WASH-1533

ENVIRONMENTAL STATEMENT

HTGR FUEL REFABRICATION PILOT PLANT

Oak Ridge National Laboratory
Oak Ridge, Tennessee

AUGUST 19

UNITED STATES ATOMIC ENERGY COMMISSION

RESPONSIBLE OFFICIAL:

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FINAL

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I. SUMMARY

This environmental statement was prepared in accordance with the National Environmental Policy Act of 1969 in support of the United States Atomic Energy Commission's proposal for legislative authorization and appropriations for a fiscal-year 1975 project. The purpose of the proposed project is to demonstrate the technology for refabrication of uranium-233 for use in high-temperature gas-cooled reactors operating on the thorium fuel cycle. The high-temperature gas-cooled reactor (HTGR) is of interest as an additional source of electrical power because of its relatively efficient use of fissionable material, its conservation of natural resources through the use of the thorium fuel cycle, and its relatively low thermal discharge rate. Although the HTGR is a commercially available type of reactor, the United States Atomic Energy Commission (USAEC) is supporting the development of processes for reprocessing and refabricating HTGR fuel.

The capital cost of this facility was estimated in mid-1973 at $10 million. Since that time, there has been additional design work done. In addition, increasing escalation and lengthening construction material deliveries are being experienced. Consequently, the AEC has undertaken to review and firm up the estimated cost prior to start of construction. However, even a several fold increase in the cost of this facility would not greatly alter the balance of the economical benefits expected to be derived from its construction and operation to HTGR fuels technology. The magnitude of the economic benefits of HTGR fuel recycle have been estimated using an analytical model of the nuclear energy industry which includes light water reactors and liquid metal fast breeder reactors as well as the HTGR. By the year 2020, savings of nuclear fuel worth approximately $2 billion in 1974 dollars are projected to result from recycling the fuel in the HTGRs. The proposed project includes the design, construction, and operation of an integrated pilot plant to develop and demonstrate the HTGR fuel refabrication technology. This project is coordinated with the HTGR fuel reprocessing pilot plant that is planned at the National Reactor Testing Station (NRTS) in Idaho Falls, Idaho. These projects complement each other in the development of HTGR fuel recycle technology.

The proposed HTGR Fuel Refabrication Pilot Plant will be installed in the existing Thorium-Uranium Fuel Cycle Development Facility (TURF) at Oak Ridge National Laboratory (ORNL). The TURF is a hot cell facility that was built specifically for pilot plant use, and the proposed pilot plant will occupy the hot cells and some adjacent building areas within the TURF. The proposed pilot plant is scheduled for two years of operation, beginning in calendar year 1978, for refabrication technology demonstration purposes. Annual operating costs during its two year life are estimated at $4 million. The plant will have the capability for performance of all processing operations beginning with the receipt of uranium nitrate solution from the National Storage Facility for uranium-233 and ending with the delivery of completed fuel elements to an operating reactor or the HTGR Fuel Storage Facility at the NRTS in Idaho. The throughput capacity of the plant will be approximately 25 kilograms of heavy metal (two and one-half fuel elements) per day, with a yearly capability of about 200 fuel elements over the 2-year operation period.

The existing TURF is situated on a knoll well above the flood plain in the Melton Valley area of ORNL, which is an area of infrequent tornados and low-probability earthquakes. The nearest population center with over 35,000 persons is 15 miles away. The ecological systems of the areas surrounding the proposed project site are typical of those in the Appalachian region of the United States.

The possible accidents which could occur during operation of the proposed pilot plant that were evaluated included those resulting from fire, explosions, criticality, and natural disturbances. Such accidents have a low probability of occurrence because of the design of the existing hot cell facility and pilot plant and because of existing administrative controls.

Construction, operation, and decommissioning of the proposed HTGR Fuel Refabrication Pilot Plant are expected to have an insignificant impact on the environment. The gaseous and liquid effluents that will result from operation of the proposed pilot plant will be discharged to existing waste handling and treatment systems, and the radioactive and chemical emissions will be several orders of magnitude lower than the established guidelines or background levels. The solid wastes generated by operation and decommissioning of the proposed pilot plant will be disposed of and stored by using procedures designed to protect the environment that will not require an extension of existing solid waste disposal facilities.

Because of its small scale and short life, the proposed project will have an insignificant effect on the long-term productivity of the environment. The irreversible and irretrievable commitment of resources for the project will consist almost entirely of materials for construction and thorium in the feed material in amounts which are not significant. The proposed project is not known to be in conflict with local, state, or regional plans or programs.

The principal benefits from the proposed project will be the generation of technological information essential to the design, construction, and operation of large-scale commercial HTGR fuel refabrication plants and the verification of process and equipment designs at a stage of development when changes will be relatively inexpensive. It is also expected that operating data from the pilot plant will make possible a more accurate assessment of the environmental effects of large-scale fuel refabrication programs.

Additional benefits of the proposed project will be the production of refabricated HTGR fuel elements for possible use in an operating HTGR.

The major alternatives to the proposed project that were considered were those of no recycling of HTGR fuel, a delay in the proposed schedule for pilot plant operation, process and equipment options, and another location for the pilot plant. It was concluded that any of those alternatives would result in either an increased environmental impact over that of the proposed project or increased costs with no reduction in environmental impact.

It was concluded that the societal and environmental costs of the proposed project will be negligible and that the monetary costs will be justified by the production of refabricated fuel elements for recycle demonstration in a HTGR and by the anticipated benefits of increased technology for HTGR fuel refabrication for future commercial application.

II. BACKGROUND AND DESCRIPTION OF PROPOSED PROJECT

The purpose of the proposed project is to demonstrate the technology for refabrication of uranium-233 for use in high-temperature gas-cooled reactors operating on the thorium fuel cycle,[1] and the projected cost of the project is $10 million (the preliminary nature of this 1973 cost estimate was discussed in Section I.) The proposed project includes the design, construction, and operation of an integrated pilot plant to develop and demonstrate the technology necessary for fabrication of HTGR fuel elements from recycled uranium-233 fuel for commercial HTGRs. This pilot plant will have the capability for performance of all processing operations beginning with the receipt of uranium nitrate solution from the National Storage Facility for Uranium-233 (Bldg. 3019 at ORNL) and ending with the delivery of completed fuel elements to an operating HTGR or to the HTGR Fuel Storage Facility at NRTS for storage. The throughput capacity of the plant will be approximately 25 kilograms of heavy metal per day or about two and one-half completed fuel elements. On the basis of a three-shift day and a five-day week and a processing campaign of about a 2-week duration every six weeks, the production capacity of the plant will be about 200 fuel elements per year over the 2-year pilot plant operation period.

Since the uranium feed material will contain gamma-emitting daughter products from uranium-232, it will be necessary for the refabrication process to be performed in a remotely operated hot cell facility. The proposed HTGR Fuel Refabrication Pilot Plant will be installed in the existing Thorium-Uranium Fuel Cycle Development Facility, Building 7930, at ORNL, which is located on the USAEC Oak Ridge Reservation in Tennessee. The USAEC Oak Ridge Reservation contains three major operating facilities: the Oak Ridge National Laboratory, the Oak Ridge Gaseous Diffusion Plant, and the Y-12 Plant. In addition, two smaller USAEC facilities are in the area. These are the UT-AEC Comparative Animal Research Laboratory and the Oak Ridge Associated Universities.

The Oak Ridge National Laboratory is a large multipurpose research laboratory whose basic mission is the discovery of new knowledge, both basic and applied, in all areas related to nuclear energy. To accomplish this mission, the Laboratory conducts research in all fields of modern science and technology. The Laboratory facilities consist of nuclear reactors, chemical pilot plants, research laboratories, radioisotope production laboratories, and support facilities.

The Thorium-Uranium Fuel Cycle Development Facility is locally referred to at ORNL as the Thorium-Uranium Recycle Facility (TURF) and is so designated in the following description and accompanying illustrations. The TURF is located in the Melton Valley area of ORNL, as is illustrated in Fig. 1, and nearby facilities include the High-Flux Isotope Reactor (HFIR), the HFIR office and maintenance building, and the Transuranium Processing Plant (TRU), as shown in Fig. 2.

A. The TURF

The TURF, Building 7930, is a three-story structure with a partial basement that was designed in accordance with the Southern Building Code for Group-G industrial occupancy. It is constructed of structural steel, reinforced concrete, and masonry. The building is of irregular shape with an overall width of 124 ft, an overall length of about 162 ft, and a gross floor area of 32,950 ft^2, exclusive of hot cells.

The first floor of Building 7930 provides space for technical personnel offices, cell operation and maintenence, a receiving area, a fuel storage room with a deep water-filled basin, hot and cold change rooms, a compressor room, and an elevator room, as shown in Fig. 3.

The second floor provides space for chemical makeup, sampling of radioactive materials, a development laboratory, a warm shop, a maintenance area, mechanical and electrical equipment rooms, a cask decontamination station, a checking and holding area, and working space around Cell A, as shown in Fig. 4.

The third floor, a high bay, includes the cell roof area and provides facilities for cell access and entry of cell services, as shown in Fig. 5. It is equipped with a 50-ton overhead traveling bridge crane with a 5-ton auxiliary hoist. Some of the third-floor space is used for cell and building ventilation equipment, and other portions will be used as necessary for mockup of cell process equipment.

A partial basement provides space for access to Cell F and for installation and maintenance of equipment in a pump room adjacent to Cell G.

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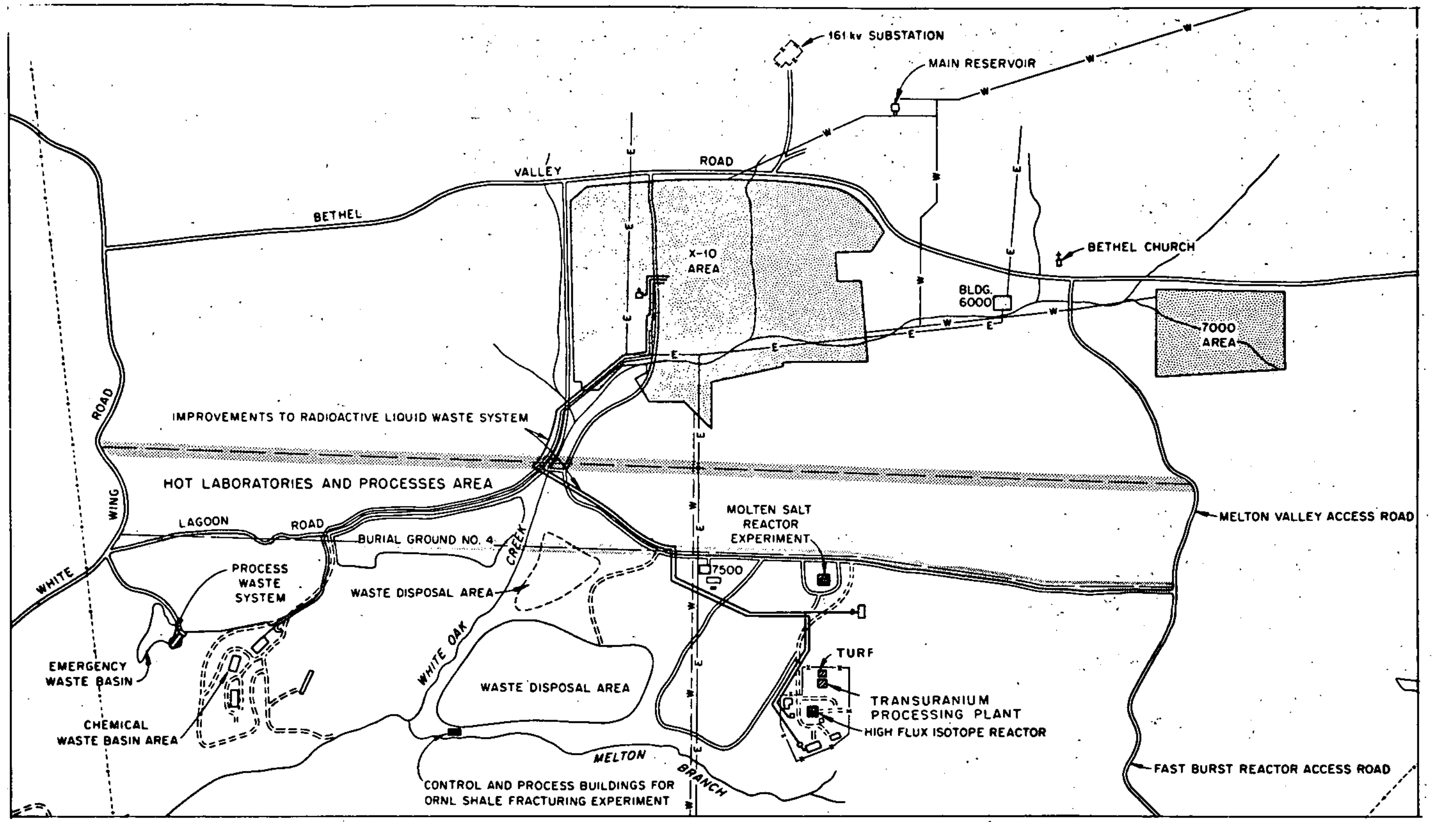

Fig. 1. Area Map of Melton Valley at Oak Ridge National Laboratory.

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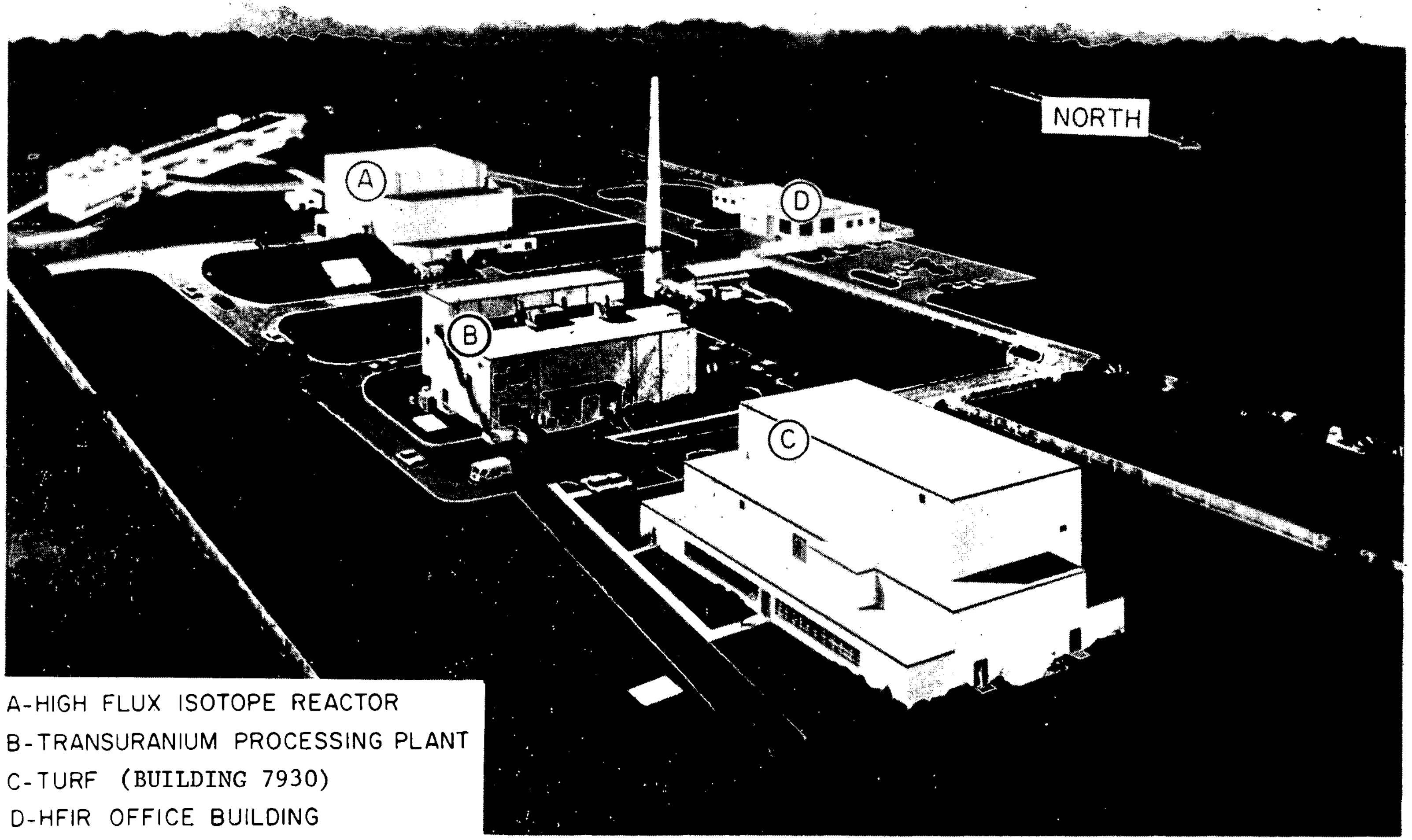

Fig. 2. The TURF and Nearby Facilities.

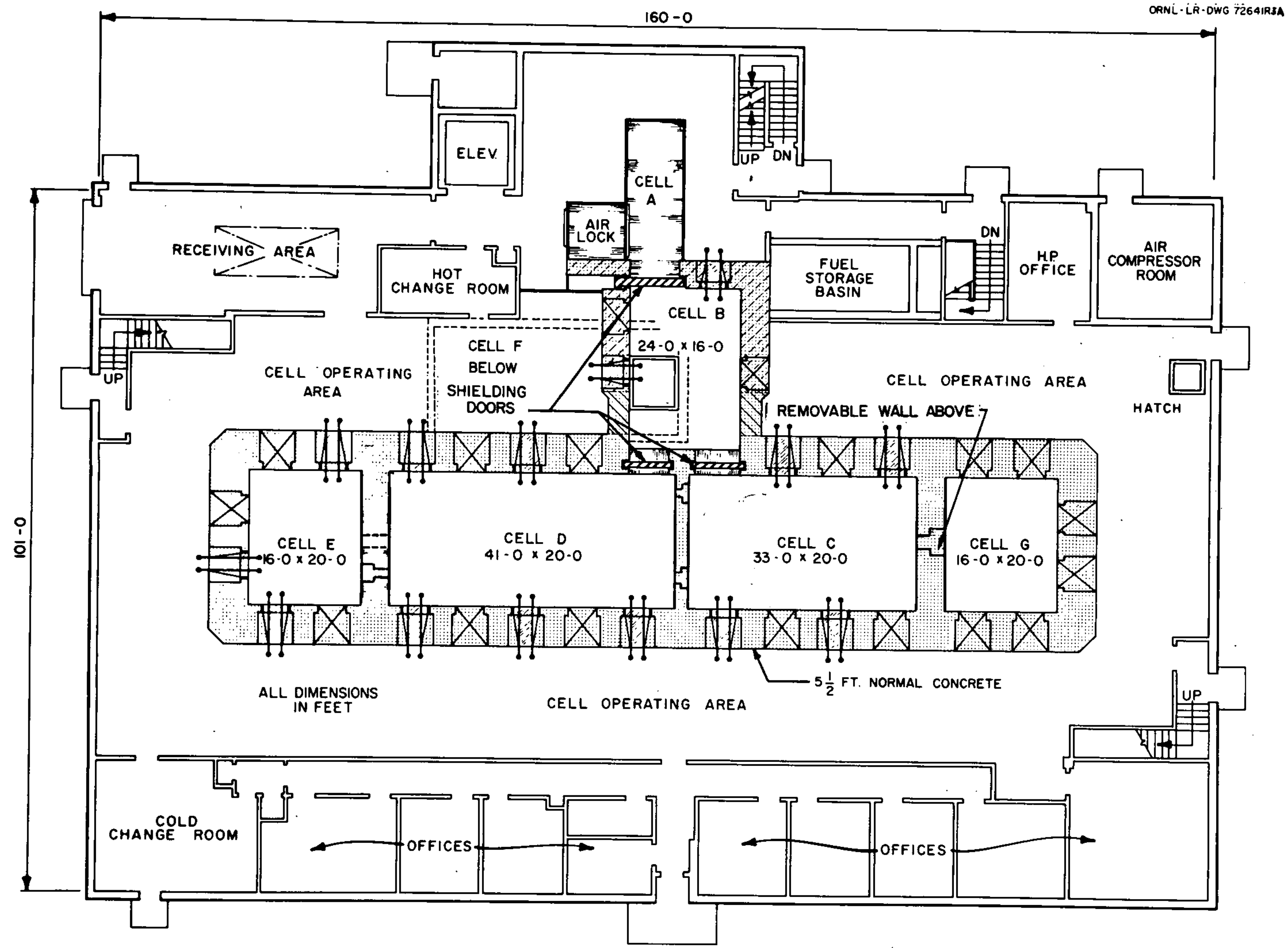

Fig. 3. First Floor Plan of Building 7930 (TURF).

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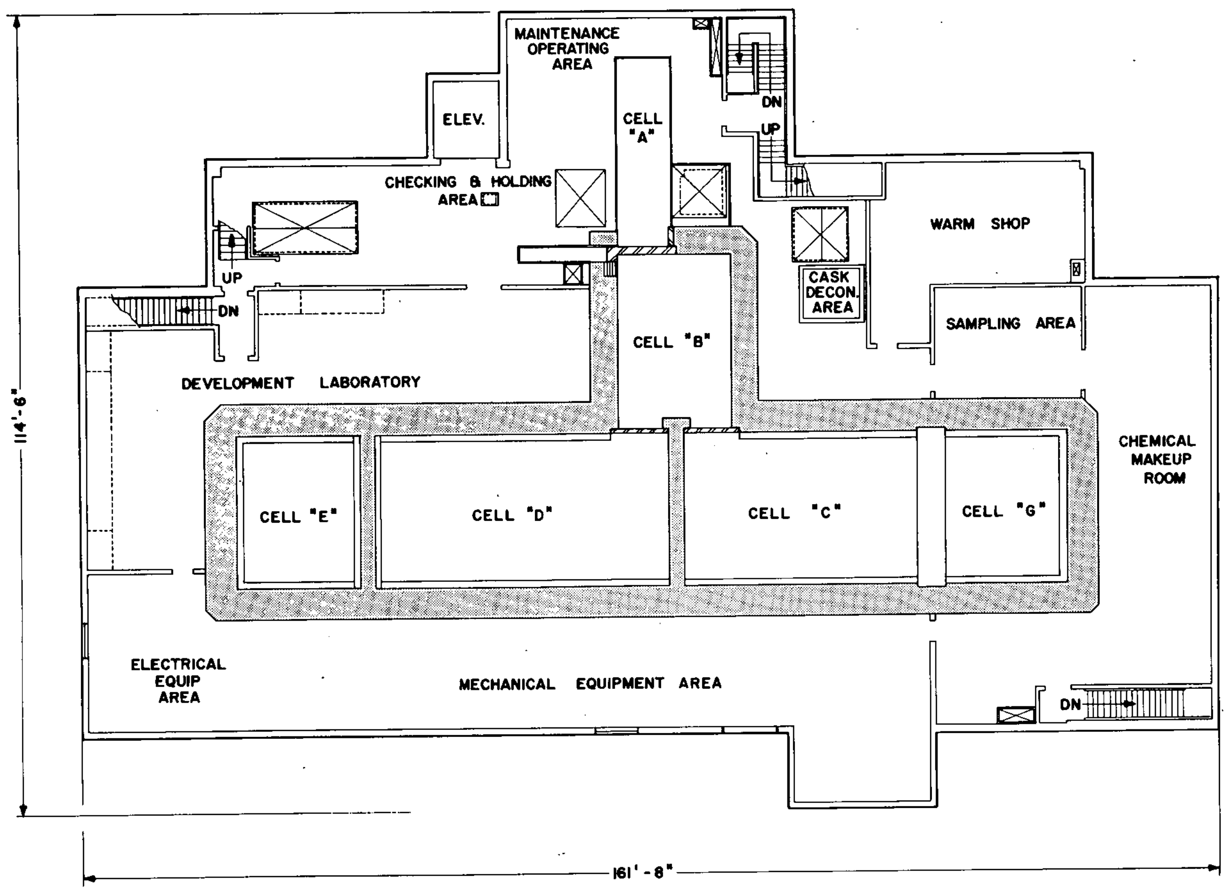

Fig 4. Second Floor Plan of Building 7930 (TURF).

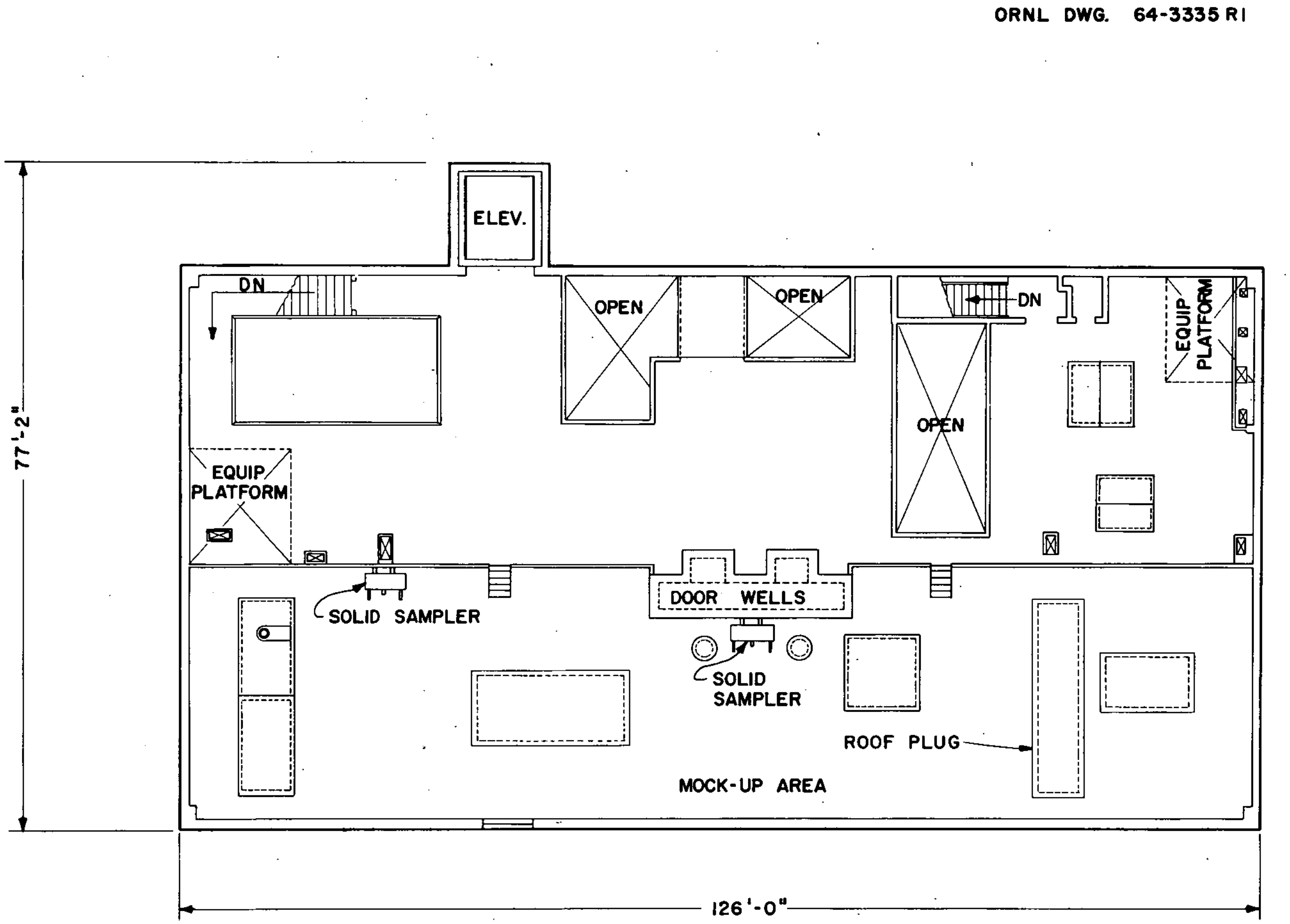

Fig. 5. Third Floor Plan of Building 7930 (TURF).

The facilities for receiving, handling, and storing radioactive materials consist of six heavily shielded cells served by an overhead crane and electromechanical manipulator system along with master-slave manipulators. In addition, there is an unshielded gloved maintenance cell, a fuel storage room with a deep water-filled basin, and a cask support and decontamination area.

1. TURF Cell Bank

The hot-cell structure, shown in Figs. 6 and 7, is in the shape of a "T". This structure is comprised of one straight section whose exterior dimensions are about 127 ft long, 31 ft wide, and 29 ft high, excluding the cell pit areas, and a second straight section about 27 ft long, 24 ft wide, and 27 ft high that is perpendicular to and abuts the first section. A lightly shielded (2 ft thick) equipment storage cell about 15 ft wide, 37 ft long, and 13 ft high is adjacent to the lower elevation of the bulk of the structure.

The four operating cells have walls of normal concrete that are 5.5 ft thick to a height of 11 ft above the floor of the operating area and 4.5 ft thick from there to the roof, which is 5-ft-thick concrete. Cell B shielding walls are of high-density Barytes concrete or equivalent that are 4 ft thick up to the second floor level and 3 ft thick from there to the ceiling. Cell F has 2 ft of normal concrete shielding for the walls and 3 ft for the ceiling. The effectiveness of each shielding window is essentially equivalent to that of the concrete wall in which it is installed.

All cells are ventilated by air drawn from the occupied areas of the building through "absolute" type air filters and thence through the cells on a once-through basis. The cell ventilation system is illustrated schematically in Fig. 8. The absolute filters on the cell air inlets and specially designed check valves prevent the flow of contaminated gas from the cells back to the occupied areas in the event of an accidental increase in cell pressure. Air leaving the cells passes through high-capacity roughing filters at the point of exit. It is then directed through two banks of absolute filters in series and released to the atmosphere from the 265-ft-high HFIR stack.

The areas of the TURF that will contain appreciable amounts of fissile material or radioactivity are designed to resist tornado and seismic occurrences. These areas are (1) Cells B, C, D, E, F, and G; (2) the liquid waste tank pit; (3) the fuel storage pit; and (4) the cell ventilation filter pit.

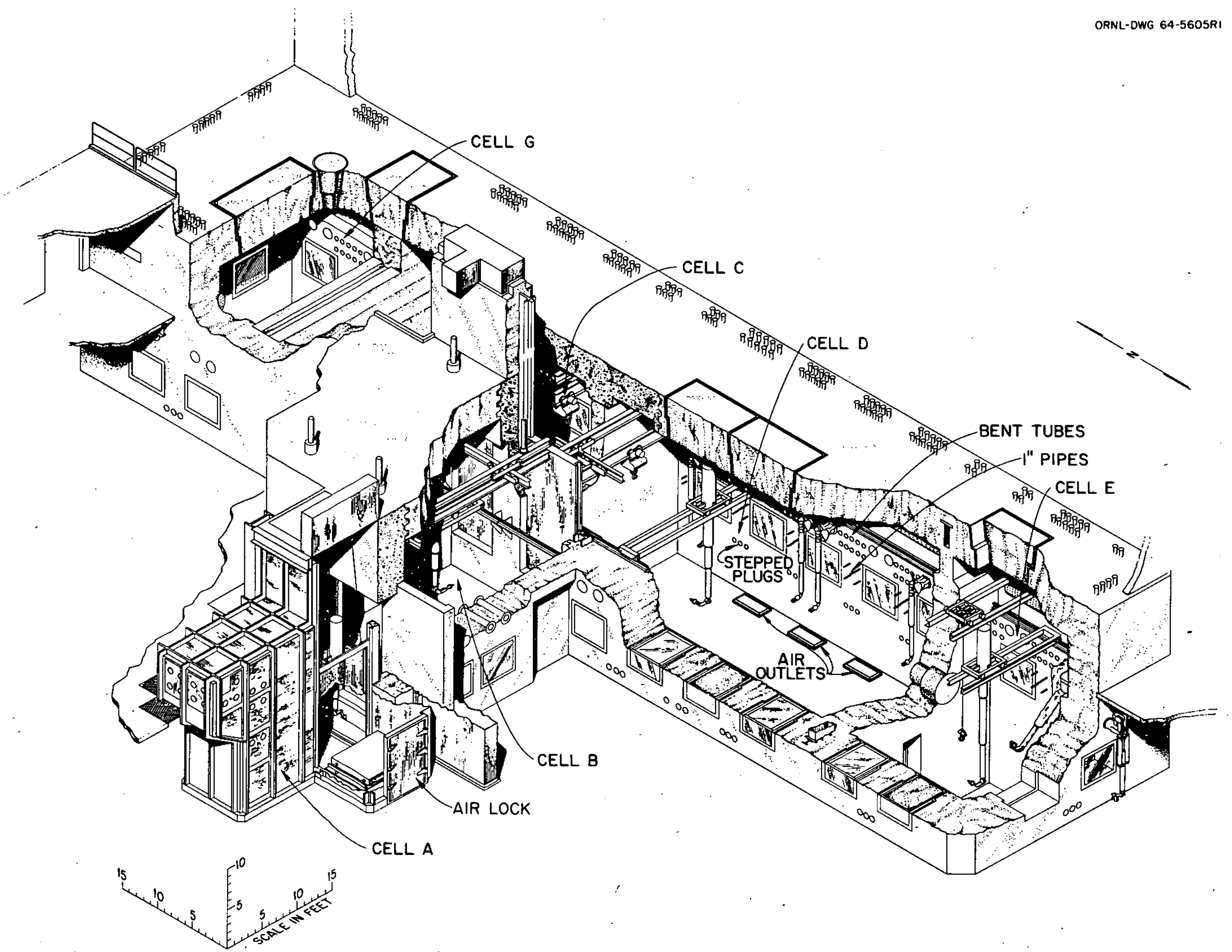

Fig. 6. TURF Cell Bank (BUILDING 7930).

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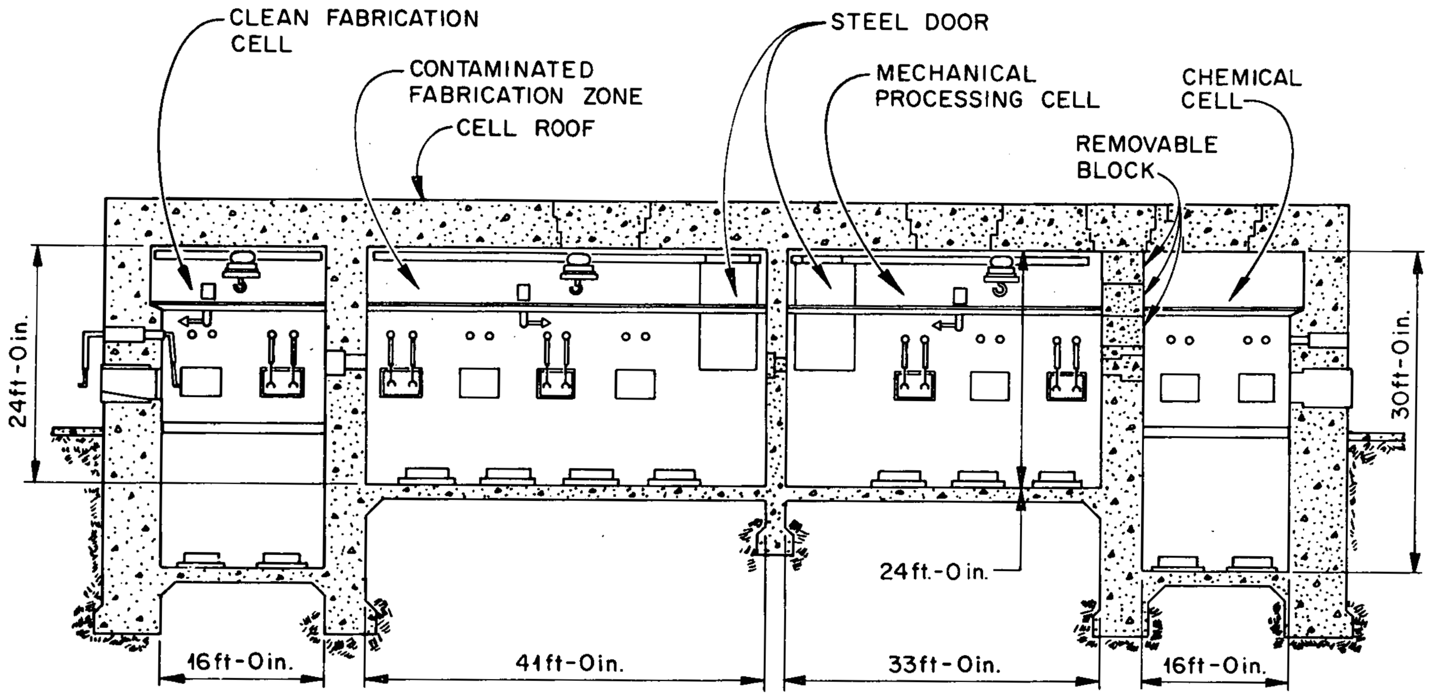

Fig. 7. Elevation View of TURF Operating Cells.

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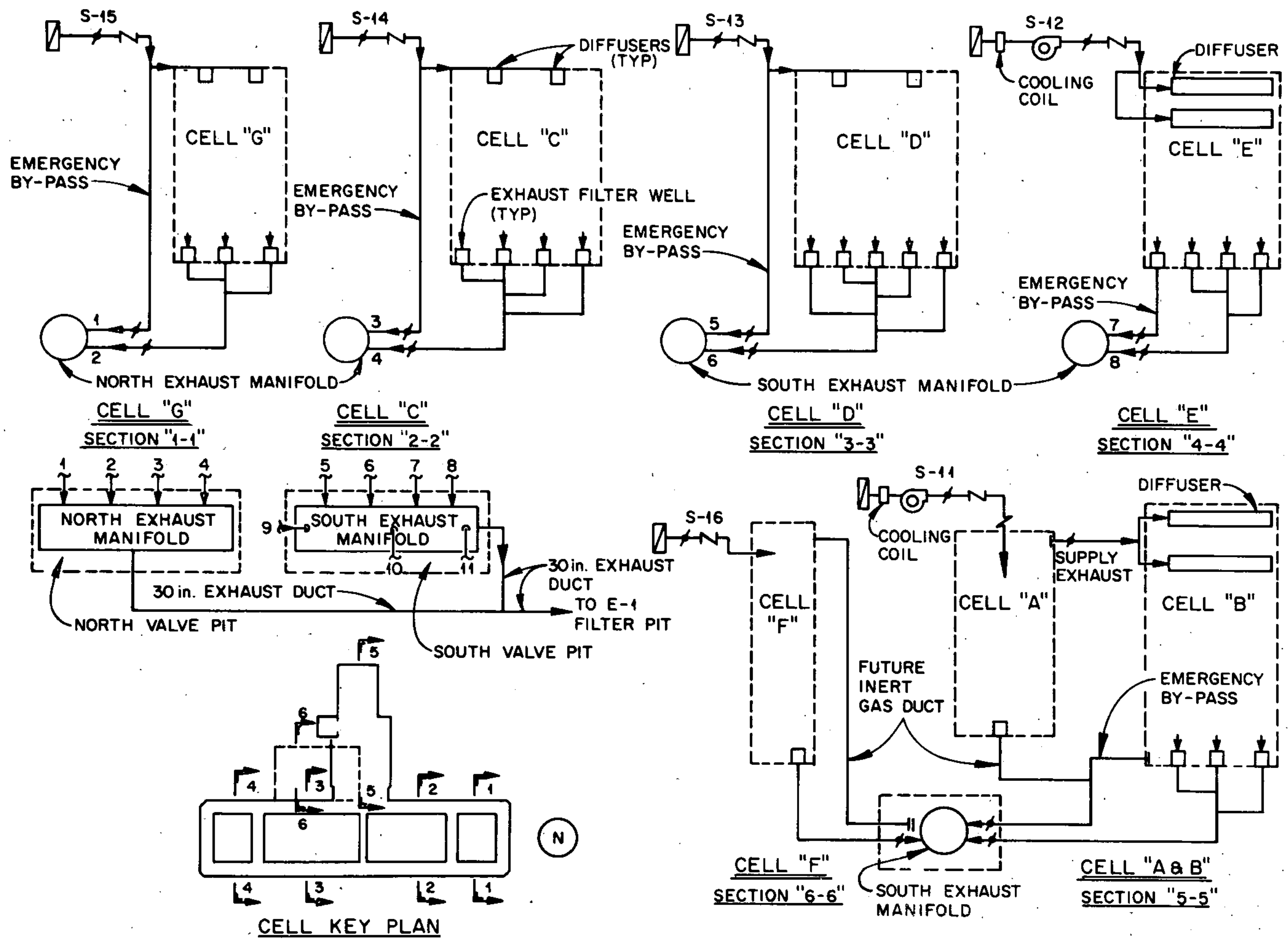

Fig. 8. Schematic Diagram of TURF Cell Ventilation System.

2. Design Basis for Cell Shielding

The radiation source that was used as a design basis for shielding calculations for the TURF cells was a fuel element containing 35 kg of a uranium-233-thorium mixture, approximately 1.75 kg of uranium-233 (with 600 ppm uranium-232), and the associated fission products that had been irradiated to 25,000 MWD/ton and decayed for 90 days.

Based on the assumption that reprocessing operations are performed with all fission products present, during normal operation, the penetrating radiation dose rate in normally occupied areas (cell operation area, operations office, change room, etc.) would be no greater than 0.25 mrem/hr with permissible hot spots in small areas, such as those opposite wall penetrations, no greater than 2.5 mrem/hr. In limited access areas not normally inhabited by operating personnel (cell roof area, sampling area, storage cell corridor, etc.), the dose rate would be less than 2.5 mrem/hr with limited area hot spots no greater than 10 times this value. The dose rate in the maintenance operating area and equipment airlock is permitted to be as high as 10 mrem/hr for short-term nonroutine operation during which the affected areas are vacated.

Since fission products will have been removed from the feed materials to the proposed pilot plant, the penetrating radiation dose rates resulting from pilot plant refabrication operations will be much lower than those of the TURF design conditions.

B. HTGR Fuel Refabrication Pilot Plant

The HTGR Fuel Refabrication Pilot Plant will be made up of all equipment, facilities, and services necessary to prepare fuel elements meeting HTGR specifications from recycled fuel, including fuel refabrication processing, waste treatment and disposal, and material handling.

The fuel refabrication processing steps include sol preparation, microsphere preparation, microsphere coating, fuel rod fabrication, and fuel element assembly. All processing equipment for the proposed pilot plant will be installed in existing processing cells and adjacent facilities in the TURF, Building 7930. The existing cells are designed to accommodate the processes involved, and major modifications to these cells will not be required. The product, materials involved, and the processing operations performed in the major systems or units of equipment in the pilot plant are described in the following subsections.

1. HTGR Fuel Element and Fuel

The fuel element for the reference 1160-MW(e) HTGR is a hexagonal block of graphite approximately 31 in. long and 14 in. across the flats, as shown in Fig. 9. These fuel elements will be stacked in a closely packed array in both the reference HTGR and the Fort St. Vrain HTGR (FSVR) currently nearing commercial operation. No supporting structure or additional moderator material is needed. The typical fuel element for the FSVR contains 108 helium coolant holes and 210 fuel holes, whereas the typical fuel element for the 1160-MW(e) HTGR contains 72 coolant holes and 132 fuel holes. A slightly modified fuel element, shown in Fig. 10, contains large holes for the control rods.

The startup fuel used in the HTGR is in the form of ceramic kernels (microspheres) coated with pyrolytic carbon and silicon carbide and bonded into rods that fit into the fuel holes in the graphite blocks.[1] The coatings on the kernels prevent the release of all but minute quantities of fission products to the reactor coolant system. An inner layer of low-density pyrolytic carbon is applied to all kernels to provide voids for the fission products and to protect the outer coating from fission recoil damage. The outer layers, which may be either a single layer of high-density pyrolytic carbon or a layer of silicon carbide sandwiched between two layers of high-density pyrolytic carbon (which is the coating used in FSVR fuel), act as a pressure vessel to contain the fission products. The silicon carbide coating on the startup fissile particles used in the 1160-MW(e) HTGR serves as an effective diffusion barrier to some fission products and also keeps fissile particles intact during the early stages of head-end reprocessing.

Although the fuel elements are similar in design with respect to geometry and dimensions, three types of elements may be used. These three types of elements are classified by the types of particles they contain, and a description of the fuel particle makeup for these three elements is given in Table 1. These three types are (1) the IM element, which contains uranium-235 and thorium and is to be used in initial and makeup fuel loadings; (2) the uranium-233 recycle element, which contains uranium-233 and thorium and is to be used as the major recycle element; and (3) the uranium-235 recycle element, which contains recycled uranium-235 and thorium and is to be used when it is desirable to pass uranium-235 through the reactor more than once. Any combination of these elements may be used in any given reactor core. Both the uranium-233 recycle elements and the uranium-235 recycle elements must be refabricated remotely.

Several types of particles are used to allow for maintaining separation of spent uranium-235 from uranium-233 to minimize cross mixing of the uranium-236 with the uranium-233 in the recycle fuel stream. The four particle types are one fertile particle and three fissile particles; a

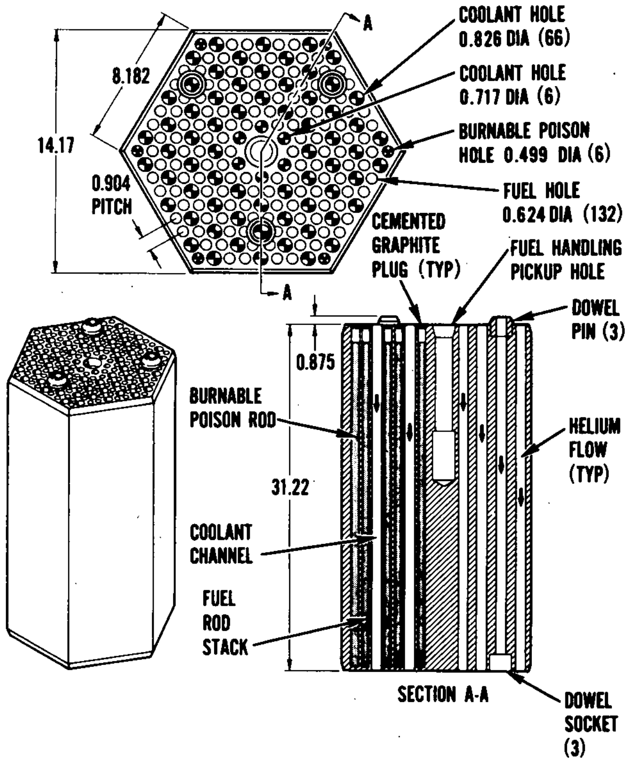

Fig. 9. Typical 1160-MW(e) HTGR Fuel Element.

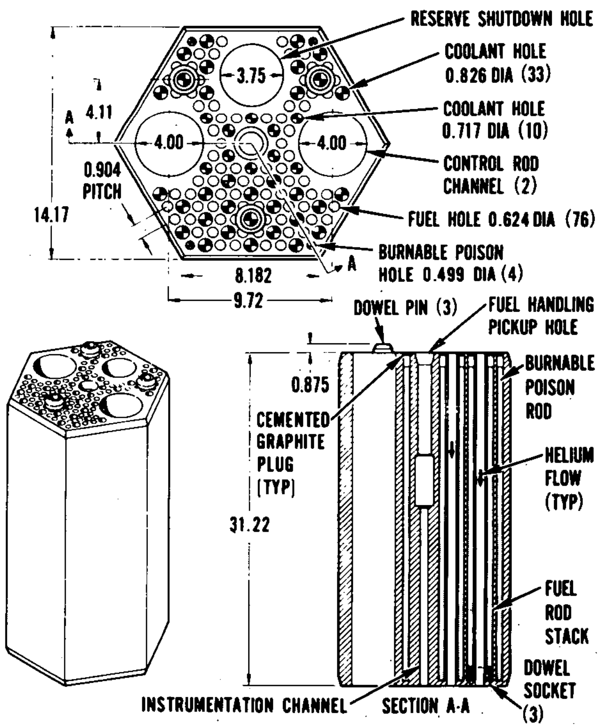

Fig. 10. Typical 1160-MW(e) HTGR Fuel Element With Control Rod Passage.

Table 1. HTGR Reference Fuel Particle Descriptions[a]

Property	IM[b] Elements		^{233}U Recycle Element		^{235}U Recycle Element	
	Fissile Particle	Fertile Particle	Fissile Particle	Fertile Particle	Fissile Particle	Fertile Particle
Isotope	^{235}U	Th	^{233}U-Th	Th	^{235}U	Th
Kernel Composition	UC_2	ThO_2	$(4.25\ Th,U)O_2$	ThO_2	UC_2	ThO_2
Kernel Diameter, μm	200	500	400	500	200	500
Type Coating[c,d]	TRISO	BISO	BISO	BISO	TRISO	BISO
Coating Thickness, μm						
Buffer Carbon	85	85	90	85	85	85
Inner Dense Carbon	25				25	
Silicon Carbide	25				25	
Outer Carbon	35	75	80	75	35	75
Total Particle Diameter, μm	540	820	740	820	540	820

[a]Particles will be bonded into fuel sticks for insertion into hexagonal graphite block fuel elements.

[b]For initial and makeup loadings.

[c]TRISO designates three types of coatings of the kernel: buffer, silicon carbide, and dense pyrolytic carbon.

[d]BISO designates two types of coatings of the kernel: buffer and dense pyrolytic carbon.

fissile particle containing new uranium-235 with both pyrolytic carbon and silicon carbide coating, a recycle uranium-235 particle containing recycled uranium-235 coated with both pyrolytic carbon and silicon carbide, and a recycle uranium-233 particle containing uranium-233 and thorium with only pyrolytic carbon coatings. Only one type of fissile particle is used in any one fuel element. Fissile particles are mixed with fertile particles before the fuel rod is formed.

2. Uranium Feed Material

The uranium-233 will be received at the National Storage Facility for Uranium-233, Building 3019, at ORNL in the form of uranium nitrate or oxide. The received material will be stored, dissolved if necessary, purified, and transferred from Building 3019 to the TURF as a uranyl nitrate solution. Receiving, storing, dissolving when necessary, and purifying of uranium-233 are an integral part of the storage operations performed in Building 3019.[2-4] The uranium feed material delivered to the pilot plant will be a solution with a uranium concentration of 100 to 250 g per liter that will contain less than 0.5 molar nitric acid when U = 100 g/liter, uranium-233 with less than 1000 ppm of uranium-232, and uranium-233 recently purified from uranium-232 daughter products.

3. Uranium Feed Material Transfer

The uranium feed material, purified uranyl nitrate solution, will be transferred from the National Storage Facility for uranium-233 at ORNL, Building 3019, to the TURF in a specially designed carrier which will be transported by truck and lowboy trailer.

The carrier in which the feed material is transported is a stainless steel toroid shielded with Barytes concrete. The 2-in.-thick vertical toroidal interior portion of the carrier is 46 in. high and has an inside diameter of 38 in. and a maximum capacity of 174 liters. The toroid is covered with a thin cadmium sheet, the Barytes concrete contains cadmium fines, and the top and bottom planes of the toroid are enclosed by a stainless steel membrane filled with paraffin. A gloved box of 1/2-in.-thick steel plate is affixed to the top of the carrier. This gloved box has 8-in.-diameter glove ports, and it contains the internal piping necessary to make and break all feed material connections under double containment conditions. Steel gussets have been installed on the carrier to protect the covered gloved box if the carrier should be involved in an accident.

The solution carrier will be filled with feed material at the loading station at Building 3019. The loaded carrier will be transferred to the truck trailer, to which it will be secured before the trailer is moved, for transport to the TURF. After the carrier has been transported to the TURF, it will be removed from the trailer and transported into the TURF through existing air locks with existing building cranes and deposited at the transfer station on top of the processing cell for unloading. Unloading of the carrier at the transfer station will be accomplished by applying vacuum to the storage tanks located in the processing cell.

Both Building 3019 and the TURF have a transfer station which affords maintenance of double containment during a feed material transfer operation. Each of the transfer stations contains the main process lines for filling and emptying the carrier as well as the services required to leak test the transfer lines, effect the transfer, and then flush and dry the transfer lines. The gloved box on the carrier is connected to the radioactive off-gas system at each station. The carrier is positioned on a movable platform for transfer operations to provide the controlled movement required to join the carrier piping with the station piping.

This transfer system is patterned after the existing procedure used at ORNL for the transfer of high-level wastes from the Transuranium Processing Plant (TRU) that has been used satisfactorily at ORNL for several years without incident.

4. Fuel Refabrication Processing

The uranium nitrate feed solution to the pilot plant will be mixed with virgin thorium nitrate solution prepared in facilities at the pilot plant. The ratio of thorium to uranium can range from 0 to 20. Typically, they are mixed in a ratio of 4.25 parts thorium to 1 part uranium and reduced to a stable thorium dioxide-uranium trioxide sol by an amine extraction process (sol preparation). The dilute sol is concentrated by evaporation and passed down through a tapered column countercurrent to upward flowing 2-ethyl-1-hexanol (2-EH) to form gel microspheres with diameters of approximately 500 microns. The microspheres are then dried and fired to form dense thorium dioxide-uranium dioxide spheres (microsphere preparation). After drying and firing, the diameter of the microspheres is approximately 350 microns. A flow diagram of these two processes is shown in Engineering Drawing F-11416-EP-001-E, which is given in Appendix E.

Before coating, the microspheres are inspected, sorted, and weighed, and those which exceed out-of-roundness, size, or density tolerances are removed. The rejected microspheres are recycled. The accepted microspheres are transferred to a fluidized-bed furnace where they are first coated with a buffer layer of porous carbon by treatment with a mixture of acetylene and inert gases, and then they are coated with a dense and impervious layer of pyrolytic carbon by treatment with propylene, proprane, or methane (microsphere coating operation). An intermediate annealing step may be used prior to deposition of the final coating layer on the microspheres to reduce cracking of the coatings under reactor service conditions. After each coating step, a sample of the microspheres is transferred to an inspection station where the microspheres are checked for size, density, coating thickness, uranium-233 content, thorium content, carbon content of the coating, surface contamination, crushing strength, and heavy metal exposed through defective coatings. The uranium content of the soot discharged to the coating furnace gaseous waste treatment system is also determined. The finish-coated microspheres are again sorted and weighed to remove those which do not meet out-of-roundness, size, and density tolerances. Batches from several furnace charges are blended to produce large, homogeneous batches for subsequent operations. A flow diagram of this process is shown in Engineering Drawing F-11416-EM-001-D, which is given in Appendix E.

The fissile thorium dioxide-uranium dioxide microspheres produced in the particle coating operation are blended with virgin thorium dioxide fertile microspheres, which are produced and coated in facilities outside of the pilot plant. The blended micropsheres are metered into the molds of a multi-stage and multi-function molding machine. The quantity of microspheres in any mold is controlled within ±0.5g of heavy metal, and the microspheres are placed in each mold so that there is no more than 10 wt % variance of heavy metal in any 1-in. length of the finished fuel rod. The rods are 1/2 to 5/8 in. in diameter and 2 to 3 in. long. The molds and contents are heated, and the microspheres in the molds are embedded in a carbonaceous matrix to form the fuel rod. Embedment is accomplished by injecting a molten mixture of carbon and pitch into the interstices between microspheres under pressure. The molded "green" fuel rods are then heated to high temperature to carbonize the matrix and drive off the volatiles (fuel rod fabrication). A flow diagram of this process is shown in Engineering Drawing F-11416-EM-007-D, which is given in Appendix E.

After an inspection step, the fuel rods are assembled in the holes of a machined graphite fuel element block, which is prepared in a facility outside the pilot plant. Approximately 2000 fuel rods are required for a single fuel element. The assembled fuel elements are inspected, packaged, and stored preparatory to shipment to the reactor. A flow diagram of the fuel element assembly process is illustrated in Engineering Drawing F-11416-EM-008-D, which is given in Appendix E.

5. Fuel Element Storage

Fuel element storage consists of the transfer of completed fuel elements, including both approved and rejected elements, from the inspection station to dry storage racks in the processing cell. The existing in-cell crane and electromechanical manipulator will be used to effect the transfer of the elements for storage.

Demonstration of the processes will require the production of about 150 acceptable recycle fuel elements. The estimated reject rate of 1% for fuel elements and the estimated rejects during initial operation will result in the need for storage of up to about 165 fuel elements. Sufficient storage space is available in the processing cell to accommodate the pilot plant production rate and shipping rate, based on the assumption that one shipping cask will be used 80% of the time.

6. Fuel Element Transfer and Shipment

Fuel transfer and shipment is comprised of the transfer of refabricated HTGR fuel elements from the processing cell into a shielded shipping container or cask (fuel element loading) and the transport of this loaded cask by motor freight to a reactor or the HTGR fuel storage facility in Idaho (fuel element shipment).

(a) Fuel Element Loading. The master-slave manipulators, the electromechanical manipulator, and the in-cell crane will be used to transfer the completed fuel elements, one at a time to an element loading station located in the processing cell. Each fuel element will be checked for radioactive contamination, and decontaminated if necessary, prior to application of a protective material around it.

After application of the protective material, each element will be transferred into a single-element cask via a transfer port in the roof of the processing cell. Hoisting of the element into the transfer cask will be accomplished by means of a hoist built into the transfer cask.

The 50-ton building crane will be used to transfer the loaded cask to the shipping cask[5] located on the trailer in the TURF receiving area. The shipping cask and can will be in the vertical position for loading. The single-element transfer cask will mate with the shipping cask, and the fuel element will be lowered into a can within the shipping cask by using the hoist built into the transfer cask. Up to three fuel elements at a time will be loaded in the shipping cask can by using this procedure. The shipping can will then be sealed, and the shipping cask cover will be sealed and leak tested in accordance with procedures described in Ref. 5.

The shipping cask will be monitored for contamination and decontaminated if necessary. The shipping cask will be lowered into shipping position and secured on the trailer. The loaded trailer will then be removed from the TURF receiving area for shipment.

<u>(b) Fuel Element Shipment.</u> Shipments of radioactive material to and from nuclear facilities are subject to the Hazardous Materials Regulations of the U.S. Department of Transportation (DOT). Those regulations are published in Title 49 of the Code of Federal Regulations (49 CFR 170-189). Additional packaging standards are imposed by the USAEC in its regulations on packaging of radioactive material for transport (10 CFR 71). All shipments of refabricated fuel elements will be made in accordance with those regulations.

An existing HTGR fuel shipping cask meets the comprehensive package design standards published in both the DOT and the USAEC regulations. The capability of the cask to withstand accident conditions and proof tests was analyzed in detail, and a design analysis report[5] was prepared for the cask. This report was reviewed by the USAEC, and after USAEC staff concurrence with the adequacy of the cask design, a specific container certification was issued for the cask. The design report and the USAEC certification were sent to the Office of Hazardous Materials, DOT, for further review and approval. The DOT authorized use of the HTGR cask under DOT Special Permit No. 6346.

To insure that the actual HTGR cask, as fabricated, does in fact meet the approved design, a quality assurance program was established for the manufacturing process. Welds were nondestructively tested for integrity, lead shielding was checked for possible voids by using gamma radiation sources, and visual inspections were made throughout the fabrication process. The finished cask was leak tested. Detailed inspections are made before and after each use of the cask to assure that it continues to meet the approved design requirements.

About 70 round trips from Oak Ridge to the point of delivery will be required to transport the refabricated fuel elements generated during operation of the proposed pilot plant. If delivery to Idaho is assumed as an average condition, each round trip will be about 4600 miles long, with the cask loaded one way and empty on the return leg of the trip. Transportation of these elements will have little or no effect on normal traffic flow. The total contained radioactivity within the HTGR shipping cask during any one shipment, based on three fuel elements per shipment, will be about 10 curies. No radiation effects to the environment or the general public are expected during shipments of refabricated fuel elements because of the low level of radioactivity involved and because the shipping cask in which the elements will be transported was designed specifically for this purpose. Experience with such transport, as reported in Ref. 6, indicates that drivers and handlers will receive no exposure above background as a result of transportation of the refabricated fuel elements.

7. Effluents and Solid Wastes

The source terms for the wastes that will be generated by operation of the proposed HTGR Fuel Refabrication Pilot Plant are given in Tables A.1 through A.4 in Appendix A. The data given in Tables A.1 through A.4 are based directly on data prepared at ORNL for an environmental survey of fuel cycles for HTGRs. The radionuclides and chemicals expected to be released in the gaseous and liquid effluents from the proposed pilot plant are discussed in detail in Section III.A.

The TURF is equipped with several systems for handling the liquid and gaseous wastes that will be generated.[7] The liquid wastes, including storm drainage, sanitary wastes, process drainage from sources other than cells, and radioactive process waste streams, are collected by networks designed and installed for this purpose. Nonradioactive process wastes are monitored for contamination and piped to retention basins which provide controlled discharge to the environment. The sanitary waste is transferred into the Melton Valley disposal system, and storm drainage is discharged directly to a natural drain.

The radioactive liquid waste solutions are impounded and treated in either the TURF waste system or in an existing ORNL radioactive waste treatment system to which they may be transferred. The TURF waste system consists of three type 304L stainless steel tanks located in a concrete pit. The liquid levels in the tanks and in the sump below the tanks are monitored frequently by operating personnel. A leak in one of the tanks would be detected promptly by a change in the liquid level in the sump and would be indicated by an alarm on the operating control panel. Any leakage collected in the sump would be pumped into an existing ORNL radioactive waste treatment system.

The gaseous wastes are handled by a vessel hot off-gas (HOG) system and a cell ventilation system designed and installed to safely handle all gases leaving the building. The gaseous wastes from the equipment within the cells and certain limited-access points adjacent to the cell bank are handled by the vessel HOG system illustrated schematically in Fig. 11. This diagram illustrates the major features of the system, including the parallel filters and fans, the scrubber pit for possible addition of a caustic cleaner, and the tie-in to the E-1 exhaust system to the HFIR stack. Each of the vessel HOG filters illustrated is comprised of two roughing filters and four HEPA (high-efficiency particulate air) filters in series.

The cell ventilation system is comprised of air supply systems that pass air into the cells where it and any gaseous waste not collected by the HOG system are collected, a filtration system, and an exhaust system. The cell ventilation system airflow pattern is illustrated schematically in Fig. 12. The system flows are as follows.

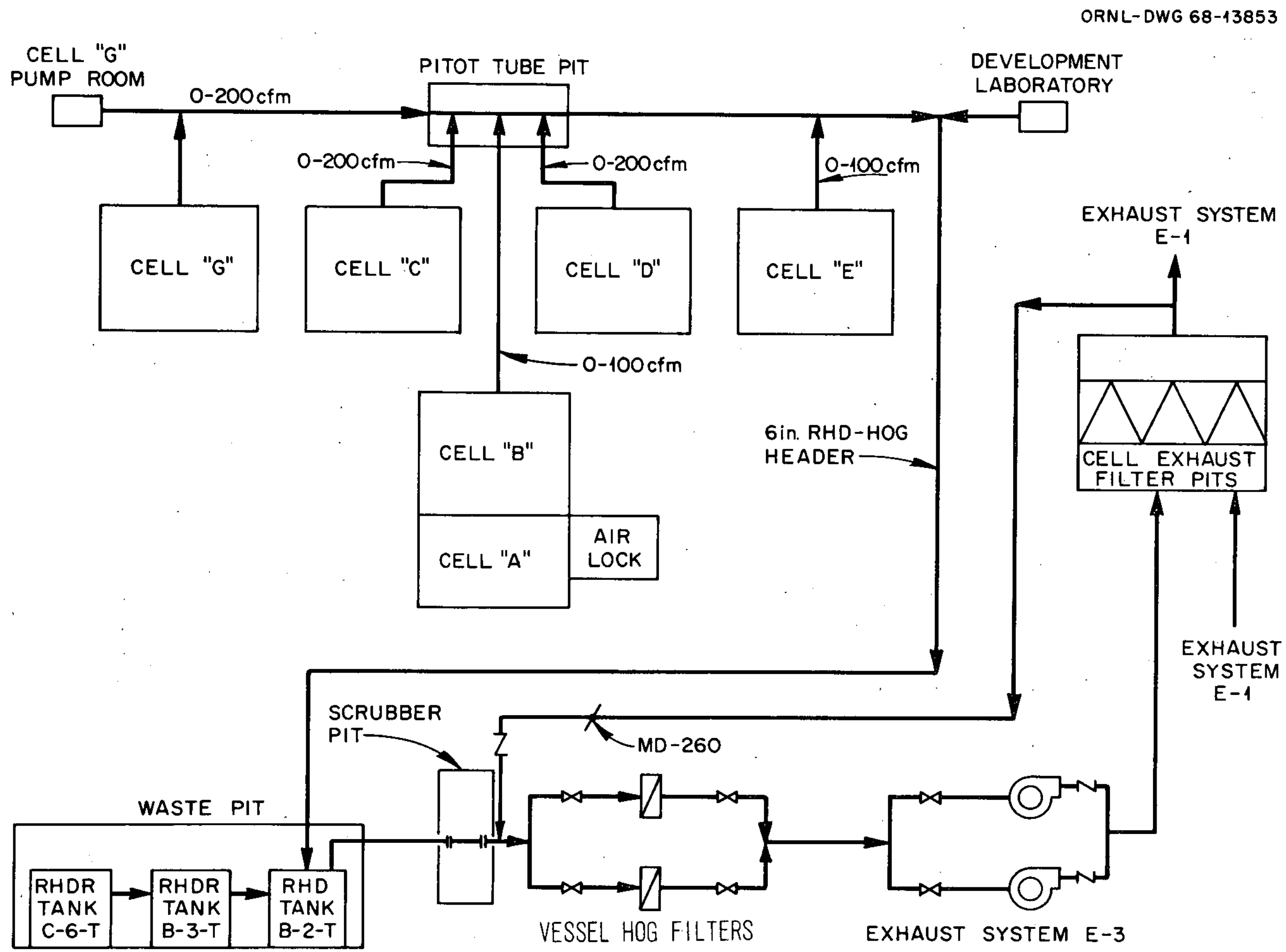

Fig. 11. Schematic Diagram of the TURF Hot Off-Gas Collection and Discharge System.

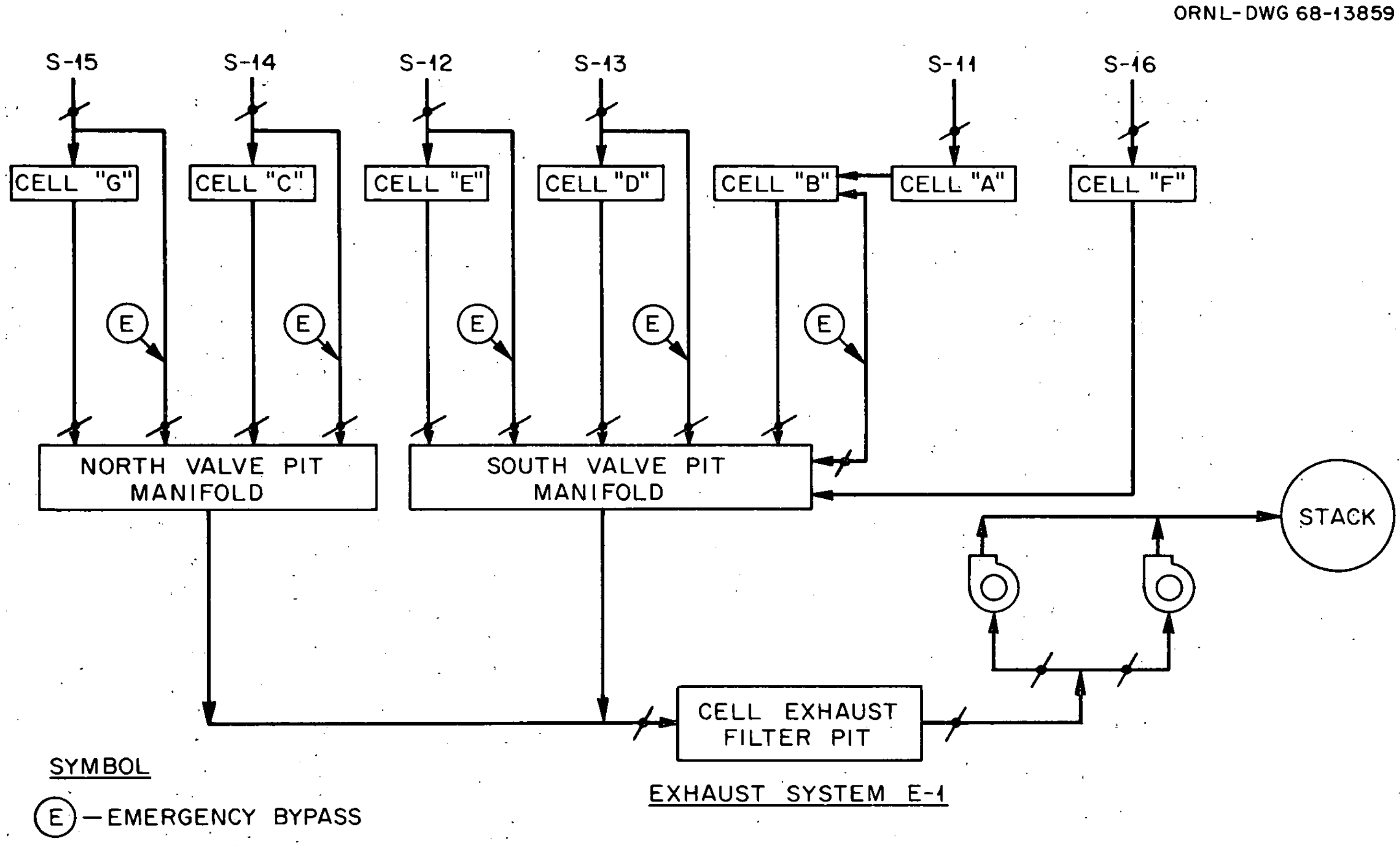

Fig. 12. Schematic Diagram of the TURF Cell Ventilation System Airflow Pattern.

Area	Flow (cfm)	Source
Cells A and B	1760	Second floor maintenance operating area
Cell C	2240	Second floor cell roof area
Cell D	2900	Second floor cell roof area
Cell E	2000	Second floor cell roof area
Cell F	500	Cell F corridor
Cell G	1033	Cell G pump room

The cell exhaust gas is filtered through high-capacity bag-type dry roughing filters that have a 0.3-micron DOP efficiency of 95%. From these in-cell filters, the gas is passed through an absolute filter pit which contains five parallel compartments, each of which contains two HEPA filters in series. From the cell exhaust filter pit, the exhaust gas is discharged to the atmosphere from the HFIR stack, which serves the HFIR, TRU, and TURF. The 265-ft-high HFIR stack has a reported capacity of 60,000 cfm and an estimated average atmospheric dispersion factor of 0.92×10^{-5} sec/m^3 (Ref. 7). However, actual measurements of stack flow and atmospheric conditions indicate that a dispersion factor of 2×10^{-7} sec/m^3 is more accurate (See Appendix D).

Solid wastes will be packaged and shipped to the existing ORNL burial grounds and placed in retrievable storage. It is intended that all wastes generated after the microsphere forming processing step will be converted to either gaseous or solid wastes.

8. Possible Accidents

Safety in the HTGR Fuel Refabrication Pilot Plant will be achieved through the design features inherent to the TURF and the pilot plant processing equipment and by strict administrative control of the operations of the facility and the processing conditions under which the fissionable or hazardous materials are to be handled. Special safeguards will minimize the probability of potentially serious accidents involving criticality, fire, or explosion. If these safeguards should fail and such an accident should occur, the TURF shielding, containment, and ventilation systems will be capable of limiting the effects of the accident to a minimal level. The safety analysis[7] for the TURF was the basis for assessing the effects of possible accidents.

9. Project Decommissioning

Project decommissioning encompasses the removal and disposal of all HTGR-related equipment from Building 7930, including equipment from the hot cells, and decontamination of the cells. All surface contamination will be removed from the hot cells to ready them for the installation of future processes. Detailed procedures will be written to provide step-by-step instructions for the removal and disposal of contaminated equipment and support systems and decontamination of the affected cells.

(a) Decommissioning of Remote Processing Cells. A general description of the procedures that will be required to remove and dispose of contaminated equipment from the remote processing cells and decontaminate the cells is outlined as follows.

1. All solid fissile material will be removed from the cells and equipment. The fissile material will be stored in the national repository in Building 3019. All solid fertile material will be placed in either sealed containers for reuse or in an existing on-site burial ground for future retrieval.

2. All liquid fissile material will be removed from the equipment, and the equipment will be flushed. The liquid fissile material will be reduced in volume by evaporation and stored in the national repository in Building 3019. All liquid fertile material will be removed from the equipment, and the equipment will be flushed. This material will be reduced in volume by evaporation and placed in sealed containers for future use.

3. The equipment will be remotely decontaminated in a decontamination cell by using the in-cell crane, electromechanical manipulator, and the master-slave manipulators. The equipment will then be monitored for beta and gamma radiation.

4. If the radiation level is reduced to an acceptable level, the equipment will be transferred via an existing remotely operated dolly into a gloved alpha cell. The equipment will then be dismantled, decontaminated further, and monitored for alpha, beta, and gamma radiation. If the equipment is clean, it will have some salvage value. If the equipment is contaminated, it will be packaged for long-term storage and retrieval at the existing ORNL burial ground.

5. After all the equipment has been removed from the cells, the cell walls, ceilings, floors, and service piping will be decontaminated remotely by using appropriate decontamination solutions. The cells will be decontaminated until no airborne activity is present and the radiation level is less than 5 millirem/hr.

6. After remote cell decontamination, personnel may enter the cells and further decontaminate them, the remaining services, and the disconnect stations. The services and disconnect stations that are contaminated will be removed and packaged for long-term storage and retrieval at the existing ORNL burial ground. Services and disconnect stations that are not contaminated will have some salvage value.

(b) Decommissioning of Cell E. A general description of the procedures that will be required to remove and dispose of contaminated equipment from Cell E and decontaminate the cell is outlined as follows.

1. All solid fissile and fertile material will be removed from Cell E. This material will be HTGR recycle fuel elements. It is assumed that some of the elements will be acceptable recycle fuel elements, and they will be loaded and shipped as described in Subsection II.B.6. However, some will be rejected and broken fuel elements.

The reject and broken elements will be placed in containers and the containers will be sealed, using the in-cell crane, electromechanical manipulator, and master-slave manipulators. The containers will be remotely leak tested in the cell; it is assumed that the containers will be contaminated. Each loaded container will be removed from the cell and placed in a second container or can, which will be sealed, leak tested, and placed in a shipping cask, as described in Subsection II.B.6. It is assumed that the cans will be delivered to the HTGR Fuel Storage Facility in Idaho for long-term storage or reprocessing.

2. It is expected that there will be no liquid fissile or fertile material in Cell E.

3. The equipment in Cell E will be remotely decontaminated in place by using an appropriate decontamination solution. The equipment will then be monitored for alpha, beta, and gamma radiation prior to removal from the cell.

4. The decontaminated equipment will then be removed from the cell via a transfer port in the cell roof and placed in a portable alpha gloved box.

5. The equipment will be dismantled and further decontaminated in the gloved box. If the equipment is still contaminated, it will be packaged for long-term storage and retrieval at the ORNL burial ground. If the equipment is clean, it will have some salvage value.

C. Anticipated Benefits

The benefits to be derived from the construction and operation of the proposed HTGR Fuel Refabrication Pilot Plant center on the technology that will be developed and demonstrated. The technical data generated by implementation of the proposed project can be used as a basis for the design and construction of large-scale commercial refabrication plants from which the primary benefits to society and the economy will occur. The proposed pilot plant will be designed to test each unit of the processing equipment similar to that to be used in a commercial plant so that the commercial plant will primarily be a scaled-up duplication of the production lines and equipment used in the pilot plant. The major benefits of the pilot plant will therefore accrue directly to the commercial refabrication plant, but the benefits that result from the operation of commercial refabrication plants will benefit the overall U.S. economy.

1. Need for Project

The proposed HTGR Fuel Refabrication Pilot Plant is intended to provide a basis for the design of commercial refabrication facilities for HTGR fuel. The HTGRs now on order are expected to be discharging uranium-233 in the early 1980s. This uranium must be stored or it can be reprocessed and refabricated and returned to the HTGRs for power generation. Optimization of economics and resource utilization requires that the uranium-233 be reprocessed, refabricated, and used as fuel.

To recycle fuel from the HTGR, it is necessary to chemically reprocess the fuel, separate the various fuel materials, reconstitute the fuel, refabricate it, and return it to the reactor. The uranium-233 which is to be returned to the reactor contains uranium-232, which has decay products with high-energy gamma radioactivity. Thus, shielded facilities and remote operations are required to carry out refabrication operations. It is also necessary that the operations be suitably contained because of high alpha radioactivity associated with the fuel material. The operations and the equipment required for the fabrication of fuel with uranium-233 therefore differ greatly from those required for fabrication of fuels containing naturally occurring isotopes. There presently is no experience relative to the remote refabrication of HTGR fuels on any scale, and there is very little experience with remote fabrication of fuels in general. The proposed HTGR Fuel Refabrication Pilot Plant will provide this experience for HTGR fuel.

A study based on data contained in Ref. 8 showed that commercial operation of HTGR fuel refabrication plants should commence in 1985, making it necessary to have the pilot information available by 1978 for design of the commercial plants (based on the assumption that a 7-year period will be required for design, construction, and placing of the commercial plant in operation). The minimum time required to design, construct, and place the pilot plant in operation is 4 years. An additional 2 years of pilot plant operation should be allowed for confirmation of the design. Therefore, it is seen that operation of the pilot plant should be started in mid-calendar year 1978, and it can be expected to end in mid-calendar year 1980. To a great extent, the design of the commercial plant will overlap the period of time during which the pilot plant will be operated. It is therefore important that the pilot plant be started at an early date to provide the data necessary for the design and construction of the commercial plant on the required schedule.

2. Schedule

The schedule for the HTGR Fuel Refabrication Pilot Plant calls for the preparation of a definitive conceptual design and the assembly of criteria for the detailed design of the proposed pilot plant in fiscal year 1974. Completion and approval of the detailed design are scheduled by the end of fiscal year 1976.

The schedule calls for equipment procurement to begin in fiscal year 1976 and proceed well into fiscal year 1977. Equipment installation will begin in late fiscal year 1976 and be completed by the end of fiscal year 1977. Unit and systems testing will begin early in fiscal year 1977 and be completed by mid-fiscal year 1978. The schedule then allows a 6-month period (the latter half of fiscal year 1978) for cold operational testing of the pilot plant. The hot demonstration is scheduled to begin in fiscal year 1979 (July 1978) and be terminated at the end of fiscal year 1980. Shutdown and decommissioning activities are tentatively scheduled for the first half of fiscal year 1981.

The quantity of spent fuel available for commercial recycle is dependent upon the schedule for HTGR power plant construction and operation. Four estimates for future HTGR installations are illustrated in Fig. 13. These estimates range from a conservative total of 20 reactors built between 1979 and 1986 and an optimistic total of 124 reactors built between 1979 and 1988. If it is assumed that commercial reprocessing operations will begin in 1986, the quantity of spent fuel available by then can be estimated from these schedules. When the 20-reactor schedule from Fig. 13 and mass balance data for the reference 1160-MW(e) HTGR cycle with no recycle are used, approximately 473 metric tons of heavy metal will be discharged by the end of 1985. In addition, approximately 182, 174, and 170 metric tons will be discharged in 1986, 1987, and 1988, respectively. Approximately 3% of the discharged heavy metal is fissionable material. Thus, even with the most conservative construction and operation schedule from Fig. 13, a substantial quantity of spent fuel containing significant amounts of fissionable material will be ready for reprocessing in the mid-1980s when the first commercial plant is planned for operation.

3. Benefits to be Derived

The HTGR is of interest as an energy system because of its relatively efficient use of fissionable material, its conservation of natural resources through the use of the thorium fuel cycle, its reduced thermal discharge rate because of its high efficiency, its favorable safety characteristics due to the high temperature capability of the graphite core, the potential for direct cycle gas turbine applications with dry cooling towers for use in water-short regions, and its

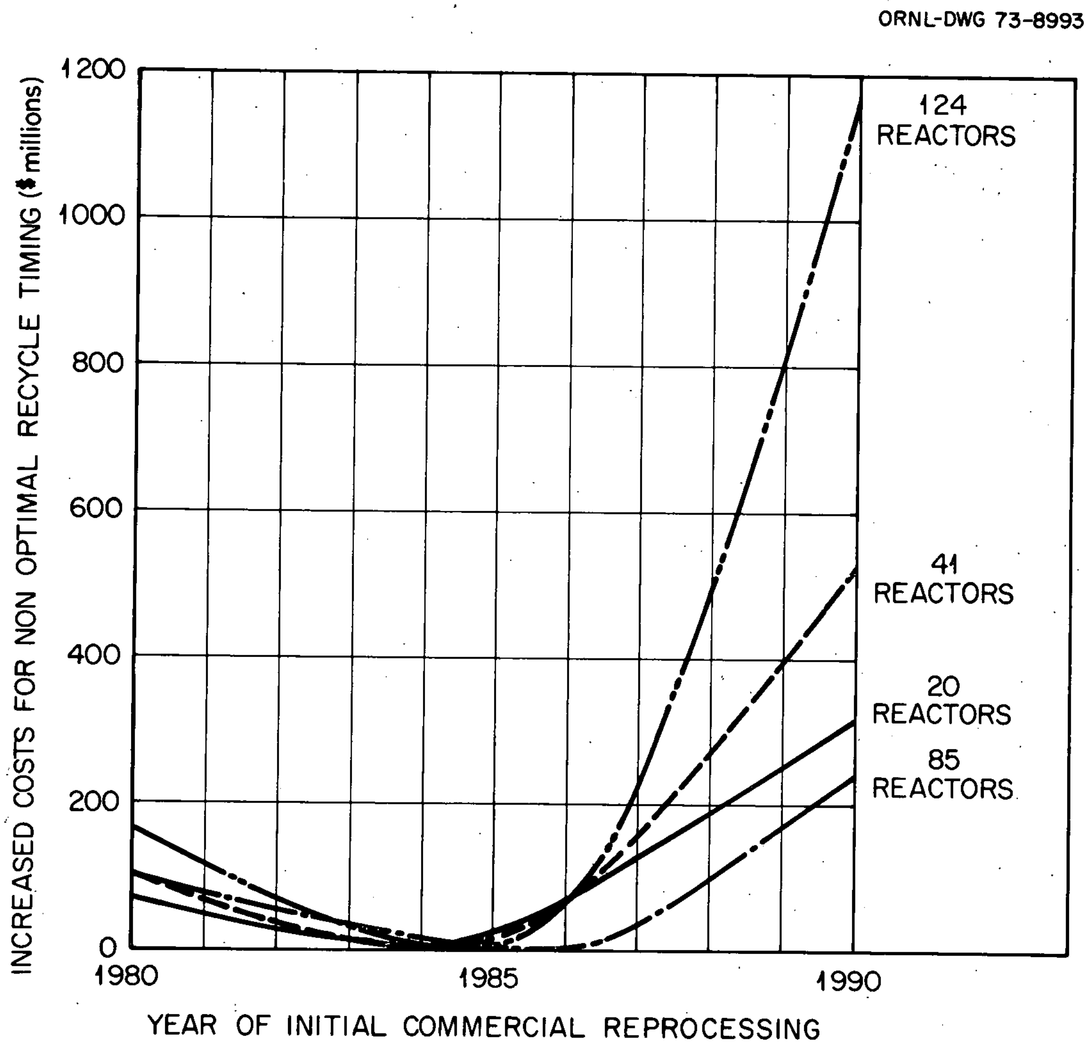

Fig. 13. Influence of Recycle Timing on Fuel Cycle Costs.

potential for high temperature process heat applications. The benefits anticipated from recycling fuel in the HTGR are estimated at $2 billion in FY 1974 dollars between now and the year 2020 in a reactor economy which includes LWRs, LMFBRs, and HTGRs.

Certain economic and energy benefits will be derived by the overall electrical power production industry from the application of the technology to be developed from implementation of this project. These benefits are described two ways: (1) benefits to the HTGR fuel cycle economy and (2) specific technical benefits from operation of the HTGR Fuel Refabrication Pilot Plant.

(a) Benefits From Fuel Recycle. The benefits to be derived from the recycle of HTGR fuel can be determined with some confidence since HTGRs can be operated without recycling fuel and the difference between the cost of recycle and non-recycle operation can be calculated. The results of one study indicate that operation of HTGRs without benefit of recycle increases the fuel cycle costs 0.2 to 0.3 mill/kWhr. Calculations made at ORNL indicate that the benefits of recycling HTGR fuel will be somewhat higher. Benefit calculations were made for HTGR economies ranging from 20 large reactors, 1160-MW(e), beginning commercial operation between 1979 and 1986 to 124 reactors beginning operation between 1979 and 1988, as illustrated in Fig. 13. The HTGR economy recently suggested in WASH-1139,[8] which predicted about 100,000 MW(e) of installed HTGR electrical capacity between 1979 and the year 2000, was also considered. The results of these benefit calculations indicate that the economically optimum time to begin reprocessing spent fuel is calendar year 1984 for the 20- and 41-reactor economies, 1985 for the 124-reactor economy, and 1986 for the 85-reactor economy. A summary of the benefits of recycling for each of these cases, determined by comparing calculated fuel cycle costs using optimal recycle with those for no recycle, is given in Table 2. The fuel cycle expenditures given represent both undiscounted values and values discounted at the beginning of 1978, using a 10% discount factor. An inflation rate of 5% per year was assumed in these calculations.

As given in Table 2, the calculated benefit of recycling HTGR fuel is about 0.45 mill/kWhr. The dollar savings varies with the size of the economy. In addition to decreasing the cost of electric power, recycling of HTGR fuel will save a considerable portion of the uranium reserves, thereby benefiting power costs for all reactor designs. Based on the mass balances for the 1160-MW(e) HTGR, operation in the non-recycle mode will require about 54% more uranium ore and separative work than operation in the recycle mode. Fuel recycling provides the additional benefits realized from not having to build and operate large, expensive storage facilities for spent fuel.

(b) Benefits From HTGR Fuel Refabrication Pilot Plant. The design, construction, and operation of the HTGR Fuel Refabrication Pilot Plant will provide information necessary for the scale-up of refabrication processes to commercial plant size. Construction and operation of the pilot plant will enable designers of the systems and equipment to confirm the design basis and criteria used for the processes, remote equipment, and handling procedures. Changes in the design basis at this stage of development would be relatively inexpensive as compared with changes in the design basis of a commercial refabrication plant.

Because of the radioactivity of the materials being processed, it will be necessary to design to strict standards

Table 2. Benefits of Recycling HTGR Fuel

Fuel Cycle Cost for[a]	Optimal Recycle	No Recycle	Difference
20-reactor economy			
(a) mill/kWhr	1.13	1.58	0.45
(b) $ billions	2.76	3.85	1.09
(c) $ billions	6.58	9.97	3.39
41-reactor economy			
(a) mill/kWhr	1.03	1.49	0.46
(b) $ billions	4.94	7.10	2.16
(c) $ billions	12.03	18.80	6.77
85-reactor economy			
(a) mill/kWhr	0.99	1.41	0.42
(b) $ billions	7.42	10.66	3.24
(c) $ billions	21.81	33.88	12.07
124-reactor economy			
(a) mill/kWhr	0.94	1.38	0.44
(b) $ billions	12.92	19.05	6.13
(c) $ billions	32.21	51.67	19.46

[a](a) = levelized fuel cycle cost
(b) = present-worthed fuel cycle cost
(c) = undiscounted fuel cycle cost

for protection of operating personnel and the environment. Operation of the pilot plant will permit confirmation of these design concepts prior to their application on a large scale. The levels of quality assurance established during design and construction of the pilot plant will be tested, and upgraded if necessary, for applicability to commercial systems during implementation of the pilot plant program.

Operation of the HTGR Fuel Refabrication Pilot Plant will provide the opportunity to assess the reliability of the processes and equipment required to refabricate HTGR fuel elements. The remote operations that are necessary for refabrication of HTGR fuels present a particular problem with respect to plant maintenance. Operation of the pilot plant will also provide the opportunity to isolate and solve maintenance problems prior to commercial application of the processes and equipment.

The product of the HTGR Fuel Refabrication Pilot Plant will be a HTGR fuel element containing uranium-233 for recycle. In conjunction with the research and development associated with the pilot plant demonstration program, a number of fuel elements will be produced to confirm on a statistical basis that uranium-233-bearing fuel elements can be transported and irradiated successfully in high-temperature gas-cooled reactors.

In addition, the proposed HTGR Fuel Refabrication Pilot Plant will be of sufficient capacity to permit testing of the economics of remote fuel refabrication processes. Data will be obtained to establish plant operating factors, equipment reliability, product characteristics, utility requirements, operating labor requirements, maintenance costs, and other pertinent cost factors.

D. Existing Environment

The proposed HTGR Fuel Refabrication Pilot Plant will be installed in the existing TURF, Building 7930, which is located on the USAEC Oak Ridge Reservation at Oak Ridge National Laboratory, as shown in Fig. 1. Nearby facilities include the HFIR and the TRU, as shown in Fig. 2.

Located in the west central portion of eastern Tennessee, as shown in Fig. 14, the Oak Ridge Reservation is bounded on the northeast, southeast, and southwest by the Clinch River and on the northwest by Black Oak Ridge. The Reservation, established in 1942 by the U.S. Army Corps of Engineers (Manhattan Engineering District) and Stone and Webster Engineering Corporation, presently covers approximately 37,000 acres.

Four separate production and research facilities are operated within the Reservation. Three of these, Oak Ridge National Laboratory (X-10), the Y-12 Plant, and the Oak Ridge Gaseous Diffusion Plant (K-25), are operated for the USAEC by Union Carbide Corporation, Nuclear Division. The Comparative Animal Research Laboratory (CARL) is located along the Clinch River between X-10 and Y-12, and it is operated by The University of Tennessee. Buffer zones are designated around each of the four facilities for health, safety, and future expansion. Access to the Reservation is limited primarily to public roads and visitor centers for reasons of health, safety, and national security.

The area surrounding the Reservation is generally rural to urban in character, with the largest population center (Knoxville, population 175,000) located 15 miles to the east. Other population centers, all with populations of less than 35,000 persons, are Oak Ridge (located on the northeast boundary), Clinton (10 miles northeast), Kingston (10 miles southwest), Harriman (10 miles west), and several smaller communities within Anderson and Roane Counties. The climatology, geolcgy, seismology, ecology of the site, and land use within the Reservation are discussed briefly in the following subsections and in more detail in Appendix B.

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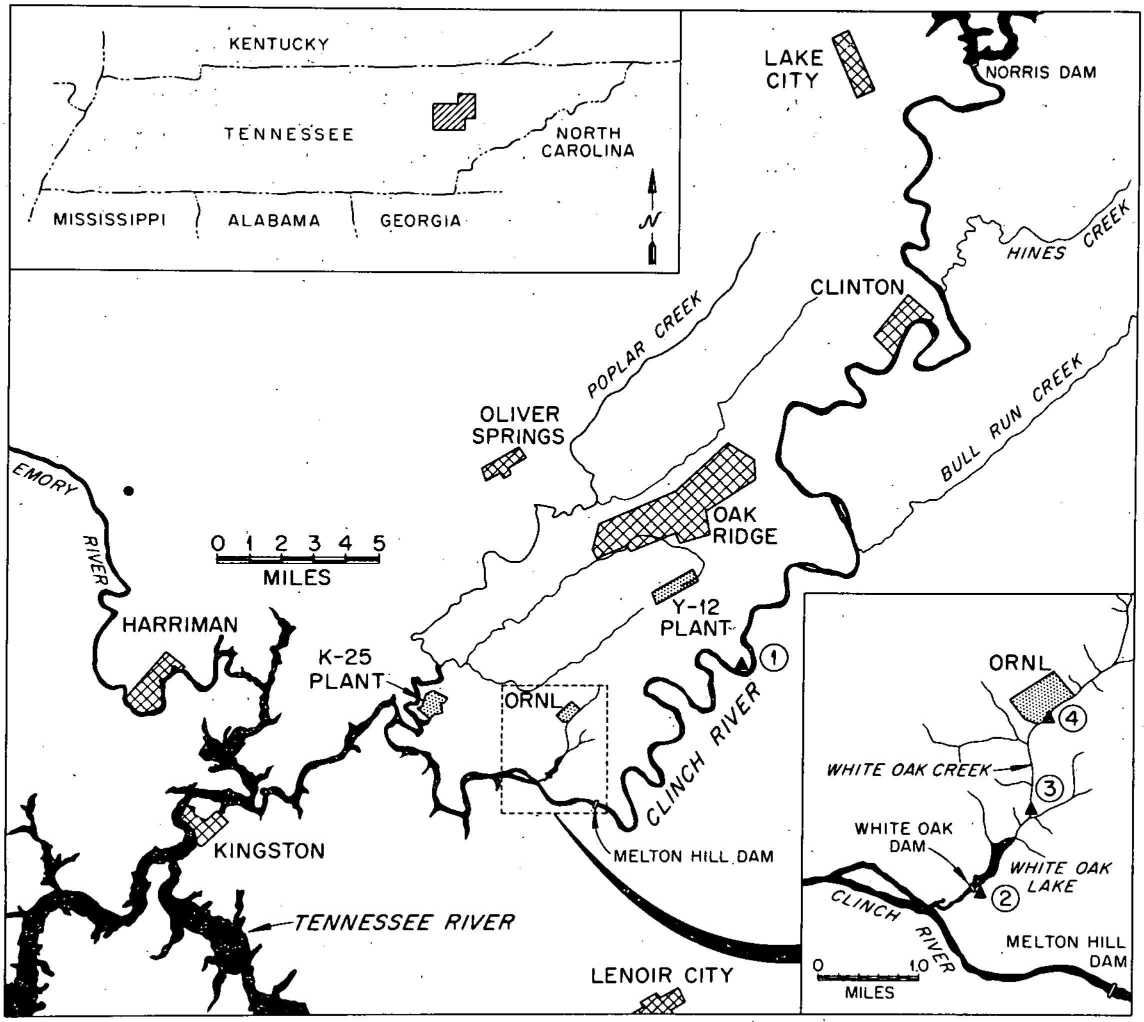

Fig. 14. Location Map of USAEC Reservation at Oak Ridge, Tennessee (numbers in circles indicate stream gaging stations).

1. Topography and Climatology

The Oak Ridge site is in the western part of the Tennessee section of the Ridge and Valley province, consisting of parallel ridges and valleys trending northeast. The range in altitude is from 720 to 1335 ft (220 to 407 m) above mean sea level.

The climate of Oak Ridge is typical of the humid southern Appalachian region.[9] The mean annual rainfall is approximately 53.5 in. (136 cm), and the mean temperature is 57.9 degrees F (14.4 degrees C). Precipitation is predominately in the form of rainfall although under unusual conditions snowfall can represent a significant portion of the total winter precipitation, as happened in the winter of

1959-1960 when 41.4 in. (105.2 cm) of snow fell.

Storm tracks appear to travel from northwest to southeast. The precipitation pattern during the year is characterized by wet winters and comparatively dry springs followed by relatively wet summers and dry autumns. July rainfall (5.6 in.) normally approaches that of the wet winter months, while June (4.0 in.) is almost as dry as the autumn months, as is shown in Fig. 15. July is generally the hottest month (76.9 degrees F), while January is the coldest (37.9 degrees F).

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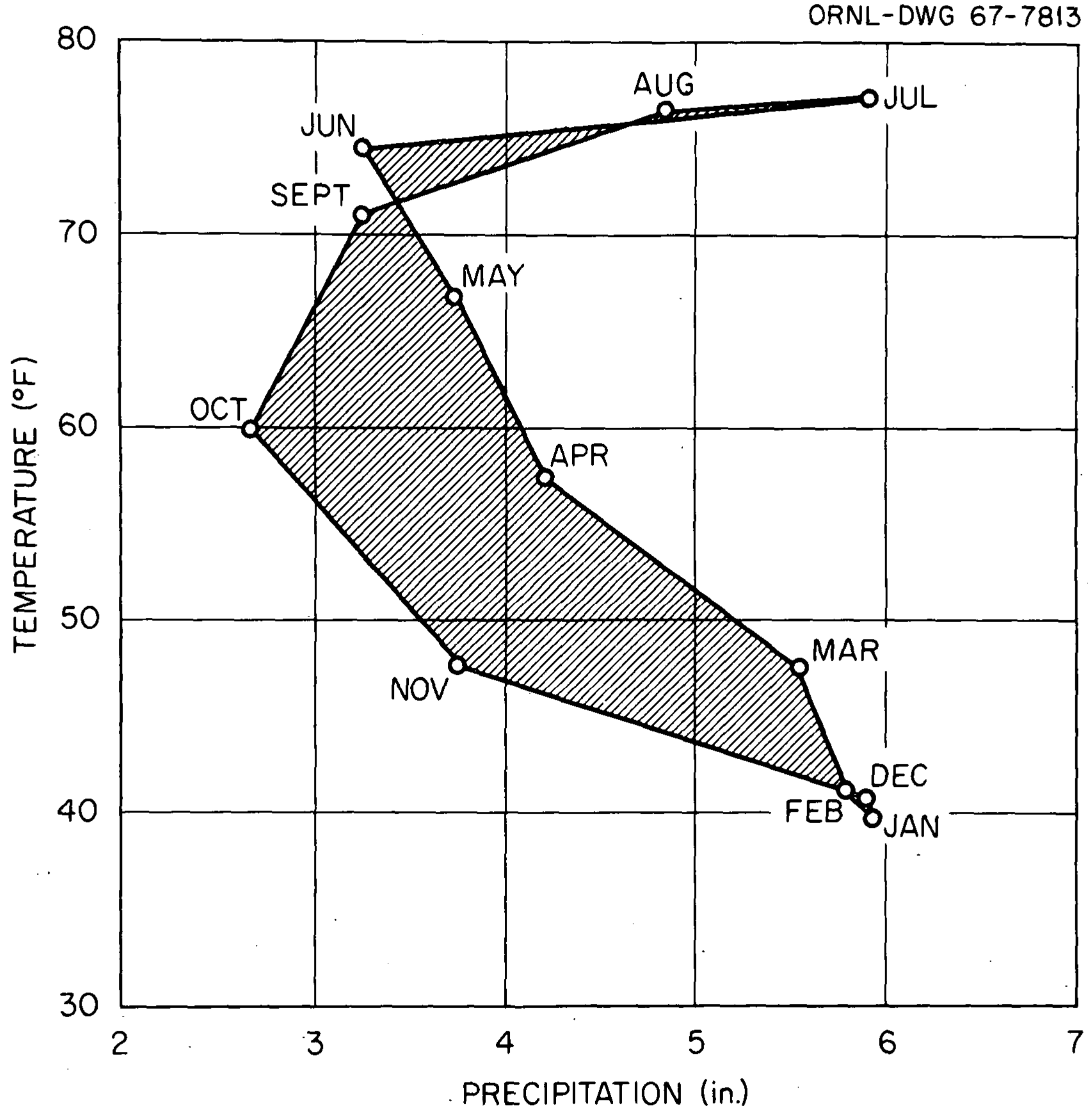

Fig. 15. Climograph of the Oak Ridge Area.

The striking feature of the Oak Ridge climate with respect to plant growth is the development of comparatively early moisture deficits in the spring. However, rainfall in July and August is normally adequate to prevent the development of severe summer deficits, which often occur in other areas of the southern United States. Additional climatological data are included in Appendix B.

2. Geology and Soils

The Oak Ridge Reservation lies in the Tennessee Valley and Ridge portion of the Appalachian Highland physiographic province. This province is characterized by a series of long narrow ridges and slightly broader intervening valleys with a pronounced northeast-southwest trend. The ridges in general are underlain by relatively resistant sandstones and competent limestones or dolomites, whereas the valleys are underlain by weaker shales and more soluble carbonate rock.

The White Oak Creek basin, upon which the TURF is situated, is underlain by four major geologic formations. The two oldest, the Rome Formation and the Conasauga Group, are made up of shale, siltstone, sandstone, and limestone and are poor water-bearing formations.[10] The two younger formations, the Knox Dolomite and the Chickamauga Limestone, are the principal water-bearing formations.

The soils of the basin belong to the red-yellow podsolic, the reddish-brown laterite and lithosol groups. These are strongly leached, low in organic matter, acidic, and generally have exchange capacities less than 10 milliequivalents per 100 g of soil. Soil profiles range in depth from 6 in. in some shale areas to approximately 15 ft in the dolomite and alluvial areas. Clay fractions present include illite, kaolinite, and montmorillinite, with base saturation ranging from 10 to more than 60 %.

3. Hydrology

Drainage of the ORNL area is to the Clinch River by way of various smaller streams. Among these streams is White Oak Creek (Fig. 14), which courses through Oak Ridge National Laboratory and forms the principal drainage system for the site. Groundwater levels in the immediate vicinity of the TURF range from 25 to more than 100 ft below surface contour. These levels undergo marked seasonal fluctuations, reaching peak levels in March and gradually declining as discharge rates exceed recharge rates.[10] Belts of residual materials overlying bedrock are relatively thin, reducing the volume available for groundwater storage. Consequently, it is estimated that the average well in the Oak Ridge area would yield less than 10 gpm. The Clinch River, which has a drainage area of 4413 square miles, is the source of most of the water used in the area.

Flow in the Clinch River is regulated at Norris Dam and at Melton Hill Dam. Stages below Melton Hill Dam are further affected by operation of Watts Bar Lake. Power generation began at Melton Hill Dam in the summer of 1964, and it exerts a significant influence on the flow patterns of the Clinch River. Operation of the turbine generators ususally coincides with peak power demands (except on weekends), resulting in intermittent flow releases as high as 18,000 cfs.[11]

These high flow releases from Melton Hill Dam cause water levels to rise rapidly, blocking the outflow of water from White Oak Creek for about 6 hours each day. White Oak Creek is impounded by White Oak Dam, which is a small highway-fill structure located 0.6 miles above the stream mouth where White Wing Road (Tennessee State Highway 95) crosses the creek. The impoundment, White Oak Lake, covers approximately 20 acres and provides the final on-site monitoring area for liquid effluents from ORNL. Upon cessation of power generation at Melton Hill Dam, the waters of White Oak Creek begin to flow into the main stream and are flushed downstream with the next power generation flow release. Monitoring stations are located on White Oak Creek, on Melton Branch, and on the Clinch River.

4. Seismology

A seismic risk map of the United States is illustrated in Fig. 16. This map was prepared for use in establishing design requirements for structures to be located in various portions of the country.[12] Within the southeastern region of the United States, the only zones of highest risk (zone 3) are those around centers of seismic activity in the Mississippi Valley and at Charleston, South Carolina, both of which are about 400 miles from the site of the proposed project. The TURF site is in an area of lesser activity assigned a zone-2 risk, indicating a potential for moderate damage. The area has experienced a recent earthquake (November 1973). The epicenter was about 30 miles southeast of the ORNL site, with an intensity of approximately IV - V (modified Mercalli). The intensity at ORNL has been estimated at about IV, and there was no observed damage.

5. Ecology of Site and Environs

The Oak Ridge Reservation is typical of the landscape and ecological systems which occur in the Appalachian Region of the eastern United States. As such, the area is comprised of a number of representative terrestrial and aquatic ecosystems, ranging from smaller, established southern coniferous forests to northern hardwood types and from smaller stream tributaries to man-made reservoir streams.

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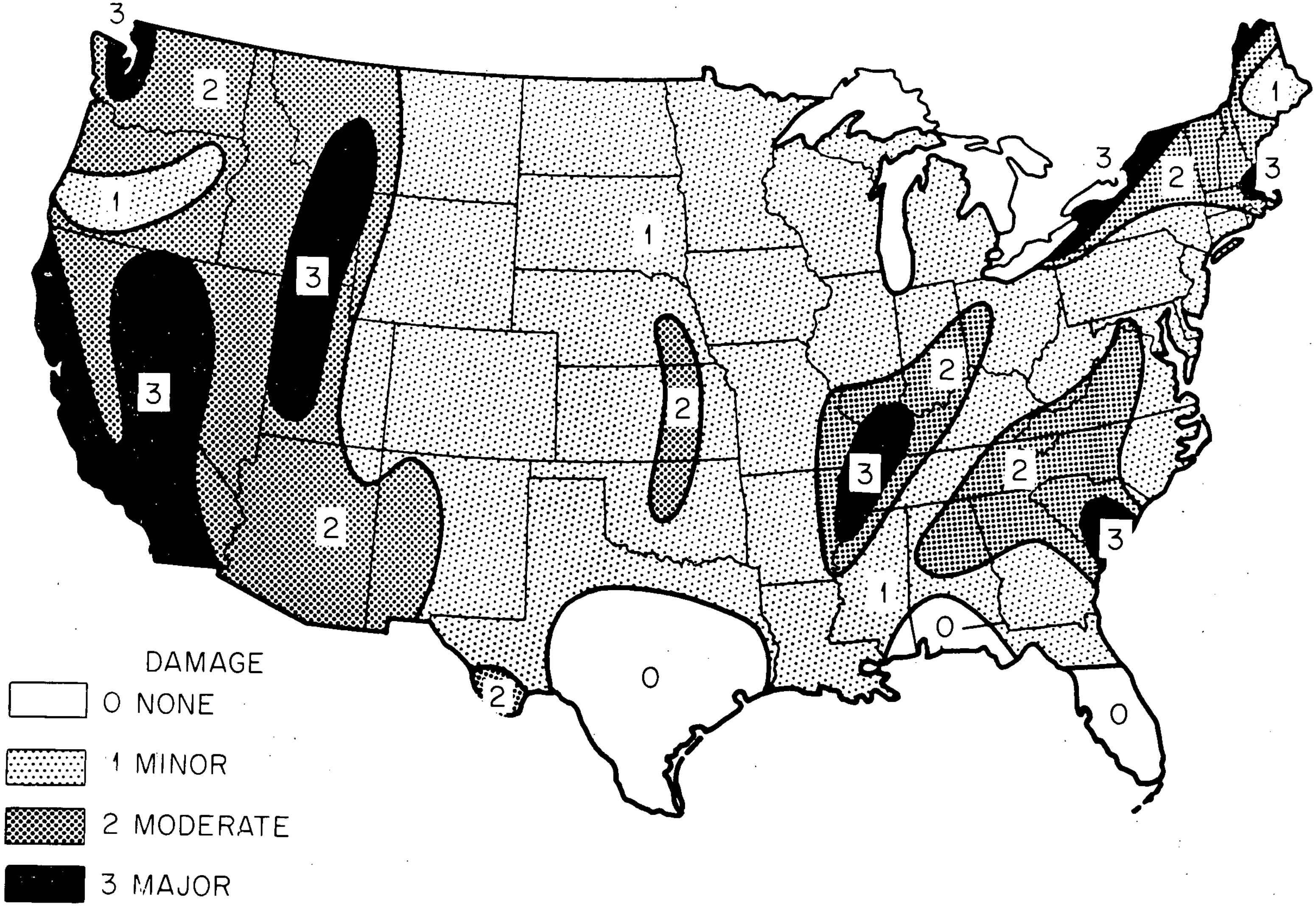

Fig. 16. Seismic Risk Map of the United States (from Ref. 12).

A preliminary inventory of the flora of the general Oak Ridge area was completed in 1966.[13] However, this inventory has since been supplemented with observations of spring flowering for 171 species of herbaceous and woody plants representing 55 plant families.[14]

Five Appalachian forest types are found naturally on the Reservation.[15] The oak-hickory type shares equal prominence with the yellow pine-hardwood type. Cove hardwoods are found interspersed between the dissected ridge systems, and northern hardwoods occur in sheltered areas on northern exposures. A minor type, white pine-hardwood, is found along the northern boundary of the property. Large areas of open land were planted to pine between 1947 and 1956, thereby creating a sixth type.

There are several available studies describing the fauna of the area, with special reference to Melton Valley wherein lies the TURF. The fauna are typical for forested and semi-forested regions of the United States, and they are described in detail in Appendix B. Over 65 separate species of birds were observed in a 1957 summer survey. The southern bald eagle (*Haliaeetus* l. *leucocephalus* L.) is listed as an endangered species whose range encompasses the local area.[16] However, no recent sitings of the bird have been reported. Typical species of mammals include mice, shrews, opossums, racoons, woodchucks, rabbits, foxes, and the white-tail deer.

Various facets of the aquatic system, represented by the White Oak Creek, White Oak Lake, Clinch River, and Tennessee River continuum, have been studied over the past two decades, particularly with respect to the behavior and transport of radioactive materials in the aquatic environment.[11] The biotic composition of White Oak Lake is typical of the present aquatic system downstream from Melton Hill Reservoir and immediately adjacent to the proposed project. White Oak Lake has been characterized as having high phytoplankton productivity and well developed benthic fauna, with the most common forms being comprised of various insect larvae.[17] Fishes present in the shallow embayment (maximum depth of 7.3 ft) include bluegill and redear sunfish, largemouth bass, warmouth, gizzard shad, golden shiners, goldfish, and the mosquitofish, *Gambusia affinis affinis*. The aquatic system is discussed further in Appendix B.

6. Land Use

The 92-square-mile Oak Ridge Reservation was originally acquired as a site for production facilities and nuclear research, and a security buffer and safety zone were established around each USEAC plant within the Reservation. The original 59,000 acres acquired in 1942 have since been reduced to approximately 37,000 acres through land transfers to the municipal government of Oak Ridge and to state and federal agencies.[15]

The allocation of land among the USAEC users is given in Table 3. Buffer areas around each of the facilities allow for increased security and protection against accidental releases

Table 3. Allocation of Land Use Among Installations in the AEC Oak Ridge Reservation[a]

Administrative Unit	Acres
Research and Management	15,108
ORNL	8,843
Y-12	3,632
K-25	5,645
UT-AEC[b]	3,786
Total	37,014

[a]Data taken from Task Force Report FY-1972 "Surveys of Real Property Holdings," AEC-ORO, June 1972.

[b]Does not include 720 acres of UT-AEC farm located within the Y-12 Plant buffer zone.

of chemical or radioactive materials and also provide room for future expansion. Little forested acreage is included in the buffer areas around the Y-12 and K-25 Plants, but extensive forested areas lie within the ORNL (X-10) and UT-AEC (CARL) sections. The remainder of the Reservation (15,000 acres) is approximately 95% forested with pine (36%), upland hardwoods (32%), mixed pine-hardwoods (21%), and cedar and miscellaneous species (11%).

It has recently been proposed that the Oak Ridge Reservation be designated an Environmental Study Park.[18] Within this context, a total of 41 study areas were delineated as being unique and important in terms of present day environmental problems. Additional discussion of historic and present land use is presented in Appendix B.

E. Monitoring of Existing Environment

The Oak Ridge National Laboratory conducts a continuous monitoring program on the USEAC-controlled reservation and the surrounding environs. A monitoring network, extending 75 miles from ORNL, provides information on quantities and concentrations of airborne radioactive pollutants. Similarly, a water and biota monitoring program is conducted on the

Clinch River, which is the eventual receiving body of water for all potentially contaminated liquid effluents leaving the controlled reservation. A comprehensive, multi-agency investigation of the potential radiation exposures received by the public use of the Clinch River waters was the subject of the 5-year Clinch River Study. In the final report of this study on the doses to populations from ORNL operations, it was concluded that average exposures were well below the applicable dose limits and that the maximum individual dose was a small fraction of the dose limits.[19] External gamma radiation levels or background levels in the ORNL area and in the Oak Ridge area are measured routinely. The background level for the Oak Ridge area off the ORNL site averages approximately 0.012 mR per hour, which is about the same as that measured prior to the start of ORNL operations.

Sanitary, chemical, and miscellaneous industrial waste effluents are monitored through an established environmental surveillance program which is conducted by the ORNL Industrial Hygiene Department and the Operations Division. A more detailed description of the environmental monitoring programs for radioactive and chemical effluents is presented in Appendix C.

III. ENVIRONMENTAL IMPACT

Construction, operation, and decommissioning of the HTGR Fuel Refabrication Pilot Plant are expected to have an insignificant impact on the environment. The construction activity will be negligible and concentrations of radioactive and chemical effluents that will result from operation of the pilot plant are expected to be several orders of magnitude below established guidelines.[20] All effluents from the proposed project will be controlled releases through existing waste disposal systems. The estimated emissions and expected impacts are discussed in the following subsections.

A. Probable Environmental Effects

The probable environmental effects of the proposed pilot plant are limited to those that will result from discharges to the atmosphere, discharges of liquids, and solid waste disposal.

1. Discharges to the Atmosphere

All atmospheric discharges from the TURF will be via the No. 7911 stack which also serves the HFIR and the TRU. This stack is 80.8 meters (265 ft) high, and it has an orifice diameter of 1.5 meters and a flow rate of 23.6 cubic meters/sec. Atmospheric dilution from this stack is considered in detail in Appendix D.

(a) Radioactive Emissions. Meteorological data for the site were used in a computerized atmospheric dispersion model to estimate radionuclide concentration as a function of direction and distance from the stack. The derivation of the atmospheric dispersion model, a summary of the meteorological data, and some results of the calculations are presented in Appendix D.

On the basis of actual measurements of stack releases, a dilution factor of 2×10^{-7} was used to calculate the maximum radionuclide concentration at the effective perimeter of the facility area. Annual radionuclide release rates and estimated concentrations at the area perimeter are given in Table 4. The concentration guides (CG)[21] for radionuclides in unrestricted areas are also given in Table 4, and the estimated concentrations at the effective perimeter are compared with those CGs. The estimated concentration of each radionuclide at the effective area perimeter is a small fraction of the respective CG, the largest fraction being 1.4×10^{-6}.

The projected radionuclide concentrations at the effective perimeter due to operation of the proposed HTGR Refabrication Pilot Plant were used to estimate the radiation dose to man at that location. The resulting dose estimates are given in Table 5. Inhalation is the only exposure mode included for internal dose (radioactive material within the body). The intake of radioactivity via terrestrial food chains was estimated to be negligible, being orders of magnitude less than the estimated inhalation intake. Discrimination factors for environmental transfers of the principal radionuclides that will be released to the atmosphere by the proposed pilot plant are on the order of 10^{-3} to 10^{-4}, and furthermore, the uptake fractions for those radionuclides following ingestion by man are of similar magnitudes.

The internal dose estimates are based on the dose model used by the International Commission on Radiological Protection (ICRP) in ICRP Publication 2.[22] The actual internal dose estimates were obtained by using INREM,[23] a computerized version of that dose model. The internal dose estimates are 50-year dose commitments (50-year dose integration period) per year of radionuclide inhalation. The dose commitment for a radionuclide intake is defined as the total dose an individual will accrue in his remaining lifetime as a result of that intake.

Table 4. Atmospheric Releases of Radioactivity to Result From Operation of Proposed HTGR Fuel Refabrication Pilot Plant

Radio-nuclide	Annual Release Rate (μCi/year)	Concentration at Effective Perimeter (μCi/cm³)	CG[a] (μCi/cm³)	Ratio[b] (EPC/CG)
^{232}U	1.7×10^{2}	1.3×10^{-18}	9×10^{-13}	1.4×10^{-6}
^{233}U	2.5×10^{2}	2.0×10^{-18}	4×10^{-12}	5.0×10^{-7}
^{234}U	8.0×10^{1}	6.2×10^{-19}	4×10^{-12}	1.6×10^{-7}
^{235}U	1.5×10^{-2}	1.1×10^{-22}	4×10^{-12}	2.8×10^{-11}
^{236}U	7.3×10^{-1}	5.7×10^{-21}	4×10^{-12}	1.4×10^{-9}
^{238}U	7.3×10^{-4}	5.7×10^{-26}	3×10^{-12}	1.9×10^{-14}
^{212}Bi	4.0×10^{-1}	3.3×10^{-21}	3×10^{-9}	1.1×10^{-12}
^{234}Pa	7.3×10^{-4}	6.2×10^{-24}	c	c
^{212}Pb	4.0×10^{-1}	3.3×10^{-21}	6×10^{-10}	5.5×10^{-12}
^{212}Po	2.6×10^{-1}	2.1×10^{-21}	c	c
^{216}Po	4.0×10^{1}	3.3×10^{-19}	c	c
^{224}Ra	4.0×10^{1}	3.3×10^{-19}	2×10^{-11}	1.6×10^{-8}
^{220}Rn	4.0×10^{1}	3.3×10^{-19}	c	c
^{228}Th	4.0×10^{0}	3.3×10^{-20}	2×10^{-13}	1.6×10^{-7}
^{232}Th	8.0×10^{-2}	6.2×10^{-22}	1×10^{-12}	6.2×10^{-10}
^{208}Tl	1.5×10^{-1}	1.2×10^{-21}	c	c

[a]Concentration Guide (CG) as stipulated in 10 CFR 20, Appendix B, Table II.

[b](Effective Perimeter Concentration)/(CG)

[c]CG values not provided in 10 CFR 20.

The total dose estimated for inhalation is thought to be pessimistic for two reasons: (1) the form (soluble or insoluble) assumed for each radionuclide was the one having the greatest dose potential and (2) the reference organ assumed for each radionuclide was the one receiving the highest dose. Because the inhalation dose estimates given in Table 5 represent a mix of forms and reference organs, it is very improbable that any single tissue in the body would receive a total dose via inhalation equal to the total given in the table for that exposure mode.

Two modes of exposure are included for external (radioactive materials outside of the body) dose. They are (1) immersion in the plume, and (2) exposure to the contaminated land surface. Factors for converting external

Table 5. Estimated Dose to Man at the Effective Perimeter of the Proposed HTGR Fuel Refabrication Pilot Plant Resulting from Atmospheric Release of Radioactivity from the Plant

Radio-nuclide	Dose (mrem per year of exposure)		
	Internal	External	
	Inhalation	Immersion	Land Surface
^{232}U	2.2×10^{-3}	2.1×10^{-11}	1.2×10^{-6}
^{233}U	8.2×10^{-4}	2.9×10^{-11}	1.1×10^{-6}
^{234}U	2.4×10^{-4}	8.4×10^{-12}	5.2×10^{-7}
^{235}U	4.1×10^{-8}	1.5×10^{-13}	1.3×10^{-9}
^{236}U	2.2×10^{-6}	6.7×10^{-14}	4.3×10^{-9}
^{238}U	2.0×10^{-11}	6.0×10^{-17}	3.8×10^{-14}
^{212}Bi	1.6×10^{-9}	3.2×10^{-12}	1.8×10^{-8}
^{234}Pa	a	1.7×10^{-13}	9.1×10^{-10}
^{212}Pb	8.4×10^{-9}	4.3×10^{-12}	2.5×10^{-8}
^{212}Po	a	b	b
^{216}Po	a	b	b
^{224}Ra	2.2×10^{-5}	2.9×10^{-11}	1.6×10^{-7}
^{220}Rn	a	b	b
^{228}Th	3.1×10^{-4}	1.0×10^{-12}	2.8×10^{-8}
^{232}Th	2.6×10^{-5}	6.4×10^{-14}	4.2×10^{-10}
^{208}Tl	a	3.6×10^{-11}	1.7×10^{-7}
Total	3.6×10^{-3}	1.3×10^{-10}	3.2×10^{-6}

[a]Radioactive half-life too short (< 3 minutes) to produce a significant dose if inhaled without parent radionuclide.

[b]Decays by emission of alpha particles and no external dose to man was computed.

radiation exposures to dose were obtained by using the computer program EXREM,[24] which contains models adapted from standard texts.[25-26] The estimates for external exposure are total air dose at the skin surface for all photon emissions. Electron emissions are not included in the dose estimates because of their minor dose contributions to internal body organs. The estimated external dose values given in Table 5 are for one year of pilot plant operation, and they are assumed to be applicable to total body and all internal tissues for purposes of adding dose estimates for the various exposure modes.

The addition of all of the dose estimates given in Table 5 yields a total dose estimate of 3.6×10^{-3} mrem per year of pilot plant operation. This small annual radiation dose is expected to have no significant impact on man. The total dose estimate is equal to a very small fraction (4×10^{-5}) of the annual dose (100 mrem/year) man normally receives from natural background radiation.

(b) Estimated Dose From Long-Lived Radionuclides After Project Decommissioning. Individuals and populations may be exposed to long-lived radionuclides for several years after the proposed pilot plant has been shut down. The long-lived radionuclides expected to result from operation of the proposed HTGR Fuel Refabrication Pilot Plant and the amounts to be deposited during operation of the plant are given in Table 6. The dose commitments per year of exposure to average individuals and the critical organs of individuals are given in Table 7. The population total body dose within 70 miles of the proposed project site (the TURF) is estimated to be 9.0×10^{-4} man-rem of exposure per year. The radionuclide contributing most of the dose to individuals and to the population is uranium-232, which accounts for 97% of the dose to the total body and 68% of the dose to bone and lungs.

(c) Chemical Emissions. The chemicals that will be emitted to the atmosphere as a result of operation of the proposed HTGR Fuel Refabrication Pilot Plant are given in Table A.1 of Appendix A. These chemical emissions are discussed individually in the following paragraphs.

Approximately 1.8 metric tons of carbon monoxide (CO) will be discharged from the pilot plant on an annual basis. The estimated concentration of CO at the site boundary will be less than 1% of the national ambient air quality standard[20] established for this gas.

The oxides of nitrogen emitted from the pilot plant will amount to about 0.124 metric ton per year. These emissions will result in ambient concentrations equivalent to 0.001 microgram per cubic meter at the site boundary.

Carbon dioxide, hydrogen, and various inert gases such as argon and helium are natural constituents of the atmosphere. The annual release of 53 metric tons of carbon dioxide, 1.8 metric tons of hydrogen, and 25 metric tons of inert gases

Table 6. Total Activity of Long-Lived Radionuclides Released During Lifetime of Proposed Project[a]

Nuclide	Radioactive Half-Life (Years)	Curies Released[b]
^{232}U	71.0	3.4×10^{-4}
^{233}U	1.6×10^{5}	5.0×10^{-4}
^{234}U	2.5×10^{5}	1.6×10^{-4}
^{235}U	7.1×10^{8}	3.0×10^{-8}
^{236}U	2.4×10^{7}	1.5×10^{-6}
^{238}U	4.4×10^{9}	1.5×10^{-9}
^{228}Th	1.9	8.0×10^{-6}
^{232}Th	1.4×10^{10}	1.6×10^{-7}

[a]Based on a two-year operating period for the proposed pilot plant.

[b]These releases divided by 3.98×10^{10} give the average concentration (Ci/m^2) within a radius of 70 miles of the TURF at the time of proposed pilot plant shutdown.

will have an insignificant effect on natural atmospheric concentrations.

Approximately 7.3 pounds each of surfactant and 2-ethyl-1-hexanol will be discharged annually. The combined resultant site boundary concentrations of these compounds are estimated at less than 88 millionths of one percent of the national air quality standards for aerosols.

Particulate matter will be removed from all gaseous waste streams through utilization of high efficiency filters with a removal efficiency greater than 99%. Atmospheric discharge of the remaining particulates, estimated to be less than 0.0003 metric ton per year, will yield negligible site boundary concentrations of these materials; 0.000004 microgram/m^3 as compared with the ambient air standard for particulates of 75 micrograms/m^3.

In summary, no significant environmental impacts may be identified with gaseous discharges from the proposed pilot plant.

Table 7. Estimated Doses From Exposure to Long-Lived Radionuclides Deposited in the Environment During the Lifetime of the Facility

Radio-nuclide	Organ Dose (mrem) per Year of Intake or Exposure[a,b]							
	Total Body				Bone		Lung	
	Inhalation	Ingestion	Submersion	Ground	Inhalation	Ingestion	Inhalation	Ingestion
^{232}U	4.5×10^{-10}	1.2×10^{-9}	2.8×10^{-13}	4.2×10^{-6}	6.5×10^{-9}	1.8×10^{-8}	1.4×10^{-8}	1.2×10^{-9}
^{233}U	1.2×10^{-10}	3.4×10^{-10}	1.9×10^{-16}	2.3×10^{-8}	2.1×10^{-9}	5.7×10^{-9}	5.2×10^{-9}	3.4×10^{-10}
^{234}U	3.9×10^{-11}	1.0×10^{-10}	5.4×10^{-17}	1.0×10^{-8}	6.2×10^{-10}	1.7×10^{-9}	1.6×10^{-9}	1.0×10^{-10}
^{235}U	7.2×10^{-15}	1.8×10^{-14}	1.2×10^{-18}	4.7×10^{-11}	1.1×10^{-13}	3.0×10^{-13}	2.8×10^{-13}	1.8×10^{-14}
^{236}U	3.4×10^{-13}	9.5×10^{-13}	4.4×10^{-19}	9.2×10^{-11}	5.6×10^{-12}	1.5×10^{-11}	1.4×10^{-11}	9.5×10^{-13}
^{238}U	3.2×10^{-16}	8.6×10^{-16}	3.0×10^{-21}	1.6×10^{-13}	5.4×10^{-15}	1.4×10^{-14}	1.3×10^{-14}	8.6×10^{-16}
^{228}Th	6.1×10^{-11}	1.3×10^{-12}	6.5×10^{-15}	9.8×10^{-8}	1.8×10^{-9}	3.8×10^{-11}	3.3×10^{-10}	1.3×10^{-12}
^{232}Th	5.4×10^{-12}	1.2×10^{-13}	4.2×10^{-20}	8.8×10^{-12}	1.7×10^{-10}	3.8×10^{-12}	1.5×10^{-12}	1.2×10^{-13}
TOTAL	6.8×10^{-10}	1.6×10^{-9}	2.9×10^{-13}	4.3×10^{-6}	1.1×10^{-8}	2.5×10^{-8}	2.1×10^{-8}	1.6×10^{-9}

[a]Internal doses are integrated from plant shutdown to 100 years later.

[b]A resuspension factor of 10^{-9}/meter was used to estimate the long-term availability of resuspended particulates for exposure via inhalation, ingestion, and submersion, as given in USAEC Report WASH-1535, "Draft Environmental Statement, Liquid Metal Fast Breeder Reactor Program, Vol. II, Environmental Impact of the LMFBR," March 1974.

2. Discharges of Liquids

A variety of systems for the safe handling of liquid wastes are incorporated in the TURF, in which facility the proposed HTGR Fuel Refabrication Pilot Plant will be installed. These include systems for handling storm drainage, sanitary wastes, and both normally nonradioactive and radioactive process wastes.[7] Storm drain and sanitary effluents are treated and discharged to Melton Branch. The sanitary waste treatment plant is of adequate capacity and provides secondary treatment of the sanitary wastes. Consequently, discharges at White Oak Dam are expected to be in compliance with applicable Tennessee water quality standards. Storm drain and non-contaminated process streams will be affected similarly by dilution with the water of White Oak Lake, rendering them in compliance with applicable Tennessee standards at the point of discharge (White Oak Dam) to the Clinch River. Radioactive process wastes are separated from the nonradioactive wastes so that almost all of the radionuclides can be removed by the ORNL radwaste treatment system.

(a) Radioactive Emissions. The radioactive process waste liquids will amount to 322 liters for each day of operation (approximately 83,700 liters per year), and these waste liquids will have the composition and quantities given in Table 8. All known radioactive wastes are pumped directly in a high-integrity stainless steel piping network to the ORNL Intermediate-Level Waste Collection and Treatment System. In this system, the liquids are made basic and piped into a 600-gallon-per-hour waste evaporator. Experience with this evaporator, which has been in operation since 1965, indicates that an average decontamination factor of approximately 10^5 can be attained for the mixture of radionuclides given in Table 8.

Process wastes susceptible to slight radioactive contamination will be monitored continuously for radioactivity. The initial collection will be in a 500,000-gallon settling basin. If it is found that the process wastes contain radioactivity, they will be pumped to the ORNL low-level waste system.

The treated effluents from the low-level system are released to White Oak Creek. The estimated average annual concentration of radionuclides at White Oak Dam that will originate from operation of the proposed pilot plant are given in Table 8. These concentrations were calculated by using the total annual activity of each radionuclide released in the process waste divided by a total decontamination factor of 5×10^5 and the White Oak Creek dilution of 1×10^{13} ml/year. Thus, the estimates in Table 8 are conservative because they ignore radioactivity loss through ion exchange in the settling basin, radioactive decay, and an average dilution of 350 by Clinch River water. When compared with the population CGs for

Table 8. Average Annual Quantities of Radionuclides in Liquids to Originate from Operation of the Proposed HTGR Fuel Refabrication Pilot Plant and Resulting Concentrations at White Oak Dam After Treatment and Dilution

Radio-nuclide	Release to Treatment System[a] (Ci/year)	Concentration at White Oak Dam (μCi/ml)	CG[b] (μCi/ml)	Ratio[c] WOD/CG
^{232}U	8.5×10^{-1}	1.4×10^{-13}	3×10^{-5}	4.6×10^{-9}
^{233}U	1.3	2.2×10^{-13}	3×10^{-5}	7.3×10^{-9}
^{234}U	4.0×10^{-1}	6.6×10^{-14}	3×10^{-5}	2.2×10^{-9}
^{235}U	7.3×10^{-5}	1.2×10^{-17}	3×10^{-5}	3.9×10^{-13}
^{236}U	3.7×10^{-12}	6.0×10^{-25}	3×10^{-5}	2.0×10^{-20}
^{238}U	4.7×10^{-3}	5.6×10^{-16}	4×10^{-5}	1.4×10^{-11}
^{212}Bi	2.0×10^{-2}	3.2×10^{-15}	4×10^{-4}	8.0×10^{-12}
^{212}Pb	2.0×10^{-2}	3.2×10^{-15}	2×10^{-5}	1.6×10^{-10}
^{212}Po	1.3×10^{-2}	2.2×10^{-15}	d	--
^{216}Po	2.0×10^{-2}	3.2×10^{-15}	d	--
^{220}Rn	2.0×10^{-2}	3.2×10^{-15}	d	--
^{224}Ra	2.0×10^{-2}	3.2×10^{-15}	2×10^{-6}	1.2×10^{-9}
^{228}Th	6.3×10^{-3}	1.0×10^{-15}	7×10^{-6}	1.0×10^{-10}
^{232}Th	1.3×10^{-4}	2.2×10^{-17}	2×10^{-6}	1.1×10^{-11}
^{208}Tl	7.3×10^{-2}	1.2×10^{-14}	d	--

[a] This radioactive effluent will also contain traces of Amberlite LA-2, n-paraffin, and 2-ethyl-1-hexanol.

[b] Concentration Guide (CG) for water as stipulated in 10 CFR 20, Appendix B, Table II.

[c] (Concentration at White Oak Dam)/(CG).

[d] No CG listed in 10 CFR 20 for this short-lived radionuclide.

continuous exposure, the estimated water concentrations are at least one hundred million times smaller. No significant environmental effects from this minuscule discharge are anticipated.

(b) Chemical Emissions. Nonradioactive process wastes are piped to retention basins adjacent to the HFIR. These are monitored for possible radioactive contamination and are subsequently discharged to the Melton Branch drainage area (non-contaminated) or to the ORNL Waste Collection and

Treatment System (in the event of accidental radioactive contamination). Routine process wastes will consist of approximately 1 liter per day of 0.88 molar sodium nitrate containing a trace of Amberlite LA-2. Discharge of this amount of waste material is not expected to result in serious detrimental effects on aquatic organisms. There are no existing data which would permit routine evaluation of long-term chronic effects on the organisms inhabiting Melton Branch and subsequent receiving waters. A conservative evaluation of the potential for short-term effects can be approached by assuming a daily discharge of 1 liter per day of nitrate wastes to be diluted by the historical minimum flow in Melton Branch (0.1 cfs).[10] The result would be a steady-state concentration of sodium nitrate in water equivalent to 0.3 mg/liter. This calculated concentration is a factor of 25 lower than concentrations shown to elicit mortality (7.5 mg/liter) in Gambusia affinis affinis (mosquitofish), an organism with particularly low tolerance for sodium nitrate.[27] The considerable latitude determined by using this conservative approach for the short-term effects suggests a very low potential for any chronic long-term detrimental effects.

3. Solid Waste Disposal

All solid chemical wastes resulting from operation of the proposed HTGR Fuel Refabrication Pilot Plant will be contaminated with radioactivity. They will therefore be handled as radioactive wastes. The average annual quantities of radionuclides expected to be present in the solid wastes are given in Table A.3 in Appendix A. These radionuclides will be contaminants on the solid chemical wastes listed in Table A.2 in Appendix A.

The solid waste contaminated with alpha emitters greater than 10 microcuries/kg will be packaged as required for temporary storage or for retention at a national repository. No releases to the environment are expected to result from these methods of solid waste storage.

4. Land Use and Construction Impact

There will be no change in land use from the current situation. The TURF, which occupies approximately 0.5 acre in a complex containing the High Flux Isotope Reactor and the Transuranium Processing Plant, will be internally adapted to accommodate the new facility.

The major construction impacts of land clearing, excavation, spoil removal, and loss of wildlife habitat occurred when the TURF facility was constructed (1965-1968). With the exception of a small cooling tower for process water, no new outdoor construction is planned. This cooling tower will be placed near the TURF on a lawn area near the building. Both dry and wet cooling towers will be evaluated for this use. If a wet cooling tower is used, the blowdown will be subjected to lime-soda treatment to remove phosphates. The chromate will be recycled back to the cooling tower, with no release to the environment.

A small lay-out yard for the materials to be used in adapting the TURF for fuel refabrication will probably be required. Existing lawn or concrete pad areas can be used for the lay-out yard, and upon completion of construction, this area can be restored promptly to its present condition.

5. Transportation

To estimate the impact resulting from the transportation of fuel and refabricated fuel elements to and from the proposed HTGR Fuel Refabrication Pilot Plant, the factors considered were (1) damage to highways and associated structures, (2) increased probability of transportation (non-radiological) accidents, (3) radiation effects on the environment in general, and (4) human radiation injury.

The HTGR Shipping cask weighs about 23 tons. Consequently, the potential damage to a road or bridge resulting from the transport of this cask was considered. Highway weight restrictions limit the routine-shipment gross weight of loaded casks to about 25 tons, although shipments up to 35 tons may be allowed by special permit from the states involved. Each shipment must meet state restrictions for protection of roadbeds and bridges, and no damage to roads or bridges is anticipated.

If the point of delivery is assumed to be Idaho, about 70 round trips will be required to transport the refabricated fuel elements generated during operation of the proposed pilot plant from Oak Ridge to Idaho. Transportation of these elements will have little or no effect on normal traffic flow. The conventional risks of injury or death due to highway accidents were also analyzed. For 70 shipments over a distance of about 4600 round-trip miles each, the accident rate would be about 0.55 accident, based on DOT statistics for an average truck accident rate of about 1.7 per million truck miles for all hazardous material carriers. In 1969, there were about 0.51 injuries and 0.039 deaths per accident. At that rate, the probability of an accident involving an injury is about 0.28 or one chance in about three. The probability of a death is about one-thirteenth that of an injury from any type of highway accident (not necessarily nuclear related).

The details of the shipping cask in which the refabricated fuel elements will be transported and the associated quality assurance program were described in Subsection II.B.6. It is not expected that the shipping cask will permit the release of appreciable quantities of radioactivity to the environment, even under accident conditions. The cask was designed[5] to meet regulations governing containers in which radioactive materials are transported (49 CFR 170-189 and 10 CFR 71), and these regulations cover both normal conditions of transport and hypothetical accident conditions. Among the requirements with which the HTGR shipping cask complies[5] are those which require the cask to be designed and constructed to withstand free falls through a distance of 30 ft onto a flat and essentially unyielding surface and through a distance of 40 in. onto a cylindrical punch without loss of contents, exposure to temperatures of 1475 degrees F for 30 minutes, and immersion in water to a depth of at least 3 ft for 24 hours. No radiation effects to the environment or to personnel are expected to result from the shipment of refabricated fuel elements because the shipping cask in which they will be transported was designed specifically for highly irradiated fuel and the level of radioactivity involved will be low.

The total contained radioactivity within the HTGR shipping cask during any one shipment, based on three fuel elements per shipment, will be about 10 curies. The potential radiation effects on the environment of shipments of reactor fuel have been investigated and reported in USAEC Report WASH-1238.[28] When the methodology described in that report is used, individuals residing within 100 ft of the center line of the truck route would be expected to receive radiation doses of about 6×10^{-4} mrem from each shipment of nuclear fuel, or an annual dose of about 0.02 mrem when 70 shipments over a 2-year period are assumed. The population dose from such traffic was estimated to be about 1.8×10^{-7} man-rem/mi for unirradiated fuel. This corresponds to population doses of less than 0.025 man-rem/year for the proposed shipment of refabricated fuel elements.

During 25 years of radioactive material transfers, there have been no known cases of radiation injury to personnel during transportation of nuclear material. Results of a 1969 survey[6] of radiation exposures during transportation indicate that the annual exposure to drivers and freight handlers who routinely handle shipments of radioactive materials is well below established radiation protection guides.

6. Noise

Noise resulting from operation of the proposed HTGR Fuel Refabrication Pilot Plant should be limited primarily to that resulting from the shipment of refabricated fuel elements. About 70 round trips from Oak Ridge to a point of delivery assumed to be Idaho will be required to transport the refabricated fuel elements generated during operation of the pilot plant. This traffic is estimated to result in infrequent noise of short duration, and although such noise could be objectionable to some persons, it would not represent an appreciable increase in either motor freight traffic or ambient noise levels in the immediate area. While there are no county or state regulations applicable to motor vehicles, workers within the confines of ORNL would be protected by the provisions of the Occupational Safety and Health Act of 1970.

The actual processing operations of the fuel refabrication facility are relatively quiet, with no significant disturbances of either operating personnel or the surrounding area expected. Typical noise levels in the immediate area of the proposed project are estimated to be below 75 decibels, measured over the entire frequency range. Virtually all of the processing will be performed behind the 5.5-ft-thick concrete walls of the TURF cells (subsection II.A.1). These processing noises are not expected to be audible off of the site.

7. Project Decommissioning

The amount of liquid radioactive effluent that will be generated by decommissioning is estimated to be 3000 liters or about 1000 gallons (less than 1 curie per liter, average energy 0.5 MeV). This effluent will be stored in the existing TURF waste tanks for subsequent transfer to the ORNL liquid radioactive waste treatment and storage system.

The volume of solid radioactive waste (shoe covers, rubber gloves, swabs, mops, rags, etc.) that will be generated is estimated to be 14 m^3 or about 500 ft^3, uncompacted. This waste will be packaged for storage and retrieval at the existing ORNL burial ground. Contaminated equipment will be decontaminated and packaged for long-term storage and retrieval at the ORNL burial ground.

Decommissioning of the project will have no adverse effect on the environment, and no increase in the size of the existing waste treatment and storage facilities will be required to handle the products of decommissioning.

B. Accidents

The accidents postulated for the proposed project have a very low proability of occurrence and are therefore separated from any consideration of probable environmental impact. The safety analysis[7] for the TURF was used in assessing the effects of maximum credible accidents, but it should be recognized that that analysis was based on possible accident conditions during fuel reprocessing operations in which large quantities of fission products would be present. Because of the absence of fission products during the fuel refabrication operations described in this report, the estimates of radiation exposure resulting from possible accidents in the proposed pilot plant are far lower than those reported in the TURF safety analysis. The facility, system, and process designs are such that should an accident occur, little or no effect would reach the environment. In the event that external waste handling systems were damaged, the pilot plant would be shut down and isolated from these systems to prevent the uncontrolled release of effluents to the environment. These accidents and their possible environmental effects are discussed in detail in the following subsections.

1. Fire

The probability of a fire in the HTGR Fuel Refabrication Pilot Plant will be low since the quantity of combustible material will be kept to a minimum that is consistent with process and building requirements. However, there is still the possibility of fire in the pilot plant because organic oils and solvents, paper, and combustible gases are used in fuel refabrication. The TURF fire protection systems will provide complete coverage to all parts of the pilot plant. The interior of the cell bank will be protected by a high-pressure, gaseous carbon dioxide system, and regions outside the cells will be protected by a conventional sprinkler system.

In the TURF safety analysis,[7] the maximum credible accident resulting from a fire could release radioactivity to a cell. If such an accident should occur, the maximum personnel dose downwind would be less than 200 mrem to the total body, 3 rem to bone, and 7 rem to the lung. No isolation of land area outside of the controlled access area would be required. The affected area would be less than that of the proposed site. The results of an independent analysis of the potential for radioactivity release following a fire were in general concurrence with the estimates previously made. In all but the most extreme conditions of structure damage and adverse meteorological conditions, personnel doses should be less than 200 mrem.

2. Explosions

The credible types of chemical explosions in the HTGR Fuel Refabrication Pilot Plant would involve limited volumes of mixtures of hydrogen, organic gases or vapors, or pyrophoric dust with air. Explosive mixtures that would comprise a significant fraction of the volume of a processing cell in the pilot plant are not credible because of the favorable balance between the rate of cell exhaust and the rate of formation of explosive material.

The control measures to be used to limit the probability of limited-volume explosions include procedures to minimize the occurrence of explosive mixtures and sources of ignition. Vessels which liberate radiolytic hydrogen and organic vapors will be purged with air to maintain lower-than-explosive concentrations. Fuel refabrication processes that employ hydrogen, combustible gases, and organic vapors will be monitored and whenever practicable, pre-diluted with inert gases to assure nonexplosive concentrations. Special operating procedures will be used to minimize the possibility of accumulation of potentially explosive mixtures of pyrophoric dust.

Process operations will be limited to those which cannot result in credible types of limited-volume explosions that would exceed the design capabilities of the TURF processing cells. The instantaneous gas generation accompanying the maximum credible explosion in TURF could result in an increase of the gas pressure in a processing cell to a maximum of about 4 in. of water (gage).[7] The pressure will return to below atmospheric in less than 1 second. The escape of aerosol through the air intakes will be negligible because of the backflow preventers on the intakes. The intake filters would not be ruptured. The integrity of all components of the containment membrane will be maintained under these accident conditions.

In the TURF safety analysis,[7] the maximum credible accident resulting from a chemical explosion considered was one in which an aerosol of irradiated fuel element dissolver solution was dispersed in the cell air. The outlet filters will withstand any shock wave or overpressure generated by the postulated chemical explosion because they were designed to withstand greater pressure than the intake filters and the full effects of a shock wave cannot reach them. If some factor other than the explosion resulted in filter failure during an explosion, the maximum population dose downwind would be less than 1 mrem.

In the HTGR Fuel Refabrication Pilot Plant, uranium-233 which has been separated from the majority of the fission products will be used. Therefore, the environmental effect of a chemical explosion with the purified uranium-233 should be less than that in the case considered in the TURF safety analysis. Therefore, no adverse environmental effects are expected to result from a chemical explosion in the HTGR Fuel Refabrication Pilot Plant.

3. Criticality

The probability of a criticality accident in the HTGR Fuel Refabrication Pilot Plant will be maintained at a low level by strict administrative control and by other safety measures, such as mass limitation of hazardous material. However, if such an accident should occur, gaseous fission products and an aerosol of nonvolatile fission products could be dispersed within the shielded hot cells, and a small portion of the materials could be released through the filtered ventilation. The high-efficiency particulate air filters are located at a sufficient distance from the processing cells that they would not be affected by a criticality incident.

In order to assess the environmental effects of a criticality accident in the proposed HTGR Fuel Refabrication Pilot Plant, a criticality incident involving 10^{19} fissions was hypothesized. It was assumed that the critical mass occurred in either a solution or in a water moderated bed of microspheres. In either case, it is expected that the heat released would boil the water, the critical mass would be dispersed, and the chain reaction would cease. It was assumed that all noble gases and halogens (or halides) would be discharged from the plant stack 15 minutes after the incident. A decontamination factor of 10^7 was used to determine the fractional release of all other fission products. For these calculations, it was also assumed that the accident occurred during F stability conditions with a wind speed of 4.4 meters/second in the northeast direction.

A person standing at the effective perimeter boundary could receive a prompt neutron plus secondary gamma dose of 0.0036 mrem. Submersion in the radioactive cloud would result in an additional dose from external radiation (0.015 mrem) and an internal dose commitment (dose integration period of 50 years) from inhalation of the radioactive gases and particulates (0.00028 mrem to the whole body, 0.00029 mrem to bone, 0.098 mrem to thyroid, and 0.0022 mrem to lung). If a person remained at the effective perimeter boundary continuously, he could receive 0.011 mrem the first year and proportionately less each following year as the radionuclides decayed and entered the soil profile.

The maximum individual doses for all pathways of exposure except prompt neutrons and secondary gammas would occur 3000 meters from the TURF. The external dose from submersion would be 0.45 mrems. A person residing continuously at this location would receive an external dose of 0.39 mrem from the first year of exposure following the postulated accident and proportionately less each following year as the radionuclides decayed and entered the soil profile. Inhalation would result in the largest dose: 0.0099 mrem to the whole body, 0.011 mrem to bone, 3.2 mrem to thyroid (iodine radionuclides), and 0.082 mrem to the lung.

4. Natural Disturbances

Consideration was given to the release of radioactivity from the proposed HTGR Fuel Refabrication Pilot Plant as a result of possible damage to the TURF from natural disturbances. The disturbances considered included (a) earthquakes, (b) flooding, (c) high winds, and (d) tornados.

(a) Earthquakes. The TURF site is located within a zone of low earthquake activity, as illustrated in Fig. 16 (subsection II.D.4), and the probability for significant earthquake damage to the TURF has been estimated to be low (Appendix B). The epicenters of damaging earthquakes of intensity VII or larger have never been recorded in the area surrounding the TURF site. From the seismic risk map (Fig. 16), which is based on known distributions of damaging earthquakes and corresponding intensities, no shockwaves from distant earthquakes that might reach the TURF site are expected to be of sufficient frequency or amplitude to impart physical damage to the structure.

The site is located in seismic risk zone 2, which has a corresponding potential for a maximum ground acceleration of from 0.03 to 0.09 g. The areas in the TURF that will contain large amounts of special nuclear material will be surrounded by thick concrete walls (subsection II.A.1). In addition, the relatively short operating life of the pilot plant will decrease the probability of damaging earthquake activity in the site area. No structural or equipment damage which would result in appreciable release of radioactive materials as a result of an earthquake is expected.

(b) Flooding. The possibility of extensive flooding of the proposed project site is considered to be extremely remote since the TURF is located on a knoll well above the valley floor and therefore above any possible flood plain. The natural grade of the surrounding area should provide adequate drainage to accomodate any maximum postulated rainfall intensity. Flooding is, therefore, not anticipated to result in damage to the proposed facility that would allow the release of radioactivity to the environment.

(c) High Winds. The specifications to which the TURF was built included the requirement that it withstand wind speeds of at least 90 miles per hour. As the maximum wind speed recorded in the area during the last 20 years was 59 miles per hour, the possibility of high winds having an adverse effect on building integrity is considered to be remote.

(d) Tornados. The project site seems protected by the Appalachian and Cumberland Mountain Ridges. Two small tornados have been identified in the vicinity of Oak Ridge within the past 20 years. The probability of damage to the TURF from tornado activity is therefore considered to be very small. In addition, the areas in the TURF that will contain large amounts of special nuclear material will be surrounded by thick concrete walls (Subsection II.A.1). The cell structures of the TURF were designed to withstand an internal shock wave of 970 psf without failure, and this would make such areas withstand damage from tornado activity.

Cell A, which is a gloved-box maintenance cell, is not designed to withstand a tornado. However, this cell will contain only equipment which has been cleaned previously, and any residual surface contamination is not expected to be released to the environment in the event of a tornado.

5. Handling Accidents

A handling accident could occur during transfer of uranyl nitrate solution from tank storage in Building 3019 to tank storage in the TURF. However, the transfer process described in Subsection II.B.3 is designed to minimize the probability of such an accident. Loading and unloading operations are performed in contained areas, and the operating procedures outlined on detailed checklists are enforced.

An accident involving overturn of the loaded trailer could possibly result in cracks in the solution carrier containment, permitting leakage of the carrier contents. There are on-site administrative controls and monitoring procedures that are intended to permit detection and confinement of any leakage under such conditions. Cleanup and decontamination of the local area would be required under such conditions.

Possible accidents during the transfer of completed fuel elements, described in Subsection II.B.6, consist of the accidental dropping of a fuel element. Depending upon the stage of the process, the consequences of dropping a fuel element could be the possible fracture of an element and the release of radioactivity into the processing cell, into the crane bay area, or into the shipping cask. No radioactivity would be released from the TURF to the atmosphere under these conditions.

The shipping cask in which completed fuel elements will be transported from the pilot plant to a reactor complies with the regulations for normal conditions of transport as well as those governing the hypothetical accident set forth by the USAEC.[5] Therefore, no release of radioactivity is expected as a result of a possible accident during shipment of completed fuel elements from the pilot plant.

A handling accident associated with project decommissioning could consist of the dropping of either a storage can or a transfer cask in the cell area or a truck accident enroute to a solid waste repository 1 to 2 miles away from the TURF. Only the truck accident could result in any release to the environment, but there would be no airborne or transferrable radioactivity because of the decontamination procedures followed prior to loading of the material in the transfer cask.

6. Response to Accidental Release of Radioactivity

The ORNL fire department and emergency squad would respond immediately to any accident at the proposed HTGR Fuel Refabrication Pilot Plant. Accidental release of radioactivity would be detected by the network of alpha, beta-gamma, and neutron detectors in the TURF and on the ORNL site. This system is described in Appendix C.

If a release of radioactivity were large enough to pose the potential for exposure of the public to harmful amounts of radioactivity, state and local authorities would be notified. Contigency plans to provide this response are a part of the operating procedures at ORNL. Areas affected by any such release would be isolated until surveyed by health physics personnel and decontaminated as required.

IV. UNAVOIDABLE ADVERSE ENVIRONMENTAL EFFECTS

Construction and operation of the proposed HTGR Fuel Refabrication Pilot Plant will result in no known significant adverse environmental impacts which cannot be avoided. The unavoidable releases will cause a maximum potential individual exposure of 3.6×10^{-3} mrem per year from gaseous effluents (compared with 100 mrem/year background) and 100 millionths of the concentration guide from liquid effluents. The chemical emissions in the liquid releases will amount to 1/25 of the concentration known to be lethal to sensitive organisms in the affected waters. However, these unavoidable releases are not expected to have any detectable effect on the environment.

V. ALTERNATIVES

Alternatives to the proposed HTGR Fuel Refabrication Pilot Plant fall generally into four categories. They are (1) the alternative of no recycling of HTGR fuel, in which case the pilot plant would not be built at all and spent fuel would be stored indefinitely; (2) an alternate schedule for building the pilot plant, which would certainly mean a delay because advancement of the present schedule is impossible; (3) alternatives to the flow sheet for fuel refabrication to be accomplished in the pilot plant because of changes in the design of recycle fuel or the development of better processes or both; and (4) an alternative location for the proposed pilot plant or for storage of completed fuel elements.

A. No Recycle

The alternative of no recycle of HTGR fuel was discussed briefly in Subsection II.C.3(a) of this statement. In that subsection it was pointed out that failure to utilize bred fuel would increase the undiscounted fuel cycle cost by $3.4 to $19.5 billion, depending on the size of the HTGR economy. This amount is equivalent to an increase in the unit cost of power from HTGRs of about 0.45 mill/kWhr on a levelized basis. According to the data given in Table 2 of Subsection II.C.3(a), this represents a 40 to 47% increase in the fuel cycle cost, again depending on the size of the HTGR economy, and it makes the HTGR less competitive with other sources of electrical power. In addition, the uranium ore and separative work requirements for each HTGR are increased by approximately 54% over those required by optimal recycle timing.

To estimate the overall environmental impact of this alternative, one must perform an extensive analysis, containing numerous simplifying assumptions, of the influence in the marketplace of the higher HTGR fuel cycle costs which result from not recycling bred fuel. It would possibly mean that fewer HTGRs would be built, while more coal-fired generating plants and more light-water-cooled reactor plants would be built.

B. Delay in Recycle

Delaying the recycling of bred fuel would increase fuel cycle costs and would therefore influence the environmental situation in a manner similar to that of no recycle. A study has been recently completed at ORNL to provide an understanding of the economics involved in the timing of the HTGR Fuel Recycle Development Program. A computer program was developed to "construct" a fuel cycle industry required to support a given HTGR economy and then compute the cost of operating this industry on the basis of available estimates of the costs of fuel cycle components. By using this computer program, the influence of constraints, such as the timing of initial commercial recycling of HTGR fuel, can be studied.

For the HTGR construction and operation schedules discussed in subsection II.C.3(a), the lowest fuel cycle costs calculated occur when initial commercial recycling is to be begun in 1984 for the 20- and 41-reactor economies, in 1985 for the 124-reactor economy, and in 1986 for the 85-reactor economy. The penalties calculated for delaying the schedule for recycling spent HTGR fuel are illustrated in Fig. 13 (subsection II.C.2). The calculated dollar values of the penalties have been present worthed to January 1978 by using a 10% discount factor. Undiscounted penalties would, of course, be much higher. The penalties represented both in present-worthed dollars and in percentages of the fuel cycle costs under optimal recycle timing are given in Table 9.

Table 9. Penalties Associated With Delay in Commercial Reprocessing of Spent HTGR Fuel

Commercial Reprocessing Delayed Until	Penalty[a] for HTGR Economy of							
	20 Reactors		41 Reactors		85 Reactors		124 Reactors	
	($\$10^6$)	(%)	($\$10^6$)	(%)	($\$10^6$)	(%)	($\$10^6$)	(%)
1984	0	0	0	0	14.2	0.19	8.0	0.07
1985	25.4	0.92	3.2	0.06	1.1	0.01	0	0
1986	68.3	2.5	66.8	1.4	0	0	47.0	0.4
1988	184.2	6.7	277.0	5.6	93.0	1.25	503.0	3.9
1990	313.0	11.3	519.0	10.5	242.0	3.25	1154.0	8.9

[a]Present worthed to January 1978 by using a 10% discount factor.

It is clear from both Fig. 13 and Table 9 that the penalties for delaying recycle are more severe for greater HTGR market penetration and for a rapid buildup of the number of on-line reactors (for example, compare the 85-reactor economy with the 124-reactor economy). From the percentage penalties given in Table 9, it appears that delays of 1 or 2 years are not significant but delays of 5 years or longer would increase HTGR fuel cycle costs significantly.

C. Flow Sheet Alternatives

The alternatives to the fuel refabrication flow sheet for the proposed pilot plant involve the processes of kernel or microsphere preparation and coating and fuel rod fabrication and carbonization. Although alternate processes for fabricating recycle fuel would have different chemical effluents, these effluents would be handled by the waste handling facilities of the pilot plant in such a manner that the environmental impact would not be significantly different from that for the reference processes.

1. Microsphere Preparation

The reference microsphere preparation process is for the preparation of thorium dioxide-uranium dioxide fissile particles. These microspheres are then coated and blended with thorium dioxide fertile particles which are fed into the refabrication pilot plant from a separate facility. This blended mixture is then formed into fuel rods.

The blending step could be eliminated by increasing the thorium-to-uranium ratio in the microspheres so that the fuel rods from the refabrication pilot plant would contain only one type of particle. This would greatly increase the amount of heavy metal passing through the refabrication pilot plant, and that might be economically undesirable.

Another alternative would be to eliminate all thorium from the fissile particles, thereby minimizing the amount of heavy metal passing through the microsphere preparation and coating steps in the pilot plant. An advanced process, the weak acid resin process, appears to be economically attractive for this purpose, but particles prepared in this manner must be proved acceptable through extended irradiation testing before changes are made in the current reference designs.

2. Microsphere Coating

The reference microsphere coating process in the pilot plant calls for the application of a multi-layer coating consisting of a buffer layer followed by a pyrolytic carbon layer, a silicon carbide layer, and another pyrolytic carbon layer. This is called a TRISO coated particle.

An alternative to the TRISO coating process is the BISO coating process, which includes no silicon carbide layer and only one pyrolytic carbon layer. The BISO coating process is considerably cheaper, but it does not have the added coating strength and resistance to fission product diffusion provided by the silicon carbide layer. Should the reference refabrication flow sheet be changed to reflect the use of a BISO coated recycle particle, silicon carbide and NaCl would both be eliminated from the source term.

3. Fuel Rod Fabrication

The reference fuel rod fabrication process is the slug injection process. Alternative processes are available but the effluents from these processes are identical to those from the reference processes.

4. Fuel Rod Carbonization

The reference fuel rod carbonization process calls for the fuel rods to be heated in the graphite fuel block. The alternative process calls for carbonization out-of-block in packed alumina. This out-of-block procedure produces about 10 cm^3 of alumina per rod carbonized. Since the alumina would be contaminated, it would be added to solid waste storage.

The hydrocarbon production for the reference and alternative processes is about the same.

D. Alternative Locations

The TURF was designed and constructed to provide facilities necessary for the installation and operation of pilot plants such as the one being proposed. There are no other existing facilities available that can provide the need of the proposed pilot plant. To install the proposed HTGR Fuel Refabrication Pilot Plant in another location would necessitate the construction of a new facility or major modifications to an existing facility, either of which would result in increased impact on the environment, extensive delay to the project, and a large capital investment for the facility itself. An alternate location for installation of the pilot plant therefore is not a viable alternative to the proposed project.

The TURF might provide a feasible location for storage of completed fuel elements as an alternative to shipment of these elements to Idaho for storage. However, because these completed fuel elements will be of the Fort St. Vrain design, they must eventually be shipped to that reactor in Colorado or to Idaho for reprocessing. The environmental consequences of these alternatives will not be appreciably different.

VI. RELATIONSHIP BETWEEN SHORT-TERM USE AND LONG-TERM PRODUCTIVITY

The HTGR Fuel Refabrication Pilot Plant will be a short-lived project with an operating duration of 2 to 3 years. Any consumption of natural resources by the proposed project will be minimal because of the small scale of the operation and its short time span.

The proposed pilot plant will be installed in an existing facility (the TURF), and this installation will involve the utilization of less than 1 acre of land exterior to the TURF for a small cooling tower for process water on a lawn area near the building. All of the decommissioning activities will occur within the existing TURF building.

The construction, operation, and decommissioning of the proposed HTGR Fuel Refabrication Pilot Plant will therefore have an insignificant effect on the long-term productivity of the environment.

VII. STATE, LOCAL, OR REGIONAL CONFLICTS

There are no known conflicts with state, local or regional plans or programs. The proposed pilot plant will be installed in an existing facility which is entirely within a security fence on the USAEC Oak Ridge Reservation. The installation will be in accordance with local planning and zoning ordinances. All wastes from the pilot plant will be expelled to existing waste disposal systems, and the incremental amount expelled will be an insignificant addition to the present waste streams. The existing limits on effluents from the waste systems will not be exceeded as a result of the addition of wastes from the pilot plant, and specific approval for waste disposal from the proposed project will not be required.

Transportation of feed material to the proposed pilot plant will occur within the USAEC Reservation boundary (Oak Ridge National Laboratory), and no public transportation or roads will be involved. Transportation of the refabricated fuel elements from the pilot plant will be in accordance with all laws and regulations governing such shipment. The required licenses and certificates for shipment of fuel elements have been obtained.

There are no known archeological sites in the immediate area of the proposed project, and the only historic landmark is the Oak Ridge Graphite Reactor, which is located 2 to 3 miles away from the TURF site. No activity associated with the proposed project will affect the archeology or historic significance of the area.

VIII. IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

Only a small amount of resources is involved in the construction and operation of a pilot plant of the scale proposed for this project. Some expenditure of materials and capital for construction, power for operation, and human skill and labor will occur, but all of this will be minor when compared with the expenditure for existing activities occurring in the area surrounding the proposed project site.

The proposed HTGR Fuel Refabrication Pilot Plant, which will be installed in an existing facility, is a recycle pilot plant whose primary input will be fissionable material that has been produced in and reclaimed from spent fuel which has already been reprocessed. The major resource that will be committed irreversibly and irretrievably is the thorium in the feed material, and some process chemicals will also be committed. The total thorium consumption will be about 4000 kg over the entire life of the project, and about 90% of this will be reclaimable after approximately 15 years. An additional resource to be consumed will be an estimated 70,000 to 100,000 gallons of fuel for truck transportation of the refabricated fuel elements from the pilot plant and about 4.4×10^6 kWhr/year of electrical energy. Other resources will be virtually undisturbed.

Use of the environment through implementation of the proposed project will not represent a significant commitment of resources because of the small scale of the pilot plant, the use of an existing facility, and the minimal release of effluents. In the event of an unanticipated release with the potential for detrimental environmental effects, the existing monitoring programs in the facility and the surrounding area would quickly detect and permit these effects to be remedied.

IX. BENEFIT-COST ANALYSIS

The relationships among the economic, societal, and environmental benefits and costs for the proposed project are such that the potential for large benefits can result with essentially no societal and environmental costs. The benefits to be derived from implementation of the proposed project will occur at two levels: (1) advanced technology for fuel refabrication and (2) the improved fuel cycle economics and resource utilization that will result from this advancement in technology.

A. Summary of Benefits

As discussed in Section II.C, the calculated benefit of recycling HTGR fuel is about 0.45 mill/kWhr with savings depending on the size of the HTGR economy. In addition to decreasing the cost of electric power, recycling of HTGR fuel will save a considerable portion of uranium reserves, thereby benefiting power costs for all reactor designs. Fuel recycling provides the additional benefits realized from not having to build and operate large, expensive facilities for storage of spent fuel.

The construction and operation of the proposed HTGR Fuel Refabrication Pilot Plant will provide essential information needed for the construction and operation of full-scale commercial fuel refabrication plants. Implementation of the proposed project will allow design changes to be made to processes, remote equipment, and handling procedures at a developmental stage when such changes are relatively inexpensive. Operation of the pilot plant will provide the information necessary to confirm the design for processes and equipment, assess equipment reliability and safety standards, and perform economic evaluations for application to full-scale commercial plants. This operation will also provide data which will make possible a better evaluation of the environmental effects of full-scale fuel recycle programs.

An additional benefit of the proposed project will be the production of 150 to 200 refabricated HTGR fuel elements for eventual use in electric power generating stations.

B. Summary of Costs

The preliminary capital cost estimate for construction of this facility was estimated in 1973 to be $10 million and the annual operating cost over the two-year period was projected to be about $4 million. The preliminary nature of the 1973 construction cost estimate was discussed in detail in Section I. Construction activity associated with the existing facility (the TURF) will result in no disruption of the local society or ecology.

The environmental impact that will result from operation of the proposed HTGR Fuel Refabrication Pilot Plant will be the release of a small quantity of effluents. The gaseous release to the atmosphere will be virtually undetectable, ranging from 1% for CO down to less than 1 ten millionth of ambient or allowable concentration for other effluents. The discharges of liquids are more significant, but they result in radioactive releases of only one hundred millionth of the allowable maximum permissible concentrations and chemical effluents of less than 1/25 of the known lethal concentration for sensitive organisms in the waters affected. The disposal of solid wastes resulting from operation of the proposed pilot plant will not result in releases to the environment and will not require expansion of existing solid waste disposal areas.

The sum of the environmental costs is therefore not expected to be significant over the entire life of the proposed project.

C. Benefit-Cost Evaluation of Alternatives

Of the alternatives evaluated, only the alternatives of not recycling HTGR fuel, of delaying recycling, and of alternative locations would result in a significantly different benefit-cost analysis. The no-recycle alternative has effects that would alter the HTGR economy to the extent that the environmental effects of such competing energy sources as fossil-fueled plants and light-water-cooled reactor plants must be considered. This alternative is discussed in detail in Subsection V.A, but it is concluded here that the implementation of this alternative would result in either a greater environmental impact or a substantially higher economic cost to achieve the same level of environmental impact that would be afforded by comparable HTGR plants. The proposed project would be affected by implementation of this alternative because the need for the pilot plant is directly associated with the need for recycling of HTGR fuel. The no-recycle alternative was therefore rejected.

The alternative of delaying the recycle of HTGR fuel affects the economics of HTGR operation but not as severely as the no-recycle alternative. This alternative is discussed in detail in Subsection V.B. The delayed recycle alternative to the proposed project was judged unacceptable because delayed pilot plant operation would result in a substantial decrease in the benefits to commercial refabrication plants from the pilot plant, increased developmental costs incurred by commercial plants and a subsequent delay in their operation pending pilot plant operation, and increased fuel cycle costs during the interim.

Process flow sheet alternatives would result in no significant change in the environmental impact of the pilot plant but might result in slightly increased costs. Developing a new or alternate site would result in increased environmental impact, increased costs, and a delay in pilot plant operation of from 3 to 5 years.

D. Conclusions

In assessing and balancing the anticipated benefits against the environmental and economic costs, and after considering the available alternatives and their environmental effects, it is concluded that the proposed HTGR Fuel Refabrication Pilot Plant project should be implemented.

X. SAFEGUARD CONSIDERATIONS

The HTGR Fuel Refabrication Pilot Plant will be operated within the framework of control procedures for special nuclear materials applicable to all such operations being performed at Oak Ridge National Laboratory. At the present time, the ORNL inventory of special nuclear materials includes about 2000 kg of uranium-233 and 2000 kg of uranium-235. The added inventory and throughput from the conduct of the proposed project will be but a small fraction of the current inventory.

A. Nature and Quantities of Special Nuclear Material

Uranium-233 will be received from the HTGR fuel reprocessing facility in Idaho in the form of uranyl nitrate solution or uranium trioxide powder. It will be stored and purified (to remove the uranium-232 daughter products and associated penetrating gamma radiation) in the National Storage Facility for Uranium-233. After purification, the material will be delivered as uranyl nitrate solution in a 174-liter shielded container to the HTGR Fuel Refabrication Pilot Plant, which is to be installed in the existing Thorium-Uranium Fuel Cycle Development Facility (TURF). The concentration of uranium will be 100 to 200 grams per liter, with less than 1000 ppm of uranium-232.

About 200 kg of uranium-233 will be processed to produce 150 to 200 fuel elements during the two-year operating period (from mid-calendar-year 1978 to mid-calendar-year 1980) of the proposed HTGR Fuel Refabrication Pilot Plant. Because of the biological hazard from the radiation associated with recycle uranium-233, all fabrication operations, including loading of the fuel rods into the hexagonal fuel elements, will be performed in a remotely operated hot-cell facility. The fuel rods are graphite "sticks", 1/2 to 5/8 in. in diameter and 2 to 3 in. long, which contain coated fissile (uranium-233) and fertile (thorium) particles, with about 0.1 to 0.4 gram of uranium-233 per rod. Each loaded fuel element will contain approximately 0.5 kg of uranium-233. The elements will be stored in dry storage racks in the processing cell pending shipment to a reactor or to the HTGR fuel storage facility in Idaho. Scrap from the refabrication operation (reject coated particles and reject fuel rods) that cannot be recycled in the TURF will be returned to Idaho for reprocessing in the HTGR fuel reprocessing facility.

B. Physical Protection

Building 3019 (National Storage Facility for Uranium-233), where the uranium-233 feed material will be stored and purified, is within the perimeter fence surrounding the ORNL site. Entrance to the ORNL site is guarded. Within the building, the material is stored in locked vaults in the shielded hot-cell facilities. Building 7930 (TURF), where fabrication operations will occur, is also within a fenced and guarded area. The shielded carrier used to transfer the material from the Storage Facility to the TURF weighs approximately 8 tons and is loaded and unloaded by a remotely operated pneumatic system with continuous monitoring of flows during transfer operations. As previously indicated, all fabrication operations will be performed remotely in hot cells.

From the standpoint of possible diversion, the most vulnerable point in the refabrication process will occur after the uranyl nitrate feed material has been purified from the uranium-232 daughter products and before its introduction into the remotely operated hot-cell facility in the TURF. At this point, the material could be handled in unshielded facilities. However, the system used to handle the purified material and transfer it to and from the shielded carrier will be shielded and remotely operated. Diversion of any uranium-233 would require extensive surrepitious modification of the system or substitution of a transfer cask with special fittings. To be successful, such surreptitous activities would require an extensive breakdown of the normal security systems and safeguards procedures.

C. Material Control and Accountability

The proposed HTGR Fuel Refabrication Pilot Plant will be operated within the framework of the control procedures for nuclear materials applicable to all operations involving special nuclear material carried out at the Oak Ridge National Laboratory. At the present time, the ORNL inventory includes about 2000 kg of uranium-233 and 2000 kg of uranium-235. The control procedures are based on written requirements and are subject to the approval of the Manager of the AEC Oak Ridge Operations Office.

In addition to the control procedures applicable to all operations involving special nuclear material, specific procedures are being developed for the HTGR fuel refabrication operation. For example, special equipment and procedures are being developed for the assay of uranium-233 thorium-232 fuel. Assay problems peculiar to remote HTGR fuel refabrication that will be investigated in time to meet the pilot plant demonstration program schedule include the development of instruments for remote operation; the adaptation and modification of assay techniques developed for uranium-235 fuels to the uranium-233 thorium-232 system; and the development and implementation of special techniques for that system, including the use of calorimetry for the assay of feed, in-process, and scrap material.

A special development program was initiated in mid-fiscal-year 1974 under the direction of the AEC Division of Nuclear Materials Security (now the Division of Safeguards and Security). The first phase of this program deals with the assay of HTGR fuel containing uranium-235, and it will be completed in the fall of 1975. Where applicable, data from this phase of the program will be used for the recycle uranium-233 fuel fabrication process.

D. Safeguard Provisions for Materials in Transit

The recycle fuel elements will be shipped in a fuel element cask which will weigh from 10 to 23 tons and will hold two or three elements containing a total of about 1.5 kg of uranium-233. Commercial carriers will be used to transport the cask in accordance with AEC transportation safeguards requirements. About 70 round trips from Oak Ridge to the delivery point will be needed to transport the 150 to 200 fuel elements to be produced over the two-year operating period.

E. Conclusions

The added inventory and throughput of special nuclear material at the ORNL site from conduct of the proposed project will be a small fraction of the current inventory at ORNL. The safekeeping of the uranium-233 feed material, fuel fabrication intermediates, and final products will not require major changes in the existing safeguards program at ORNL. The inherent radioactivity of the products requires remote handling procedures which enhance the security of the material by minimizing direct operator contact and deterring potential diverters.

The physical protection system now in existence at ORNL is adequate for the anticipated forms and quantities of HTGR fuel materials. The plans for safeguarding the material during shipment are adequate, and the security of the material in transit is enhanced by the fabricated form in which the uranium-233 is found, the penetrating radiation present in the fuel, and the massive shipping container used.

Research and development on measurement problems associated with HTGR fuel materials are being conducted in a timely fashion so that improved measurement techniques will be available to apply to the pilot plant operation and validate them for later safeguards application at the full-scale commercial recycle fuel fabrication facility.

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APPENDIXES

Appendix A

SOURCE TERMS FOR WASTES TO BE GENERATED BY HTGR FUEL REFABRICATION PILOT PLANT OPERATION

Table A.1. Chemical Effluents From Stack Resulting From HTGR Fuel Refabrication Pilot Plant Operation (Based on 25 Kilograms of Heavy Metal, U + Th, per Day)

Species	Annual Release Rate (tonne/year)	Concentration ($\mu g/m^3$)	
		At Stack Exit[a]	At Site Boundary[b]
H_2	1.8	2.6×10^3	0.015
Inert (Ar,He)	25.0	3.6×10^4	0.20
CO_2	53.0	7.2×10^4	0.40
CO	2.7	3.6×10^3	0.020
NO_x	0.124	174	0.00001
Surfactant	0.0033	4.8	0.000029
2-ethyl-1-hexanol	0.0033	5.2	0.000029

[a]Just prior to leaving top of the stack on the basis of a stack flow rate of 60,000 scfm.

[b]Based on dispersion factor (χ/Q) of 2×10^{-7}.

Table A.2. Solid Chemical Effluents Resulting From HTGR Fuel Refabrication Pilot Plant Operation (Based on 25 Kilograms of Heavy Metal per Day)[a]

Chemical	Annual Release Rate (tonne/year)
Ash[b]	0.0040
NaCl[c]	3.3
SiC[c]	0.21
$NaNO_3$	5.2
$NaHCO_3$	2.6
Volume of alpha-contaminated non-burnable solids (filters, tools, etc.)	3×10^3 ft^3/yr

[a]All of these solid effluents will be contaminated with the radionuclides listed in Table A.3 and will be shipped to a waste management facility.

[b]The ash will result from burning of waste carbon, based on the assumption that the soot and graphite components from the coating furnace will be burned in the HTGR Fuel Refabrication Pilot Plant.

[c]This is based on the assumption that all of the particles coated in the HTGR Fuel Refabrication Pilot Plant will be TRISO. If they are BISO, there will be no NaCl or SiC.

Table A.3. Radionuclides in Solid Effluents Resulting From HTGR Fuel Reprocessing Pilot Plant Operation (Based on 25 Kilograms of Heavy Metal per Day)

Radionuclides	Annual Release Rate (Ci/year)
^{232}U	8.5
^{233}U	13.0
^{234}U	4.0
^{235}U	7.3×10^{-4}
^{236}U	3.7×10^{-2}
^{238}U	3.7×10^{-5}
^{212}Bi	0.20
^{212}Pb	0.20
^{212}Po	0.13
^{216}Po	0.20
^{224}Ra	0.20
^{220}Rn	0.20
^{228}Th	0.20
^{232}Th	4.0×10^{-3}
^{208}Tl	7.3×10^{-2}

Table A.4 Radiological Effluents From Stack Resulting From HTGR Fuel Refabrication Pilot Plant Operation (Based on 25 Kilograms of Heavy Metal per Day)

Radionuclide	Annual Release Rate (Ci/year)	Concentration At Stack Exit[a]	(μCi/ml) At Site Boundary[b]
^{232}U	1.7×10^{-4}	2.3×10^{-13}	1.3×10^{-18}
^{233}U	2.5×10^{-4}	3.6×10^{-13}	2.0×10^{-18}
^{234}U	8.0×10^{-5}	1.1×10^{-13}	6.3×10^{-19}
^{235}U	1.5×10^{-8}	2.0×10^{-17}	1.2×10^{-22}
^{236}U	7.3×10^{-7}	1.0×10^{-15}	5.6×10^{-21}
^{237}Np	2.0×10^{-15}	2.7×10^{-24}	1.6×10^{-29}
^{238}U	7.3×10^{-10}	1.0×10^{-18}	5.6×10^{-24}
^{240}Pu	4.1×10^{-27}	5.5×10^{-36}	3.3×10^{-41}
^{212}Bi	4.0×10^{-7}	5.8×10^{-16}	3.3×10^{-21}
^{234}Pa	7.3×10^{-10}	9.8×10^{-19}	5.6×10^{-24}
^{212}Pb	4.0×10^{-7}	5.8×10^{-16}	3.3×10^{-21}
^{212}Po	2.6×10^{-7}	3.7×10^{-16}	2.1×10^{-21}
^{216}Po	4.0×10^{-5}	5.8×10^{-14}	3.3×10^{-19}
^{228}Ra	5.6×10^{-8}	7.6×10^{-17}	4.3×10^{-22}
^{224}Ra	4.0×10^{-5}	5.8×10^{-14}	3.3×10^{-19}
^{220}Rn	4.0×10^{-5}	5.8×10^{-14}	3.3×10^{-19}
^{228}Th	4.0×10^{-6}	5.8×10^{-15}	3.3×10^{-20}
^{231}Th	1.5×10^{-8}	2.0×10^{-17}	1.2×10^{-22}
^{232}Th	8.0×10^{-8}	1.1×10^{-16}	6.3×10^{-22}
^{234}Th	7.3×10^{-10}	9.8×10^{-19}	5.6×10^{-24}
^{208}Tl	1.5×10^{-7}	2.1×10^{-16}	1.2×10^{-22}

[a] Just prior to leaving top of stack on the basis of a stack flow rate of 60,000 scfm.

[b] Based on a dispersion factor (χ/Q) of 2×10^{-7}.

Appendix B

CHARACTERIZATION OF EXISTING ENVIRONMENT

The United States Atomic Energy Commission's Oak Ridge Reservation presently consists of approximately 37,000 acres of land adjacent to the City of Oak Ridge in Anderson and Roane Counties, Tennessee. The land is part of an original 92-square mile tract purchased in 1942 to serve as an atomic development and production center for the U.S. Army Corps of Engineers Manhattan Project. The Reservation, which may be visualized as an irregular land mass encompassing the USAEC installations illustrated in Fig. 14 (Subsection II.D), is located 15 miles west of Knoxville, Tennessee, the major population center in the area. The Tennessee Valley Authority's Melton Hill and Watts Bar Reservoirs on the Clinch and Tennessee Rivers, respectively, form eastern, southern, and western boundaries of the property and the City of Oak Ridge lies along the northern perimeter.

The Reservation is located in the Ridge and Valley physiographic province, which is characterized by parallel ridges of sandstone, shale, and cherty dolomite separated by valleys of less weather resistant limestone and shale. The ridges are oriented southwest-northeast, and elevations range from 750 to 800 ft at the valley floor to 1000 to 1200 ft at the ridge crests.

The ecological systems of the Reservation are characteristic of those found in the intermountain regions of Appalachia from the Allegheny Mountains in southern Pennsylvania to the southern extension of the Cumberlands in northern Alabama. The area has been under governmental control for the past 30 years and has not been unduly disturbed except for experimental use and regulated forest management.

Climatology

The National Oceanographic and Atmospheric Administration (NOAA) has operated a meteorological observation program at Oak Ridge for over 20 years. In addition to recording day-to-day weather data for the plant sites (X-10, Y-12, and K-25) and Oak Ridge townsite, the NOAA staff has maintained a research and development program to improve the reliability of prediction and measurement of meteorological parameters which influence safe conduct of operations on the Oak Ridge Reservation. A monthly climatic summary for the Oak Ridge area, based on 20 years of records, is given in Table B.1. Seasonal wind speeds and directions in the Oak Ridge area during periods of lapse and inversion conditions are presented in Fig. B.1.

Table B.1. Monthly Climatic Summary for the Oak Ridge Area Based on a 20-Year Record[a]

Month	Temperature (°F) Mean	Temperature (°F) Maximum	Temperature (°F) Minimum	Precipitation (in.) Rain	Precipitation (in.) Snow	Solar Radiation (kcal cm^{-2} $month^{-1}$)
Jan	37.9	47.0	28.8	5.3	3.4	5.6
Feb	40.9	51.2	30.6	5.3	2.6	6.7
March	47.5	58.7	36.3	5.6	1.3	10.1
April	59.0	71.1	46.9	4.4	0.01	12.3
May	66.8	79.1	54.5	3.6	0	15.3
June	74.0	85.2	62.7	4.0	0	15.1
July	76.9	87.3	66.4	5.6	0	13.4
Aug	76.0	86.7	65.2	3.8	0	13.5
Sept	70.1	81.5	58.7	3.3	0	11.3
Oct	59.3	71.3	47.2	2.7	0	9.6
Nov	46.9	57.8	35.9	4.2	0.5	5.8
Dec	39.7	48.8	30.6	5.7	2.5	4.7
Annual	57.9			53.5	10.3	123.4

[a]"Daily, Monthly, and Annual Climatological Data for Oak Ridge, Tennessee, January 1951 through December 1971," Air Resources Atmospheric Turbulence and Diffusion Laboratory, Oak Ridge, Tennessee, July 1972.

During the 20-year period of record (1951-1971), the extremes of daily temperature have varied from a low of -9 degrees F in January to a high of 105 degrees F in July.

The average wind speed in the Oak Ridge area is 4.4 miles per hour (mph). The peak gust of record was 59 mph. Calm conditions prevail 10% of the time. Storm tracks travel northwest to southeast.

The average annual rainfall in the Oak Ridge area is 53.5 in. Annual snowfall averages 10.3 in., and 95% of this precipitation occurs between December and March. The average number of thunderstorms per year is 53, and there are 24 days of heavy fog. Clear conditions prevail 30% of the time; partly cloudy, 25%; and cloudy, 45%.

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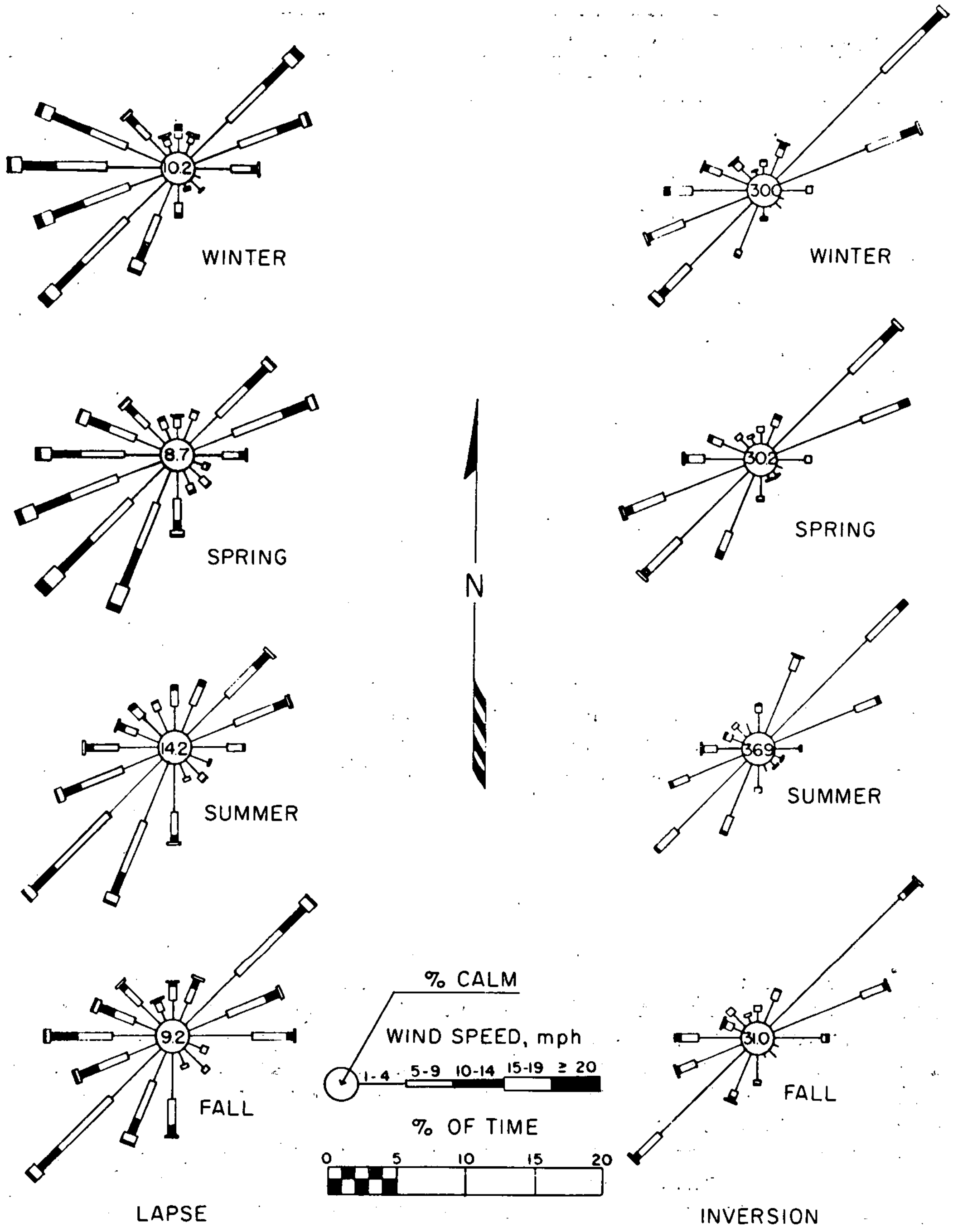

Fig. B.1. Wind Speed and Direction During Lapse and Inversion.

Geology and Soils

The geology and soils of the Oak Ridge area have been reported on by several investigators. A generalized soils map which includes summarizations of mineralogical soil and rock types is given in Ref. B.1. A geologic map of the area is presented in Ref. B.2.

Of particular importance to the present project is a discussion of the geologic features of White Oak Creek Basin, which is located in Roane County, Tennessee, in the southern part of the Oak Ridge Reservation. The Basin has an area of 6.01 square miles, and it drains to the Clinch River by way of White Oak Creek.

Four major rock units or formations occur in the Basin. In descending order of age, these are the Rome formation, underlying Haw Ridge; the Conasauga Group, underlying Chestnut Ridge and Melton Hill; and the Chickamauga Limestone, underlying Bethel Valley. These rocks originated early in the Paleogoic era as masine sediments and became uplifted toward the end of the era. A mantle of residual material is nearly everywhere present, extending to depths of 100 ft in some areas, particularly over the Knox Dolomite.

Soils of the area are described in detail in Ref. B.1. These belong primarily to the broad groups of red-yellow podsolic, reddish brown lateric, and lithosols and are, in general, strongly leached, acidic, low in organic matter, and with exchange capacities of less than 10 milliequivalent per 100 grams of soil. Depths of soil profiles within the basin vary from 6 in. in some of the shale and sandstone areas to more than 15 ft in areas overlying dolomitic limestone and within alluvial deposits along drainageways.

Soils derived from Knox Dolomite contain kaolinite as the principal clay fraction, those from the Conasauga Shale contain illite and vermiculite, and those derived from Chickamauga Limestone contain a mixture of kaolinitic and illitic materials, with some units having significant montmorillonitic contents. The base saturation ranges from 10 to 60% within the various groups. The radionuclide specificity of the respective clay minerals has been determined, particularly with respect to the behavior of radioactive cesium, strontium, and cobalt, in sediments of White Oak Lake and the Clinch River (Ref. B.3).

Hydrology

Drainage of the area is to the Clinch River by way of various small streams. Included among these streams is White Oak Creek, which courses through Oak Ridge Naticnal Laboratory and forms the principal drainage system for the site. The average annual discharge measured at White Oak Dam for the period 1968-1972 is 11 cfs.

Within the area, major aquifers are associated with the Knox Dolomite formation. Water occurs to a lesser extent in small openings along points and bedding planes in the shale and sandstone rocks of Pottsville age and of the Rome Formation. Belts of residual materials overlying bedrock are relatively thin, reducing the volume available for groundwater storage. Consequently, it is estimated that the average well in the Oak Ridge area would yield less than 10 gpm (Ref. B.4).

The Clinch River, including its Melton Hill Lake impoundment, has a drainage area of 4413 square miles, and it is the source of most of the water in the area. Water pumped by the Oak Ridge pumping station is delivered to ORNL, the Y-12 Plant, and to the city of Oak Ridge. Waste water from ORNL is returned to the Clinch River via White Oak Creek, from the Y-12 Plant via East Fork Poplar Creek, and from the city of Oak Ridge via East Fork Poplar Creek and via a tributary at river mile 51.1. The Gaseous Diffusion Plant (K-25) is served by a separate pumping station, with waste water from the plant being returned directly to the river.

Operation of the TVA multipurpose dams for flood control, navigation, and power generation results in regulated flow in the Clinch and Tennessee Rivers. Navigation locks are incorporated in all dams on the Tennessee River and in Melton Hill Dam on the Clinch. During the winter months, following cessation of heavy precipitation and runoff, reservoir levels are raised to provide increased hydroelectric capability. Subsequent power releases cause pulsations in river flows. Within the Clinch River, these discharges may reach 18,000 cfs, and they are not attenuated significantly between Melton Hill Dam and the mouth of White Oak Creek.

These high flow releases cause water levels to rise rapidly, blocking the outflow of water from White Oak Creek for about 6 hours each day. Upon cessation of power generation, the waters of White Oak Creek begin to flow into the main stream and are flushed downstream with the next power release, becoming thoroughly mixed in about 7 miles (Ref. B.4).

Morton (Ref. B.5) observed that the dispersion process due to intermittent releases by Melton Hill Dam was not greatly different than that for steady flow conditions, and that downstream dye concentrations could be predicted on the basis of a uni-dimensional transport equation incorporating eddy diffusion coefficients computed from steady-flow tracer tests.

In general, the waters of small streams in the Oak Ridge area are of the calcium-magnesium-bicarbonate type. Uncontaminated major sources range in hardness from moderate to very hard, with low contents of sodium, potassium, and chloride (Ref. B.4). No significant irrigation usage is apparent.

Seismology

The Oak Ridge Reservation lies in the Southern Appalachian seismotectonic province, which is characterized by a series of northeast to southwest trending folds and thrust faults in Paleozoic rocks. The region has been the source of continuing minor seismic activity. A chronological listing of the complete seismic history of the southeast region (including earthquakes with epicenters outside the region which produced detectable tremors within the specified area) is presented in Ref. B.6.

The epicenters of 270 earthquakes which occurred during the 40-year period, 1930-1969, are plotted in Fig. B.2 according to their equivalent Richter magnitude. An approximate relationship is given by $R = (2/3)M + 1$, where R = Richter magnitude and M = intensity. This plot does not include the two largest seismic events in the history of the southeast. These were the 1811-1812 shocks at New Madrid, Missouri, Intensity XII, and the 1886 shock of Charleston, South Carolina, Intensity X. The intensity at the project site from these shocks was probably about VI or less. Two major centers of seismic activity are apparent from Fig. B.2. These centers are within the Mississippi Valley area and on the coast of South Carolina in the Charleston area. A third zone of relatively high seismicity coincides with the southern portion of the Appalachian Mountain geologic province.

A more detailed analysis of the seismicity of the southeastern United States can be obtained from an analysis of recurrence curves of the type shown in Fig. B.3. While the "fit" of the data are not good, extrapolation of the curve for the Southern Appalachian Region suggests a once-per-40-year quake of intensity VIII (modified Mercalli), a once-per-100-year shock of intensity IX, and a recurrence interval between destructive shocks of 106 years, as determined from statistical treatment of past records (Ref. B.6). Seismic evaluations of the Oak Ridge area suggest that within a 100-year period there exists a 50% probability for ground motion acceleration to exceed 0.03 to 0.09g.

Area Access

Access for other than employees to the USAEC Oak Ridge Reservation is limited to public roads. However, the public road network within the area is well developed. State highway 62 bisects the Reservation east and west, providing a direct route to Knoxville. State highways 95 and 61 run north and south through Oak Ridge, while U. S. Highway 25W, which connects Knoxville, Tennessee, and Lexington, Kentucky, passes 4 miles northeast of the eastern boundary of the Reservation. Interstate Highway 40 connecting Knoxville and Nashville,

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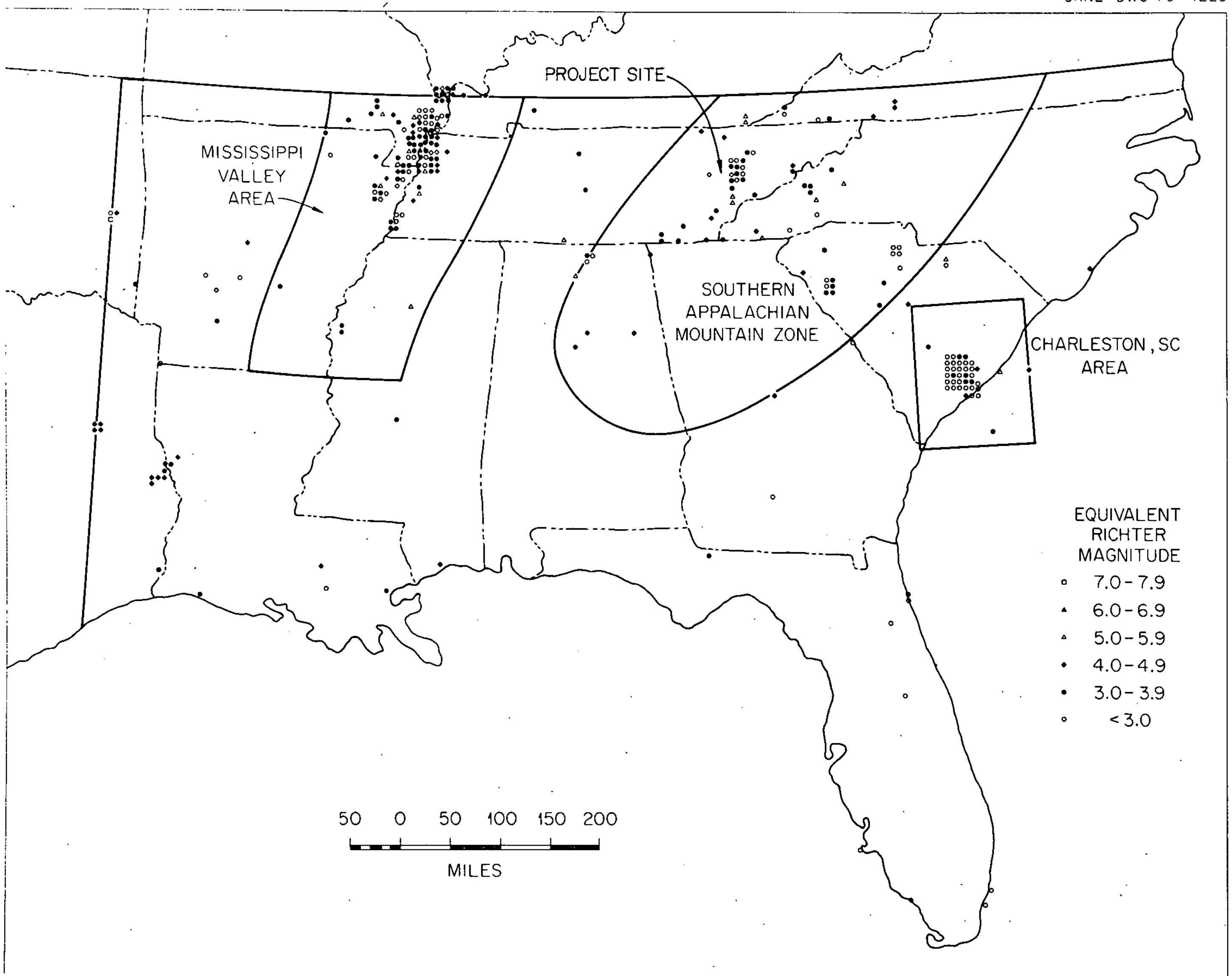


Fig. B.2. Epicenter Locations for Southeast Region Earthquakes in the Period 1930 Through 1969.

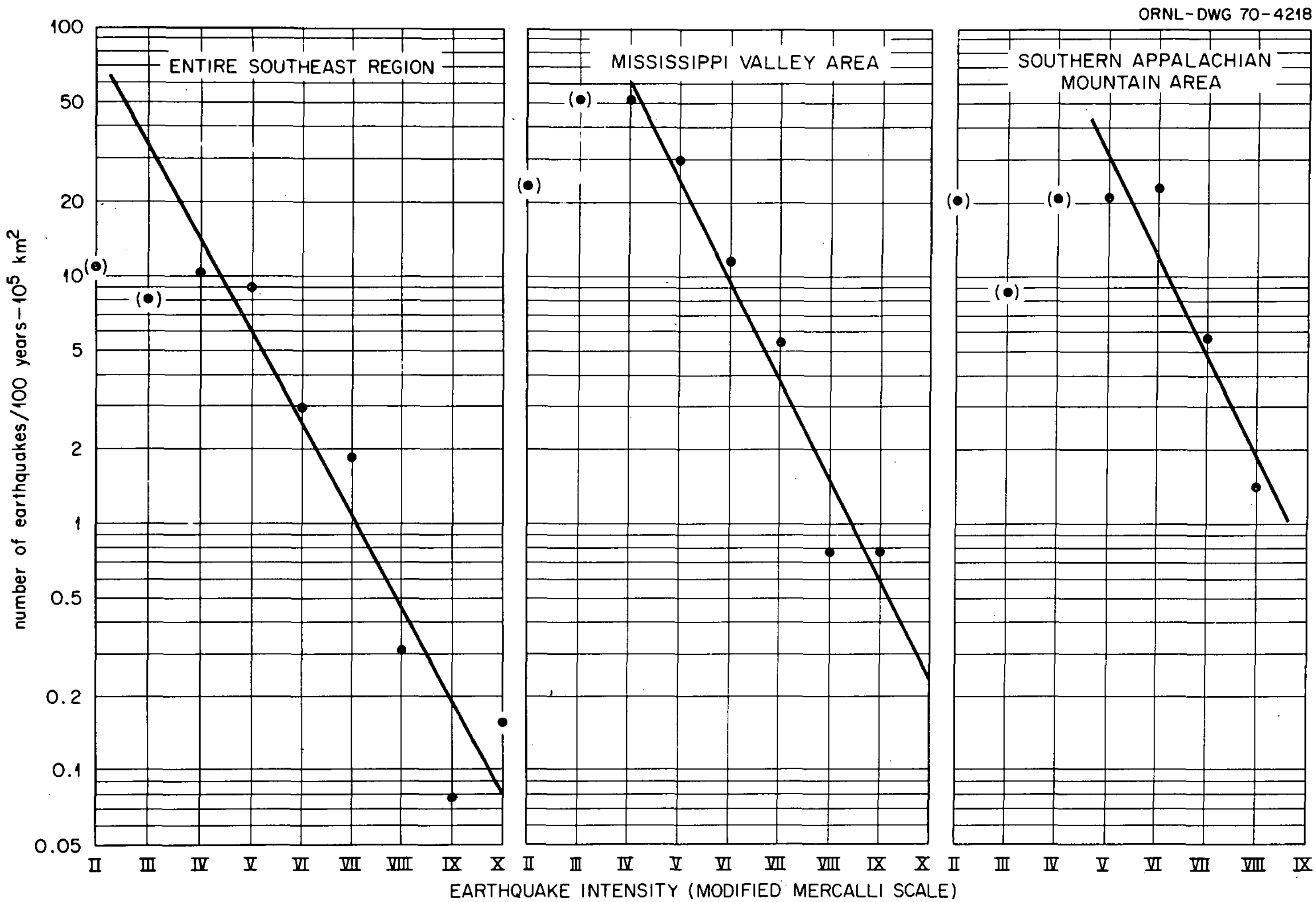


Fig. B.3. Recurrence Curves for (a) Total Southeast Region, (b) Mississippi Valley Area, and (c) Southern Appalachian Mountain Zone. (Curves represent least-squares fits of the relationship log N = a + bI, where N is the number of earthquakes per 100 years and per 100,000 km^2 of intensity, I.)

Tennessee, is 2 miles southeast of the western boundary of the Reservation. The primary and secondary road system of the Reservation is excellent.

The area is adequately served by rail transportation, with connecting points located at Harriman, Tennessee. The Clinch River waterway forms the southern boundary of the Reservation and joins the Tennessee River system 10 miles downstream. A 9-ft navigation channel extends above Clinton, Tennessee, to Clinch River Mile 61.

Ecology of Site and Environs

The Oak Ridge Reservation is typical of the landscape and ecological systems which occur in the Appalachian Region of the eastern United States. As such, the area is comprised of a number of representative terrestrial and aquatic ecosystems that range from smaller, established southern coniferous forests to northern hardwood types and from small stream tributaries to man-made reservoir systems.

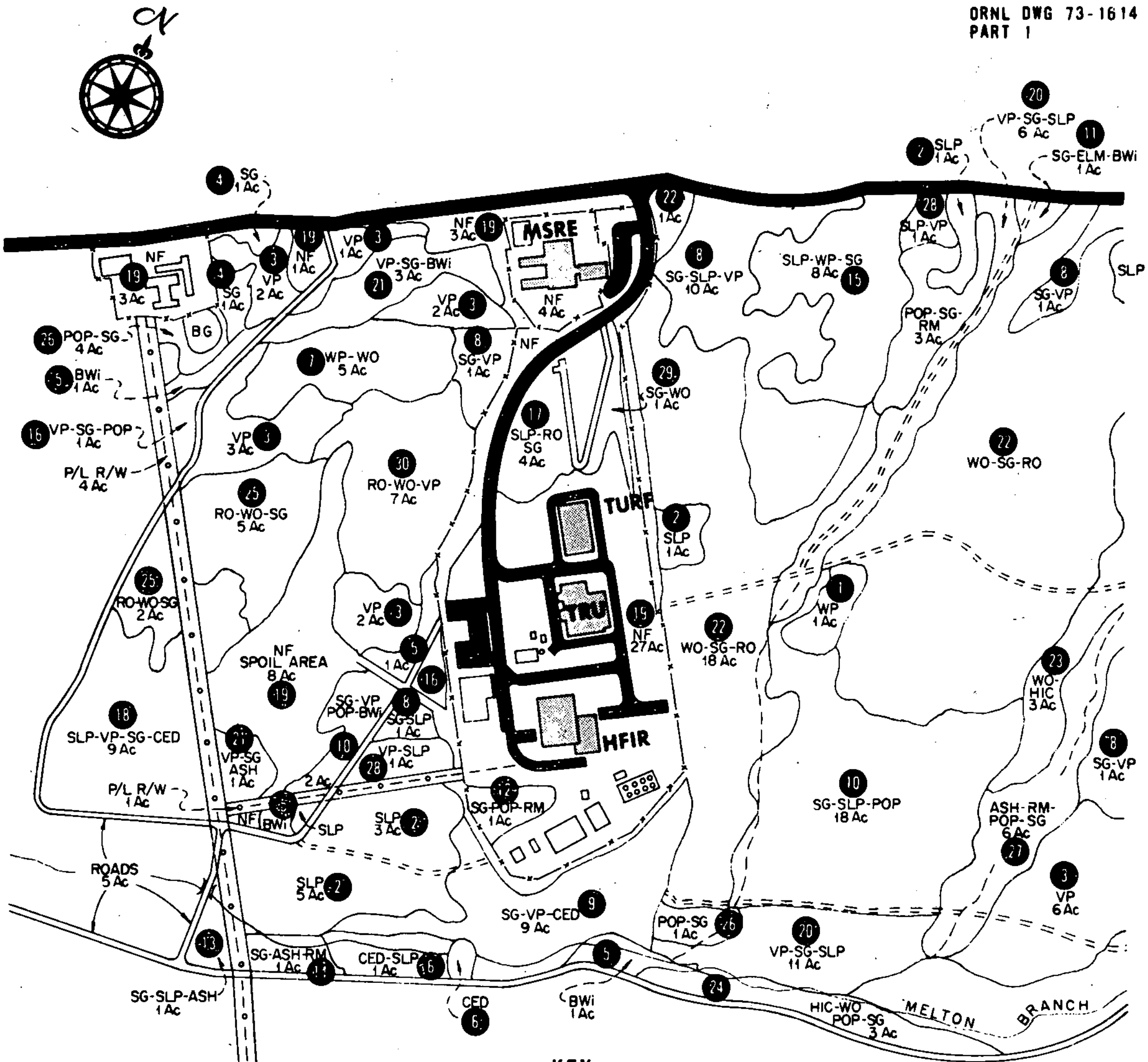
A preliminary inventory of the flora of the general Oak Ridge area was completed in 1966 (Ref. B.7). This inventory has since been supplemented with observations of spring flowering for 171 species of herbaceous and woody plants representing 55 plant families (Ref. B.8).

Five Appalachian forest types occur naturally on the Reservation (Ref. B.9). The oak-hickory type shares equal prominence with the yellow pine-hardwood type. Cove hardwoods are found interspersed between dissected ridge systems, and northern hardwoods occurr in sheltered areas with northern exposures. A minor type, white pine-hardwood, is found along the northern boundaries of the property. Between 1947 and 1950, large areas of open land were planted to loblolly pine, creating a sixth forest type.

A detailed map of the dominant vegetation within the immediate area of the proposed facility is illustrated in Fig. B.4. The area is relatively heavily wooded with a large proportion of the total cover being comprised of sweet gum and white and red oaks. Yellow poplar, ash, and red maple are present on more mesic sites, and short-leaf and virginia pine are scattered along roads and in open areas generally as a result of managed plantings.

There are several available studies describing the fauna of the area, with special reference to Melton Valley wherein lies the site of the proposed fuel refabrication pilot plant. A 1958 survey of summer bird populations at 157 stations resulted in the recording of 1870 individuals representing 65 separate species (Ref. B.10). Density of individuals was highly correlated with vegetation cover, with the greater number of birds being observe in habitats characterized by low growing herbaceous material interspersed with younger trees. A greater diversity of species, with lesser numbers of individuals was found to be typical for forested habitats.

ORNL DWG 73-1614
PART 1



KEY

STRA #	VEGETATION TYPE	ACRES
1	WP	1
2	SLP	10
3	VP	19
4	SG	2
5	BWi	3
6	CED, CED-SLP	1
7	WP-WO	5
8	SG-VP, SG-SLP, SG-SLP-VP	15
9	SG-VP-CED	9
10	SG-SLP-POP, SG-VP-POP-BWi	20
11	SG-ELM-BWi	1
12	SG-POP-RM	1
13	SG-SLP-ASH	1
14	SG-ASH-RM	1
15	SLP-WP-SG	8
16	VP-SG-POP	1
17	SLP-RO-SG	4
18	SLP-VP-SG-CED	9
19	NF BUILDING SITES	46
20	VP-SG-SLP	18
21	VP-SG-ASH, VP-SG-BWi-VP-SG-POP	5
22	WO-SG-RO	52
23	WO-HIC	3
24	HIC-WO-POP-SG	3
25	RO-WO-SG	7
26	POP-SG, POP-SG-RM	4
27	ASH-RM-POP-SG	6
28	SLP-VP, VP-SLP	2
29	SG-WO	1
30	RO-WO-VP	7
31	POWER LINE R/W	5
32	ROADS	5
	TOTAL ACREAGE	275

Fig. B.4. Vegetation Type Map for the Area Surrounding the TURF.

ORNL DWG 73-1614
PART 2

COMMON NAME	CODE	SCIENTIFIC NAME
ASH	ASH	FRAXINUS SP.
BLACK GUM	BG	NYSSA SYLVATICA
CEDAR	CED	JUNIPERUS VIRGINIANA
ELM	ELM	ULMUS AMERICANA
HICKORY	HIC	CARYA SP.
RED MAPLE	RM	ACER RUBRUM
YELLOW POPLAR	POP	LIRIODENDRON TULIPIFERA
NORTHERN RED OAK	RO	QUERCUS RUBRA
SWEETGUM	SG	LIQUIDAMBAR STYRACIFLUA
SHORTLEAF PINE	SLP	PINUS STROBUS
BLACK WALNUT	BWi	JUGLANS NIGRA
WHITE OAK	WO	QUERCUS ALBA
WHITE PINE	WP	PINUS MONTICOLA
VIRGINIA PINE	VP	PINUS VIRGINIANA

Legend for Fig. B.4.

Summer birds typical of habitats represented in Fig. B.4 include the red-eyed vireo, Carolina wren, tufted titmouse, Carolina chickadee, and numerous other pure forest as well as edge species.

In contrast to area bird populations, which were shown to be dependent upon vegetation cover, mammalian faunal makeup is more directly linked with soil fertility and depth of humus and litter layers (Ref. B.11). Typical species include mice, shrews, opossums, racoons, woodchucks, cottontail rabbits, and the gray fox. White-tail deer have been observed in the area, and appear to be increasing in numbers, as evidenced by an increasing frequency of road kills on the Reservation.

The herpetofauna of the area have been described, including a categorization of habitat types (Ref. B.12). Various species of salamanders, turtles, frogs and toads, lizards, and snakes, including the northern copperhead, make up this particular component of the area's biota. Various facets of the aquatic system, represented by the White Oak Creek-White Oak Lake-Clinch River-Tennessee River continuum, have been studied over the past several decades, particularly with regard to the behavior and transport of radioactive materials in the aquatic environment (Ref. B.13). For the most part these investigations were conducted prior to the establishment of Melton Hill Reservoir, and they were primarily concerned with selected organisms (e.g., tubificid worms, crayfish, Chironomid larvae, clams, and several species of fish, including white crappies, carp, and smallmouth buffalo) as they related to the transport of radioactive materials.

A characterization of fishes common to the Clinch River system prior to the establishment of Melton Hill Reservoir

(Ref. B.13) showed major groups to include the Centrarchidai (sunfishes, basses and crappies), Catostomidae (suckers), and Ictaluridae (catfishes). Except for carp, the Cyprinidae (minnows) were poorly represented, primarily due to a lack of suitable habitat. Forage for piscivorous fish is provided by large populations of Clupeidae (threadfin shad, gizzard shad). In addition to the above groups, sauger and white bass, both carnivorous species, are regularly caught.

The fisheries resources of the Tennessee River system are exploited by both commercial and sports fishermen. Some commercially harvested nongame species (e.g., carp, buffalo) are marketed for human consumption. Records of commercial takes from the Tennessee River, 1946-1963, show harvests ranging from a low of 1,073,000 lb in 1947 to 8,532,000 lb in 1963, comprised mainly of catfish and buffalo (Ref. B.13).

Typical of the present aquatic system downstream from Melton Hill Reservoir and immediately adjacent to the proposed facility is the biotic composition of White Oak Lake at ORNL. The lake has been characterized as having high phytoplankton productivity and a well-developed benthic fauna, with the most common forms being comprised of various insect larvae (Ref. B.14). Fishes present in the shallow embayment (maximum depth 7.3 ft) include bluegill and redear sunfish, largemouth bass, warmouth, gizzard shad, golden shiners, goldfish, and the mosquitofish, _Gambusia affinis affinis_.

Land Use

The 92-square-mile Oak Ridge Reservation was originally acquired as a site for production facilities and nuclear research, and a security buffer and safety zone were established around each AEC plant. The original 59,000 acres acquired in 1942 have since been reduced to approximately 37,000 acres through land transfers to the municipal government and to state and federal agencies (Ref. B.9). A study of aerial photographs made in 1942 indicates that about 43% of the area was at that time comprised of pastures and fields. The remaining areas were forested.

The amount of timber harvested for construction of the Oak Ridge facilities is unknown. In 1947, Management Services Incorporated, an AEC contractor, began a reforestation program which ended in 1960. During that period, approximately 9 million pine seedlings were planted in old field and open areas to the extent that as of 1965, approximately 4300 acres of shortleaf, loblolly, and eastern white pine plantations existed in the Reservation (Ref. B.9).

A 1961 survey of forest lands by the TVA summarized then extant timber resources of the Reservation, leading to the establishment of a forest management program at ORNL in 1964.

The present allocation of land use among plant installations is given in Table 3 (subsection II.D.6). Buffer areas around each of the facilities provide increased security and protection against accidental release of chemical or radioactive materials and also provide room for future expansion. Little forested acreage is included in the buffer areas around the Y-12 and K-25 Plants, but extensive forested areas lie within the ORNL and UT-AEC sections. Excluding buffer areas around USAEC facilities, the remainder of the Reservation is subdivided into 24 management compartments that range in size from 400 to 1200 net manageable acres (Ref. B.9). Approximately 93% of the total manageable land (15,000 acres) is forested in pine (36%), upland hardwoods (32%), mixed pine-hardwoods (21%), and cedar and miscellaneous species (11%).

Objectives of the present forest management plan are a maximization of yield and quality of timber resources to assure a substantial yield of high-quality stumpage within the constraints of primary research and production objectives of the AEC facilities. Twenty-five research areas, totalling 2300 acres, are reserved for ecological studies. These areas provide a variety of landscape units for research and permit the use of a holistic approach to ecosystem analysis. It was recently proposed that the Oak Ridge Reservation be designated an Environmental Study Park (Ref. B.15). Within this context, a total of 41 study areas were delineated as being unique and important in terms of present-day environmental problems. The location of the existing TURF and its conversion as proposed herein will not jeopardize or exert any measurable influence on any of the designated study areas.

One historic landmark, the Oak Ridge Graphite Reactor, is located on the USAEC Oak Ridge Reservation at Oak Ridge National Laboratory.

Regional Demography

As previously discussed, the proposed HTGR Fuel Refabrication Pilct Plant is to be installed in the existing TURF, which is located in the Melton Valley area of Oak Ridge National Laboratory. Incremental population data, based on the 1970 United States Census, out to a distance of 70 miles in all directions from the TURF site are given in Table B.2. The total population in this area is 1,025,864. The two largest cities near the plant site are Knoxville, Tennessee, and Oak Ridge, Tennessee. The city limit of Knoxville, which has a population of 175,000, is approximately 13 miles toward the east of the plant site. The populated area of Oak Ridge (population, 28,000) begins at approximately 5 miles north of the plant site.

Table B.2. Incremental Population Data for TURF Site

Direction	Distance (miles)											
	0-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50	50-60	60-70
N	0	0	0	0	1,490	5,578	2,177	1,441	2,223	4,509	13,686	7,314
NNE	0	0	0	0	1,461	13,783	4,362	11,189	12,674	6,119	7,978	17,980
NE	0	0	0	0	0	9,713	12,479	7,167	4,392	7,476	21,097	8,781
ENE	0	0	0	0	0	0	27,462	74,686	18,723	13,872	23,240	31,800
E	0	0	0	0	0	3,059	44,883	100,488	11,793	12,900	8,965	21,468
ESE	0	0	0	0	0	6,096	5,363	36,015	4,132	6,840	346	0
SE	0	0	0	0	0	1,167	4,304	15,010	46	0	0	0
SSE	0	0	0	0	1,374	7,277	1,200	4,091	469	0	0	0
S	0	0	0	0	0	943	8,742	7,309	6,560	1,222	4,101	2,055
SSW	0	0	0	0	0	721	2,055	7,897	21,582	10,527	17,018	34,253
SW	0	0	0	0	0	733	1,840	1,909	3,962	8,578	10,312	21,909
WSW	0	0	0	0	0	622	9,862	3,495	4,562	4,204	5,894	2,799
W	0	0	0	0	0	666	13,099	4,595	9,038	7,318	4,129	14,856
WNW	0	0	0	0	0	587	2,971	1,543	0	4,151	5,055	29,862
NW	0	0	0	0	0	1,073	4,804	1,538	1,896	7,552	2,396	9,358
NNW	0	0	0	0	0	1,495	0	1,152	4,559	4,676	2,097	8,030
Total	0	0	0	0	4,325	53,518	145,673	279,525	106,611	99,433	126,314	210,465

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Appendix C

ENVIRONMENTAL MONITORING OF EXISTING ENVIRONMENT

The Oak Ridge National Laboratory conducts a continuous program of surveillance over the Oak Ridge reservation and its surrounding environs to monitor all types of environmental pollution. This program has been in effect for approximately 30 years to assure the continuing safety and protection of installation personnel and the general public. Similar programs of surveillance are conducted at the Oak Ridge Y-12 Plant and the Oak Ridge Gaseous Diffusion Plant (K-25) which are close by and share the same environment. All programs are coordinated by the inter-plant office of Safety and Environmental Protection.

Radioactive Effluents

Information derived from the ORNL radioactivity monitoring program is contained in the "Annual Environmental Monitoring Report, USAEC Oak Ridge Facilities" issued by the Union Carbide Office of Safety and Environmental Protection. In addition, the ORNL Inspection Engineering Department issues reports on testing of pollution control devices, chiefly filters.

Atmospheric Releases

Atmospheric releases are monitored with in-plant and in-stack monitors, a local air monitoring network, perimeter air monitoring network, and remote air monitoring network, and a milk sampling network.

(a) In-Plant and In-Stack Monitors. It has been a long-standing policy to monitor all effluents at the points of release to the environment to obtain accurate estimates of total releases. Monitoring data indicate that yearly releases have decreased steadily although operations involving radioactivity are still widespread and the sensitivity and accuracy of monitoring equipment have improved.

(b) Local Air Monitoring (LAM) Network. Atmospheric contamination and fallout on the ORNL site are monitored with continuous airflow filters, fallout trays, and rain collectors. There are 22 monitoring stations which comprise the LAM network at ORNL. Three of these stations are located in the Melton Valley area, and one of these (station 20) is adjacent to the TURF. The real-time readings for instruments at all LAM sites are telemetered to a central readout panel.

(c) Perimeter Air Monitoring (PAM) Network. The PAM network consists of nine stations located on the perimeter of the AEC-controlled area, as illustrated in Fig. C.1, and it provides data for evaluation of the impact of all Oak Ridge operations on the immediate environment. These stations are similar to the ones in the LAM network, and the readings are also continuously telemetered to a central readout panel.

(d) Remote Air Monitoring (RAM) Network. The Ram network consists of eight stations located outside the AEC-controlled area at distances of from 12 to 75 miles from ORNL, as is shown in Fig. C.2. This system provides data to aid in the evaluation of local conditions and to assist in determining the spread or dispersal of contamination if a major incident should occur.

(e) Milk Sampling Network. Samples of raw milk are collected at 12 sampling stations located within a radius of 50 miles of ORNL. Samples are taken on a weekly basis from the eight stations shown in Fig. C.3. These stations are located outside the AEC-controlled area within a 12-mile radius of ORNL. Samples are collected every 5 weeks from the four remaining stations, all of which are located outside the 12-mile radius up to distances of about 50 miles. The samples are prepared in a radioanalytical laboratory for counting iodine-131 and strontium-90.

Liquid Releases

Low-level radioactive liquid wastes originating from ORNL operations are discharged, after preliminary treatment, to White Oak Creek, which is a small tributary of the Clinch River. The radioactive content of the White Oak Creek discharge is determined at White Oak Dam, which is the last control point along the stream prior to the entry of White Oak Creek into the Clinch River.

(a) In-Plant Monitors. All facilities at ORNL are equipped with continuously operating radiation monitors. Radiation and contamination detection and alarm systems are installed in the TURF to continuously and automatically monitor the air contamination level and gamma and neutron radiation levels.

(b) White Oak Dam Monitoring Station. Samples of White Oak Creek effluent are collected at White Oak Dam by a continuous stream flow proportional sampler. The samples are analyzed weekly for transuranic alpha emitters, total strontium, and iodine-131. Composite samples are analyzed for all individual radionuclides present in detectable quantities. The monitoring station at White Oak Dam provides information to determine the percentage distribution and concentrations of

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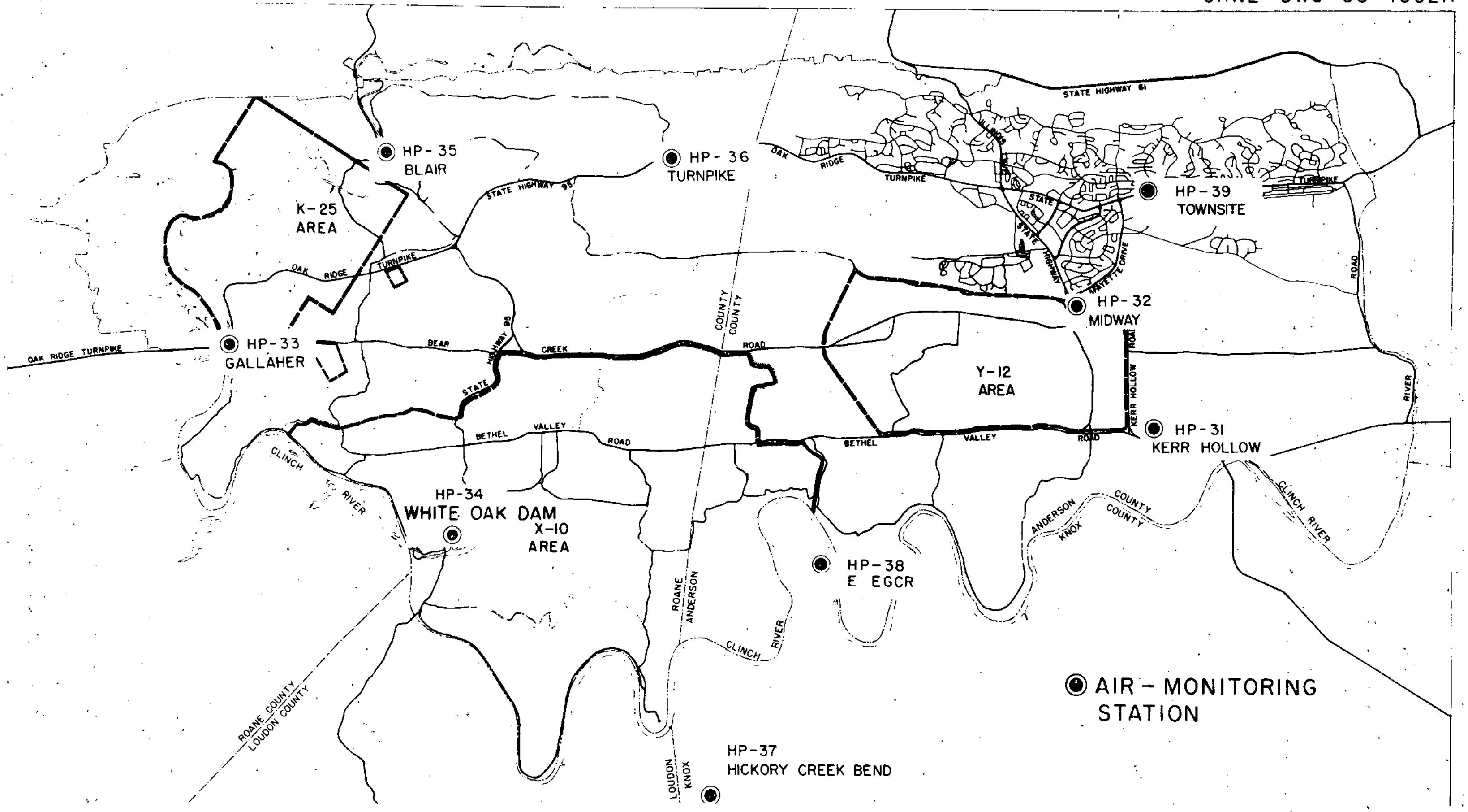

Fig. C.1. Perimeter Air Monitoring (PAM) Network.

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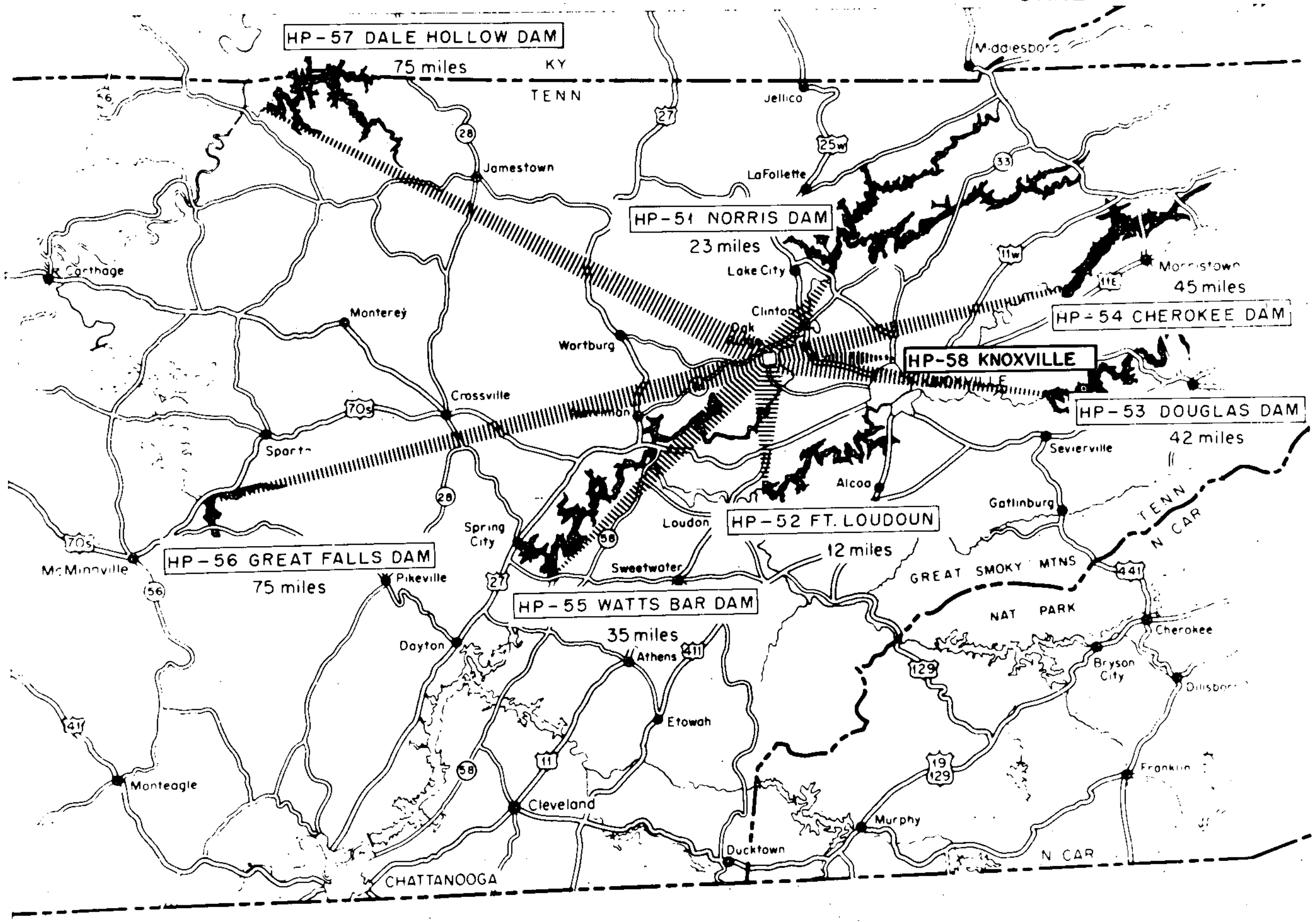


Fig. C.2. Remote Air Monitoring (RAM) Network.

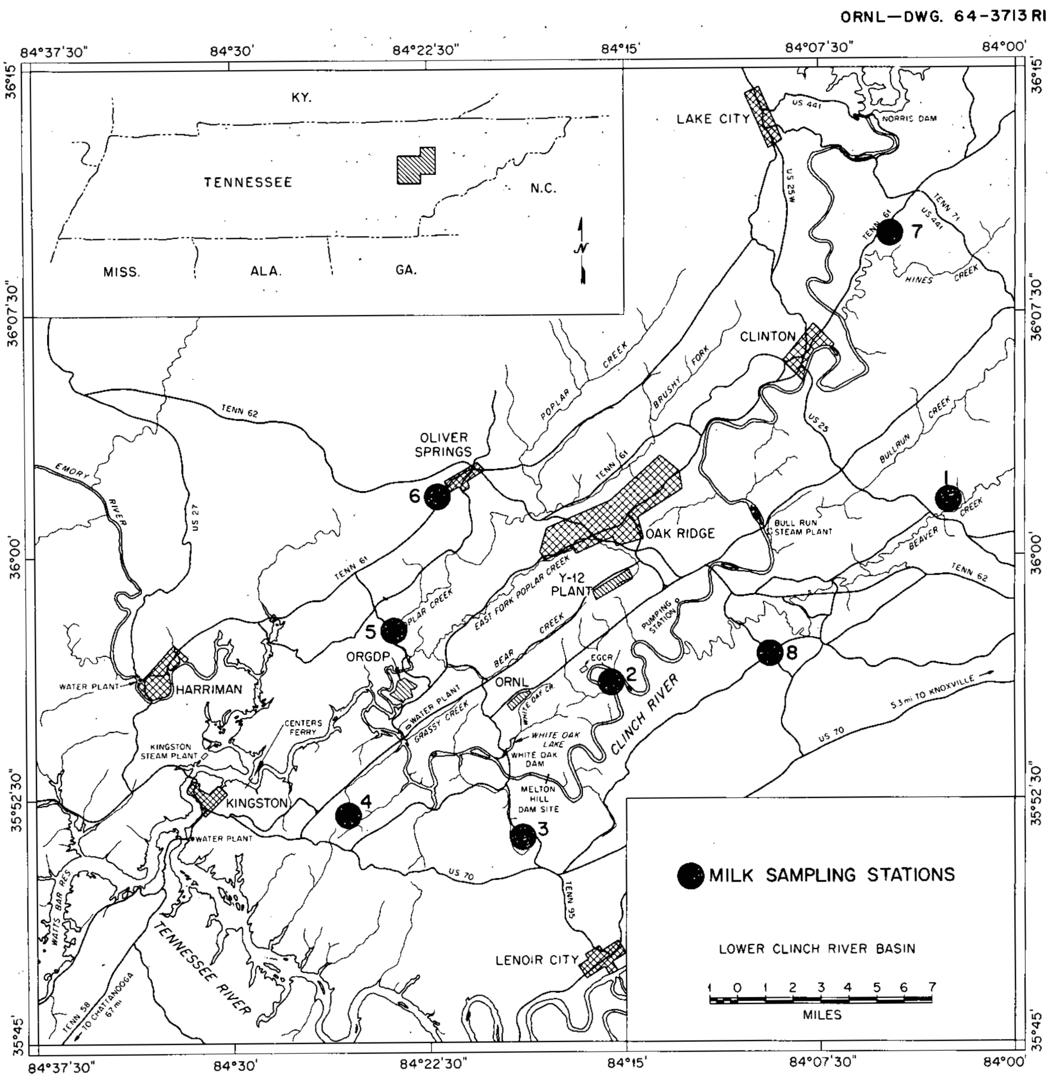


Fig. C.3. Location of Milk Sampling Stations.

the various radionuclides in the effluent stream and to calculate the quantity of each radionuclide released to the Clinch River.

<u>(c) Clinch River Monitoring Stations.</u> As a follow-up to monitoring at White Oak Dam, two sampling stations are maintained in the Clinch River below the point cf entry of the wastes. One is located at the water intake to the Oak Ridge Gaseous Diffusion Plant, and the other is located at Centers Ferry, near Kingston, Tennessee. Background or comparison data are provided by a sampling station at Melton Hill Dam, located upstream from the confluence of White Oak Creek and the Clinch River.

Nonradioactive Effluents

A surveillance program for assessing effluent waste waters from ORNL and the subsequent levels of chemical pollutants in the Clinch River has been in operation since 1962. The locations of six sampling points are shown on Fig. C.4.

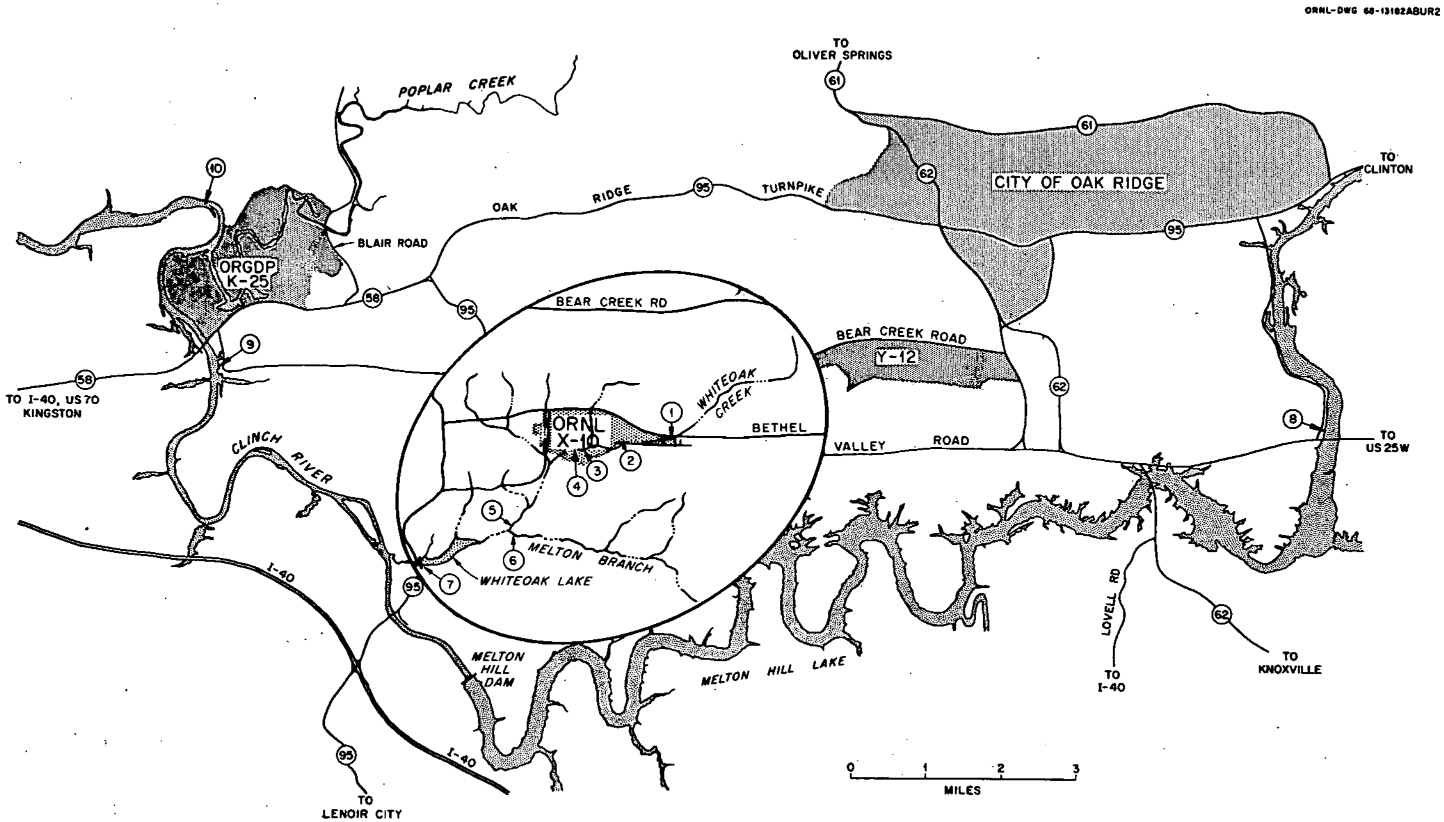


Fig. C.4. Location of Sampling Stations for Nonradioactive Effluents.

Appendix D

ATMOSPHERIC DISPERSION OF STACK RELEASES

The equation used to estimate the radionuclide air concentrations at ground level is the Gaussian plume equation of Pasquill[1] as modified by Gifford.[2]

$$\chi = \frac{Q}{\pi\sigma_y\ \sigma_z\mu} \exp\left(-\frac{y^2}{2\sigma_y{}^2} - \frac{h^2}{2\sigma_z{}^2}\right),$$

where

χ = radionuclide concentration in air at ground level at a point x meters downwind from the plant and y meters in the crosswind direction, Ci/m^3,

Q = uniform rate of release of the radionuclide from the plant, Ci/sec,

y = distance crosswind from the center line of plume, m,

h = effective stack height, m,

μ = wind speed, m/sec,

σ_y = horizontal dispersion coefficient, m, and

σ_z = vertical dispersion coefficient, m.

The downwind distance (x) comes into the Pasquill equation through the parameters σ_y and σ_z, which are functions of both x and the degree of atmospheric stability. Pasquill devised a classification scheme for atmospheric stability that consists of six categories ranging from A, the most turbulent category, to F, the most stable category. The plume disperses rapidly in both the horizontal and vertical directions in category A, and it disperses slowly in category F. Plots of σ_y and σ_z as a function of x for each of the six atmospheric stability categories derived from Pasquill's classification scheme can be found in the USAEC report Meteorology and Atomic Energy 1968.[3]

The meteorological information required to compute average ground-level air concentrations of a radionuclide as a function of distance and direction from a plant uniformly releasing a radionuclide from its stack is

1. the annual frequency of each of the six Pasquill atmospheric stability categories,
2. the annual frequency with which the wind blows toward each of 16 directions away from the plant, and
3. wind speeds as a function of wind direction and atmospheric stability category.

Meteorological data for the plant site, based on U. S. Weather Bureau observations, are given in Tables D.1 and D.2 for C and E stabilities, the two generalized stabilities applicable to the area.[4]

The effective stack height, h, in the Pasquill equation is the sum of the physical stack height, h_o, and the plume rise, which is k/μ for a plume rise resulting from momentum. The physical stack height is 80.8 meters and the stack constant, k, is 29 $meters^2/sec$.

An effective perimeter was established for the AEC-controlled reservation with respect to the plant site.[4] Dilution factors at ground level were obtained in a computer run using the input data of Tables D.1 and D.2. The dilution factors for each direction from the stack at the distance in meters at the edge of the effective area perimeter are given in Table D.3. The log polar isopleths of expected annual average stack dilution factors for the plant site are shown in Fig. D.1. A low inversion lid was assumed for category E, and this maximizes the ground-level air concentrations for this category because it imposes a restriction on vertical dispersion. No correction was made for ground deposition of particulates. The dilution factors in Table D.3 are thus maximized because a plume is depleted by particle deposition.

The least dilution occurs in the northeast sector and results in a χ/Q of 2×10^{-7} sec/m^3 (see Table D.3). This conservative χ/Q is used to dilute the expected annual average atmospheric releases listed in the text.

Table D.1. Frequency of Wind Speed and Wind Direction Under C-Stability Conditions at Oak Ridge National Laboratory (Based on Observations Made by the United States Weather Bureau)

Wind Direction	Wind Speed (Miles per Hour)							
	0.5	2.5	7.0	12.0	17.0	22.0	27.0	29
SSW	0.001065	0.002813	0.004800	0.004610	0.003561	0.002337	0.000238	0.000016
SW	0.001828	0.005818	0.009219	0.008774	0.005102	0.002766	0.000366	0.000016
WSW	0.001319	0.003513	0.005977	0.003942	0.001701	0.000397	0.000016	0.0
W	0.001780	0.004753	0.004514	0.001749	0.000397	0.000207	0.000016	0.000016
WNW	0.001001	0.001812	0.001399	0.000477	0.000032	0.000048	0.000016	0.0
NW	0.001272	0.002225	0.001510	0.000525	0.000111	0.000064	0.0	0.000032
NNW	0.001303	0.002051	0.002003	0.000954	0.000334	0.000191	0.000079	0.000032
N	0.002051	0.005341	0.008854	0.005945	0.003227	0.002066	0.000477	0.000318
NNE	0.001685	0.005293	0.010221	0.006469	0.003449	0.001764	0.000620	0.000207
NE	0.002607	0.008758	0.013543	0.008536	0.003227	0.001446	0.000350	0.000302
ENE	0.001240	0.004546	0.008266	0.007566	0.003052	0.001828	0.000604	0.000493
E	0.001224	0.004006	0.008138	0.008917	0.005786	0.003481	0.001256	0.000445
ESE	0.000381	0.002273	0.003815	0.005818	0.003672	0.001987	0.000477	0.000127
SE	0.000381	0.001780	0.003799	0.003910	0.002130	0.001160	0.000159	0.000048
SSE	0.000302	0.001160	0.001907	0.001319	0.000890	0.000318	0.000048	0.0
S	0.000556	0.002130	0.002655	0.001764	0.000922	0.000556	0.000048	0.0

Table D.2. Frequency of Wind Speed and Wind Direction Under E-Stability Conditions at Oak Ridge National Laboratory (Based on Observations Made by the United States Weather Bureau)

Wind Direction	Wind Speed (Miles per Hour) 0.5	2.5	7.0	12.0	17.0	22.0	27.0	29
SSW	0.002035	0.006533	0.012573	0.013861	0.011620	0.005850	0.000286	0.000079
SW	0.004324	0.013050	0.026275	0.026371	0.016817	0.007312	0.000429	0.000064
WSW	0.002480	0.006915	0.012033	0.008965	0.002416	0.000572	0.0	0.0
W	0.004419	0.010380	0.012478	0.005198	0.000970	0.000223	0.0	0.0
WNW	0.002464	0.005198	0.004085	0.001415	0.000302	0.000079	0.0	0.0
NW	0.003799	0.007662	0.006215	0.002225	0.000668	0.000254	0.000016	0.000016
NNW	0.002394	0.006994	0.007741	0.004292	0.001224	0.000684	0.000127	0.000095
N	0.004657	0.013336	0.023494	0.017262	0.008393	0.004165	0.000509	0.000350
NNE	0.004832	0.013018	0.023859	0.017676	0.007487	0.002813	0.000318	0.000143
NE	0.007662	0.022715	0.037211	0.019663	0.006104	0.001749	0.000254	0.000175
ENE	0.002066	0.007646	0.014576	0.013527	0.005214	0.001860	0.000302	0.000207
E	0.002432	0.007010	0.015673	0.015291	0.007423	0.002893	0.000493	0.000064
ESE	0.001446	0.003576	0.008250	0.007487	0.003259	0.001319	0.000318	0.000095
SE	0.001701	0.004260	0.008250	0.007328	0.002686	0.000699	0.000048	0.000048
SSE	0.000827	0.002925	0.004769	0.003116	0.001256	0.000334	0.000016	0.0
S	0.001780	0.004276	0.007884	0.006152	0.002861	0.000779	0.000079	0.0

Table D.3. Annual Average Stack Dilution Factors of Effective Area Perimeter

Direction from Stack	Distance (meters)	Dilution Factor (μCi/m^3 per μCi/sec)
N	3465	1.08×10^{-7}
NNE	3925	9.30×10^{-8}
NE	3315	1.72×10^{-7}
ENE	3315	7.20×10^{-8}
E	3355	7.52×10^{-8}
ESE	3160	4.21×10^{-8}
SE	2780	4.76×10^{-8}
SSE	2935	2.47×10^{-8}
S	3505	3.62×10^{-8}
SSW	3580	5.62×10^{-8}
SW	3660	1.06×10^{-7}
WSW	3885	5.30×10^{-8}
W	4380	6.20×10^{-8}
WNW	3350	4.03×10^{-8}
NW	3085	6.26×10^{-8}
NNW	3050	5.38×10^{-8}

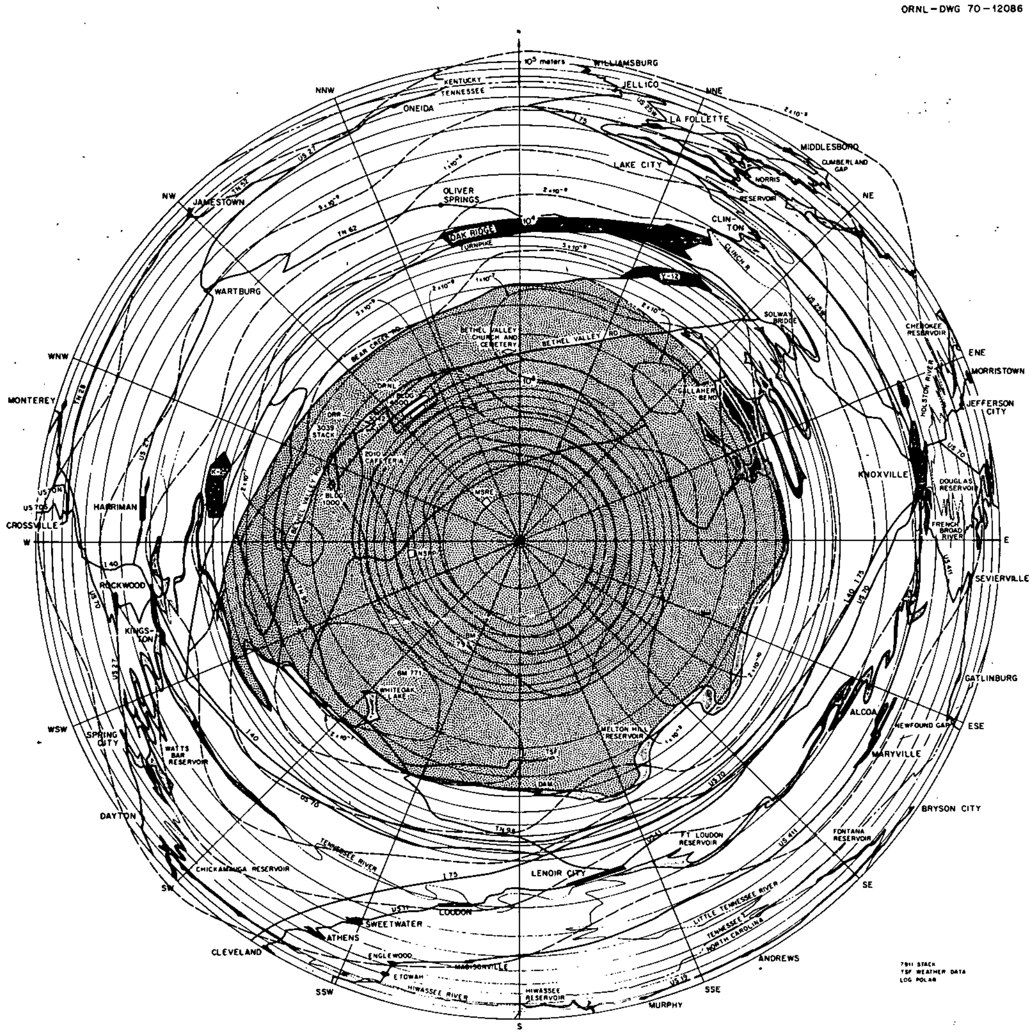


Fig. D.1. Log Polar Isopleths of Expected Annual Average Stack Dilution Factors for the Plant Site.

References

1. F. Pasquill, Meteorol. Mag., Vol. 90, p. 1063 (1961).

2. F. Gifford, Nuclear Safety, 4(2): 47 (1961).

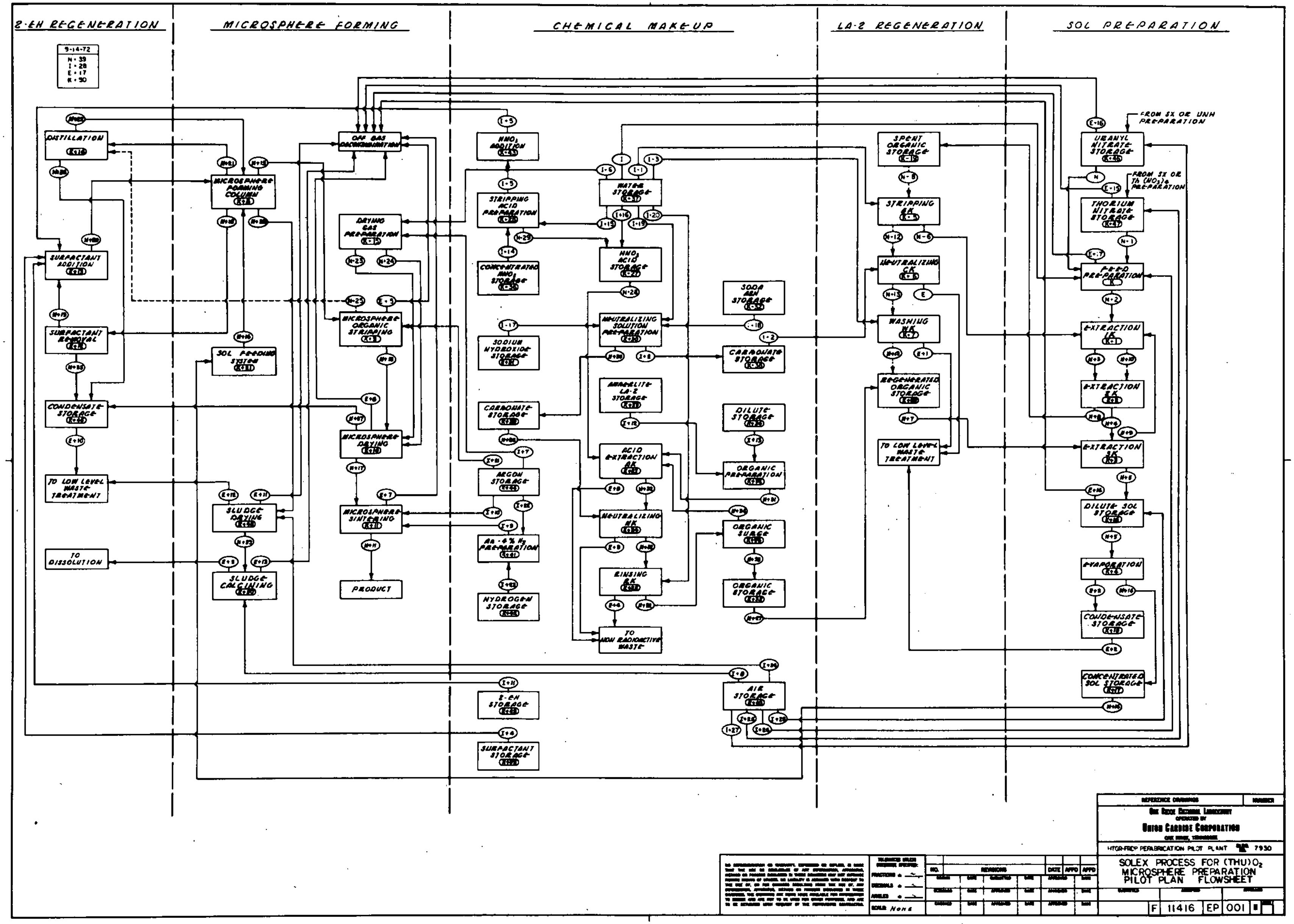
3. D. H. Slade, editor, "Meteorology and Atomic Energy 1968," USAEC Report TID-24190, U.S. Atomic Energy Commission, latest printing August 1972.

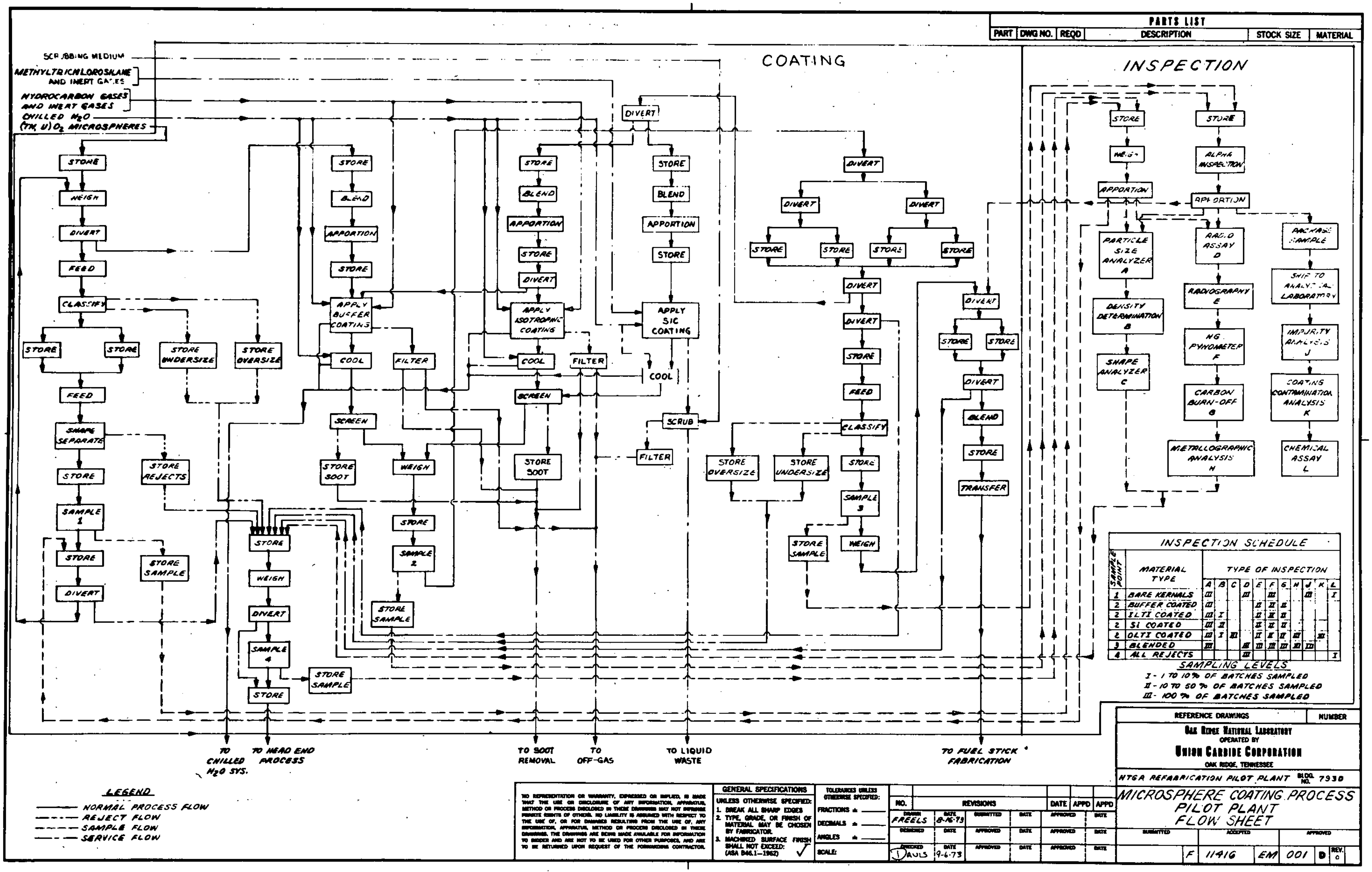
4. F. T. Binford, T. P. Hamrick, and Beth H. Cope, "Some Techniques for Estimating the Results of the Emission of Radioactive Effluent from ORNL Stacks," USAEC Report ORNL-TM-3187, Oak Ridge National Laboratory, October 1970.

Appendix E

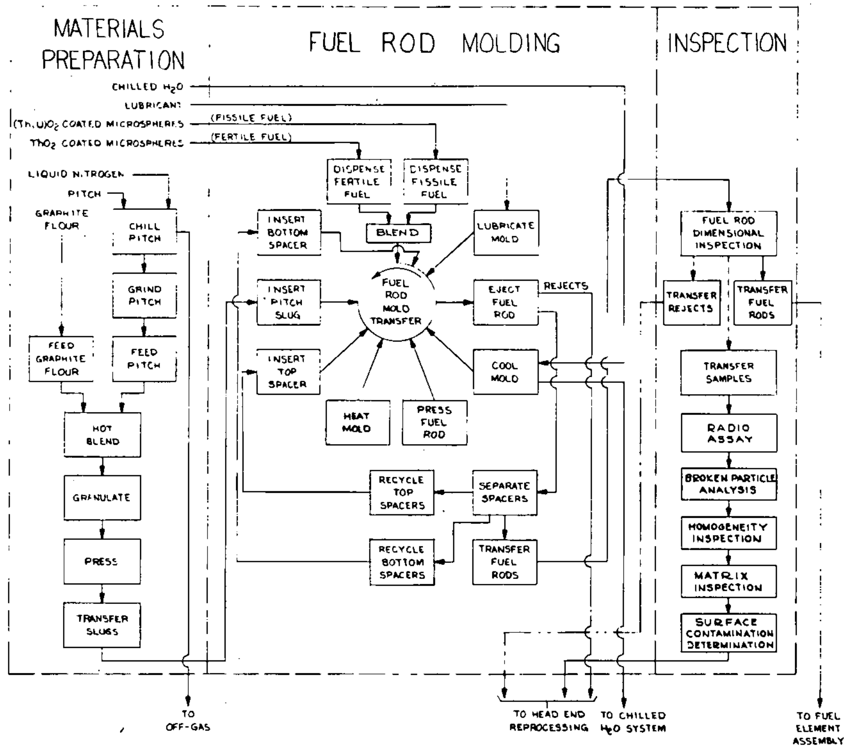
ENGINEERING DRAWINGS

Drawing Number	Title
F-11416-EP-001-E	SOLEX Process for $(ThU)O_2$ Microsphere Preparation, Pilot Plant Flow Sheet
F-11416-EM-001-D	Microsphere Coating Process, Pilot Plant Flow Sheet
F-11416-EM-007-D	Fuel Rod Fabrication, In-Block Carbonization Flow Sheet
W-11416-EM-008-D	Fuel Element Assembly, In-Block Carbonization Flow Sheet


2-EH REGENERATION
MICROSPHERE FORMING
CHEMICAL MAKE-UP
LA-2 REGENERATION
SOL PREPARATION
DISTILLATION
SURFACTANT ADDITION
SURFACTANT REMOVAL
CONDENSATE STORAGE
TO LOW LEVEL WASTE TREATMENT
TO DISSOLUTION
MICROSPHERE FORMING COLUMN
SOL FEEDING SYSTEM
SLUDGE DRYING
SLUDGE CALCINING
OFF GAS DECONTAMINATION
DRYING GAS PREPARATION
MICROSPHERE ORGANIC STRIPPING
MICROSPHERE DRYING
MICROSPHERE SINTERING
PRODUCT
HNO3 ADDITION
STRIPPING ACID PREPARATION
CONCENTRATED HNO3 STORAGE
SODIUM HYDROXIDE STORAGE
CARBONATE STORAGE
ARGON STORAGE
Ar-4% H2 PREPARATION
HYDROGEN STORAGE
2-EH STORAGE
SURFACTANT STORAGE
WATER STORAGE
HNO3 ACID STORAGE
NEUTRALIZING SOLUTION PREPARATION
AMBERLITE LA-2 STORAGE
ACID EXTRACTION AK
NEUTRALIZING NK
RINSING RK
TO NON RADIOACTIVE WASTE
SODA ASH STORAGE
CARBONATE STORAGE
DILUTE STORAGE
ORGANIC PREPARATION
ORGANIC SURGE
ORGANIC STORAGE
AIR STORAGE
SPENT ORGANIC STORAGE
STRIPPING AK
NEUTRALIZING CK
WASHING WK
REGENERATED ORGANIC STORAGE
TO LOW LEVEL WASTE TREATMENT
URANYL NITRATE STORAGE
FROM SX OR UNH PREPARATION
FROM SX OR Th (NO3)4 PREPARATION
THORIUM NITRATE STORAGE
FEED PREPARATION
EXTRACTION 1K
EXTRACTION 2K
EXTRACTION 3K
DILUTE SOL STORAGE
EVAPORATION
CONDENSATE STORAGE
CONCENTRATED SOL STORAGE
9-14-72
N = 39
I = 28
E = 17
K = 50
Oak Ridge National Laboratory
Operated by
Union Carbide Corporation
HTGR-FRCP REFABRICATION PILOT PLANT 7930
SOLEX PROCESS FOR (THU)O2
MICROSPHERE PREPARATION
PILOT PLAN FLOWSHEET
F 11416 EP 001
SCALE None


PARTS LIST
PART | DWG NO. | REQD | DESCRIPTION | STOCK SIZE | MATERIAL
COATING
INSPECTION
SCRUBBING MEDIUM
METHYLTRICHLOROSILANE AND INERT GASES
HYDROCARBON GASES AND INERT GASES
CHILLED H2O
(TH, U)O2 MICROSPHERES
STORE
WEIGH
DIVERT
FEED
CLASSIFY
STORE UNDERSIZE
STORE OVERSIZE
SHAPE SEPARATE
STORE REJECTS
SAMPLE 1
STORE SAMPLE
BLEND
APPORTION
APPLY BUFFER COATING
APPLY ISOTROPIC COATING
APPLY SIC COATING
COOL
FILTER
SCREEN
STORE SOOT
SAMPLE 2
SCRUB
SAMPLE 4
STORE OVERSIZE
STORE UNDERSIZE
SAMPLE 3
TRANSFER
PARTICLE SIZE ANALYZER A
DENSITY DETERMINATION B
SHAPE ANALYZER C
ALPHA INSPECTION
RADIO ASSAY D
RADIOGRAPHY E
HG PYNOMETER F
CARBON BURN-OFF G
METALLOGRAPHIC ANALYSIS H
PACKAGE SAMPLE
SHIP TO ANALYTICAL LABORATORY
IMPURITY ANALYSIS J
COATING CONTAMINATION ANALYSIS K
CHEMICAL ASSAY L
INSPECTION SCHEDULE
SAMPLE POINT | MATERIAL TYPE | TYPE OF INSPECTION A B C D E F G H J K L
1 | BARE KERNALS | A III, D III, F III, J III, L I
2 | BUFFER COATED | A III, E II, F II, G II
2 | ILTI COATED | A III, B I, E II, F II, G II
2 | SI COATED | A III, B II, E II, F II, G II
2 | OLTI COATED | A III, B I, C III, E II, F II, G II, H III, K III
3 | BLENDED | A III, D III, E III, F III, G III, H III, J III
4 | ALL REJECTS | D III, L I
SAMPLING LEVELS
I - 1 TO 10% OF BATCHES SAMPLED
II - 10 TO 50% OF BATCHES SAMPLED
III - 100% OF BATCHES SAMPLED
TO CHILLED H2O SYS.
TO HEAD END PROCESS
TO SOOT REMOVAL
TO OFF-GAS
TO LIQUID WASTE
TO FUEL STICK FABRICATION
LEGEND
NORMAL PROCESS FLOW
REJECT FLOW
SAMPLE FLOW
SERVICE FLOW
GENERAL SPECIFICATIONS
UNLESS OTHERWISE SPECIFIED:
1. BREAK ALL SHARP EDGES
2. TYPE, GRADE, OR FINISH OF MATERIAL MAY BE CHOSEN BY FABRICATOR.
3. MACHINED SURFACE FINISH SHALL NOT EXCEED: (ASA B46.1—1962)
TOLERANCES UNLESS OTHERWISE SPECIFIED:
FRACTIONS ±
DECIMALS ±
ANGLES ±
SCALE:
NO. | REVISIONS | DATE | APPD | APPD
DRAWN FREELS 8-16-73
CHECKED DAULS 9-6-73
REFERENCE DRAWINGS | NUMBER
OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE CORPORATION
OAK RIDGE, TENNESSEE
HTGR REFABRICATION PILOT PLANT BLDG. NO. 7930
MICROSPHERE COATING PROCESS
PILOT PLANT
FLOW SHEET
SUBMITTED | ACCEPTED | APPROVED
F 11416 EM 001 D REV. 0

PARTS LIST					
PART	DWG NO.	REQD	DESCRIPTION	STOCK SIZE	MATERIAL



REFERENCE DRAWINGS | NO.

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE CORPORATION
OAK RIDGE, TENNESSEE

HTGR REFABRICATION PILOT PLANT BLDG. NO. 7930

FUEL ROD FABRICATION
IN-BLOCK CARBONIZATION
FLOW SHEET

GENERAL SPECIFICATIONS
UNLESS OTHERWISE SPECIFIED:
1. BREAK ALL SHARP EDGES
2. TYPE, GRADE, OR FINISH OF MATERIAL MAY BE CHOSEN BY FABRICATOR.
3. MACHINED SURFACE FINISH SHALL NOT EXCEED: √ (ASA B46.1–1962)

TOLERANCES UNLESS OTHERWISE SPECIFIED:
FRACTIONS ±
DECIMALS ±
ANGLES ±
SCALE:

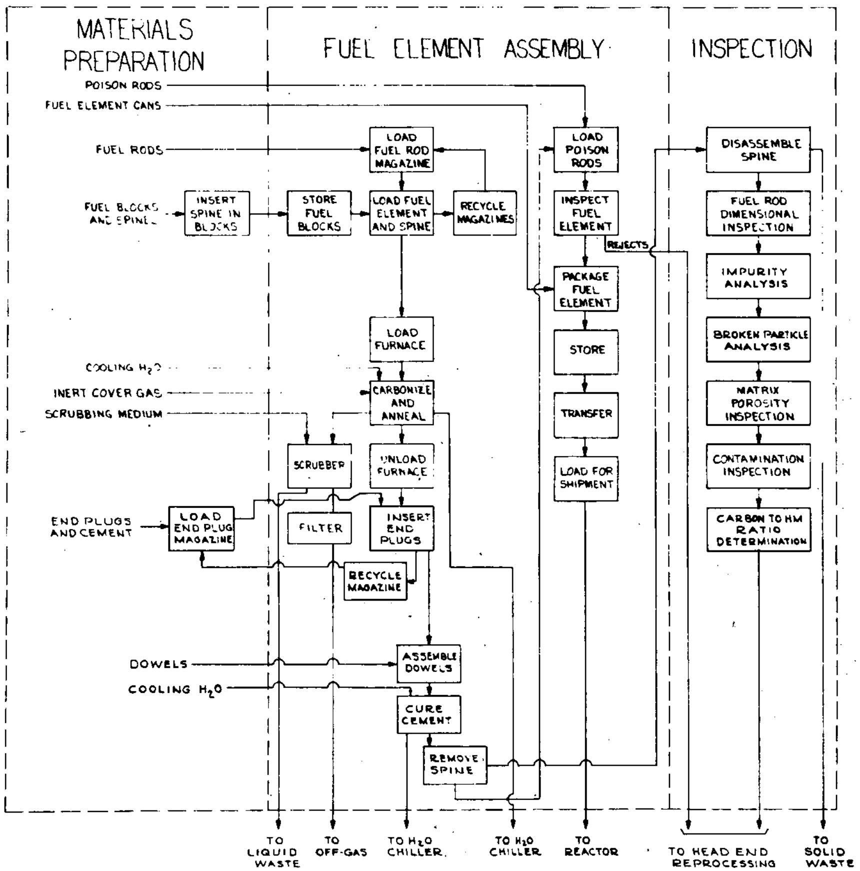
NO.	REVISIONS	DATE	APPD	APPD

DRAWN	DATE	SUBMITTED	DATE	APPROVED	DATE
N. ROBERTS	8-21-73				
DESIGNED	DATE	APPROVED	DATE	APPROVED	DATE
CHECKED	DATE	APPROVED	DATE	APPROVED	DATE
Davis	9-4-73				

SUBMITTED	ACCEPTED	APPROVED

F 11416 EM 007 D REV. 0

PARTS LIST					
PART	DWG NO.	REQD	DESCRIPTION	STOCK SIZE	MATERIAL



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UNLESS OTHERWISE SPECIFIED:
1. BREAK ALL SHARP EDGES
2. TYPE, GRADE, OR FINISH OF MATERIAL MAY BE CHOSEN BY FABRICATOR.
3. MACHINED SURFACE FINISH SHALL NOT EXCEED: (ASA B46.1–1962) ✓

TOLERANCES UNLESS OTHERWISE SPECIFIED:
FRACTIONS ±
DECIMALS ±
ANGLES ±
SCALE:

NO.	REVISIONS	DATE	APPD	APPD

DRAWN	DATE	SUBMITTED	DATE	APPROVED	DATE
N. ROBERTS	8-21-73				
DESIGNED	DATE	APPROVED	DATE	APPROVED	DATE
CHECKED	DATE	APPROVED	DATE	APPROVED	DATE
Davis	9-6-73				

REFERENCE DRAWINGS	NUMBER

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE CORPORATION
OAK RIDGE, TENNESSEE

HTGR REFABRICATION PILOT PLANT — BLDG. NO. 7930

FUEL ELEMENT ASSEMBLY IN-BLOCK CARBONIZATION FLOW SHEET

SUBMITTED | ACCEPTED | APPROVED

W 11416 EM 008 D REV. 0

Appendix F

COMMENTS RECEIVED ON THE DRAFT ENVIRONMENTAL STATEMENT AND AEC'S RESPONSE

The following letters were received by the AEC in response to a request for comments on the draft Environmental Statement (WASH-1533) for the HTGR Fuel Refabrication Pilot Plant which was issued for comments in January 1974.

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
WASHINGTON, D.C. 20250

February 19, 1974

Mr. J. L. Liverman
Biomedical and Environmental
Research and Safety Programs
U.S. Atomic Energy Commission
Washington, D.C. 20545

Dear Mr. Liverman:

The Agricultural Research Service has received three Atomic Energy Commission Draft Environmental Impact Statements: WASH-1532; WASH-1533; and WASH-1534. We have reviewed these and have no comments to make at this time.

Sincerely,

R. C. Reeve

Ronald C. Reeve
Acting Assistant Administrator
National Program Staff

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

AUG 16 1974

Mr. Ronald C. Reeve
Acting Assistant Administrator
National Program Staff
U.S. Department of Agriculture
Washington, D.C. 20250

Dear Mr. Reeve:

Thank you for your letter of February 19, 1974 concerning your review of the Atomic Energy Commission's draft environmental statement for the HTGR Fuel Refabrication Pilot Plant, Oak Ridge National Laboratory, Oak Ridge, Tennessee, and advising us that you have no comments. The statement has been revised in response to comments received from other reviewing organizations.

We appreciate your continued interest in our programs. Copies of the final statement are enclosed for your information.

Sincerely,

James L. Liverman

James L. Liverman
Assistant General Manager for
Biomedical and Environmental
Research and Safety Programs

Enclosure:
Final Environmental Statement for HTGR
Fuel Refabrication Pilot Plant, ORNL,
Oak Ridge, Tennessee (5 copies)

OFFICE OF THE ASSISTANT SECRETARY OF COMMERCE
Washington, D.C. 20230

March 19, 1974

Mr. James L. Liverman
Assistant General Manager
for Biomedical and Environmental
Research and Safety Programs
Atomic Energy Commission
Washington, D. C. 20545

Dear Mr. Liverman:

The draft environmental impact statement for WASH-1533 - HTGR Fuel Refabrication Pilot Plant, Oak Ridge National Laboratory, Tennessee, which accompanied your letter of February 5, 1974, has been reviewed and the following comments are offered for your consideration.

Since the effluent release from the proposed facility is through a common stack shared also by the High-Flux Isotope Reactor and the Transuranium Processing Plant, the assessment of the environmental impact should be on the sum of all three facility gaseous effluents. Only effluent releases from the proposed facility are listed.

There is a discrepancy in the height of the stack. Page 61 lists 75.8m while Appendix D (p. 142) lists 80.8m.

Thank you for giving us an opportunity to provide these comments, which we hope will be of assistance to you. We would appreciate receiving a copy of the final statement.

Sincerely,

Sidney R. Galler
Sidney R. Galler
Deputy Assistant Secretary
for Environmental Affairs

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

AUG 16 1974

Dr. Sidney R. Galler
Deputy Assistant Secretary
for Environmental Affairs
U. S. Department of Commerce
Washington, D. C. 20230

Dear Dr. Galler:

Thank you for your letter of March 19, 1974, which provided comments on the Atomic Energy Commission's draft environmental statement for the HTGR Fuel Refabrication Pilot Plant, Oak Ridge National Laboratory (ORNL), Oak Ridge, Tennessee. The statement has been revised in response to your comments and comments from other agencies.

With respect to your suggestion that we assess the environmental impact of gaseous effluents from other facilities where a common stack is used, the scope of this statement is limited to effluents from the subject fuel refabrication plant which contributes only a small percentage of the effluents. However, an assessment of the environmental impact of all the operations at the ORNL site is in preparation and will be completed by the end of this year. This assessment will cover all the waste management activities at the site including the gaseous effluents from the other operating facilities using the common stack.

We appreciate your continued interest in our programs. Copies of the final statement are enclosed for your information.

Sincerely,

James L. Liverman
Assistant General Manager for
Biomedical and Environmental
Research and Safety Programs

Enclosure:
Final Environmental Statement - HTGR
Fuel Refabrication Pilot Plant, ORNL,
Oak Ridge, Tennessee (WASH-1533)
(4 copies)

STATE OF TENNESSEE
OFFICE OF URBAN AND FEDERAL AFFAIRS
SUITE 1312
ANDREW JACKSON STATE OFFICE BUILDING
NASHVILLE 37219

GARY S. SASSE
DIRECTOR

615-741-2714

March 19, 1974

Mr. James L. Liverman
Assistant General Manager for
Blomedical & Environmental Research
and Safety Programs
United States Atomic Energy Commission
Washington, D. C. 20545

Re: Draft Environmental Statements
1. Radioactive Waste Facilities (WASH-1532
2. HTGR Fuel Refabrication Pilot Plant (WASH-1533)

Dear Mr. Liverman:

In conformance with guideline procedures stipulated in OMB Circular A-95 and in conformance with the Governor's Executive Order 6, designating the Office of Urban and Federal Affairs as the State Clearinghouse for Federal grant programs, we have reviewed your draft environmental statements for the above mentioned proposed projects at the Oak Ridge National Laboratory.

Our evaluation of submitted materials identified no conflicts with existing or planned State activities. Therefore, we deem the proposal acceptable on the basis of information made available to us at this time. If our office, as the State Clearinghouse, can be of further assistance, please do not hesitate to contact us.

Sincerely,

Suzanne M. Bentley

Suzanne M. Bentley
Grant Review Coordinator

SMB/prp

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

AUG 16 1974

Honorable Winfield Dunn
Governor of Tennessee
Nashville, Tennessee 37219

Dear Governor Dunn:

Thank you for the letter of March 19, 1974 from the Office of Urban and Federal Affairs, State of Tennessee, concerning your review and comments on the Atomic Energy Commission's draft environmental statement for the HTGR Fuel Refabrication Pilot Plant, Oak Ridge National Laboratory, Oak Ridge, Tennessee. The statement has been revised in response to comments received from the reviewing organizations.

We appreciate your continued interest in our programs. A copy of the final statement is enclosed for your information.

Sincerely,

James L. Liverman
Assistant General Manager for
Biomedical and Environmental
Research and Safety Programs

Enclosure:
Final Environmental Statement for HTGR
Fuel Refabrication Pilot Plant, ORNL,
Oak Ridge, Tennessee (1 copy)

cc: Tilden J. Curry, Exec. Dir., State
Planning Office, w/encl. (1 copy)
Suzanne M. Bentley, Grant Review
Coordinator, Office of Urban and
Federal Affairs, State of Tennessee,
w/encl. (1 copy)

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20201

MAR 22 1974

Mr. James L. Liverman
Assistant General Manager
for Biomedical and Environmental
Research and Safety Programs
Atomic Energy Commission
Washington, D. C. 20545

Dear Mr. Liverman:

Thank you for your letter of February 5 requesting comments on the draft Environmental Impact Statement for WASH-1533 - HTGR Fuel Refabrication Pilot Plant, Oak Ridge National Laboratory, Tennessee. Based on the review by appropriate program agencies and regional offices, we have determined that the proposed construction, operation and decommissioning of the HTGR Fuel Refabrication Pilot Plant would be expected to have a minimal impact on the environment. All effluents from the proposed project will be controlled releases through existing waste disposal systems. The construction of the facility will in fact require only remodification of already constructed facilities.

Unavoidable radioactivity releases to the environment will cause a maximum potential individual exposure of 3.6×10^{-3} millirems per year from gaseous effluents. The concentration of radioactivity in the liquid effluents will be 100 millionth of the concentration guide and the resultant exposure to populations will be negligible.

The result of accidents have been analyzed in the report. The major impact from radiation would be the result of a fire. The maximum personnel dose down-wind in the case of a maximum credible accident of this type would be less than 200 millirem to any individual and no isolation of land area outside the controlled access area would be required. The consequences of explosions or criticality accidents would be less. Exposures resulting from the transportation of materials to and from the pilot plant would appear to be insignificant and probably unmeasurable.

Thank you for the opportunity to comment on this statement.

Sincerely,

Charles Custard
Director
Office of Environmental Affairs

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

AUG 16 1974

Mr. Charles Custard, Director
Office of Environmental Affairs
U.S. Department of Health, Education,
and Welfare
Washington, D.C. 20201

Dear Mr. Custard:

Thank you for your letter of March 22, 1974 concerning your review and comments on the Atomic Energy Commission's draft environmental statement for the HTGR Fuel Refabrication Pilot Plant, Oak Ridge National Laboratory, Oak Ridge, Tennessee. The statement has been revised in response to comments received from the reviewing organizations.

We appreciate your continued interest in our programs. Copies of the final statement are enclosed for your information.

Sincerely,

James L. Liverman
Assistant General Manager for
Biomedical and Environmental
Research and Safety Programs

Enclosure:
Final Environmental Statement for HTGR
Fuel Refabrication Pilot Plant, ORNL,
Oak Ridge, Tennessee (3 copies)

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

MAILING ADDRESS:
U.S. COAST GUARD (G-WS/73)
400 SEVENTH STREET SW.
WASHINGTON, D.C. 20590
PHONE: (202) 426-2262

25 MAR 1974

Mr. James L. Liverman
Assistant General Manager for
Biomedical and Environmental
Research and Safety Programs
Atomic Energy Commission
Washington, D. C. 20545

Dear Mr. Liverman:

This is in response to your letter of 5 February 1974 addressed to Mr. Martin Convisser concerning the draft environmental impact statement for the HTGR Fuel Refabrication Pilot Plant, Oak Ridge, Anderson County, Tennessee.

The concerned operating administrations and staff of the Department of Transportation have reviewed this draft statement. We have no comments to offer nor do we have any objection to this draft statement.

The opportunity to review this draft statement is appreciated.

Sincerely,

[illegible]
[illegible] Guard
[illegible]
[illegible]
By [illegible]

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

AUG 16 1974

Captain R. I. Price
Deputy Chief
Office of Marine Environment
and Systems
U.S. Coast Guard
400 Seventh Street, SW.
Washington, D.C. 20590

Dear Captain Price;

Thank you for your letter of March 25, 1974 concerning your review of the Atomic Energy Commission's draft environmental statement for the HTGR Fuel Refabrication Pilot Plant, Oak Ridge National Laboratory, Oak Ridge, Tennessee, and advising us that you have no comments. The statement has been revised in response to comments received from other reviewing organizations.

We appreciate your continued interest in our programs. A copy of the final statement is enclosed for your information.

Sincerely,

James L. Liverman
Assistant General Manager for
Biomedical and Environmental
Research and Safety Programs

Enclosure:
Final Environmental Statement for HTGR
Fuel Refabrication Pilot Plant, ORNL,
Oak Ridge, Tennessee

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

In reply refer to:
PEP ER 74/179

APR 1 1974

Dear Mr. Liverman:

Thank you for your letter of February 5, 1974, transmitting copies of the AEC's draft environmental statement dated January 1974, on the HTGR Fuel Refabrication Pilot Plant, Oak Ridge National Laboratory, Roane County, Tennessee.

Our comments are presented according to the format of the statement or according to subject.

General

We recommend that a comprehensive impact statement be prepared for the Oak Ridge National Laboratory site as we note that WASH-1532, ER 74/180, entitled Radioactive Waste Facilities, Oak Ridge National Laboratory is also currently under review in the Department, and the effluents produced by the HTGR refabrication facility are to be processed in the referenced waste facility. We suggest that evaluation of separate units can sometime allow pertinent aspects of the total system to escape evaluation as noted in Effluents and Solid Wastes, below.

We also recommend that all comments in this statement be correlated with WASH-1532, ER 74/180.

Fuel Element Shipment

Safe operation of high-temperature, gas-cooled reactors is dependent upon the integrity of the graphite coating on the uranium-thorium microspheres. Thus, moisture must not be allowed to contact this coating during storage or transfer. While we assume moisture in the storage areas and in the shipping container will be monitored, a statement to this effect in the final statement is suggested.

Effluents and Solid Wastes

Storage tanks to be used for the liquid radioactive wastes from the plant have been referred to briefly. For example, it is estimated on page 29 that about 1,000 gallons of such wastes would be stored in existing TURF waste tanks following the decommissioning of the plant. Another draft statement WASH-1532 shows on page 23 that 760,000 gallons of such wastes would be produced annually by operation of the Pilot Plant, and that storage would initially be in stainless steel tanks. However, neither draft statement provides a description of the storage tanks, or whether they are doubly contained, or whether they are equipped with adequate monitoring devices to detect leakage of radioactive liquids. It seems essential to include a discussion of the design and safeguards for these tanks in the final statement.

The only reference to storage of liquid radioactive wastes from the plant appears to be in connection with the 1,000 gallons of wastes resulting from decommissioning, as referred to above, and this relatively small quantity of liquid would have a level of activity of less than 4 curies per gallon. With regard to liquid wastes expected to be generated by normal operation of the plant, however, it is stated on page 68 only that "all known radioactive wastes are pumped directly . . . to the ORNL Intermediate-Level Waste Collection and Treatment System." It is also stated on the same page that "the liquids are made basic and piped into a 600-gallon-per-hour waste evaporator." These statements give no suggestion that the wastes would not be promptly processed by the evaporator, nor is lengthy storage of the wastes mentioned anywhere in the environmental statement. It is only by reference to another environmental statement, WASH-1532, that information on this can be obtained, indicating that Pilot Plant liquid wastes would be allowed to decay for at least 5 years, even before being processed by the evaporator. We recommend that the final statement should discuss any potential environmental impacts of storage of the liquid wastes for more than 5 years, and clarify the planned ultimate disposition of the wastes.

Although the statement provides a comprehensive description in Table 6 of radionuclides anticipated in the radioactive liquid wastes, the concentrations shown are in the greatly diluted effluent. The original concentrations would evidently be higher by a factor of 5×10^{18}. Using the factors given on page 70, it appears that the liquid must originally have a concentration equivalent to about 2.6 curies per gallon of uranium-232 and 4.2 curies per gallon of uranium-233. The total activity of the liquid waste at the time of final processing prior to discharge would evidently be in the vicinity of 20 curies per gallon. If these estimates are correct based on incomplete information in the statement, each gallon of the liquid waste would contain about twice the radioactivity of a cask containing three completed fuel elements for offsite shipment. In addition, information in the other environmental statement previously referenced, WASH-1532, page 22, suggests that this level of activity is present after at least 5 years of decay and at an unspecified amount of dilution. Both environmental statements should provide an unequivocal estimate of the radioactivity of the waste as it is initially stored, and of the total radionuclide content at that time. For example, no mention has been made of its content of cesium-137, strontium-90, or cerium-144. In addition, the toxic longevities of the various waste components should be specified.

With regard to the analysis of potential accidents, no consideration appears to have been given to the possibility of leakage of the liquid waste from its storage tanks. Since leakage of Pilot Plant waste was not discussed in the environmental statement for Radioactive Waste Facilities, WASH-1532, we feel that the present statement should discuss the environmental consequences of tank leakage and adequacy of monitoring devices and other safeguards.

Need for Project

Justification of the project on the basis of a lack of experience with remote fabrication of these fuel elements is presented. This justification is unclear because of the statement on page 19 that says the Fort St. Vrain Reactor, which uses the same type of fuel element, is currently nearing commercial operation. Thus, the justification does not appear to be adequately substantiated.

To support the need for the pilot plant, the statement on page 41 might better read, "There presently is no experience relative to the remote refabrication of HTGR fuels on any scale. Further, except for production of minor quantities of fuel for the Fort St. Vrain Reactor, there is no experience in remote fabrication of these fuels."

Seismology

In regard to seismic risk, it is stated on page 55 that "the TURF site is in an area . . . assigned a zone -2 risk, indicating a potential for moderate damage." The only specific mention of ground accelerations considered in design of the plant is the statement on page 119 that "within a 100-year period there exists a 50% probability for ground motion acceleration to exceed 0.03 to 0.09 g." However, the actual ground accelerations used as a basis for design of the plant have not been identified. Although it seems evident that the design of the thick-walled hot cells is more than adequate, it would be advisable to include a discussion of seismic design because highly radioactive material will not be confined entirely to the cells. It is noted on pages 33 and 73 that each shipment of three completed fuel elements would contain total radioactivity of about 10 curies, and would be protected by a 23-ton cask. However, it seems evident that a single gallon of liquid waste from the plant would contain considerably more than 10 curies of activity, yet no information has been provided on the adequacy of the facilities to contain this liquid in the event of seismic activity. The seismic design criteria applied to all structures that would be used for fabrication of HTGR fuel elements and for containment of the resulting radioactive wastes should be evaluated in the final statement, and any significant differences in these criteria for the various structures should be explained.

Land Use

We understand that at a previous date, the AEC transferred about 800 acres of former Reservation lands bordering the Clinch River to the City of Oak Ridge for future development as a regional park and that, to date, no development has taken place because of lack of funds.

We note that brief mention is made of a recent proposal, ". . . that the Oak Ridge Reservation be designated an Environmental Study Park." The information presented is limited, and a considered judgment cannot be made regarding the matter of best potential land use. Thus, we suggest that the final statement present and assess all environmental and related aspects of the Environmental Study Park proposal.

We hope these comments will be helpful to you in the preparation of a final statement.

Sincerely yours,

Royston C Hughes

Assistant Secretary of the Interior

Mr. James L. Liverman
Assistant General Manager
For Biomedical and Environmental
Research and Safety Programs
Atomic Energy Commission
Washington, D. C. 20545

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

AUG 16 1974

Mr. Royston C. Hughes
Assistant Secretary of the Interior
U.S. Department of the Interior
Washington, D.C. 20240

Dear Mr. Hughes:

Thank you for your letter of April 1, 1974 which provided comments on the Atomic Energy Commission's draft environmental statement for the HTGR Fuel Refabrication Pilot Plant, Oak Ridge National Laboratory (ORNL), Oak Ridge, Tennessee. The statement has been revised in response to your comments and comments from other agencies.

With respect to your recommendation that a comprehensive impact statement be prepared for the ORNL site, an environmental assessment of the impact of all operations at the ORNL site is in preparation and will be completed by the end of this year. The assessment will cover the waste management activities including radioactive effluents from other operating facilities. The radioactive effluent contribution of the subject fuel refabrication pilot plant represents only a small percentage of the total. The enclosed staff response covers other specific concerns which you raised.

We appreciate your continued interest in our programs. Copies of the final statement are enclosed for your information.

Sincerely,

James L. Liverman
James L. Liverman
Assistant General Manager for
Biomedical and Environmental
Research and Safety Programs

Enclosures:
1. Staff Response to Interior Comments
2. Final Environmental Statement - HTGR
Fuel Refabrication Pilot Plant, ORNL,
Oak Ridge, Tennessee (WASH-1533)
(7 copies)

ENCLOSURE 1

STAFF RESPONSE TO COMMENTS FROM THE
DEPARTMENT OF THE INTERIOR

Fuel Element Shipment

Atmospheric moisture has no detrimental effect on the pyrolytic carbon coating of fuel microspheres. The dense pyrolytic carbon coating is impermeable to and nonreactive with atmospheric moisture. The assembled graphite fuel element will not be adversely affected by atmospheric moisture expected to be encountered in storage or shipping.

Effluents and Solid Wastes

The final statement has been revised to include a description of the TURF waste tanks for collecting the liquid radioactive wastes prior to transferring them to the ORNL Intermediate-Level Waste Collection and Treatment System.

It should be noted, however, that the 760,000 gallons per year of Pilot Plant Wastes referred to in the comments from the Department of the Interior are for the operation of several pilot plants postulated in WASH-1532 (Environmental Statement, Radioactive Waste Facilities, Oak Ridge National Laboratory), not for the HTGR Fuel Refabrication Pilot Plant. The quantities and radionuclide contents of the liquid radioactive effluents expected from the HTGR Fuel Refabrication Pilot Plant are as was indicated in WASH-1533. They will be processed by the evaporator of the ORNL Intermediate-Level Waste Collection and Treatment System without lengthy holdup.

The liquid radioactive wastes from the HTGR Fuel Refabrication Pilot Plant will contain about 0.00012 curies per gallon. These wastes will be concentrated by evaporation in the ORNL Intermediate-Level Waste Collection and Treatment System. About 2×10^{-6} of the radioactivity in the liquid effluents from the HTGR Fuel Refabrication Pilot Plant will be released to the environment in the condensate from the evaporators. The concentration of radionuclides at the point of release from the ORNL site, considered to be White Oak Dam, resulting from the operation of the HTGR Fuel Refabrication Pilot Plant can best be determined by applying the decontamination factor for the evaporator and the dilution factor for White Oak Creek to the expected annual release rate for each radionuclide. The concentrations determined in this manner are given in table 8 of WASH-1533.

Need for Project

The initial fuel for the Fort St. Vrain Reactor will contain ^{235}U and thorium, which was fabricated by contact means in an unshielded facility. Only the recycle fuel, which contains ^{233}U or recycle ^{235}U requires remote fabrication. At present there is no experience in the remote fabrication of HTGR fuels.

Seismology

The final statement has been revised to incorporate information on the seismic design criteria for the facility (TURF). It should be noted, however, that the liquid effluents from the HTGR Fuel Refabrication Pilot Plant will contain about 0.00012 curies per gallon. The ten curies per gallon mentioned in the comments from the Department of the Interior were apprently determined from the data given in WASH-1532, "Radioactive Waste Facilities, Oak Ridge National Laboratory," for "future pilot plants," which is not relevant to the HTGR Fuel Refabrication Pilot Plant.

Land Use

The final statement has been revised to indicate that the HTGR Fuel Refabrication Pilot Plant will have no influence on the proposed designation of the Oak Ridge Reservation as the Environmental Study Park.

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
Southeastern Area, State and Private Forestry
Atlanta, Georgia 30309

8420

April 2, 1974

Mr. James L. Liverman
Assistant General Manager
Biomedical & Environmental Research and
Safety Programs
AEC, Oak Ridge National Laboratory
Oak Ridge, Tennessee 37830

Dear Mr. Liverman:

Here are Southeastern Area, State and Private Forestry comments on the draft environmental statement covering the HTGR Fuel Refabrication Pilot Plant at Oak Ridge National Laboratory.

We see no environmental conflict in conducting needed fuel refabrication research on a short-term, pilot basis within the ORNL reservation. We commend your delineation of 41 areas within the reservation for the study of unique or important environmental problems.

Please keep us fully informed of study areas established in forested sections of the reservation and let us know if we can be of assistance in the design of such studies.

Sincerely,

FREDERICK W. HONING
Area Environmental Coordinator

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

AUG 16 1974

Mr. Frederick W. Honing
Area Environmental Coordinator
Forest Service
U.S. Department of Agriculture
Atlanta, Georgia 30309

Dear Mr. Honing:

Thank you for your letter of April 2, 1974 concerning your review and comments on the Atomic Energy Commission's draft environmental statement for the HTGR Fuel Refabrication Pilot Plant, Oak Ridge National Laboratory, Oak Ridge, Tennessee. The statement has been revised in response to comments received from the reviewing organizations.

We appreciate your continued interest in our programs. Copies of the final statement are enclosed for your information.

Sincerely,

James L. Liverman
Assistant General Manager for
Biomedical and Environmental
Research and Safety Programs

Enclosure:
Final Environmental Statement for HTGR
Fuel Refabrication Pilot Plant, ORNL,
Oak Ridge, Tennessee (5 copies)

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
561 U. S. Courthouse, Nashville, Tennessee 37203

April 2, 1974

Mr. James L. Liverman
Assistant General Manager
Biomedical and Environmental Research
and Safety Programs
Oak Ridge National Laboratory
Oak Ridge, Tennessee

Dear Mr. Liverman:

Subject: Draft Environmental Statement, HTGR Fuel Refabrication Pilot Plant and Radioactive Waste Facilities, Oak Ridge National Laboratory, Oake Ridge, Tennessee

Reference is made to the draft environmental statement for subject HTGR Fuel Refabrication Pilot Plant and Radioactive Waste Facilities, Oak Ridge National Laboratory, Oak Ridge, Tennessee which was referred to the Soil Conservation Service for review and comment.

The proposed project will not conflict with any present or proposed programs of this agency.

The primary concern of this agency is with adequate control of erosion and sedimentation during and after construction of a project. Since this project involves an insignificant amount of soil disturbance, soil erosion and sedimentation does not appear to be an environmental problem.

We appreciate the opportunity to review and comment on this draft environmental statement.

Sincerely,

W. R. Hurst Jr.
Acting

Paul M. Howard
State Conservationist

cc: Kenneth E. Grant, Administrator
Soil Conservation Service
Washington, D. C.

Council on Environmental Quality
722 Jackson Place, N. W.
Washington, D. C. 20006
Attention: General Counsel

Office of the Coordinator of Environmental
Quality Activities
Office of Secretary, USDA
Washington, D. C. 20250

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

AUG 16 1974

Mr. Paul M. Howard
State Conservationist
Soil Conservation Service
U.S. Department of
Agriculture
561 U.S. Courthouse
Nashville, Tennessee 37203

Dear Mr. Howard:

Thank you for your letter of April 2, 1974 concerning your review and comments on the Atomic Energy Commission's draft environmental statement for the HTGR Fuel Refabrication Pilot Plant, Oak Ridge National Laboratory, Oak Ridge, Tennessee. The statement has been revised in response to comments received from the reviewing organizations.

We appreciate your continued interest in our programs. Copies of the final statement are enclosed for your information.

Sincerely,

James L. Liverman
Assistant General Manager for
Biomedical and Environmental
Research and Safety Programs

Enclosure:
Final Environmental Statement for HTGR
Fuel Refabrication Pilot Plant, ORNL,
Oak Ridge, Tennessee (5 copies)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

10 APR 1974

OFFICE OF THE
ADMINISTRATOR

Dr. James A. Liverman
Assistant General Manager
for Biomedical and Environmental Research
and Safety Programs
U.S. Atomic Energy Commission
Washington, D.C. 20545

Dear Dr. Liverman:

The Environmental Protection Agency has reviewed the draft environmental statement for the HTGR Fuel Refrabrication Pilot Plant-Oak Ridge National Laboratory, Oak Ridge, Tennessee, issued on February 6, 1974. Our detailed comments are enclosed.

In our opinion, in order to provide a more complete and useful analysis of this facility, the following three additional subjects should be included in the final statement:

1. An analysis of the consequences of the discharge and dispersal of long-lived radionuclides into the general environment. The recently published EPA report entitled "Environmental Radiation Dose Commitment: An Application to the Nuclear Power Industry," presents general concepts for calculating the cumulative consequences of the release of long-lived radionuclides to the environment.

2. An evaluation of the amount of increased radiation exposure due to inhalation since the gaseous effluents from this facility are to be combined with those from two other facilities on the Oak Ridge site and released through a common stack.

3. A discussion of the alternative of storing the fabricated fuel at ORNL rather than shipping the assemblies to the NRTS in Idaho as presently planned.

In light of the above and in accordance with EPA procedure, we have classified the project as ER (Environmental Reservations) and rated the draft statement as Category 2 (Insufficient Information). If you or your staff have any questions concerning our classification or comments, please don't hesitate to call on us.

Sincerely,

Sheldon Meyers

Sheldon Meyers
Director
Office of Federal Activities

Enclosure

EPA# D-AEC-00105-TN

ENVIRONMENTAL PROTECTION AGENCY

WASHINGTON, D.C. 20460

APRIL 1974

ENVIRONMENTAL IMPACT STATEMENT COMMENTS

HTGR Fuel Refabrication Pilot Plant

TABLE OF CONTENTS

INTRODUCTION AND CONCLUSIONS

The Environmental Protection Agency has reviewed the draft statement for the HTGR Fuel Refabrication Pilot Plant-Oak Ridge National Laboratory, Oak Ridge, Tennessee, prepared by the Atomic Energy Commission (AEC) and issued on February 6, 1974. Following are our major conclusions:

1. The final statement should include an analysis of the consequences of the discharge and dispersal of long-lived radionuclides into the general environment. The recently published EPA report entitled "Environmental Radiation Dose Commitment: An Application to the Nuclear Power Industry," presents general concepts for calculating the cumulative consequences of the release of long-lived radionuclides to the environment.

2. The radioactive discharges from this plant are mixed in a common stack with the discharge from two other facilities. The amount of increase in radiation exposure due to the additional inhaled radioactivity from this facility should be discussed in the final statement.

3. The alternative of storing the fabricated fuel at ORNL rather than shipping the assemblies to the NRTS in Idaho was not discussed in the draft statement. We believe this alternative should be discussed in the final statement.

RADIOLOGICAL ASPECTS

Radiation Exposure

The draft statement indicates that the gaseous effluents from the HTGR Fuel Refabrication Pilot Plant are to be released to the atmosphere through the 250 ft. High Flux Isotopes Reactor (HFIR) stack. The radioactive discharges from this plant and their relationship to the overall radiation levels in the area due to the combined releases from all site plants should be discussed in the final statement. The expected increase in radiation exposure due to inhaled radioactivity should be included in this discussion.

The final statement should also include an analysis of the consequences of the discharge and dispersal of long-lived radionuclides into the general environment. By virtue of the long persistence of these materals their consequences may extend over many generations and, in this respect, these discharges can represent irreversible public health commitments. The recently published "Environmental Radiation Dose Commitment: An Application to the Nuclear Power Industry" (EPA-520/4-73-002) presents general concepts for calculating the cumulative consequences of the release of long-lived radionuclides to the environment. In our opinion, such cumulative consequences should be added to other environmental costs in the cost-benefit anaysis.

Air Cleaning

The methods of air cleaning for the process cell exhaust are described as being, "...four HEPA (high-efficiency particulate air) filters in series...", on page 34; and "...five parallel compartments, each of which contains six HEPA filters," on page 36. The final statement should clarify the discussion of the HEPA filter system.

Decommissioning

Decommissioning is not discussed in any detail in the draft statement. The final statement should include the added environmental costs of decommissioning the facility. These costs should include descriptions and quantities of wastes in the form of solids or air and water-borne releases.

Accidents

In the discussion of possible accidents within the facility, the radiation dose from releases during a fire (page 78) indicates the personnel dose downwind would be less than 200 mrem. This discussion should be expanded in the final statement to indicate the radiation dose expected to the lung and bone in addition to the whole-body dose.

The discussion of the criticality accident (page 80) should be expanded in the final statement. The maximum dose to an individual at the site boundary should be estimated for release of iodines, noble gases and any direct radiation. The probability of a criticality and the estimated yield should indicate the dose commitment period considered. Also, the probability and effects of a tornado on the plant should be estimated.

While the probability of occurrence for each type of accident or natural disturbance is small, each could involve the release of radioactivity to the environment. The draft statement does not indicate the emergency response capability of the operator to minimize the environmental impact of different types of events. The final statement should include emergency plans of the operator as well as any involvement of state and local authorities.

Transportation

With regard to the transportation of the completed fuel assemblies, it is stated that they will be shipped to Idaho or to a reactor. If the fuel is shipped to Idaho, the accident rate would be 0.55 accidents plus those potential accidents which would eventually occur during shipments from Idaho to the reactors. The alternative of storing the fuel at ORNL until shipment directly to the reactors was not addressed although it is apparent that this alternative would have a significantly smaller impact based on current projected locations of HTGR's. We believe this alternative should be considered in the final statement.

NON-RADIOLOGICAL ASPECTS

Biological

Storm drainage is to be discharged directly to the Melton Valley storm drainage system and the sanitary wastes are to be discharged to the Melton Valley area municipal treatment plant. Both the storm and sanitary wastes are to be monitored prior to discharge. Additional discussion is necessary to describe the nature of the agreement with the Melton Valley waste disposal authority, the quantities and nature of wastes involved, and the additional burden to be placed on the existing system. Also, with regard to the sanitary wastes, a discussion is needed on the pretreatment standards that will be met prior to discharge to the municipal treatment system. In addition, the final statement should further discuss the cumulative effects of the wastes from the proposed pilot facility in relation to the discharges from other facilities at ORNL.

Chemical

The discharge of chemical emissions in the liquid waste releases, while containing only 1/25 of the concentrations known to be lethal to aquatic organisms (page 85), could have long-term chronic effects that have not been considered. We recommend that the long-term effects of such emissions be examined in the final statement.

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

AUG 16 1974

Mr. Sheldon Meyers, Director
Office of Federal Activities
U.S. Environmental Protection
Agency
Washington, D.C. 20460

Dear Mr. Meyers:

Thank you for your letter of April 10, 1974 which provided comments on the Atomic Energy Commission's draft environmental statement for the HTGR Fuel Refabrication Pilot Plant, Oak Ridge National Laboratory (ORNL), Oak Ridge, Tennessee. The statement has been revised in response to your comments and comments from other agencies.

With respect to your suggestion that an assessment be made of the radioactive discharges from this plant and their relationship to the overall radiation levels in the area due to the combined releases from all site plants, the scope of this statement is limited to effluents from the subject fuel refabrication plant which contribute only a small percentage of the effluents. However, we are preparing an environmental assessment of the impact of all operations at the ORNL site including the radioactive effluents from other operating facilities. This assessment will be completed by the end of this year. The enclosed staff response covers other specific concerns which you raised.

We appreciate your continued interest in our programs. Copies of the final statement are enclosed for your information.

Sincerely,

James L. Liverman
Assistant General Manager for
Biomedical and Environmental
Research and Safety Programs

Enclosures:
1. Staff Response to EPA Comments
2. Final Environmental Statement - HTGR
Fuel Refabrication Pilot Plant, ORNL,
Oak Ridge, Tennessee (WASH-1533)
(3 copies)

ENCLOSURE 1

STAFF RESPONSE TO COMMENTS FROM THE
ENVIRONMENTAL PROTECTION AGENCY

RADIOLOGICAL ASPECTS

Radiation Exposure

The final statement has been revised to indicate that the dose shown in table 5 of WASH-1533 is the increase in dose to man due to additional inhalation of radionuclides resulting from the operation of the HTGR Fuel Refabrication Pilot Plant.

Revisions were also made to include an analysis of the consequences of the discharge and dispersal of long-lived radionuclides into the general environment.

Air Cleaning

Corrections have been made to indicate that the vessel hot off-gas system has two roughing filters and four HEPA filters in series before it ties into the cell exhaust system. The cell exhaust passes through one roughing filter and two HEPA filters in series.

Decommissioning

The final statement has been revised to include descriptions and quantities of wastes resulting from decommissioning the facility.

Accidents

The final statement has been revised to provide the radiation dose expected to the lung and bone in the event of a fire in the facility.

Revisions have been made to provide calculated doses expected from the release of halogens and noble gases and from direct radiation resulting from a criticality accident of 10^{19} fissions. Revisions have also been made to describe the probable effects of a tornado.

Transportation

The final statement has been revised to consider the alternative of storing the completed fuel elements at TURF rather than shipping them to Idaho.

It should be noted that since the purpose of the HTGR Fuel Refabrication Pilot Plant is only to develop and demonstrate the technology for remote fabrication of recycle fuel and not to fabricate large quantities of fuel for reactors, the projected locations of HTGRs have little bearing on the choice of storing the fuel at ORNL or shipping it to Idaho for storage.

NONRADIOLOGICAL ASPECTS

Biological

The final statement has been revised to provide additional discussion on the treatment and discharge of storm drain and sanitary effluents and the pretreatment standards expected to be met prior to discharge.

Chemical

The final statement has been modified to provide additional discussion on the expected long-term chronic effects of chemical emissions.