dried, granulated, a lubricant added, and the mixture blended and pressed into the desired shape (EIA 1977).

The off-gases from these operations contain organic vapors and small particles of UO_2. The gases pass through absolute filters before discharge to the in-plant exhaust system (EE 1975).

Some contaminated oil will result from the pellet presses. If the oil is free of metal contaminants, it may be burned in the incinerator.

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*This information provided by Gene Coryell, NRC, June 1981.

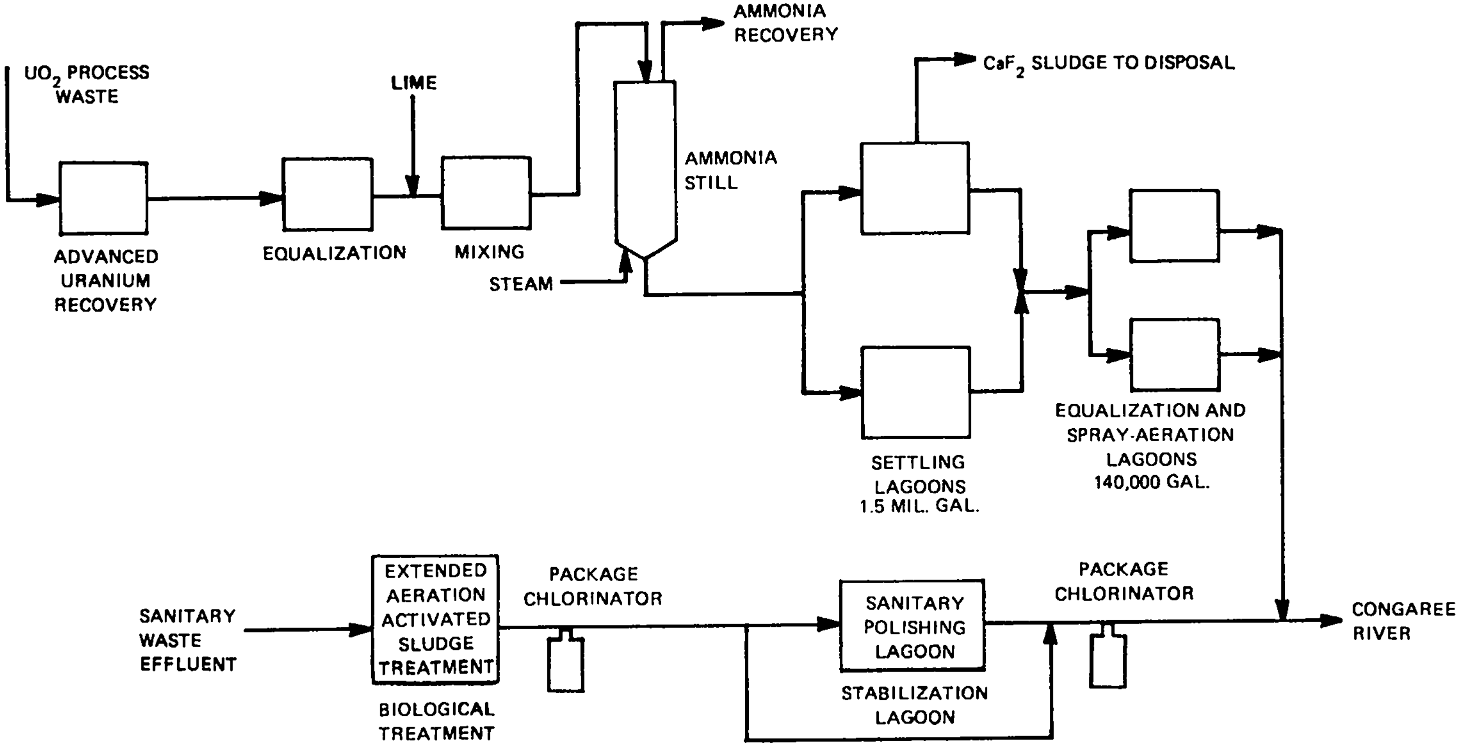

Fig. III-4. Westinghouse waste treatment system.

Source: S.C. Department of Health and Environmental Control.

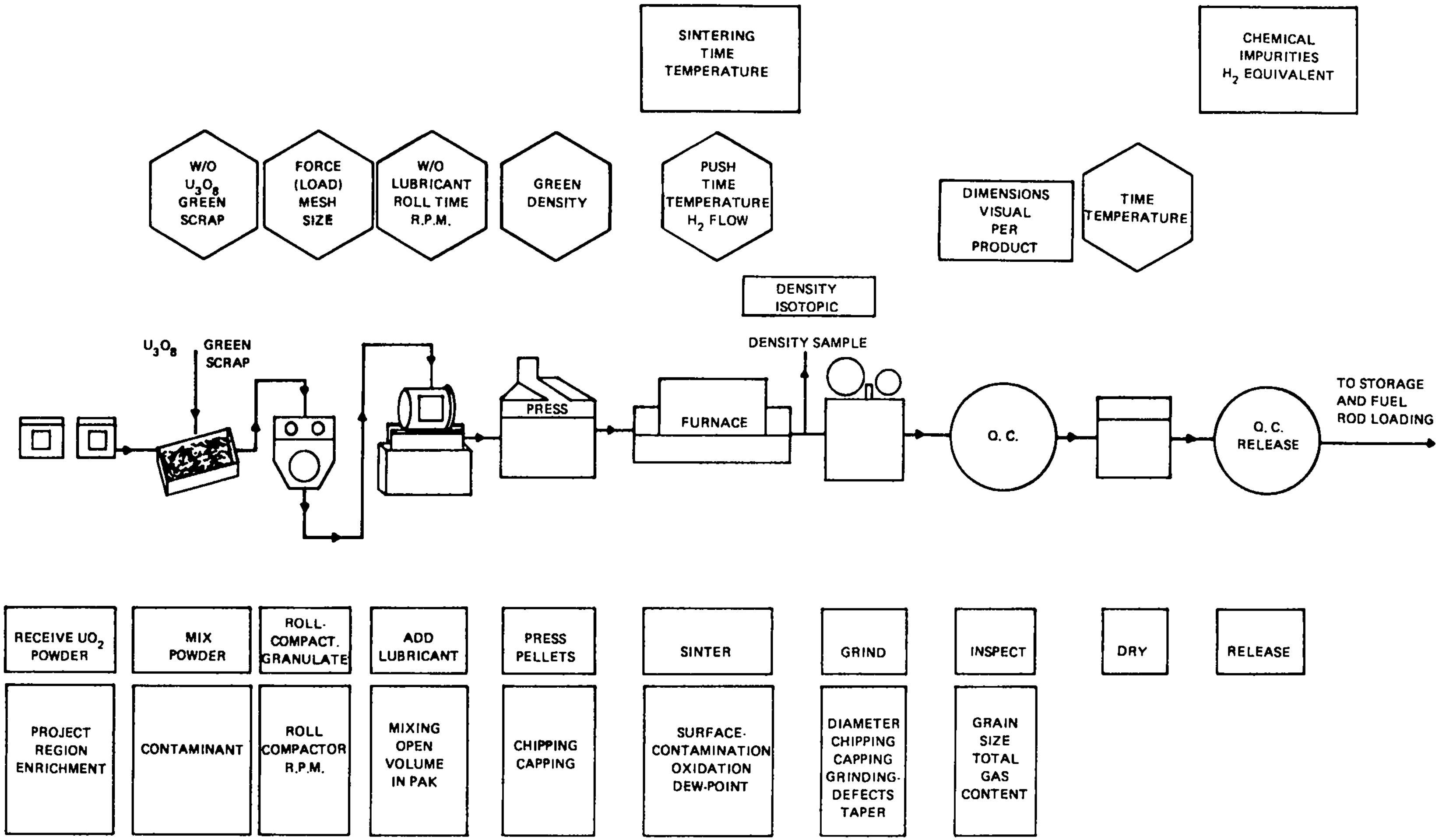

Fig. III-5. Pelleting process.

Source: Westinghouse Electric Corporation.

Reject material from the operations, including vacuum cleaner cleanup material, undergoes granulation (crush, size, and granulate) and reenters the main process stream during powder preparation (EE 1975).

b. Sintering. The pellets are loaded into molybdenum "boats" that pass through a sintering furnace (Fig. III-5). Here, under a reducing atmosphere of hydrogen, the pellets achieve the desired density. Off-gases pass through a dropout pot, heater, and HEPA filter (EIA 1977).

When a furnace is cleaned or otherwise opened, nitrogen is first bled through the system to ensure that all hydrogen is out of the system before oxygen is allowed into the furnace. These nitrogen off-gases receive similar cleanup treatment.*

Reject pellets are sent to oxidation-reduction treatment. Here the pellets are heated in an air atmosphere to form U_3O_8 and then heated in a reducing atmosphere to convert the material to UO_2 (EIA 1977).

The off-gases from these operations contain UO_2 fines, NH_3, N_2, H_2, and H_2O. The gases are treated similarly to those from sintering.

The treated UO_2 from oxidation-reduction reenters the main process line at the powder preparation section (EE 1975).

c. Grinding. Trays of sintered pellets are loaded onto the rotary feed table of a centerless grinder (Fig. III-5). A diamond wheel is used on the grinder together with a water lubricant. Air discharge contains small particles of UO_2 and is passed through a filter before discharge (EE 1975).

The water from the grinding operation is passed through a high efficiency centrifuge to remove particles of UO_2, and the water is recycled. When the amount of very fine suspended UO_2 has built up in the grinding liquid, the liquid is withdrawn and allowed to stand to settle the fine particles of UO_2. This recovered UO_2 is refed back into the circuit. The reject liquids and residues are processed through wet scrap recovery.*

The ground pellets are inspected for dimensions and density. Rejects are sent to the oxidation-reduction section (EE 1975).

d. Stacking and Drying. The pellets that meet the desired specifications are loaded onto corrugated fiberglass trays, processed through a drying oven, and then placed in storage before processing in the fuel rod leading circuit (Fig. III-5).

5. Rod Loading

a. Loading. The trays of dried pellets are transferred to the area of rod loading. Each linear array of pellets is weighed, and the array is then loaded into a cleaned Zircaloy fuel tube that has one end cap already in place (EIA 1977).

b. Final Cap Weld. The fuel tube then has both the final cap welds made, and the fuel rod is passed to rod inspection (EIA 1977).

c. Inspection. Inspection operations include dimensional inspection, radiography, gamma scanning, and leak testing (EIA 1977).

6. Fuel Bundle Assembly

a. Assembly. The inspected fuel rods and the cleaned fuel bundle hardware (end fittings and fuel rod holding cage) are brought together in the assembly area. The fuel rods are inserted into the rod holding cage, and the end fitting is attached to the end of the fuel bundle assembly (EIA 1977).

b. Inspection. The fuel assembly is cleaned, inspected, and packaged for shipping (EIA 1977).

7. Auxiliary Process Operations

a. Wet Scrap Recovery. In addition to the dry scrap recovery processes discussed previously in each appropriate section, two wet scrap recovery operations also occur in the plant. The wastes are treated in batch operations and are typically "dirty" wastes, that is, chemically contaminated, compared to "clean" wastes processed by dry reprocessing techniques. These dirty wastes include system cleanout residue, maintenance cleanup materials, incinerator ash, and analytical laboratory wastes. The contaminants include uranium, ammonia, nitrates, fluoride, organics, soap, and other secondary contaminants (EIA 1977).

The basic processes in the scrap recovery operations consist of dissolution of solids in nitric acid to produce

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*This information provided by Gene Coryell, NRC, June 1981.

impure uranyl nitrate, removal of uranium through solvent extraction, and stripping to produce concentrated uranyl nitrate. The uranium may be precipitated as UO_4 through addition of $NH_4(OH)$ and H_2O_2, dewatering the UO_4, and calcining to UO_2, or it may be (a more frequent occurrence) fed back after pH adjustment into the conversion circuit. Various types of wastes enter the circuit where appropriate (EE 1975).

In general, off-gases from the wet scrap recovery operations pass through a scrubber and filter, or filter, before discharge. Before off-gases from the dissolution tanks go to the scrubber, they are routed through a reflux condenser located directly above the tank, from which the condensate can drain back to the tank (EIA 1977).

The liquid wastes produced in the wet scrap recovery process join other liquid streams and are treated to precipitate uranium, to remove ammonia, and to precipitate calcium fluoride (as described previously) (EIA 1977).

*b. **Incineration**.* There is one incinerator at the site. This incinerator has a rated capacity of 500 lb/h (277 kg/h) for solid wastes and an auxiliary waste burner for incineration of combustible liquids. There are two combustion chambers in series with auxiliary gas/oil burners in each chamber (two-stage combustion).

The incinerator, using a hydraulic ram feeder, burns paper, shoe covers, gloves, plastic bags, mops, boxes, filters, and other combustible contaminated solid wastes, and some contaminated oil from the pellet pressing operation, machinery, etc.

Off-gases from incineration pass through (1) a quench tower, (2) a venturi scrubber, (3) a packed column (for HCl removal), (4) a condenser, (5) a heater, and (6) HEPA filtration before discharge to the air. It is estimated that HCl concentrations should be less than 25 ppm in the stack discharge gases.

The scrubbing liquid is adjusted for pH and reused in the gas scrubbing system. Bleed is sent to the liquid waste treatment facility.*

The ashes from incineration are recycled back to the wet scrap recovery section to remove residual quantities of SNM.

*c. **Plating**.* Nickel plating operations for grid straps are also performed at the plant. Discharges to the air include the plating tank hoods and nickel plating room exhaust (EIA 1977).

The nickel-contaminated waste streams are treated in a precipitation system and an ion exchange system and then recycled back to the nickel plating system. Nickel contaminated wastes are disposed of by burial in a commercial chemical disposal facility.

*d. **Cylinder Cleanup**.* At present, UF_6 shipping containers are sent to Nuclear Fuel Services for cleanup. Testing and valve replacement are performed at the NFCS.

However, Westinghouse has plans to eventually install a cylinder cleanup facility at NFCS. In this proposed facility, the cylinders will be triple flushed with water to remove all the UF_6. The liquid will then be fed into the ADU conversion stream.**

*e. **Laboratory**.* A laboratory for process control, quality assurance, etc., is also operated at the facility (EIA 1977).

*f. **Waste Packaging**.* Waste packaging operations are conducted at the facility. All worker clothing, after gamma scanning, is sent in 55-gallon barrels to an off-site laundry (EIA 1977).

Radioactive wastes are packaged for burial in an approved commercial burial site. Other wastes that are free of above-background levels of activity are disposed of at a regular landfill site (EIA 1977).

C. Wastes and Effluents

1. Gaseous

Table III-1 indicates the types of gaseous discharges produced in each process step. The treatment of these discharges has been discussed in the previous section.

2. Liquid

Table III-2 indicates the types of liquid discharges produced in each process line. The treatment of these discharges was discussed in the process discussion in Section B.

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*Information submitted to South Carolina Department of Health and Environmental Control, August 3, 1979, by Westinghouse Electric Corporation.

**This information provided by Gene Coryell, NRC, June 1981.

TABLE III-1

GASEOUS WASTES

Source	Pollutants	Treatment
UF_6 vaporizer	UF_6, HF	Scrub, filter
UF_6 hydrolysis	UF_6, HF	Scrub, filter
pH adjustment	Vapors	Scrub, filter
Precipitation	ADU, NH_3, HF	Scrub, filter
Dewatering	ADU, NH_3, NH_4F	Scrub, filter
Calcination	NO_x, UO_2, NH_3, H_2, N_2, ADU	Scrub, filter
Waste treatment still	NH_3	—
Milling	UO_2	Filter
Blending	Organics, UO_2	Filter
Packaging	UO_2	Filter
Mix-compact, press, dry, vacuum clean	Organics, UO_2	Filter
Sintering	N_2, H_2, UO_2, organics	Oxidation, filter
Oxidation–reduction	UO_2, U_3O_8, H_2, N_2	
Grinding	UO_2	Filter
Pellet drying	H_2O	—
Rod loading	UO_2	Filter
Wet scrap recovery (WSR), solvent extraction and strip	HNO_3, NO, NO_2 solvent	Scrub, filter
WSR precipitation	H_2O_2, NH_4OH, nitrogen compounds, uranium	Scrub, filter
WSR thermal processing	UO_4, UO_2	Scrub, filter
Incineration	HCl, U compounds NO_x, SO_2	Scrub, filter
Preparation of fuel assembly components		
Machining	Acetone, alcohol machining chips	
Cleaning	Detergent	
Testing and inspection	Acetone, alcohol	
Fabrication of fuel rod assemblies		
Fuel tube preparation	Cleaning compound	
Welding end caps	UO_2, helium, alcohol	
Testing	Acetone, alcohol	
Fabrication of fuel hardware		
Assembly	Acetone, alcohol	
Weld	Argon	
Plate	Nickel	Commercial disposal
Fuel bundle assembly		
Assembly	Acetone, alcohol	
Clean and inspect	Acetone, alcohol	
Laboratory	Chemical fumes, UO_2	

TABLE III-2

LIQUID DISCHARGES

Origin	Contents
Process liquid from UF_6 conversion and dry and wet scrap recovery	H_2O, UO_2, NH_4F, NH_4OH, HF, organic solvent, nitrogen compounds
Sanitary drain from main building	Sanitary wastes, perhaps some uranium in shower water
Cooling tower blowdown	H_2O, Nalpac 8241, Nalpac 8240 Nalco 80, Nalco 39, Nalco 918, Nalco 7313
Fuel fabrication liquid waste	H_2O, UO_2
Sanitary drain, including boiler blowdown, deionizer flush, and backwash	Nalco 19, Nalco 711, Nalco 356, Nalco 752, H_2SO_4 and NaOH
X-ray film development	Fixer and developer
Cafeteria and kitchen	Wash water (soap, etc.)
Chemical (nonradioactive) waste	HNO_3, HF, H_2SO_4, HCl, NaOH, $NaCO_3$, trisodium phosphate, nickel and iron salts, boric acid, Enthone Corp L–90, Conversion Corp Kenvert #183

Source: EIA

3. Solid

Solid contaminated wastes include used process equipment, residues from scrap recovery, and filters. The largest quantity of solid wastes is the CaF_2 residues cleaned from the lagoons. At present, all the CaF_2 sludge has been removed from the lagoon, which was full, and sent to burial (that is, sludges generated over 10 yr of operation). The present mode of operation is to fill a lagoon with treated slurry, decant the clarified liquid from the top, and discharge to the Congaree River in accordance with NPDES Permit requirements. The dried, stabilized CaF_2 is then sent to LLW burial.

At present, most of the filters are sent to burial; however, some are incinerated. As the backlog of combustible material is disposed of in the new incineration system, it is anticipated that a larger percentage of filters will be incinerated.*

D. Waste and Effluent Data

1. Releases to the Air

a. Nonradioactive. Table III-3 indicates the average emission rates for ammonia and fluorides at two different

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*This information provided by Gene Coryell, NRC, June 1981.

TABLE III-3

EMISSION OF PROCESS GASES

Chemical	Average (g/s) at Plant Throughput 400 MtU	 1600 MtU
Ammonia (NH_3)	6.49	25.96
Fluorides (F^-)	∼0.002	0.0079

Source: Westinghouse Electric Corporation, July 1981.

throughputs as given by Westinghouse. In the April 1977 Environmental Impact Appraisal, it was reported: "No data were available to describe ambient atmospheric concentration values for either ammonia or fluorides or to describe deposition values for ammonia. Average annual fluoride deposition was 0.3 $\mu g/cm^2$ yr."

NRC staff have expressed concern over the possibility of ambient levels of fluoride compounds causing on-site plant damage and chronic fluorosis in livestock that consume forage produced on and near the NFCS if the facility runs throughputs of 1600 MtU/yr (EIA 1977).

The NO_x emissions from the nickel-plating-room stack are less than 2 ppm. No data are available on NO_x emissions caused by the wet scrap recovery operations.

b. Radioactive. In-stack monitoring for radionuclides is conducted at the plant. Table III-4 indicates this stack release data. Using this stack release data for 1975-1978 and uranium releases in liquid* and reasonable atmospheric dispersion and dose models, an analysis was made by the NRC staff to determine if the EPA required level of less than 25 mR/yr total exposure for the general population was being met by the NFCS. It was found that inhalation of radionuclides was, at least in the short-term time frame, the main pathway for exposure. The calculations indicated that if a residence were to be located in the future at the nearest site boundary in which a critical individual (young child) lived, the annual lung dose would be 10.7 mR/yr (RA, NRC).

2. Liquid Effluents

a. Nonradioactive. Table III-5 gives both 1975-1976 and, for comparison, very recent data submitted to EPA by Westinghouse for contaminants in the liquid discharged to the Congaree River. Table III-6 indicates concentrations rather than quantity of contaminants in the recent discharge.

Table III-7 was included (though rather old data are given) to indicate other elements that are in the liquid discharge. Table III-8 indicates 13 months of monitoring of the Congaree River above and below the discharge.

As can be seen from Table III-5, because of better liquid treatment, total discharges of ammonia, fluorine, and nickel have been reduced.

b. Radioactive. Data for discharges of uranium in liquids as submitted by Westinghouse to the NRC are given in Table III-9.

In addition to the isotopes of uranium, the liquid-waste streams contain small amounts of ^{231}Th, ^{234}Th, and ^{234}Pa, giving some beta-gamma activity (EIA 1977).

3. Solid Wastes

The main solid waste is the spent lime-CaF_2 sludges. In the 1977 Environmental Impact Appraisal, it was reported that the west lagoon contained approximately 1.5 million gal. (5.68×10^3 m^3) of partially dewatered spent CaF_2 sludge (this has now been sent to LLW burial), which contained 4 to 10 µCi of uranium per

TABLE III-4

SEMIANNUAL AIRBORNE RADIOACTIVE RELEASES IN µCi

Period	^{234}U	^{235}U	^{238}U	Gross α
July–Dec 1975	963.6	50.3	244.1	1258
Jan–June 1976	1128.1	56.8	270.7	1455.6
July–Dec 1976	1095.0	118.7	288.4	1502.1
Jan–June 1977	1198.7	44.3	285.9	1528.9
July–Dec 1977	1916.0	90.5	440.5	2447
Jan–June 1978	1186.3	48.6	284.1	1519
July–Dec 1978	919.3	40.0	182.7	1142[a]
Jan–June 1979				1040[b]
July–Dec 1979				1008.8[c]
Jan–June 1980				536.8[d]

[a] If individual radionuclide composition is assumed to average same as the liquid: 80.5% ^{234}U, 3.5% ^{235}U, 16% ^{238}U.

[b] If individual radionuclide composition is assumed to average same as the liquid: 80% ^{234}U, 4.0% ^{235}U, 16% ^{238}U.

[c] If individual radionuclide composition is assumed to average same as the liquid: 76.7% ^{234}U, 3.8% ^{235}U, 19.5% ^{238}U.

[d] If individual radionuclide composition is assumed to average same as the liquid: 75.5% ^{234}U, 3.7% ^{235}U, 20.8% ^{238}U.

Source: Westinghouse Electric Corporation reports to NRC.

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*See Table III-9.

TABLE III-5

NFCS MONITORING OF NPDES—LIMITED EFFLUENTS
(Values are lb/day except where otherwise noted)

Month	Ammonia, N		Fluoride		Nickel		Fecal Coliform as Number per 100 mℓ		pH		Total Suspended Solids		Oil and Grease		BOD_5		Flow (Mgd)	
	Av	Max	Av	Max	Av	Max	Av	Max	Av	Max	Av	Max	Av	Max	Av	Max	Av	Max
Sept 1975	49.7	101	33	48	0.40	0.58	<5	<5	8.8	9.5	17	23	5	6	15.4	23.0	0.1367	0.2129
Oct 1975	43.0	93	21	76	0.41	0.84	<5	<5	8.7	9.6	12	15	9	18	4.2	7.5	0.1402	0.1690
Nov 1975	78.0	223	20	52	0.48	0.62	131	356	8.8	9.9	16	24	6	8	5.1	10.4	0.1362	0.2059
Dec 1975	56.9	181	15	50	0.72	1.34	<5	<5	8.6	9.2	10	17	6	8	10.5	17.8	0.0673	0.1360
Jan 1976	113.8	224	19	49	0.91	1.43	<5	<5	8.7	9.4	22	32	6	10	9.6	17.4	0.1026	0.1969
Feb 1976	96.3	207	13	47	1.03	1.35	<5	<5	8.9	9.8	17	19	5	6	4.6	6.5	0.0907	0.1651
Mar 1976	40.6	153	11	36	0.43	0.58	<5	<5	8.9	10.4	21	37	3	4	2.3	4.2	0.0749	0.0889
Apr 1976	65.4	148	19	75	0.57	0.70	<5	<5	8.9	9.9	22	50	6	13	3.3	6.4	0.0802	0.1441
May 1976	62.2	142	21	100	0.33	0.69	31	56	8.2	8.9	9	17	6	6	7.3	12.8	0.1054	0.1630
June 1976	38.2	102	27	92	0.37	0.88	<5	<5	8.4	9.2	14	21	5	6	5.1	7.4	0.0376	0.2001
July 1976	24.2	54	14	43	0.61	1.45	<5	<5	7.5	8.9	12	21	5	7	1.7	3.2	0.1166	0.1743
Aug 1976	39.7	114	25	78	0.32	0.74	39	100	7.1	7.8	9	13	5	6	8.0	9.4	0.1168	0.1957
Mean	59.0	145	19.8	62.2	0.55	0.93	<20	<45	8.5	9.4	16	24	6	9	6.4	10.5	0.1004	0.1710
Highest for 12 months	113.8	224	33	100	1.03	1.45	39	100	8.9	10.4	22	50	9	18	15.4	23.0	0.1402	0.2129
Dec 1980	29.0	97.1	13	43.5	0.18	0.25	3	3	8	10.4	41.2	102.1	18.1	18.3	8.9	16.0	0.1081	0.2008
Jan 1981	27.8	119.4	10.1	24.8	0.07	0.11	3	3	8.3	10.1	17.0	30.6	7.3	13.7	5.5	6.4	0.1093	0.2110
Feb 1981	25.0	48.1	11.6	19.1	0.16	0.50	6	9	7.6	10.0	23.4	44.8	7.2	14.8	14.6	26.6	0.1328	0.1897

Source: R. Fisher, WNFCS, letter to E. Y. Shum, Nuclear Regulatory Commission, Washington, DC, October 12, 1976, Docket No. 70-1151.

Source: NPDES reports to EPA.

TABLE III-6

MONITORING DATA FOR THE NPDES PERMIT 001 DISCHARGE

	Flow ($m^3/s \times 10^{-2}$)			BOD (mg/ℓ)		TSS (mg/ℓ)		Fluoride (mg/ℓ)		NH^3 mg/ℓ		Nickel (mg/ℓ)		Oil & Grease (mg/ℓ)	
Period	Min	Av	Max	Av	Max	Av	Max	Av	Max	Av	Max	Av	Max	Av	Max
Dec 1980	0.15	0.47	0.88	7.3	11.0	29.1	61.5	15.8	31.0	45.5	208.0	0.14	0.17	5.8	11.0
Jan 1981	0.16	0.48	0.92	5.8	8.0	18.0	30.0	11.2	19.0	30.6	97.0	0.09	0.14	8.3	17.0
Feb 1981	0.26	0.58	0.83	12.8	19.0	19.8	32.0	10.4	15.0	22.1	43.0	0.14	0.37	6.3	11.0

Source: NPDES reports to EPA.

pound (EIA 1977). Currently, CaF_2 sludge, all of which is dried and sent to LLW burial, contains ≈0.2-1.0 µCi per pound.*

The EIA also indicates that 40 to 60 bales of combustible contaminated waste and 4 bales of noncombustible contaminated waste will be generated per day at the 1600 MtU level (EIA 1977). This level has been substantially reduced at present because of the installation of the new incinerator.

4. Monitoring Program

Although Sections 1-3 indicate the publicly available data, Westinghouse does have a surveillance monitoring program (Table III-10). The program is described in the EIA and in a recent update by Westinghouse, as indicated below, for the radiological parameters.*

a. Air Monitoring. Air-sampling stations for air-particulate monitoring are located (1) at the nearest site boundary in the prevailing wind direction (3000 ft northeast of the plant), (2) at the site boundary (1900 ft east-northeast), (3) near the meteorological tower (1950 ft west-northwest), (4) in the town of Hopkins (2.9 miles northeast, the nearest town and the first town in the direction of the prevailing winds), and (5) at the employee front parking lot (450 ft northeast) where concentration is expected to be maximum.

---

*This information provided by W. L. Goodwin, July 1981.

TABLE III-7

AVERAGE WATER-CHEMICAL-EFFLUENT DATA FOR 400-MtU/YEAR OPERATION

	Discharged to River	
Parameter	Quantity (lb/day)	Concentration (mg/ℓ)
Silver (Ag)	0.075	0.15
Iron (Fe)	0.52	1.03
Sodium (Na)	30	60
Calcium (Ca)	293	584
Magnesium (Mg)	1.38	2.75
Manganese (Mn)	0.035	0.07
Molybdenum (Mo)	0.095	0.19
Nickel (Ni)	0.5	1
Boron (B)	0.22	0.43
Chloride (Cl)	24.8	49.5
Phosphorus as –P	0.75	1.5
Kjeldahl (nitrogen)	244[c]	488
Ammonia (NH_3)[a]	200[b,c]	399
Fluoride (F)	122.8[c]	61.5
Sulfate (SO_4)	42.6	85
Sulfite (SO_3)	0.63	1.26
Sulfide (S)	trace	trace
COD	58	116
BOD_5	10.9	21.5
Phenols	trace	trace
Surfactants	0.035	0.07
Oil and Grease	4.3	8.67
Hardness (as $CaCO_3$)	293	583.5
Total suspended solids	8.0	15.8
Total volatile solids	310	619
Total solids	281	560.8
Total dissolved solids	273	544
pH (units)		8.9

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[a] Ammonia discharges were for May 1974.

[b] This value is believed to be much lower than that for other months; however, it is in compliance with the May 1, 1974, permit of an average and maximum discharge of 231 lb/day. Westinghouse Columbia has applied for a variance to this NPDES permit for an average of 1700 lb/day and a maximum of 4000 lb/day until June 30, 1975.

[c] Before NPDES requirements.

Source: EIA 1977.

TABLE III-8

RESULTS OF 13 MONTHS (JULY 1, 1975 to JULY 30, 1976) OF NFCS MONITORING OF THE CONGAREE RIVER AT TWO STATIONS ABOVE THE DISCHARGE POINT AND TWO BELOW

Station	Ammonia, NH_3(N) (mg/ℓ) Av	Ammonia, NH_3(N) (mg/ℓ) Max	Fluoride (mg/ℓ) Av	Fluoride (mg/ℓ) Max	pH Av	pH Max
Ten miles above NFCS discharge at Blossom Street Bridge, Columbia, South Carolina	0.45	1.50	0.41	0.83	7.38	7.55
NFCS discharge point	0.63	1.30	0.38	0.78	7.20	7.31
Mouth of Mill Creek, less than one mile below discharge	0.62	1.00	0.36	0.66	6.80	7.39
601 Bridge, 35 miles below NFCS discharge point	0.67	1.20	0.37	0.72	7.02	7.12
Recommended maximum safe concentration for aquatic biota	0.9[a]		1.5[b]		6.5 – 8.5[c]	

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[a] The recommended safe level is 0.02 mg/ℓ of undissociated ammonia. At a temperature of 25°C, which would be expected in the Congaree River in summer, and at a pH of 7.6, the maximum recorded pH above, a total ammonia concentration of 0.9 mg/ℓ would yield a concentration of 0.02 mg/ℓ of undissociated ammonia. (From Environmental Protection Agency, Offices of Water and Hazardous Material, *Quality Criteria for Water*, Washington, DC, 1976.

[b] From Resource Agency of California, State Water Quality Control Board, *Water Quality Criteria*, 2nd ed., J. E. McKee and H. W. Wolf (Eds.), 1963.

[c] From Environmental Protection Agency, Offices of Water and Hazardous Material, *Quality Criteria for Water*, Washington, DC, 1976.

Source: R. Fischer, WNFCS, letter to E. Y. Shum, Nuclear Regulatory Commission, Washington, DC, October 12, 1976, Docket No. 70-1151.

The air monitors continuously accumulate air particulates with an air sampler that pumps air through a filter. The filters are analyzed with the following frequencies: monthly for gross alpha activity and quarterly for isotopic uranium activity.

b. Water Monitoring. Well water is taken from three on-site wells. The well locations are shown in Fig. III-6. Well water is analyzed monthly for gross alpha and beta activity and quarterly for isotopic uranium activity. Monitoring wells, 24 of which are concentrated near the waste treatment area, are also used to monitor water quality.

Surface water samples are taken monthly by collecting 1-ℓ grab samples from the five locations shown in Fig. III-6. A comparison of samples from a location downstream 500 yd from the discharge point (2) with upstream samples (1) and (3) provides a measurement of possible contamination to the river from plant discharges. Locations (4) and (5) indicate possible contamination from accidental releases from the holding pond.

TABLE III-9

DISCHARGES OF URANIUM IN LIQUIDS[a]
(μCi)

Period	^{234}U	^{235}U	^{238}U
July-Dec 1975	52 322.4	2732.2	13 251.4
Jan-June 1976	35 968.5	1810.0	8 632.5
July-Dec 1976	40 941.0	4446.0	10 812.0
Jan-June 1977	46 664.0	1735.0	11 126.0
July-Dec 1977	63 100.0	2994.0	14 474.0
Jan-June 1978	49 036.0	2023.0	11 763.0
July-Dec 1978	78 095.0	3409.0	15 529.0
Jan-June 1979	86 213.0	4258.0	17 275.0
July-Dec 1979	138 624.0	6819.0	35 288.0
Jan-June 1980	77 790.0	3557.0	20 352.0

[a] Values were obtained by compositing proportional samples before discharge to the Congaree River.

Source: Westinghouse Electric Corporation reports to NRC.

Analyses are performed with the following frequencies: monthly for gross alpha and beta activity and quarterly for isotopic uranium activity.

*c. **Area Monitoring (Fallout, Vegetation, Soil, and Fish).*** Monitoring for wet fallout is performed at six stations. Analyses are monthly for gross alpha and quarterly for isotopic uranium. Composite aliquot samples are used for uranium analysis.

Sampling and analyses of vegetation samples are performed at four locations. Either grass (hay) or another agricultural crop appropriate to the growing season is collected and analyzed on a semiannual basis for gross alpha and beta activity and for isotopic uranium activity. Sediment samples taken annually from the Congaree River at approximately 500 ft downstream of the discharge are similarly analyzed.

TABLE III-10

COLUMBIA SITE MONITORING PROGRAM

Types of Sample	Number of Locations[a]	Type of Analysis	Frequency
Air Particulate	5[b]	Gross α, β[c,d]	Continuous sampling
Fallout	6	Gross α, β[c,d]	Monthly
Vegetation (Crops)	4	Gross α, β[c,d] + F^- and isotopic U	Semiannually
Well Water	3	Gross α, β,[c,d]	Monthly
Surface Water	5	Gross α, β[c,d]	Monthly
Fish	2	Gross α, β[c,d]	Annually
Soil	4	Total U + F^- and isotopic U	Semiannually
Sediment	1	Total U + F^- and isotopic U	Annually
TLD	3[e]	Gamma Dose	Quarterly

[a] Sampling locations shown on attached figures.

[b] All samplers are located on Westinghouse property. Four are operated by Westinghouse and one is operated by the state of South Carolina.

[c] Westinghouse will assume all of the gross alpha is caused by uranium enriched to 4% ^{235}U unless a uranium analysis has been performed.

[d] In the event Westinghouse decides to fabricate plutonium fuel assemblies on-site, isotopic plutonium analyses will be performed three months before the fuel arrives, during fabrication, and three months after the final shipment of plutonium-bearing fuel.

[e] The TLD analyses are performed by the state of South Carolina.

Source: Westinghouse, July 1981.

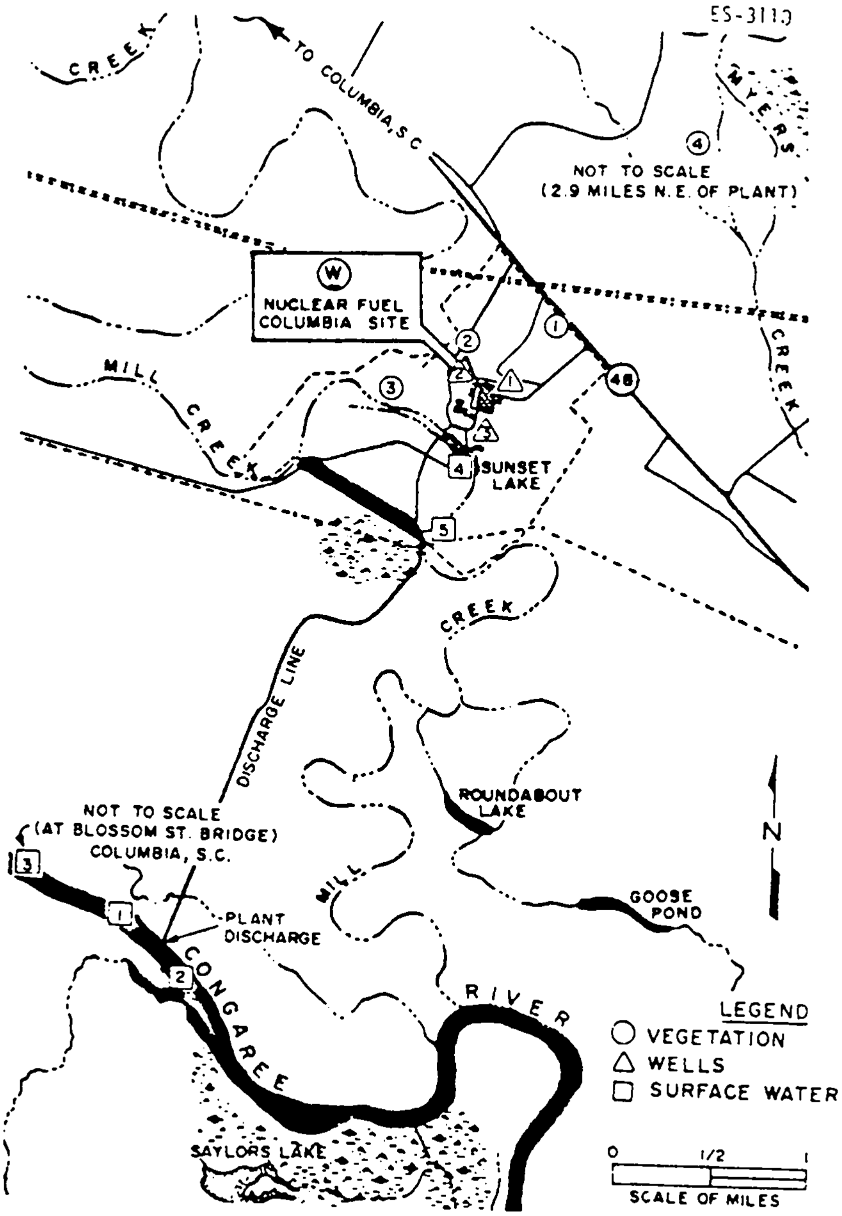

Fig. III-6. Locations of proposed vegetation and well- and surface-water-monitoring stations.

Source: EIA 1977.

Samples of fish from the Congaree River downstream of the plant discharge and from Sunset Lake are analyzed annually for gross alpha and beta activity and for isotopic uranium activity.

The programs for nonradiological monitoring as outlined in the EIA and by Westinghouse are:

- Atmospheric Monitoring

Particulate fluoride concentrations inside process-gas-effluent stacks are monitored daily with glass suction filters. Periodically (no period given), gas-impinger samples from effluent stacks are collected and analyzed for both particulate and gaseous fluoride emissions. Fluoride deposition is monitored periodically at the site boundary with calcium oxide fallout papers.

Ammonia concentrations in process-gas-effluent stacks are monitored occasionally with gas impingers. The ammonia concentration in the atmosphere at the site boundary is measured at unspecified time intervals with a universal sampling pump and detector tube (ER 1977).

- **Monitoring of the Surface Waters**

The NFCS is required to monitor effluents in accordance with the schedule and methods described in the NPDES permit.

Congaree River

The NFS monitors the Congaree River at four stations: (1) at Blossom Street bridge in Columbia, (2) at the NFCS discharge, (3) downstream of the discharge at the mouth of Mill Creek, and (4) at 601 Bridge, 35 miles downstream of the NFCS facility. Ammonia, fluoride, and pH are monitored monthly.

Sunset Lake and Mill Creek

Sunset Lake and Mill Creek are monitored monthly for ammonia, fluorides, and pH at five stations: (1) at the entrance to the NFCS property where Mill Creek enters Sunset Lake, (2) at the road station where the drainage culvert from the plant storm sewer enters upper Sunset Lake, (3) at the causeway station where the dam separates the upper and lower portions of Sunset Lake, (4) at the spillway station where Sunset Lake enters Mill Creek, and (5) at the exit from the NFCS property, the point on Mill Creek where water from Sunset Lake mixes with water diverted through the canal.

- **Groundwater Monitoring**

Three on-site wells are monitored monthly for fluoride, ammonia, and pH (Fig. III-6). The wells were at the site as part of an existing irrigation program before the NFCS plant was constructed.

- **Terrestrial Monitoring**

Soil and vegetation samples are collected in the vicinity of environmental air samplers semiannually and analyzed for gross alpha, beta, or total uranium and fluoride and isotopic uranium.

- **Aquatic**

Currently, sediments are analyzed for F^-.

E. Conclusions

1. Monitoring

It would be helpful to have publicly available, through a published yearly summary, the data obtained in the air, water, and area surveillance monitoring program described in the preceding section and better data on the source of contamination of the water of the spring discharging to the pond.

In addition to ambient air monitoring for total gross alpha and beta, the size distribution and solubility of the uranium particulate would aid in dose assessment.

The concentrations of uranium in surrounding soils and subsoils should be determined at least annually at several sites surrounding the facility in addition to those locations already in the surveillance program. Air and soil sampling stations should be located at points predicted from stack emission modeling to have the maximum concentrations of uranium in the ambient air.

Concentrations of uranium in algae above and below the outfall should be measured.

The concentrations of fluoride compounds in plants and soils at several (more than 4) appropriate locations surrounding the facility should be determined at least quarterly. These locations should be located at areas predicted, through modeling, to have maximum concentrations.

The emissions of fluoride compounds and ammonia should be accurately measured on a regular basis.

Material balances for all materials going into the plant should be run. In particular, more data should be obtained on releases of nitrogen compounds and silver (see Table III-7).

2. Solid Waste Disposal

The adequacy of LLW burial for final disposal of uranium-containing wastes should be determined.

3. Waste Treatment

It would be beneficial to incinerate all reduction offgases to oxidize excess hydrogen and organic compounds.

In addition, techniques to (1) improve the performance of the ammonia still and (2) decrease the concentrations of fluoride compounds in the discharge might be investigated.

4. Inadvertent Discharges and Fugitive Emissions

No information was obtained regarding quality and types of inadvertent discharges caused by cleanup equipment malfunction, line breaks, loss of power, etc. More data are needed on occasional inadvertent releases and on fugitive emissions.

REFERENCES

Discharge Monitoring Report, submitted by Westinghouse Electric Corp. to the South Carolina Department of Health and Environmental Control (NPDES permit), December 1980, January 1981, February 1981.

Effluent Monitoring Report, submitted by Westinghouse Electric Corp. to the NRC on a semiannual basis for the years 1979 and 1980.

Environmental Evaluation for Westinghouse Nuclear Fuel Division, Columbia, South Carolina, Westinghouse Electric Corp., Pittsburgh, Pennsylvania, 1975.

Environmental Impact Appraisal of the Westinghouse Nuclear Fuel Columbia Site (NFCS) Commercial Nuclear Fuel Fabrication Plant, Columbia, South Carolina, US NRC, Office of Nuclear Material Safety and Safeguards, Division of Fuel Cycle and Material Safety, Washington, DC, April 1977.

Incinerator Permit Application and related documents submitted by Westinghouse Electric Corp. to the South Carolina Department of Health and Environmental Control, August 3, 1979.

Radiological Assessment of Individual Dose Resulting from Routine Operation—Demonstration of Compliance with 40 CFR 190, NRC (no date).

Review of Application to Authorize Operation of Advanced Waste Treatment Process, Applications dated April 7 and June 24, 1980, 07001151A03S.

CHAPTER IV

GENERAL CONCLUSIONS AND RECOMMENDATIONS

A. Effluent/Waste Characterization

The types and quantities of effluent/waste streams coming from a fuel fabrication facility are dependent upon which operations in fuel fabrication are being performed and the processes in use to perform the operation. In general, however, at least some of the liquid and gaseous effluent streams contain

(1) uranium compounds,
(2) nitrogen compounds,
(3) fluoride compounds,
(4) organic compounds,
(5) metals (from fuel holder preparation, chemical laboratory operations, etc.), and
(6) acids.

Solid wastes may include

(1) fluorine- and nitrogen-containing sludges;
(2) spent resins and sorbed oils;
(3) uranium-contaminated failed equipment (including filters, paper, rags - both combustible and noncombustible);
(4) uncontaminated-with-uranium failed equipment, etc. (combustible and noncombustible); and
(5) uncontaminated machining chips, etc.

Depending upon the concentration, rate of discharge, final treatment/disposal, etc., the contaminants in the effluent/waste streams may adversely affect the environment. Because fluorine-containing compounds are one of the major effluent/wastes, Table IV-1 has been included to indicate limits placed on fluorine by the state of Washington, whereas Table IV-2 has been included to indicate effects on vegetation, cattle, and human subjects for particular concentrations of fluoride compounds.

B. Effluent/Waste—Monitoring

If the effects on the environment of the discharge of fluoride, nitrogen, organic, and uranium-containing compounds are to be better understood, comprehensive

TABLE IV-1

STATE OF WASHINGTON FLUORIDE STANDARDS

Type	Shall Not Exceed Concentration F^-	Time Period
Forage (dry wt)	40 ppm	12 consecutive months
Forage (dry wt)	60 ppm	2 consecutive months
Forage (dry wt)	80 ppm	Once in any two consecutive months
Cured forage for sale (dry wt)	40 ppm	Any time
Ambient air	3.7 $\mu g/m^3$[a]	Average any 12 consecutive hours
Ambient air	2.9 $\mu g/m^3$[a]	Average any 24 consecutive hours
Ambient air	1.7 $\mu g/m^3$[a]	Average any 7 consecutive days
Ambient air	0.84 $\mu g/m^3$[a]	Average any 30 consecutive days
Ambient air	0.5 $\mu g/m^3$[a]	Average March 1 through October 31

[a] Calculated as HF.

Source: State of Washington Department of Ecology, Chapter 18-48 WAC, effective February 4, 1971.

monitoring programs are needed with data being made publicly available. These monitoring programs should include

(1) splitting of samples at least occasionally for laboratory control checks.

(2) occasional determination of solubility and size distribution of uranium isotope particulate emissions for each facility.

(3) routine monitoring for fluorine and uranium in surrounding soils, plants, and aquatic life. Because fluorine concentrations vary in plants, monitoring of plant fluorine content should be done at least quarterly (and preferably monthly). Monitoring locations should be those locations that atmospheric modeling indicates will be regions of highest concentration.

(4) determination of organic discharges (including 8-OH) and their effects on the environment.

(5) independent routine in-stack monitoring in all relevant stacks for uranium, total fluorine, oxides of nitrogen, and ammonia discharge.

(6) hydrotesting of underground waste lines to ensure that pipes are not leaking.

C. Effluent/Waste Generation and Treatment-Recommendations for Studies (Including Industry-Sponsored Studies)

Additional studies needed of effluent/waste generation and treatment include

(1) Evaluate in detail the uranium content and matrix for wastes going to LLW burial (see Subsection F);

(2) Evaluate techniques for determining uranium in CaF_2 sludge as to accuracy, cost, etc., and determine if further development work is needed on techniques to more accurately determine uranium content;

(3) Define what level of uranium in CaF_2 sludge is acceptable if sludge is to be disposed of off-site in a landfill other than a LLW burial site;

(4) Examine the possibility for recovery of HF acid in off-gases and conversion of CaF_2 sludge to HF acid and final fate of resulting sludge from conversion;

TABLE IV-2

SUMMARY OF EFFECTS OF FLUORIDE ON VEGETATION, CATTLE, AND HUMAN SUBJECTS

Mean Concentrations					
Hydrogen Fluoride in Air (mg/m^3)	Total Fluoride in Ration, Diet, or Water (mg/kg)	Mean Daily Intake of Fluoride (mg/day)	Duration of Exposure	Species	Effect Reported
0.00025	–	–	7 weeks	Chinese apricot	Less than 1% necrosis on foliage
<0.0005	–	–	18 months	Citrus	No effects on growth or physiology of plant
0.0006	–	–	1 week	Sorghum	Threshold for foliar markings
≃0.0007	–	–	2 weeks	Sorghum	Foliar lesions and reduced growth if exposed during anthesis
0.0009	–	–	17 weeks	Orchard grass and alfalfa	No effect on yield, no foliar lesions
0.0011	–	–	7 weeks	Chinese apricot	Some necrosis on foliage
0.0015	–	–	1 day	Gladiolus	Less than 2% necrosis
			1 day	Ponderosa pine	Less than 1% necrosis on young needles
			1 week	Sweet corn	Threshold for foliar markings
0.0018	–	–	2 weeks	Apple	Threshold for foliar lesions
0.0021	–	–	10 weeks	Bean	Significant effect on reproduction, but no foliar lesions
0.0029	–	–	22 weeks	Tomato	No effect on growth nor injury to foliage
0.0050	–	–	1 day	Gladiolus	About 5% necrosis of leaves
0.0063	–	–	2 weeks	Tomato	No injury
0.010	–	–	1 day	Tomato and some tree fruits	Threshold for foliar lesions
≃0.1	–	–	Single exposure	Man	Perceptible odor concentration for hydrogen fluoride
2.5	–	–	Daily	Man	8-hr daily exposure ACGIH threshold limit value for hydrogen fluoride
≃25.0	–	–	Single exposure	Man	Tolerable, with conjunctival and respiratory discomfort only for several minutes
≃100.0	–	–	Single exposure	Man	Highest tolerable concentration for 1 min, marked conjunctival and respiratory irritation
	–	0.2 – 1.2	Daily	Man	Average daily intake from American diet and water supply
	2 – 8[a]	–	Years	Man	Mottled enamel[b]
	20 – 30	–	Several years	Cattle	Threshold of discernible dental mottling[b]
	30 – 40	–	Several years	Cattle	Evident dental mottling[b]
	40 – 50	–	Several years	Cattle	Threshold of enamel hypoplasia,[b] moderate periosteal hypertosis
	>50	–	Several years	Cattle	Decreased milk production, significant incidence of lameness[c]
	40[d]	–	Several years	Man[e]	Loss of body weight
	>50[a]	–	Months to years	Man[e]	Thyroid injury
	>100[a]	–	Months	Man[e]	Renal injury
	–	20 – 80	10–20 years	Man	Crippling fluorosis
	–	2500 – 5000	Single dose	Man	Death in 2–4 hr

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[a] In water.

[b] Dental effects seen only if fluoride is ingested during period of tooth formation.

[c] Based on feeding experiments lasting 1.6-8 yr.

[d] In diet.

[e] Based on data from animals extrapolated to man.

Source: Fluorides, National Academy of Sciences, Washington, DC, 1971.

(5) Compare the liquid waste/effluent and resource requirements associated with the wet ADU process with those produced in the dry direct conversion process;

(6) Study other UF_6 to UO_2 processes not now in use in the United States as to effluent/waste streams and resource requirements;

(7) Compare, for the dry process, the use of HF recovery towers and/or scrubber systems vs dry limestone beds as to efficiency, final disposal needed, etc.;

(8) Compare the use of filtration (including various techniques) vs use of the centrifuge in dewatering operations;

(9) Compare processes for recovering uranium from the ADU process spent liquors and other uranium-containing spent liquors;

(10) Investigate more fully the use of steam stripping to recover the maximum amount of NH_3 in NH_3-containing effluent streams;

(11) Determine techniques for effective recovery of nitric acid and use of such techniques as a catalytic converter for NO_x control in off-gases;

(12) Investigate the use of incinerators both as a means of oxidizing toxic compounds and for recovering uranium as to operating problems, cost, reduction of volume to burial, etc.;

(13) Investigate the use of ion exchange or reverse osmosis to remove metals produced in liquid wastes coming from plating, etching, etc., operations.

D. Inadvertent Discharges and Fugitive Emissions

This report did not attempt to determine the frequency and quantity of inadvertent discharges caused by equipment malfunction, power failure, etc. Fugitive emissions from sources such as unmonitored discharge vents, transfer points, seal leaks, storage areas, etc., were also not identified. These types of discharges should be identified and quantified. Mass balances should be run for all chemicals used at a facility.

E. Accidents and Decommissioning

This report did not attempt to determine the likelihood, seriousness, and consequences of accidents. In addition, the wastes generated and effluent streams present during decommissioning and decontamination operations were not considered. These operations also need additional study on a specific facility-by-facility basis.

F. Long-Term Effects

The long-term aspects of the following need further study.

(1) Buildup of radionuclides in surrounding soils and waters and pathways of exposure;

(2) Concentrations of radionuclides in solid wastes and their effect in determining long-term disposal techniques;

(3) Long-term disposal of solid wastes and sludges, including nonradioactive wastes.

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