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**Preliminary Draft
Environmental Impact Statement for
Hot Engineering Test Project at
Oak Ridge National Laboratory**

J. W. Boyle

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ENVIRONMENTAL IMPACT STATEMENT FOR HOT ENGINEERING TEST PROJECT AT
OAK RIDGE NATIONAL LABORATORY

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Prepared by
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1. SUMMARY

The project considered in this document is the Hot Engineering Test Project (HETP), which is to be located in largely existing facilities at Oak Ridge National Laboratory (ORNL). The project is a part of the National High Temperature Gas-Cooled Reactor Fuel Recycle Program, which seeks to demonstrate the technological feasibility of the recycle processes. The HETP will attempt to confirm the operability of the processes (proven feasible in cold or nonradioactive, bench-top experimentation) under the more realistic radioactive condition. As such, the operation will involve the reprocessing and refabrication of spent HTGR fuel rods obtained from the Fort St. Vrain reactor. The reference fuel is highly enriched uranium.

In addition to addressing the impacts to be expected from routine operation of the project, this report examines technical aspects of the processes involved, safeguards and transportation concerns, accident scenarios, the existing environment at the site, and possible alternatives to the project and presents a cost-benefit analysis.

Salient aspects of the report are:

1. No significant radiological impacts are expected from routine operation of the facility to any biota or ecosystem. Concentrations of one or more radionuclides in Whiteoak Lake will increase as a result of the combination of HETP wastes with other ORNL wastes. Total concentrations in receiving waters are expected to be well below recommended limits.
2. Nonradiological effects from construction activities and routine operation should be insignificant on land and water use and on terrestrial and aquatic ecosystems.
3. No significant socioeconomic impacts should occur from either construction or operation of the facility.
4. Some conservative accident scenarios depict significant releases of radioactivity. Analyses indicate, however, that effects should be localized and would not be severe for all but the most unlikely of such incidents.
5. No significant long-term commitment of resources is expected to be required for the project. Nor are any large quantities of scarce or critical resources likely to be irreversibly or irretrievably committed to the project.
6. Principal alternatives considered were: relocation of the project site, postponement of the project schedule, project cancellation, and chemical process variations. Considering the objectives of the National HTGR Recycle Development Program, none were judged to be as feasible as the proposed project.

2. PURPOSE AND DESCRIPTION OF HOT ENGINEERING TEST PROJECT

The National High-Temperature Gas-Cooled Reactor (HTGR) Fuel Recycle Program requires a Hot-Fuel Recycle Reference Facility (HRRF), which will demonstrate processes that are licensable and economically and technologically feasible. In support of the HRRF, the program plan calls for several steps to achieve the overall objective.

Cold development of the HTGR Fuel Recycle Process by use of ^{238}U as a substitute for the more radioactive fissile isotope contained in spent fuel has reached the stage that large-scale equipment is being tested.

Hot-engineering-scale tests using feed materials that would be typical for an HTGR fuel-recycle facility are required to demonstrate the operability of the cold processes developed. The reference fuel in this EIS is highly enriched uranium (HEU). Some assurance of the feasibility of the processes has been derived from known radiolysis data and laboratory-scale testing. However, full assurance can be obtained only with the higher levels of radioactivity associated with engineering-scale tests. Thus the need for the Hot-Engineering Tests (HET).

The purpose of the HTGR Fuel Recycle HET is to demonstrate those aspects of the HTGR Fuel Reprocessing and Refabrication Processes that can be proved only with the presence of the high level of radioactivity and fission products associated with irradiated fuel elements. The HET will provide verification and process data in a radiation environment which cannot be obtained in cold development work. The radiation environment is to be provided in the reprocessing demonstration by processing irradiated fuel containing fission products and in the refabrication demonstration by bred ^{233}U , containing ^{232}U and associated daughter products, from the National Uranium-233 Repository (NUR).

The HET will be located at the Oak Ridge National Laboratory (ORNL) at Oak Ridge, Tennessee. The principal building used will be the Thorium-Uranium Recycle Facility (TURF), Building 7930. Support locations will include:

1. Refabrication. Feed-material preparation in ORNL Building 3019.
2. Reprocessing. Unirradiated feed material preparation at General Atomic Company (GAC) in San Diego, California.
3. Reprocessing. Irradiated feed material shipment from Idaho National Engineering Laboratory (INEL) at Idaho Falls, Idaho.
4. Reprocessing. Irradiated feed material segmenting in ORNL Building 3026D.
5. Radioactive material storage in ORNL Building 7503.
6. Other support locations at ORNL, such as the Waste Burial Ground and the High Radiation Level Analytical Laboratory in Building 2026.

The overall HET project is divided into three parts -- Reprocessing Facility, Refabrication Facility, and Support Facility. The reprocessing and refabrication demonstrations are separate and distinct tests, which share the common support facility. The HET duration schedule anticipates fiscal year 1980 construction funding and is presented in Fig. 2.1.

Because of the national concern about nuclear proliferation, the utilization of proliferation resistant nuclear fuels is desirable. Amendments to the Conceptual Design Report and associated Cost Estimate are in preparation using medium enriched uranium (MEU) reference fuel.

2.1 DESCRIPTION OF SPENT-FUEL REPROCESSING

Reprocessing implies that spent fuel elements will undergo mechanical and chemical treatment for the purpose of reclaiming fertile and fissile heavy metals contained in them. Figure 2.2 illustrates in simplified form the major steps of reprocessing a spent fuel element. Because of the high radiation level associated with spent reactor fuels, the spent-fuel element must be properly shielded at all times, which requires special shipping casks and remote operation of process equipment in heavily shielded hot cells.

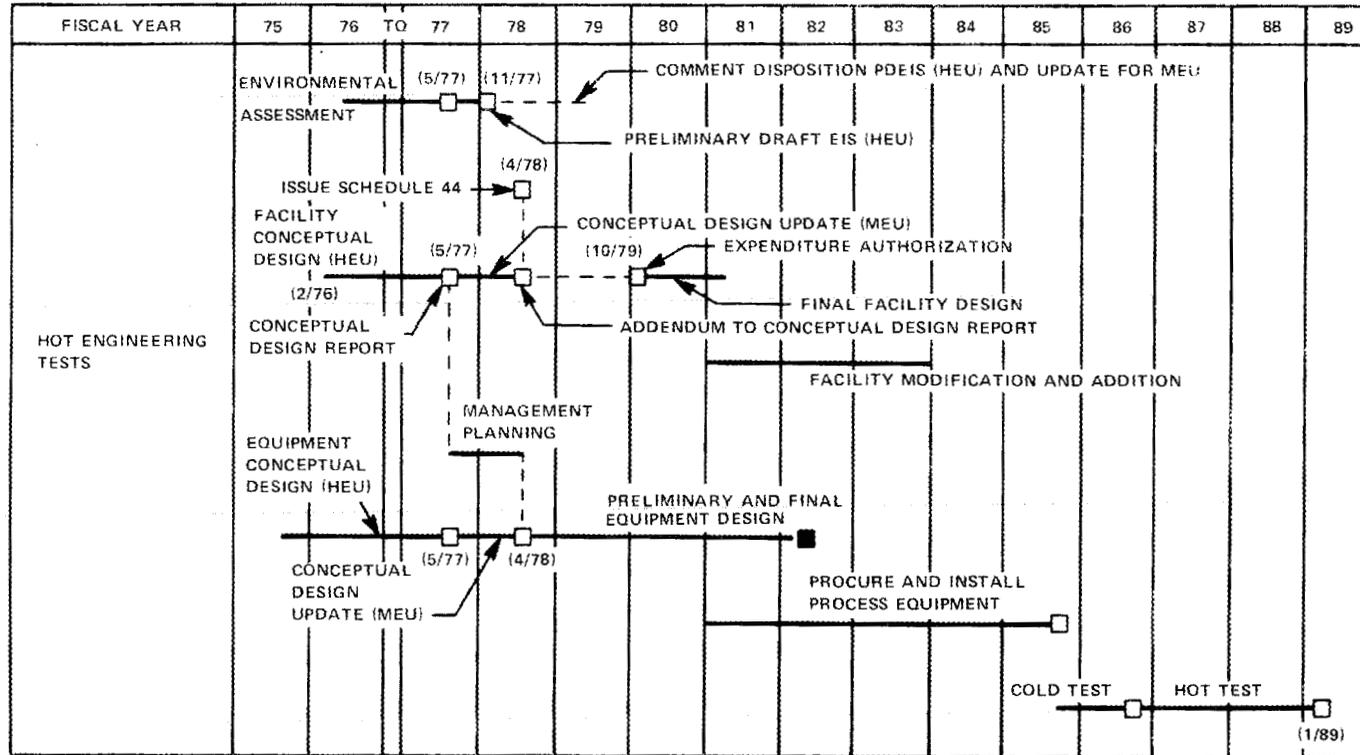
The first stage of reprocessing involves mechanically segmenting (sawing) the fuel element block into smaller pieces to facilitate mechanical crushing of the element. Important precautions of these two operations are the containment of dusts and off-gases that may be produced during operation. Filters and necessary off-gas treatment are utilized in conjunction with these process functions.

The properly sized particles resulting from crushing then undergo a fluidized-bed burning before being crushed and burned again in a separate fluidized-bed burner. These steps are necessary to remove carbonaceous filler material which bonds the heavy metal fuel particles together. As with segmenting and crushing, proper treatment of off-gas from the burner is provided.

Ash material produced from the burning steps is then leached with acid solution to dissolve the heavy metals that they contain. An insoluble material (SiC) used as a coating for heavy metals results from this dissolution step along with the feed solution material required for further reclamation steps. Off-gases produced from the dissolver are treated independently of other off-gases in the system. The insoluble leached hulls are recovered, washed, dried, collected, and stored in metal drums.

Solvent extraction is responsible for processing the acid solutions from dissolution in such a way as to remove highly radioactive fission products that are associated with spent reactor fuels and to separate and reclaim the heavy metals which will be used for reactor fuel recycle. This function is performed through five principal columns used to contact the acid solutions with the appropriate extracting material. Primary wastes are liquid in form. Liquid organic wastes are absorbed on vermiculite and sent to the solid-waste storage area (Sect. 2.3.2.3). Aqueous wastes are treated as intermediate-level wastes (Sect. 2.3.2.2). Off-gases from this system are treated in the same manner as those produced in the dissolution step.

The final step of reprocessing is concentration by evaporation of the product solutions from the solvent extraction step. Major wastes will result in the form of evaporation overhead condensate, which will be sent to the intermediate-level waste system for disposal. The product solutions are stored.



NOTES

- (1) NUMBERS IN PARENTHESES DENOTE CALENDAR YEAR
- (2) HEU – HIGHLY ENRICHED URANIUM
MEU – MEDIUM ENRICHED URANIUM
- (3) □ DENOTES KEY MILESTONES
- (4) ■ DENOTES MILESTONE BELIEVED TO BE ON CRITICAL PATH

Fig. 2.1. Preliminary Hot Engineering Test Project schedule.

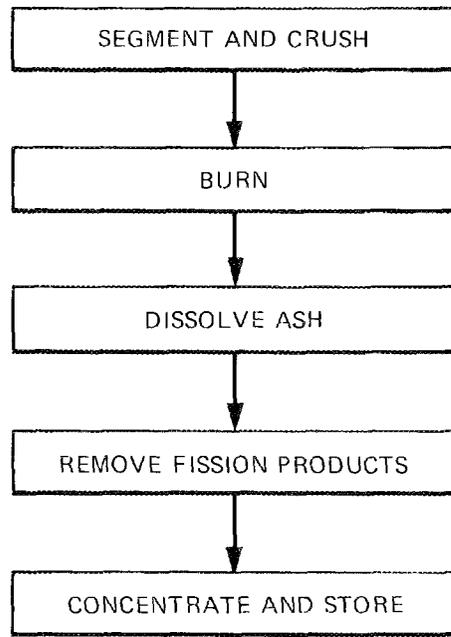
**REPROCESSING PRODUCES URANYL NITRATE
AND THORIUM NITRATE SOLUTIONS**

Fig. 2.2. Major steps in spent-fuel reprocessing.

For greater details of the operational functions of spent-fuel reprocessing, see Appendix A.

2.2 DESCRIPTION OF FUEL-ROD REFABRICATION

Refabrication of HTGR fuel elements is the process of taking the purified product solutions from the reprocessing operation containing the reclaimed heavy metals and fabricating a new fuel block suitable for use in a reactor. The purpose of the HET is to demonstrate only those parts of the reprocessing and refabrication processes that are sensitive to the radioactive environment of a hot cell facility. Therefore, refabrication in HET will use feed material currently stored in the National Uranium Repository (NUR) at ORNL and will carry the process only partially through the full refabrication process — that is, to the fabrication of fuel rods that are suitable for loading into the graphite fuel block. The major steps of fuel-rod refabrication are illustrated in simplified form in Fig. 2.3.

The HET will address four major steps in the refabrication process for HTGR fuel rods: (1) resin fuel kernel preparation, (2) resin carbonization, (3) microsphere coating, and (4) fuel rod fabrication. In addition the HET will have the necessary waste handling operations and sample handling equipment to support the HET equipment. All of these operations are to be performed in the shielded alpha facilities of the Thorium Uranium Recycle Facility (TURF), Building 7930.

REFABRICATION PREPARES "GREEN" FUEL RODS

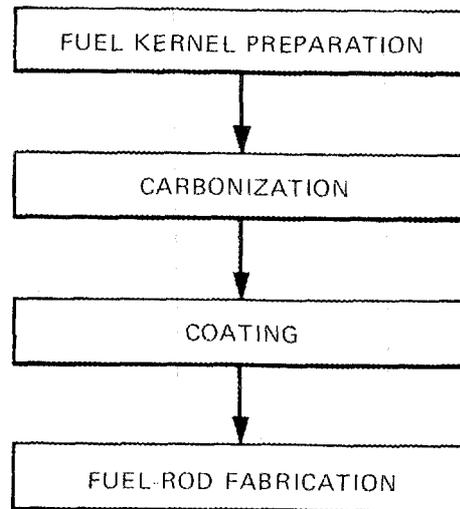


Fig. 2.3. Major steps in fuel-rod refabrication.

The resin fuel kernel preparation system receives uranyl nitrate solution from the NUR and loads the uranium onto ion exchange resin beads. In this step, acid-deficient uranyl nitrate solution is circulated through hydrogen-form resin beads, and uranium is loaded on these beads through an ion exchange involving UO_2^{2+} and H^+ ions. The loaded resin fuel kernels are then dried and transferred to the resin carbonization system.

The purpose of the resin carbonization step is to produce a fissile fuel kernel, uranium dioxide dispersed in an elemental carbon matrix, from the resin beads loaded with uranium. This is accomplished by heating the loaded resin particles in an inert-atmosphere, fluidized-bed, induction furnace. After cooling in the furnace, the particles are weighed and sampled. The loaded resin particles have a nominal diameter of 550 μm and a density of 1.7 g/cm^3 , and the carbonized resin particles have a diameter of 370 μm and a density of 2.5 g/cm^3 .

The furnace effluent and the spent pneumatic transfer gas (air or argon) are treated to remove hydrocarbon compounds driven off in the carbonization step and the ^{220}Rn present from the decay of ^{232}U . The furnace effluent is considered a combustible off-gas, and the transfer gas is considered noncombustible. The gases are treated separately.

The microsphere conversion and coating step produces coated fuel particles suitable for fabrication into fuel rods. The particles are processed five times in the conversion and coating furnace. The first process step converts part of the uranium dioxide in the fuel kernels to uranium carbide. The second through the fifth steps apply coatings of carbon and SiC (referred to as TRISO) to the converted fuel particles.

The off-gas treatment consists basically of two scrubbers: (1) a perchloroethylene scrubber to quench the off-gas and to remove soot and hydrocarbons and (2) a caustic scrubber to remove hydrogen chloride gas. After treatment, the furnace off-gas is routed to the facility combustible off-gas equipment. The spent transfer gas and any vessel off-gas is routed to the facility noncombustible off-gas equipment for radon removal and other processing. The spent perchloroethylene solvent is pumped to the process support system for reclamation. Spent sodium hydroxide scrub solution is sent to the ORNL ILW system (Sect. 2.3.2.2).

The purpose of the fuel rod fabrication step is to form a limited number of 5/8-in.-diam by 2-1/2-in.-long (1.59-cm by 6.35-cm) "green" (uncarbonized) fuel rods to test the product from the microsphere conversion and coating step and to supply the needs of the nondestructive assay development program. This is accomplished by homogeneously blending in batches (about 0.5 kg of uranium or 2.5 kg of particles) coated fissile particles (UO_2/UC) from the microsphere conversion and coating step with coated fertile particles (ThO_2) and shim particles (graphite) to form "green" fuel rods by the slug-injection process.

The refabrication process is described in much greater detail in Appendix B.

2.3 SUPPORT FACILITIES

2.3.1 Process support

The support facilities for reprocessing and refabrication interface with many operations within the HETP. Some important responsibilities of these support facilities are (1) handling, storage, and transportation of radioactive and nonradioactive materials; (2) furnishing utility services for the HETP; and (3) providing equipment and facilities for receiving, decontaminating, sampling, monitoring, assaying, and treating for disposal all solid, liquid, and gaseous wastes generated by the reprocessing and refabrication operations. All discharges to the environment are through ORNL waste disposal facilities, which are discussed in Sect. 2.3.2.

The reprocessing and refabrication support facilities are described in greater detail in Appendix C.

2.3.2 ORNL waste-disposal facilities

The HETP waste-handling facilities (see Sects. A.9, B.7, and C.8) interface with the ORNL waste-disposal facilities. Most operational releases to the environment from HETP operations are through ORNL facilities. Radioactive and nonradioactive wastes, whether gas, liquid, or solid, are combined and handled together as radioactive wastes. This policy is followed for both HETP and the entire laboratory. The estimated chemical requirements for the reprocessing and refabrication phases of the HET are given in Tables 2.1 and 2.2. Nearly all of these materials will eventually be disposed of through the ORNL waste-disposal facilities as gaseous, liquid, or solid wastes.

Table 2.1. Estimated chemical requirements, Hot-Engineering Test reprocessing

| Chemical | Estimated quantity per program |
|--|------------------------------------|
| CO ₂ | 461,000 liters (STP) |
| NH ₃ | 23,400 liters (STP) |
| O ₂ | 1.7 X 10 ⁷ liters (STP) |
| Tributylphosphate | 90 liters |
| <i>n</i> -Dodecane | 210 liters |
| HNO ₃ (in liquid effluent) | 2,400 kg |
| HF | 3 kg |
| Al(NO ₃) ₃ | 60 kg |
| Aluminosilicate catalysts and molecular sieves | 560 liters |

Table 2.2. Estimated chemical requirements, Hot-Engineering Test refabrication

| Chemical | Estimated quantity per program |
|---|--------------------------------|
| HNO ₃ | 1,000 kg |
| Th(NO ₃) ₄ | 3,000 kg |
| Al(OH) ₂ NO ₃ | 1,000 kg |
| NH ₄ Ac (ammonium acetate) | 100 kg |
| HAc (acetic acid) | 50 kg |
| NaOH | 700 kg |
| Perchloroethylene | 5,000 kg |
| Argon | 20,000 kg |
| Helium | 60 kg |
| Acetylene | 50 kg |
| Propene | 250 kg |
| Acrylic acid resin | 50 kg |
| Sulphonated styrene resin | 40 kg |
| CaO | 20 kg |
| Disecundary butyl phenyl phosphonate | 500 liters |
| Diethylbenzene | 530 liters |
| Amberlite LA-2 ^a secondary amine | 2 liters |
| Methyltrichlorosilane | 400 liters |
| Petroleum pitch | 4 kg |
| Graphite powder | 2 kg |
| Carbon shim particles | 2 kg |
| Hydrogen | 210 kg |

^aTrademark of Rohm and Haas Co., Philadelphia, Pa.

2.3.2.1 Gaseous wastes

Gaseous wastes from HETP operations are released at five locations (Table 2.3). The four stacks also serve other ORNL operations. It is Laboratory policy that the control and cleanup of waste gas, prior to its release, is the responsibility of the individual facility creating the gas. This is the reason the HETP has its own waste disposal facilities. At each location the particulate matter is expeditiously removed by a system of filters (roughing filters followed by absolute filters), which removes essentially all the particulate matter.

The origin of the waste gases that are discharged through the stacks fall into two classifications: cell-ventilation air and process off-gas. Each is served by its own collection system. Cell ventilation systems (sometimes called the "high-volume-low-level" systems) collect and clean the air from processing-equipment cells and laboratory analytical hoods. All major cell-ventilation ducts are monitored by tape monitors and are provided with flow-measuring devices.

Table 2.3. Gaseous release points for HETP facilities

| Stack | Diameter (ft) | Height (ft) | Normal air flow (cfm) | Building served |
|---------------------|---------------|-------------|-----------------------|--|
| 3020 | 5.75 | 200 | 36,000 | 3019 (building and cell ventilation) |
| 3039 | 8 | 250 | 135,000 | 3019 (off-gas) 3026D |
| 7512 | 3 | 100 | 20,000 | 7503 |
| 7911 | 5 | 250 | 36,000 | 7930 |
| 7930 (Roof vent) | 0.17 | 65 | ~2 | 7930 Refabrication: microsphere conversion and coating, and fuel-rod fabrication |

Important ducts in the 3039 stack area also have sampling ports to which collection samplers employing filter-charcoal cartridges may be attached. Ventilation air from Building 7503 in Melton Valley is discharged through the 7512 stack, which is equipped with absolute filters.

Off-gas is a stream of gaseous waste of much smaller volume than cell-ventilation waste but of much higher radioactivity. Off-gas lines are connected directly to operating equipment for venting or pressure-reduction purposes. In addition to radioactive emissions, off-gas systems must also dispose of organic vapors and acid and caustic fumes. A central system, terminating at the 3039 stack, serves the Bethel Valley area of the laboratory. The treatment facility includes a caustic scrubber for the removal of reactive gases and a high-efficiency filter unit to remove particulate matter. In Melton Valley, off-gas discharges from Building 7930 are through the 7911 stack, which is equipped with absolute filters.

The only HET operational gaseous discharges of significance are through either the 3039 stack in Bethel Valley, the 7911 stack in Melton Valley, or the roof vent on Building 7930. Table 2.4 lists the nonradioactive gases released from these discharge points. Table 2.5 lists the radioactivity from HET operations released through the stacks. Release rates of ^{85}Kr via the 7911 stack during fertile particle-burning campaigns are estimated to be about 300 Ci/week.

Table 2.4. Estimated annual routine HETP releases^a
of nonradioactive gases^b
(Project to last two years)

| Chemical | Total release | |
|-------------------------|-----------------|--------------------------|
| | Volume (liters) | Weight (kg) |
| 3039 Stack | | |
| Carbon dioxide | 8,600 | 17 |
| 7911 Stack | | |
| Carbon dioxide | 13,000,000 | 26,000 |
| Carbon monoxide | 15,000 | 19 |
| Nitrogen oxides | 210 | 0.44 (as NO_2) |
| Ammonia | 230 | 0.17 |
| Building 7930 roof vent | | |
| Argon | 3,200,000 | 5,700 |
| Helium | 110,000 | 20 |
| Carbon dioxide | 2,400 | 4.7 |
| Carbon monoxide | 6,800 | 8.5 |
| Hydrogen | 1,300,000 | 120 |
| Tetrachloroethylene | 97,000 | 410 |
| Acetylene | 1,900 | 2.2 |
| Propene | 13,000 | 24 |

^aEstimates include appropriate clean-up decontamination factors for processes involved.

^bReleases less than 100 g/year are not included.

Table 2.5. Estimated annual routine HETP gaseous releases^a of radionuclides

(Project to last 2 years)

| Radionuclide | 3039 Stack | | Radionuclide | 9711 Stack | |
|--------------------|------------------------|--------------------------------|--------------------|------------------------|--------------------------------|
| | Total release (pCi) | Average release rate (pCi/sec) | | Total release (pCi) | Average release rate (pCi/sec) |
| ³ H | 1.0 X 10 ¹⁴ | 3.2 X 10 ⁶ | ³ H | 3.5 X 10 ¹² | 1.1 X 10 ⁵ |
| ³⁶ Cl | 4.3 X 10 ¹⁰ | 1.4 X 10 ³ | ¹⁴ C | 6.6 X 10 ¹² | 2.1 X 10 ⁵ |
| ³⁹ Ar | 5.2 X 10 ¹² | 1.6 X 10 ⁵ | ³² P | 1.1 X 10 ¹⁰ | 3.3 X 10 ² |
| ⁸⁵ Kr | 1.0 X 10 ¹³ | 3.3 X 10 ⁵ | ³³ P | 7.9 X 10 ¹¹ | 2.5 X 10 ⁴ |
| ^{129m} Xe | 4.8 X 10 ³ | 1.5 X 10 ⁻⁴ | ³⁵ S | 5.0 X 10 ¹¹ | 1.6 X 10 ⁴ |
| ^{131m} Xe | 1.2 X 10 ³ | 3.7 X 10 ⁰ | ³⁶ Cl | 3.9 X 10 ³ | 1.2 X 10 ¹ |
| ¹³³ Xe | 1.7 X 10 ⁴ | 5.5 X 10 ⁻⁴ | ³⁷ Ar | 8.4 X 10 ¹⁰ | 2.7 X 10 ³ |
| ²²⁰ Rn | 9.9 X 10 ⁴ | 3.1 X 10 ⁻³ | ³⁹ Ar | 1.8 X 10 ¹⁰ | 6.3 X 10 ² |
| | | | ⁸⁵ Kr | 1.5 X 10 ¹⁶ | 4.7 X 10 ³ |
| | | | ¹²⁹ I | 3.2 X 10 ⁷ | 1.0 X 10 ⁰ |
| | | | ¹³¹ I | 5.9 X 10 ⁷ | 1.9 X 10 ⁰ |
| | | | ^{129m} Xe | 7.5 X 10 ⁶ | 2.4 X 10 ⁻¹ |
| | | | ^{131m} Xe | 2.0 X 10 ¹¹ | 6.2 X 10 ³ |
| | | | ²²⁰ Rn | 2.0 X 10 ⁵ | 6.4 X 10 ⁰ |

^a Estimates include appropriate cleanup decontamination factors for processes involved.

2.3.2.2 Liquid wastes

Two types of liquid radioactive wastes are produced at ORNL: intermediate-level and process (low-level) wastes.

Intermediate-level waste (ILW) is composed of a mixture of all of the liquid wastes other than process waste that are produced in hot-cell, pilot-plant, and reactor operations, including relatively small volumes of organic reagents and solvents. Thus the high-level wastes produced in pilot plants and hot cells are diluted by the lower level research wastes to form ILW. An evaporator has been used since 1965 to concentrate the ILW supernatant by a factor of 20 to 30; the concentrated product is stored prior to disposal by hydrofracture.

The shale-fracturing process is a waste-disposal method currently in use at ORNL for the permanent disposal of locally generated ILW solutions. In this process the waste solution is mixed with a solids blend of cement and other additives; the resulting grout is injected into an impermeable shale formation at a depth of 200 to 300 m (700 to 1000 ft), well below the level of groundwater. The initial fracture in the shale is generated by the hydraulic pressure of a small volume of water. Waste grout is then injected into this initial fracture. The injection pressure is sufficiently high to propagate a thin horizontal crack in the shale. As the injection of the grout continues, this crack is filled by the grout and is further extended so that a thin, approximately horizontal, grout sheet several hundred feet across is formed during the course of the injection. The grout sets a few hours after completion of the injection, thereby permanently fixing the radioactive wastes in the shale formation. Subsequent injections form sheets parallel to the first injection and a few feet above it. Monitoring wells are used to determine periodically the permeability of the shale cover rock at a depth of 180 m (600 ft). Any significant increase in this permeability would be a matter for further investigation. No such change has yet been noted.

Process waste-flows from Buildings 3019 and 3026D and other buildings in Bethel Valley are surged in a large earthen basin and processed through the process waste-treatment plant, which

uses a scavenging-precipitation-ion exchange process to give ^{137}Cs and ^{90}Sr decontamination factors of several hundred. The effluent is monitored and discharged into Whiteoak Creek. Process wastes in Melton Valley (Building 7930) pass through retention basins. If radioactivity is detected by the inlet flow monitors, the process waste is impounded into a holdup basin, from which it can be pumped to the treatment system in Bethel Valley.

The liquid wastes from HET operations consist of either ILW or low-level process wastes. As discussed above, ILW wastes are not released to the environment, but are fixed in solidified grout deep underground. It therefore follows that the only liquid release of radioactivity to the environment is from the process-waste system. It is assumed that radioactivity in this system arises only from carry-over of activity in the condensate from the ILW waste evaporator. Using a decontamination factor of 1×10^7 and an average flow in Whiteoak Creek¹ of 1×10^{13} ml/year, the activity and concentration of radioactivity released from Whiteoak Dam are shown in Table 2.6. Radionuclides are listed in column 1; total Ci/year discharged to the ILW system are listed in column 2; total Ci/year (from waste evaporator) released to Whiteoak Creek are listed in column 3, and the resulting average concentration released at Whiteoak Dam ($\mu\text{Ci/ml}$) is listed in column 4. No dilution by the Clinch River was assumed; the HET operational phase is expected to last for 2 years.

Because all radioactive liquid wastes and liquid effluents containing chemicals are discharged to the ILW system, the nonradioactive chemical releases to the environment are essentially zero. Nonradioactive or low-level process waste consists mainly of cooling water and condensate.

2.3.2.3 Solid wastes

Solid radioactive wastes generated at ORNL are collected in suitable containers and periodically transported to one of the solid-waste storage areas, commonly called "burial grounds," in which they are stored either above or below the land surface. More than 75% of the waste currently buried is low-level material consisting of a heterogeneous mass of absorbent paper, all types of glassware, scrap metal, dirt, various filter media and frames, lumber, wire, depleted uranium, animal carcasses used for biological experiments, and experimental equipment that cannot be economically decontaminated. HET operations will contribute to this waste.

Waste at ORNL is handled in accordance with UCC-ND Standard Practice Procedure D-5-15, "Waste Management and Environmental Pollution Control." The initial handling and packaging of radioactive wastes at the point of origin is governed by two requirements: (1) to protect personnel from exposure to direct radiation and contamination and (2) to ensure that the various classes of materials are placed in appropriate containers for the types of storage prescribed.

A number of different types of facilities are used for the storage of solid radioactive wastes. These range from (1) trenches in which the material is placed and buried to (2) stainless-steel-lined auger holes for cylindrical drums or packages of various diameters to (3) above-ground roofed buildings. The choice of facility depends on whether or not the material will need to be retrieved and on the intensity and character of the radiation involved. The HET solid wastes (Sects. A.9.3, B.7.3, and C.8) will conform to ORNL procedures and become a part of ORNL wastes. Solid wastes expected from HET operations are listed in Table 2.7.

Table 2.6. Annual flows of radionuclides in liquid effluent streams

| RADIONUCLIDE | RELEASE TO TREATMENT SYSTEM (CHIEFS) | RELEASE TO ENVIRONMENT (CHIEFS) | CONCENTRATION ^a (MICROCURIES PER MILLILITER) |
|--------------|--------------------------------------|---------------------------------|---|
| BE- 10 | 4.7E-03 | 4.7E-10 | 4.7E-17 |
| P- 32 | 7.8E-05 | 7.8E-12 | 7.8E-19 |
| P- 33 | 5.9E-03 | 5.9E-10 | 5.9E-17 |
| S- 35 | 3.8E-03 | 3.8E-10 | 3.8E-17 |
| K- 40 | 1.2E-06 | 1.2E-13 | 1.2E-20 |
| CA- 41 | 3.9E-02 | 3.9E-09 | 3.9E-16 |
| CA- 45 | 4.0E-03 | 4.0E-10 | 4.0E-17 |
| CA- 47 | 5.0E-14 | 5.0E-21 | 5.0E-28 |
| SC- 46 | 1.0E-06 | 1.0E-07 | 1.0E-14 |
| SC- 47 | 2.1E-13 | 2.1E-20 | 2.1E-27 |
| SC- 48 | 4.9E-31 | 4.9E-38 | 4.9E-45 |
| CO- 51 | 1.3E-00 | 1.2E-07 | 1.2E-14 |
| MN- 54 | 4.6E-00 | 4.6E-07 | 4.6E-14 |
| FA- 55 | 1.1E-02 | 1.1E-05 | 1.1E-12 |
| FE- 59 | 4.5E-01 | 4.5E-08 | 4.5E-15 |
| CU- 58 | 3.8E-00 | 3.8E-07 | 3.8E-14 |
| CO- 60 | 2.2E-03 | 2.2E-04 | 2.2E-11 |
| NI- 59 | 3.0E-02 | 3.0E-09 | 3.0E-16 |
| NI- 63 | 4.6E-00 | 4.6E-07 | 4.6E-14 |
| ZN- 72 | 1.6E-27 | 1.6E-24 | 1.6E-41 |
| GA- 72 | 2.3E-27 | 2.3E-24 | 2.3E-41 |
| AS- 77 | 5.0E-31 | 5.0E-38 | 5.0E-45 |
| SE- 77M | 1.5E-33 | 1.5E-40 | 1.5E-47 |
| SE- 79 | 3.9E-01 | 3.9E-08 | 3.9E-15 |
| RE- 86 | 9.6E-01 | 9.6E-08 | 9.6E-15 |
| RE- 87 | 2.3E-05 | 2.3E-12 | 2.3E-19 |
| SR- 89 | 3.9E-04 | 3.9E-03 | 3.9E-10 |
| SR- 90 | 5.9E-04 | 5.9E-03 | 5.9E-10 |
| Y- 90 | 5.9E-04 | 5.9E-03 | 5.9E-10 |
| Y- 91 | 5.2E-04 | 5.2E-03 | 5.2E-10 |
| ZR- 93 | 1.3E-00 | 1.3E-07 | 1.3E-14 |
| ZR- 95 | 6.8E-04 | 6.8E-03 | 6.8E-10 |
| NE- 92 | 1.0E-06 | 1.0E-13 | 1.0E-20 |
| NE- 93M | 2.0E-01 | 2.0E-08 | 2.0E-15 |
| NE- 94 | 9.9E-06 | 9.9E-13 | 9.9E-20 |
| NB- 95 | 1.3E-05 | 1.3E-02 | 1.3E-09 |
| NB- 95M | 1.4E-03 | 1.4E-04 | 1.4E-11 |
| MO- 93 | 9.1E-04 | 9.1E-11 | 9.1E-18 |
| MO- 99 | 8.7E-15 | 8.7E-22 | 8.7E-29 |
| TC- 99 | 3.3E-00 | 3.3E-07 | 3.3E-14 |
| TC- 99M | 8.3E-15 | 8.3E-22 | 8.3E-29 |
| AU-103 | 1.4E-02 | 1.4E-05 | 1.4E-12 |
| RD-106 | 3.6E-02 | 3.6E-05 | 3.6E-12 |
| RH-103M | 3.8E-03 | 3.8E-04 | 3.8E-11 |
| RH-105 | 1.4E-32 | 1.4E-29 | 1.4E-46 |
| RH-106 | 9.9E-03 | 9.9E-04 | 9.9E-11 |
| PD-107 | 4.7E-03 | 4.7E-10 | 4.7E-17 |
| CD-109 | 2.2E-06 | 2.2E-13 | 2.2E-20 |
| CD-113M | 5.1E-00 | 5.1E-07 | 5.1E-14 |
| CD-115 | 9.2E-22 | 9.2E-29 | 9.2E-36 |

Table 2.6 (continued)

| RADIONUCLIDE | RELEASE TO TREATMENT SYSTEM (CURIES) | RELEASE TO ENVIRONMENT (CURIES) | CONCENTRATION (MICROCURIES PER MILLILITER) |
|--------------|---|---------------------------------------|---|
| CD-115M | 6.0E-00 | 6.3E-07 | 6.9E-14 |
| IN-114 | 1.5E-01 | 1.5E-08 | 1.5E-15 |
| IN-114M1 | 1.6E-01 | 1.6E-08 | 1.6E-15 |
| IN-115M | 1.0E-01 | 1.0E-08 | 1.0E-15 |
| SN-117M | 1.0E-02 | 1.0E-09 | 1.0E-16 |
| SN-119M | 2.0E-00 | 2.0E-07 | 2.0E-14 |
| SN-121M | 1.7E-02 | 1.7E-10 | 1.7E-17 |
| SN-123 | 1.1E-03 | 1.1E-04 | 1.1E-11 |
| SN-125 | 7.2E-03 | 7.2E-10 | 7.2E-17 |
| SN-126 | 2.2E-01 | 2.2E-08 | 2.2E-15 |
| SB-124 | 6.4E-01 | 6.4E-06 | 6.4E-13 |
| SB-125 | 4.2E-03 | 4.2E-04 | 4.2E-11 |
| SB-126 | 5.7E-01 | 5.7E-08 | 5.7E-15 |
| SB-126M | 2.2E-01 | 2.2E-08 | 2.2E-15 |
| SB-127 | 4.8E-10 | 4.8E-17 | 4.8E-24 |
| TE-123M | 2.5E-01 | 2.5E-08 | 2.5E-15 |
| TE-125M | 1.7E-03 | 1.7E-04 | 1.7E-11 |
| TE-127 | 2.7E-03 | 2.7E-04 | 2.7E-11 |
| TE-127M | 2.8E-03 | 2.8E-04 | 2.8E-11 |
| TE-129 | 4.0E-02 | 4.0E-05 | 4.0E-12 |
| TE-129M | 6.2E-02 | 6.2E-05 | 6.2E-12 |
| TE-131M | 1.7E-09 | 1.7E-06 | 1.7E-03 |
| TE-132 | 8.5E-12 | 8.5E-19 | 8.5E-26 |
| I- 129 | 2.4E-06 | 2.4E-13 | 2.4E-20 |
| I- 131 | 4.3E-06 | 4.3E-13 | 4.3E-20 |
| I- 132 | 7.8E-16 | 7.8E-23 | 7.8E-30 |
| CS-134 | 1.0E-05 | 1.0E-02 | 1.0E-09 |
| CS-135 | 1.0E-01 | 1.0E-08 | 1.0E-15 |
| CS-136 | 1.9E-00 | 1.9E-07 | 1.9E-14 |
| CS-137 | 3.9E-04 | 3.9E-03 | 3.9E-10 |
| BA-137M | 5.8E-04 | 5.8E-03 | 5.8E-10 |
| BA-140 | 2.8E-01 | 2.8E-06 | 2.8E-13 |
| LA-140 | 3.3E-01 | 3.3E-06 | 3.3E-13 |
| CE-141 | 1.2E-04 | 1.2E-03 | 1.2E-10 |
| CE-143 | 2.1E-34 | 2.1E-41 | 2.1E-48 |
| CE-144 | 2.4E-05 | 2.4E-02 | 2.4E-09 |
| PR-143 | 6.3E-01 | 6.3E-06 | 6.3E-13 |
| PR-144 | 2.4E-05 | 2.4E-02 | 2.4E-09 |
| ND-147 | 2.8E-00 | 2.8E-07 | 2.8E-14 |
| FM-147 | 2.4E-04 | 2.4E-03 | 2.4E-10 |
| PM-148 | 4.6E-01 | 4.6E-06 | 4.6E-13 |
| PM-148M | 5.7E-02 | 5.7E-05 | 5.7E-12 |
| PM-149 | 6.4E-20 | 6.4E-27 | 6.4E-34 |
| SM-151 | 2.1E-02 | 2.1E-05 | 2.1E-12 |
| SM-153 | 4.0E-23 | 4.0E-30 | 4.0E-37 |
| EU-152 | 2.3E-00 | 2.3E-07 | 2.3E-14 |
| EU-154 | 4.1E-03 | 4.1E-04 | 4.1E-11 |
| EU-155 | 3.2E-03 | 3.2E-04 | 3.2E-11 |
| EU-156 | 3.5E-01 | 3.5E-06 | 3.5E-13 |
| TB-160 | 2.7E-01 | 2.7E-06 | 2.7E-13 |

Table 2.6 (continued)

| RADIONUCLIDE | RELEASE TO TREATMENT SYSTEM (CURIES) | RELEASE TO ENVIRONMENT (CURIES) | CONCENTRATION (MICROCURIES PER MILLILITER) |
|--------------|---|---------------------------------------|---|
| TE-161 | 2.2E-07 | 2.2E-14 | 2.2E-21 |
| DY-166 | 4.5E-18 | 4.5E-25 | 4.5E-32 |
| HO-166 | 3.3E-17 | 3.3E-24 | 3.3E-31 |
| HO-166M1 | 3.2E-04 | 3.2E-11 | 3.2E-18 |
| EA-167 | 1.6E-05 | 1.6E-12 | 1.6E-19 |
| W- 181 | 5.1E-01 | 5.1E-08 | 5.1E-15 |
| W- 185 | 4.1E-01 | 4.1E-06 | 4.1E-13 |
| TL-207 | 2.2E-02 | 2.2E-09 | 2.2E-16 |
| TL-208 | 1.2E-01 | 1.2E-06 | 1.2E-13 |
| TL-209 | 3.4E-04 | 3.4E-11 | 3.4E-18 |
| PE-209 | 1.6E-02 | 1.6E-09 | 1.6E-16 |
| PE-210 | 2.3E-06 | 2.3E-13 | 2.3E-20 |
| PE-211 | 2.2E-02 | 2.2E-09 | 2.2E-16 |
| PE-212 | 3.3E-01 | 3.3E-06 | 3.3E-13 |
| PE-214 | 2.0E-05 | 2.0E-12 | 2.0E-19 |
| BI-210 | 2.3E-06 | 2.3E-13 | 2.3E-20 |
| BI-210M | 3.8E-07 | 3.8E-14 | 3.8E-21 |
| BI-211 | 2.2E-02 | 2.2E-09 | 2.2E-16 |
| BI-212 | 3.3E-01 | 3.3E-06 | 3.3E-13 |
| BI-213 | 1.6E-02 | 1.6E-09 | 1.6E-16 |
| BI-214 | 2.0E-05 | 2.0E-12 | 2.0E-19 |
| PO-210 | 8.5E-02 | 8.5E-09 | 8.5E-16 |
| PO-211 | 6.6E-05 | 6.6E-12 | 6.6E-19 |
| PO-212 | 2.1E-01 | 2.1E-06 | 2.1E-13 |
| PO-213 | 1.5E-02 | 1.5E-09 | 1.5E-16 |
| PO-214 | 2.0E-05 | 2.0E-12 | 2.0E-19 |
| PO-215 | 2.2E-02 | 2.2E-09 | 2.2E-16 |
| PO-216 | 3.3E-01 | 3.3E-06 | 3.3E-13 |
| PO-218 | 2.0E-05 | 2.0E-12 | 2.0E-19 |
| AY-217 | 1.6E-02 | 1.6E-09 | 1.6E-16 |
| RA-222 | 1.7E-05 | 1.7E-12 | 1.7E-19 |
| FR-221 | 1.5E-02 | 1.5E-09 | 1.5E-16 |
| FR-223 | 3.1E-04 | 3.1E-11 | 3.1E-18 |
| RA-223 | 2.2E-02 | 2.2E-09 | 2.2E-16 |
| RA-224 | 3.3E-01 | 3.3E-06 | 3.3E-13 |
| RA-225 | 1.6E-02 | 1.6E-09 | 1.6E-16 |
| RA-226 | 2.0E-05 | 2.0E-12 | 2.0E-19 |
| RA-228 | 8.0E-03 | 8.0E-10 | 8.0E-17 |
| AC-228 | 1.6E-02 | 1.6E-09 | 1.6E-16 |
| AC-227 | 2.2E-02 | 2.2E-09 | 2.2E-16 |
| AC-228 | 8.0E-03 | 8.0E-10 | 8.0E-17 |
| TH-227 | 1.8E-06 | 1.8E-13 | 1.8E-20 |
| TH-228 | 2.7E-03 | 2.7E-10 | 2.7E-17 |
| TH-229 | 1.3E-06 | 1.3E-13 | 1.3E-20 |
| TH-230 | 2.8E-07 | 2.8E-14 | 2.8E-21 |
| TH-231 | 2.4E-07 | 2.4E-14 | 2.4E-21 |
| TH-232 | 1.4E-06 | 1.4E-13 | 1.4E-20 |
| TH-234 | 3.2E-04 | 3.2E-11 | 3.2E-18 |
| PA-231 | 1.8E-01 | 1.8E-08 | 1.8E-15 |
| PA-232 | 3.2E-38 | 3.2E-45 | 3.2E-52 |

Table 2.6 (continued)

| RADIONUCLIDE | RELEASE TO TREATMENT SYSTEM (CURIES) | RELEASE TO ENVIRONMENT (CURIES) | CONCENTRATION (MICROCURIES PER MILLILITER) |
|---------------------|--------------------------------------|---------------------------------|--|
| PA-233 | 9.2E-04 | 9.2E-03 | 9.2E-17 |
| PA-234 | 3.9E-03 | 3.9E-10 | 3.9E-17 |
| PA-234 ^M | 3.9E-00 | 3.9E-07 | 3.9E-14 |
| U- 232 | 1.3E-02 | 1.3E-09 | 1.3E-16 |
| U- 233 | 9.0E-02 | 9.0E-10 | 9.0E-17 |
| U- 234 | 1.9E-03 | 1.9E-10 | 1.9E-17 |
| U- 235 | 7.0E-07 | 7.0E-14 | 7.0E-21 |
| U- 236 | 2.4E-05 | 2.4E-12 | 2.4E-19 |
| U- 237 | 1.7E-05 | 1.7E-12 | 1.7E-19 |
| U- 238 | 3.1E-08 | 3.1E-15 | 3.1E-22 |
| U- 240 | 2.6E-17 | 2.6E-24 | 2.6E-31 |
| NP-237 | 2.5E-01 | 2.5E-08 | 2.5E-15 |
| NP-238 | 7.8E-21 | 7.8E-28 | 7.8E-35 |
| NP-239 | 1.7E-00 | 1.7E-07 | 1.7E-14 |
| NP-240 ^M | 1.1E-13 | 1.1E-20 | 1.1E-27 |
| PU-236 | 2.9E-01 | 2.9E-08 | 2.9E-15 |
| PU-238 | 5.0E-03 | 5.0E-04 | 5.0E-11 |
| PU-239 | 4.0E-00 | 4.0E-07 | 4.0E-14 |
| PU-240 | 4.4E-00 | 4.4E-07 | 4.4E-14 |
| PU-241 | 2.7E-03 | 2.7E-04 | 2.7E-11 |
| PU-242 | 6.2E-02 | 6.2E-09 | 6.2E-16 |
| PU-243 | 1.0E-06 | 1.0E-13 | 1.0E-20 |
| PU-244 | 1.1E-13 | 1.1E-20 | 1.1E-27 |
| AM-241 | 6.8E-00 | 6.8E-07 | 6.8E-14 |
| AM-242 | 2.7E-01 | 2.7E-08 | 2.7E-15 |
| AM-242 ^M | 2.7E-01 | 2.7E-08 | 2.7E-15 |
| AM-243 | 1.7E-00 | 1.7E-07 | 1.7E-14 |
| AM-245 | 1.0E-06 | 1.0E-13 | 1.0E-20 |
| CM-242 | 5.3E-02 | 5.3E-05 | 5.3E-12 |
| CM-243 | 1.5E-01 | 1.5E-08 | 1.5E-15 |
| CM-244 | 6.6E-02 | 6.6E-05 | 6.6E-12 |
| CM-245 | 1.9E-01 | 1.9E-08 | 1.9E-15 |
| CM-246 | 1.1E-01 | 1.1E-08 | 1.1E-15 |
| CM-247 | 1.1E-06 | 1.1E-13 | 1.1E-20 |
| CM-248 | 1.1E-05 | 1.1E-12 | 1.1E-19 |
| CM-249 | 2.5E-09 | 2.5E-16 | 2.5E-23 |
| CM-250 | 5.5E-12 | 5.5E-19 | 5.5E-26 |
| EK-249 | 7.0E-02 | 7.0E-09 | 7.0E-16 |
| CF-249 | 1.3E-04 | 1.3E-11 | 1.3E-18 |
| CF-250 | 1.3E-03 | 1.3E-10 | 1.3E-17 |
| CF-251 | 1.4E-05 | 1.4E-12 | 1.4E-19 |
| CF-252 | 6.2E-03 | 6.2E-10 | 6.2E-17 |
| CF-253 | 8.1E-07 | 8.1E-14 | 8.1E-21 |
| CF-254 | 4.2E-08 | 4.2E-15 | 4.2E-22 |
| ES-253 | 1.0E-05 | 1.0E-12 | 1.0E-19 |

^aAt Whiteoak Dam.

Table 2.7. Estimated volume of solid waste produced by HETP

| Source | Volume (liter) | Comment |
|--|------------------------------------|---|
| Reprocessing | | |
| SiC hulls and insols | 750 | Fissile alpha classification likely on this item |
| Sintered metal filters | 50 | |
| Spent catalyst and molecular sieves | 600 | |
| Tritiated water on molecular sieve | 50 | 820 Ci |
| Organic liquids in vermiculite | 300 | |
| Miscellaneous solid wastes | 2,000 | Poorly defined; believed conservative |
| Decommissioning | <u>40,000</u> | Poorly defined; believed conservative |
| Total | ~44,000 (1600 ft ³) | |
| Refabrication | | |
| Organic liquid waste in vermiculite | 80 | Assumed volume four times that of vermiculite |
| Solid process waste | 100 | |
| Miscellaneous solid waste | 5,000 | Manipulator boots, bags, etc. |
| Failed equipment items | 3,000 | From 2 yr of hot operation |
| Decommissioning | <u>60,000</u> | Volume of cell used divided by 4 |
| Total | ~68,000 (2400 ft ³) | |
| Support facilities | | |
| Construction | 310,000 | Waste from pre-HETP cleanup of cell G (7930) is not included |
| Operation | 92,000 | Possibly 2900 liters will have fissile alpha classification |
| Decommissioning | <u>57,000</u> | |
| Total | ~460,000 (16,000 ft ³) | |
| Grand total | ~580,000 (20,000 ft ³) | |

2.3.2.4 Sanitary wastes

ORNL has a central sanitary sewer system to which Buildings 3019 and 3026D are connected. Sewage is treated in two-stage series-flow aeration lagoons, which are lined with membranes to prevent infiltration. Air is supplied by a blower and distributed by a manifolded-header system to aerators located on the lagoon bottoms. The two lagoons contain approximately one million gallons (3800 m³) each, providing a total detention time of about 14 days. The exposed water surface area is about 0.75 acre (0.3 ha) per lagoon. The effluent discharge limits in the NPDES permit are given in Table 2.8 together with the compliance experience.

The sanitary wastes from the Melton Valley area are trucked to and treated at the Main Sanitary Facility discussed above.

Table 2.8. National Pollutant Discharge Elimination System (NPDES) experience for main sanitary facility for 1976

| Effluent characteristic | Discharge limitation | Percentage of measurements in compliance |
|--|------------------------------------|--|
| Ammonia (N) ^a | 5 mg/liter, 15 lb/day | 15 |
| Biochemical oxygen demand (BOD) ^a | 20 mg/liter, 60 lb/day | 44 |
| Suspended solids (SS) ^a | 30 mg/liter, 90 lb/day | 92 |
| Fecal coliform bacteria | 400/100 ml (weekly geometric mean) | 92 |
| Chlorine residual | 0.5 to 2.0 ppm | 97 |
| pH | 6.0 to 9.0 (standard units) | 100 |

^aDaily maximum.

Source: Energy Research and Development Administration, *Environmental Monitoring Report, United States Energy Research and Development Administration, Oak Ridge Facilities, Calendar Year 1976*, Y/UB-6, Union Carbide Corp., May 1, 1977.

2.3.3 Buildings

2.3.3.1 Building 3019

Building 3019 will house equipment for feed-material preparation and will store ²³³U feed material to be supplied to refabrication from the National ²³³U Repository located in this building. Analytical support will accompany Building 3019 process and other facility operations.

Building 3019 was constructed in 1943 and is a three-level steel-frame structure with concrete-block and metal siding. It has a gross floor area of about 1410 m² (15,200 ft²) and contains 15 shielded cells. This building (also 3026D, 7503, and 7930) was constructed before tornadoes and earthquakes became design factors. Because of the short duration (2 years for hot operation) of the HETP and the low probability of a severe tornado occurring in the Oak Ridge area, a limited tornado design criteria for Buildings 3019, 7503, and 7930 was considered acceptable.^{2,3} The tornado design basis consists of a maximum wind speed of 250 km/hr (156 mph), a pressure drop of 2200 Pa (0.32 psi), and a rate of pressure drop of 1030 Pa/sec (0.15 psi/sec). The earthquake design basis approved for the same buildings is a peak horizontal ground acceleration of 0.15 g and a peak vertical acceleration of 0.10 g. These values were based on independent investigations^{4,5} made for establishing seismic-design criteria for gaseous diffusion plants.

Portions of the buildings to be used by the HETP could not survive the limited conditions listed above. In a study⁶ by the Ralph M. Parsons Company, it was shown that in their present condition unreinforced concrete-block walls in both Buildings 3019 and 7930 would fail and that cell windows and service connections would be vulnerable to fragments from these walls. To reduce this risk, metal siding will be added to the inside surfaces of such walls. In addition, certain structural members of the buildings will be strengthened.

Wastes

Wastes that are produced by HET operations in Building 3019 are summarized in Table 2.9.

In Building 3019, where freshly separated uranium feed solutions (Sect. B.1) are prepared for the resin-loading operations, the potentially hazardous effluents are acid vapors and radon.

Table 2.9. HET wastes handled in Building 3019 -- uranium feed (System 4400)

| Waste component | State | Quantity | Disposal |
|----------------------------------|--------|--------------------------|---------------------------------|
| (1) Extraction column waste | Liquid | 63 liter/hr | Intermediate-level waste system |
| (2) Evaporator condensate | Liquid | 17 liter/hr | Intermediate-level waste system |
| (3) Ion exchange waste | Liquid | 130 liter (maximum) | Intermediate-level waste system |
| (4) Vessel off-gas | Gas | 14 m ³ /min | 3039 stack |
| (5) Cell--building ventilation | Gas | 1000 m ³ /min | 3020 stack |
| (6) Organic liquid (vermiculite) | Solid | | Solid-waste storage areas |

The off-gas streams from the vessels are therefore sent through a caustic scrubber, a radon trap, and HEPA filters before being discharged to the ORNL central off-gas facility (Sect. 2.3.2.1) and subsequently to the atmosphere through the 3039 stack. Process off-gas from Building 3019 contributes a nominal 14 m³/min (500 cfm) to the overall stack flow of 3800 m³/min (135,000 cfm). Cell and building ventilation air is discharged through a series of HEPA filters to the 3020 stack. Nominal output (for current levels) from the Building 3020 stack is approximately 1000 m³/min (36,000 cfm), half from Building 3019 cell ventilation and half from Building 3019 ventilation air.

Essentially six types of liquid-waste streams are produced by HET operations: high-level radioactive waste, intermediate-level process wastes, potentially contaminated process aqueous wastes, organic process wastes, sanitary wastes, and storm drainage. Of these, only the storm drainage is discharged directly to the surrounding environment. Sanitary wastes are transported by gravity through an 8-in. vitrified clay sewer that runs along the south side of Hillside Avenue and turns south at Fifth Street enroute to the pumping station. From the pumping station, the wastes are conveyed to the main sewer-treatment plant (Sect. 2.3.2.4).

Contaminated liquid wastes generated in Building 3019 are collected in special tanks, monitored, treated, and pumped via high-integrity stainless-steel piping to the ORNL ILW collection and treatment system (Sect. 2.3.2.2). Potentially contaminated aqueous wastes, principally process cooling water, are generated in Building 3019 and collected in a surge basin from which they are pumped to the ORNL Low-Level Waste Treatment Plant. Organic liquid wastes are disposed of by adsorption on a solid such as vermiculite and treated as a solid waste for disposal.

In general, all solid chemical wastes from operation of the HET can potentially be contaminated with radioactive material and are handled as radioactive solid wastes. All radioactive solid waste is collected and packaged for disposal in the ORNL solid waste storage area.

Safeguards

Existing safeguards in Building 3019 are being upgraded as part of an ongoing ORNL-wide program. When completed, all current DOE requirements for physical protection will be satisfied.

Specific physical safeguards are provided. These are based on the state and quantities of special nuclear materials and meet ERDA Manual Chapter 2405 and ORNL Laboratory Protection Division requirements.

Except for waste assay (for which R&D is required), accountability for special nuclear material is discussed in the Reprocessing and Refabrication Conceptual Design Reports, Documents X-OE-42 and -43.

2.3.3.2 Building 3026D

Building 3026D will house equipment for segmenting HTGR fresh and irradiated fuel elements for use as fuel reprocessing material. The HETP material will be present as whole elements or segments thereof, not in a readily dispersible form. The only dispersible material will be the very small quantity of graphite block cuttings contained in the off-gas system of the segmenting enclosure or in cans awaiting transfer to the burial ground. As this material contains principally small quantities of activation products, the associated hazard will be relatively small.

Building 3026D was constructed in 1944 and 1945 and is a three-level wooden-frame structure, built around three concrete-and-steel cells, with a total floor area of about 38 m² (410 ft²). The walls and floors are of stainless steel. The wooden frame structure, however, was not built to withstand the limited tornado-design criteria or the earthquake-design-basis criteria approved for the other three buildings involved in the HETP (Sect. 2.3.3.1). Because of the short duration of the HETP, the small hazard associated with the small amount of dispersible material present, the very low probability of occurrence of a severe tornado or earthquake in the Oak Ridge area, and the special design provisions to be made in the segmenting process to insure containment of radioactive material, tornado and earthquake protection of this building was not deemed necessary.⁷ The large cell is equipped with a CO₂ fire protection system.

Wastes

All operations generate or have the potential for generating radioactive wastes. All forms of these wastes (gas, liquid, and solid), are properly treated before removal from containment areas. Appropriate retrievable storage is required for solid scrap and waste.

In Building 3026D where fuel segmenting (Sect. A.1) is done, the graphite dust resulting from sawing the fuel element is the only dispersible material in the cell that contains radioactivity. This dust is expected to contain a conservatively estimated maximum of 50 Ci of radioactivity per fuel element. The sawing operation is conducted in enclosed equipment, which was designed to collect continuously and to contain the dust in a receiver that is protected against damage from falling or moving objects within the cell.

The off-gas treatment system consists of a high-efficiency (95% by the National Bureau of Standards Atmospheric Stain Test) filter, a charcoal filter for iodine and radon removal, and an ultra-high-efficiency (99.97% by the dioctyl phthalate Smoke Test) HEPA filter. The filters are contained in the "physically secure receiver," which is disposed of periodically (maximum time of one campaign consisting of 12 fuel elements). The probability of release of significant quantities of radioactivity is insignificant. All gaseous discharges from Building 3026D are through the 3039 stack.

Under normal operations, the only liquid waste from Building 3026D is sanitary waste, which is discharged to the ORNL central sanitary waste facility (Sect. 2.3.2.4).

Solid wastes from Building 3026D will be packaged, assayed in Building 7930 (Sect. 2.3.3.4), and sent to the ORNL solid waste storage area.

Safeguards

An ultrasonic intrusion detection system is provided to cover cell A roof plugs, cell A south door, and the floor plug to the transfer tunnel in the operating gallery.

2.3.3.3 Building 7503

Building 7503 was constructed in 1954 and modified in 1961 to house the Molten-Salt Reactor Experiment. It will be used to store radioactive materials for the HET. The fire-alarm and sprinkler system is in service and is maintained by the ORNL Fire Department. See Sect. 2.3.3.1 for tornado and earthquake design criteria.

Wastes

No particular environmental considerations exist regarding gaseous effluents associated with either the transport of material (Sect. 2.4.2) between the various buildings involved in the HET or with the storage of material in Building 7503. The material is to be in leak-tight containers. A new storage-cell ventilation system, hardened to withstand natural disturbance loads, is to be added to remove the decay heat. After passing through HEPA filters, the cell exhaust air is to be discharged through the existing 100-ft-high stack (stack 7512).

There will be no liquid or solid waste generated by HET in Building 7503. A septic tank is available for sanitary wastes.

2.3.3.4 Building 7930

Building 7930 will house the major test equipment for the HET reprocessing and refabrication processes. The operations in Building 7930 are by far the greatest potential source of gaseous, liquid, and solid effluents of environmental concern.

Building 7930, the Thorium-Uranium Recycle Facility (TURF), is a three-floor building with a gross floor area of 3300 m² (35,000 ft²), containing six shielded cells. It is constructed of reinforced concrete and steel with concrete-block and brick-veneer walls. The building is provided with a fire-sprinkler system; the cells are provided with an automatic CO₂ system.⁸ The adequacy of the in-cell CO₂ system has been reviewed and modifications recommended.⁹ For a discussion on upgrading the building to meet tornado and earthquake design criteria, see Sect. 2.3.3.1.

Wastes

All gaseous effluents from both reprocessing and refabrication operations, except for those in refabrication which emit combustible gases, will feed into the hot off-gas (HOG) system of TURF and exhaust through the 7911 stack (Sect. 2.3.2.1), which also serves the High Flux Isotope Reactor (HFIR) and the Transuranium Processing Facility (TRU). Those streams containing combustible off-gases will be scrubbed, dried, filtered, passed through radon traps, and discharged through HEPA filters to small separate stacks on the roof of TURF.

The gaseous streams from the various process vessels of reprocessing contain radionuclides and chemicals in the form of gases, condensable vapors and aerosols, and particulates. The gaseous radioactive isotopes of concern are tritium, ^{14}C (as CO and CO_2), ^{32}P , ^{33}P , ^{35}S , ^{37}Ar , ^{85}Kr , ^{129}I , ^{131}I , ^{220}Rn , and ^{222}Rn . Special systems upstream of the HOG system control tritium, iodine, and radon. Similar systems are to be provided for control of the condensable vapors, aerosols, and particulates (Sects. A.9.1, B.7.4, B.7.5, and C.8). Further control is effected by the HEPA filters at the 7911 stack (Sect. 2.3.2.1).

The major nonradioactive chemical effluents in the gaseous streams are: (1) CO , CO_2 , O_2 , NO_x , and various condensable vapors and aerosols from reprocessing and (2) H_2 , Ar , He , CO_2 , NO_x , and aromatic hydrocarbons from refabrication. A development program is currently under way to identify the quantities of parthenogenic active hydrocarbons in combustible off-gases. This study will identify methods of removal from the waste gases and develop monitoring instrumentation methods. Special systems are to be provided for condensing the vapors and aerosols as well as for converting CO to CO_2 and NO_x to N_2 and O_2 before discharge to the HOG system (Sects. A.9.1, B.7.4, B.7.5, and C.8). The final gaseous chemical effluents discharged from the stack are mostly CO_2 , N_2 , and O_2 .

Liquid intermediate-level wastes (ILW) are neutralized and pumped directly in a high-integrity stainless-steel piping network to the ORNL ILW collection and treatment system (Sect. 2.3.2.2). This waste is made basic, evaporated, and concentrated and the concentrated waste disposed of by shale fracturing. Process wastes that are susceptible to radioactive contamination are monitored continuously for radioactivity. The initial collection is in a retention pond; if found to contain radioactive material, the waste is diverted to a second pond from which it can be pumped to the ORNL low-level waste system (Sect. 2.3.2.2). The sanitary waste flow from the 7900 area is currently small, and the entire flow is being temporarily transported to the main sewage-treatment plant in Bethel Valley. Operation of facilities for HET requires between 30 to 40 additional personnel in the 7930 area. Assuming average sanitary waste flows of 75 liters (20 gal) per capita per day, as much as 2300 to 3800 liters per day (600 to 1000 gpd) of sanitary waste can be added to the existing flow. This additional flow might require operating the package-treatment plant as opposed to transporting the augmented flow to the main sewage-treatment plant. If the Melton Valley sewage-treatment plant is used, effluents are to be in compliance with the NPDES permit.

Organic liquid wastes are to be absorbed on vermiculite or similar material and treated as a solid, canned, and disposed of as solid waste. All radioactive solid waste is to be collected and packaged for disposal in the ORNL burial ground (Sect. 2.3.2.3). The disposal of waste in shielded casks is to be minimized because of space limitations in the burial grounds, provided the appropriate health physics requirements can be satisfied by other forms of containment (i.e., drums). Solid wastes consist primarily of drier insolubles from the dissolution step, scrap material from various operations, catalysts and absorbents from off-gas handling, and failed equipment. All solid waste is to be sorted, reduced or compacted, packaged, and disposed of in the burial grounds.

Heat dissipation

Most of the waste heat from this building is discharged to the atmosphere via a new 450-ton cooling tower.

Waste assay station

A new station for assaying solid waste collected in 30- and 55-gal drums (Sects. A.9.3 and C.8) is to be located on the third floor. The station is to consist of a segmented gamma scanner and a neutron irradiator and detectors. Approximately 2 years of development is required for this station.

Safeguards

The following features are to be provided to ensure physical protection of this area:

1. Special fencing and perimeter illumination; fence to be equipped with an intrusion alarm and TV cameras.
2. Hardened monitoring station with monitoring devices for personnel, vehicles, and packages; fenced corridor between this station and Building 7930.
3. Entrances and exits to be equipped with alarms; all glass in exterior openings to be covered by metal bars.
4. Access doors to processing and special nuclear material storage areas to be controlled with simple key-card system and equipped with alarms.
5. In-cell surveillance furnished by TV cameras provided for processing requirements; out-of-cell TV surveillance with fixed cameras in areas adjacent to processing cells.
6. Intrusion detection devices to be installed at all cell-access locations.

2.4 TRANSPORTATION

Chemicals (listed in Tables 2.1 and 2.2) and irradiated and nonirradiated fuel elements for the HETP are to be shipped to ORNL mainly by commercial motor transport, similar to most other shipments to and from ORNL. Onsite transfer of irradiated material will be made between four buildings -- 3019, 3026D, 7503, and 7930.

2.4.1 Offsite transportation

Irradiated HTGR fuel elements are to be shipped from the Idaho National Engineering Laboratory storage facility near Idaho Falls, Idaho, by commercial carrier (truck) to Building 7930 at ORNL. Over a 2-year period, 24 trips (four elements per trip) will be required to transport 96 fuel elements. A modified Peach Bottom Cask (PB-2) will be used;¹⁰ each load will contain four cannisters with each cannister containing one Fort St. Vrain (FSV) fuel element.

Fresh unirradiated fuel elements are to be supplied by General Atomic Company and shipped from San Diego, California, to ORNL by commercial carrier. Four trips (maximum) will be required to transfer a total of 24 to 30 elements over an expected 3-month period.

Table 2.10 gives the expected chemical composition of both fresh and irradiated fuel elements, which composition is yet to be verified (TBV-23). Table 2.11 gives the calculated radioactivity and decay heat for an element after a burnup of six equivalent full-power years (100,000 MW-days/ton).

Table 2.10. Fuel element composition^a

| Component | Weight (kilograms per fuel element) | | |
|--|-------------------------------------|--------------|-------|
| | Fresh | Spent | |
| Graphite block including fuel plugs and dowels | | | 88.4 |
| Fuel-rod matrix | | | 4.21 |
| Fissile particles (av ρ = 2.35 g/cc) | | | 17.1 |
| Outer PyC coating | | 5.54 | |
| SiC coating | | 4.58 | |
| Inner-PyC coating | | 1.95 | |
| Buffer coating | | 1.55 | |
| Kernel (av ρ = 9.01 g/cc) | | 3.50 | |
| | <u>Fresh</u> | <u>Spent</u> | |
| Uranium | 0.62 | 0.23 | |
| Thorium | 2.56 | 2.39 | |
| Fission products | | 0.54 | |
| Other heavy metals | | 0.02 | |
| Carbon | 0.32 | 0.32 | |
| Fertile particles (av ρ = 3.16 g/cc) | | | 16.2 |
| Outer PyC coating | | 3.03 | |
| SiC coating | | 2.42 | |
| Inner PyC coating | | 1.43 | |
| Buffer coating | | 1.14 | |
| Kernel (av ρ = 8.81 g/cc) | | 8.22 | |
| | <u>Fresh</u> | <u>Spent</u> | |
| Uranium | | 0.23 | |
| Thorium | 7.49 | 6.93 | |
| Fission products | | 0.33 | |
| Other heavy metals | | 0.00 | |
| Carbon | 0.73 | 0.73 | |
| Burnable poison rod (av ρ = 1.6 g/cc) | | | 0.10 |
| Boron | | 0.004 | |
| Carbon | | 0.001 | |
| Matrix | | 0.095 | |
| Total weight | | | 126.0 |

^aThe fissile and fertile particles are to contain dense spherical metal carbide particles produced by the VSM (Vanek, Simad, Meyers) General Atomic Company process and TRISO coated as described in Sect. B.4. Calculations based on *FSV Fuel Element O.C.*, GA-A13772, Feb. 16, 1976.

Table 2.11. Spent fuel element definition after full burnup

| | 180 days of decay | 1-½ years of decay |
|----------------------------------|-------------------|--------------------|
| Radioactivity^a | | |
| Ci per fuel element | | |
| Fissile fraction | 39,400 | 17,800 |
| Fertile fraction | 36,300 | 16,400 |
| Decay heat^a | | |
| BTU per hr per fuel element | | |
| Fissile fraction | 810 | 360 |
| Fertile fraction | 740 | 340 |

^aRadioactivity and decay heat calculated for full burn-up, 6 equivalent full power years (100,000 MW-days/ton).

2.4.2 Onsite transportation

Onsite transportation of radioactive materials occurs between buildings at ORNL. Quantities of materials and transfer interfaces between buildings are listed in Table 2.12.

Table 2.12. Onsite transportation of radioactive material

| Between buildings | Material | Characteristics |
|------------------------------|----------------------------------|--|
| 3019 and 7930 | Uranyl nitrate solution | (a) Quantity per transfer = 9 kg ^{233}U (b) Total activity per transfer = 135 Ci (assuming no fission products, 250 ppm ^{232}U and secular equilibrium) (c) Source term = 0 (casks will be sealed and release will be zero except under accident conditions) |
| 7930 and 3019 | Uranyl nitrate solution | (a) Quantity per transfer = 2.7 kg ^{233}U (assuming 30% "left over" due to equipment breakdown, operational delays of various sorts, etc.) (b) Total activity per transfer = 135 Ci (same as first transfer) |
| 3026 and 7503 or 7930 | Segmented fuel elements | (a) Quantity per transfer: Fissile fuel element = 2.6 kg Th Fertile fuel element = 7.2 kg Th (b) Total activity per transfer (180 day cooling): Fissile fuel element = 39,000 Ci Fertile fuel element = 36,000 Ci (c) Source term = 0 |
| 7930 and 7503 | Burned fuel particles | (a) Quantity per transfer: fissile fuel element = 2.6 kg Th fertile fuel element = 7.2 kg Th (b) Total activity per transfer (180 day cooling): fissile fuel element = 39,000 Ci fertile fuel element = 36,000 Ci (c) Source term = 0 |
| 7930 and Analytical stations | Samples in individual bottles | (a) Quantity per transfer <1 g Th (b) Total activity <1 Ci |
| Analytical and 7930 stations | Liquid or solid form, in bottles | (a) Quantity per transfer <1 g U plus same fission products (b) Total activity is indefinite (c) Source term = 0 |
| 7930 and Burial ground | Miscellaneous solids | (a) Quantity per transfer = 2.5 kg (b) Total activity (assumes 10% of total activity in fuel element is sent to burial ground in one container) = 3900 Ci (maximum) (c) Source term = 0 |

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3. CHARACTERIZATION OF THE EXISTING ENVIRONMENT

3.1 SITE LOCATION AND LAYOUT

The proposed Hot Engineering Test Project (HETP) will be housed in four existing buildings located at Oak Ridge National Laboratory in Oak Ridge, Tennessee.

3.1.1 East Tennessee and Oak Ridge area

The city of Oak Ridge lies in an area of hills and valleys northwest of the Great Smoky Mountains and southeast of the Cumberland Mountains in the eastern part of the state. Oak Ridge National Laboratory (ORNL) is located in a Department of Energy (DOE) reservation and lies approximately 8 miles (~13 km) southwest of the Federal Building in Oak Ridge. Figure 3.1 shows its location in Tennessee and its relation to surrounding communities. The DOE reservation is in a rural setting and is bounded by the Clinch River on its eastern, southern, and western borders.

The total population of the five nearest cities (15-mile radius) amounts to approximately 50,000 people. Knoxville, the nearest major metropolitan area (about 175,000 people), is located 20 miles (~32 km) east of Oak Ridge. According to the 1970 Federal census, the five surrounding counties have a combined population of 413,000.

The area to the north of Oak Ridge is mountainous and sparsely settled, and portions of the land are used for underground and strip coal mining.

Three prominent TVA facilities: two coal-fired steam plants (Kingston and Bull Run) and a hydroelectric-generating station (Melton Hill Dam) are operating in the area.

Four DOE plant complexes are located on the reservation (Fig. 3.2):

1. Y-12 Plant (Y-12),
2. Oak Ridge Gaseous Diffusion Plant (ORGDP),
3. Comparative Animal Research Laboratory (CARL),
4. Oak Ridge National Laboratory (ORNL).

The Y-12 plant (850 acres) is located on the eastern boundary of the reservation. The plant employs approximately 4800 people and functions mainly in the design and production of nuclear weapon components.

The ORGDP (1740 acres) employs approximately 6300 people. Located in the northwest portion of the DOE reservation, it functions primarily as a facility for the enrichment of uranium hexafluoride (UF₆) for use in commercial light-water reactors and nuclear weaponry.

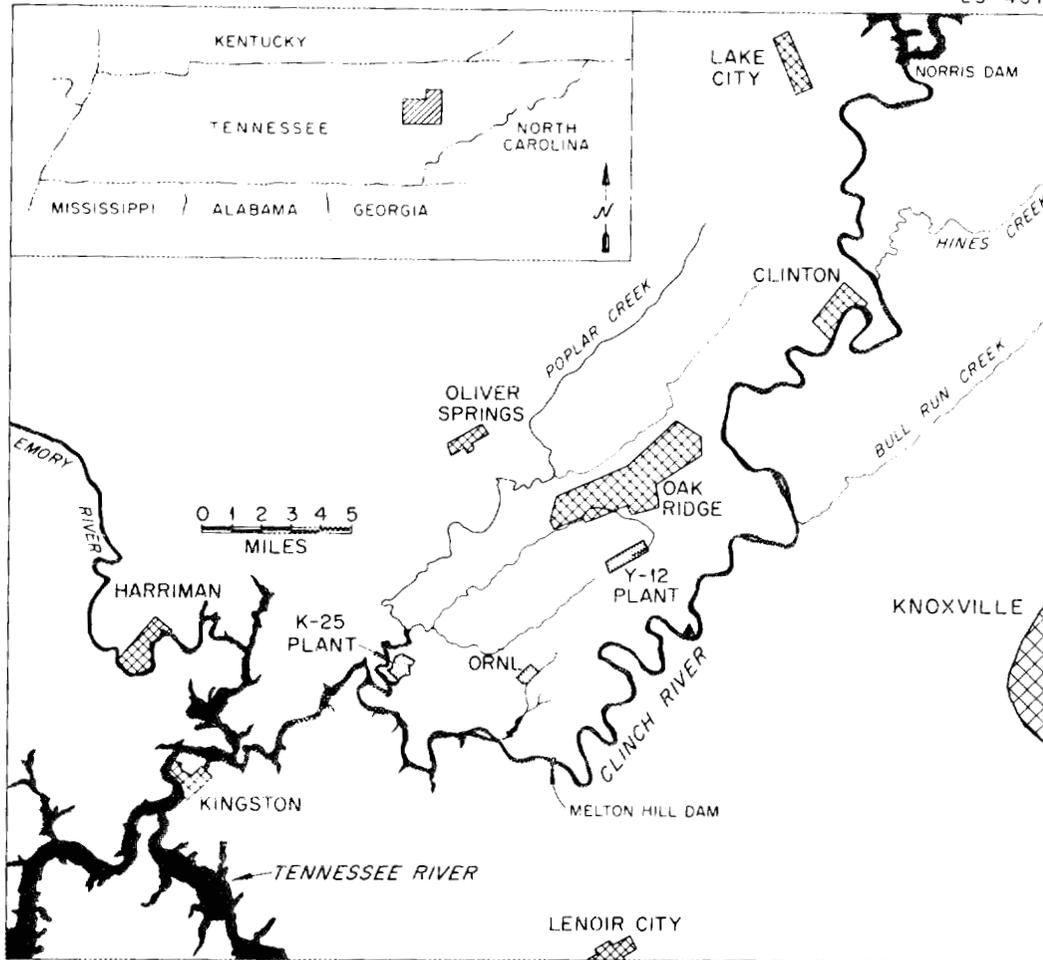


Fig. 3.1. Area of the Department of Energy reservation showing the three plants (K-25, ORNL, and Y-12), the city of Oak Ridge, and the surrounding communities.

CARL (a facility operated by the University of Tennessee for DOE) uses several areas of the DOE reservation for research on mammalian metabolism and the toxic effects of energy-related activities on mammals. Specific lands are designated to support this research program as the needs arise.

3.1.2 ORNL

Oak Ridge National Laboratory, centrally located on the southern border of the reservation, is the main research laboratory on the reservation. ORNL's facilities include nuclear reactors (research), chemical pilot plants (related to coal conversion technology, etc.), radioisotope production facilities, and research facilities in physics, chemistry, and the environmental sciences. Historically, reactor technology has been a major programmatic effort at ORNL, and the present program emphasizes the development and evaluation of two advanced reactor types and fuel cycles associated with them: the Liquid-Metal Fast Breeder Reactor (LMFBR) and the High-Temperature Gas-Cooled Reactor (HTGR).

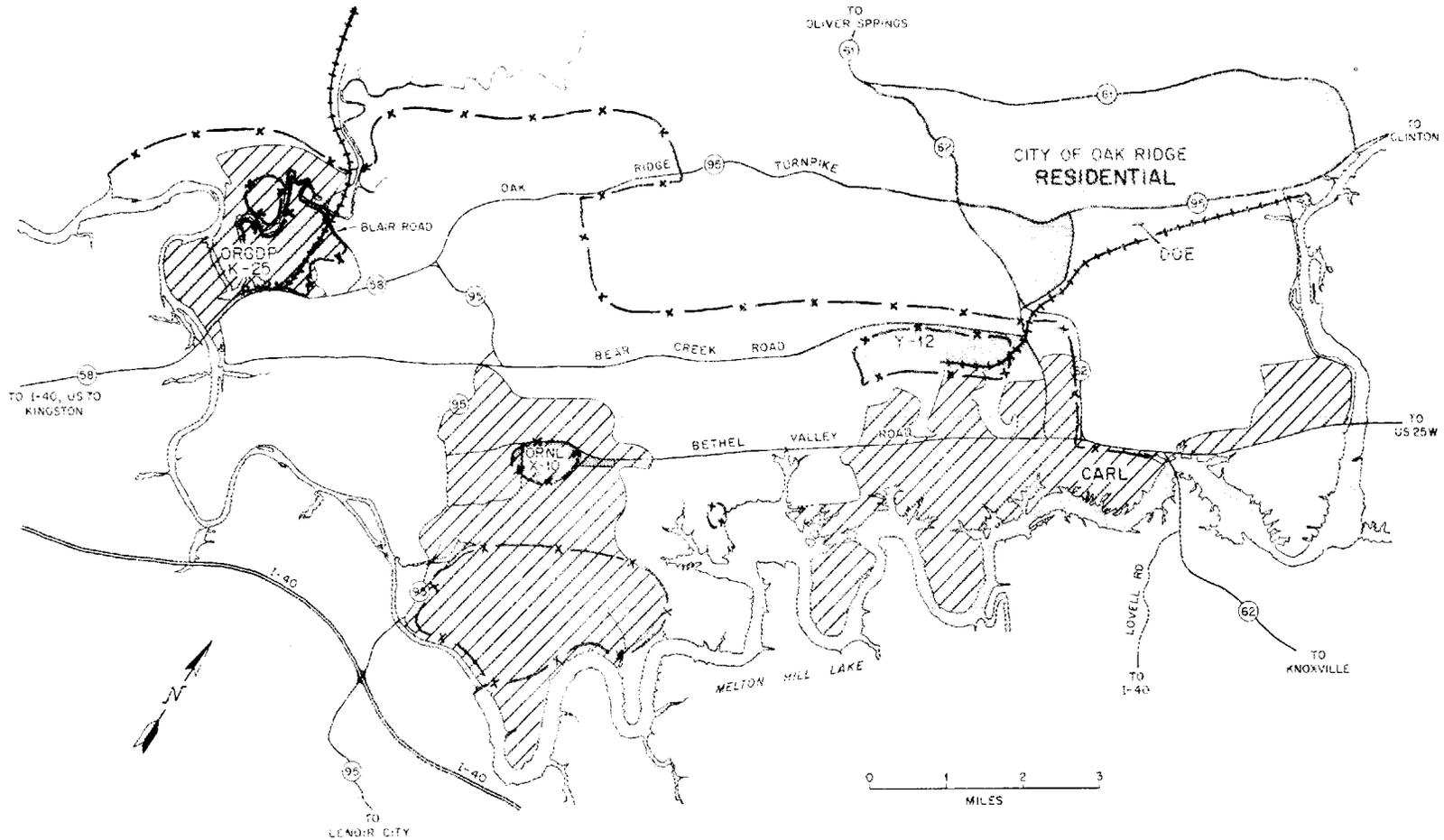


Fig. 3.2. Map showing the boundaries of the four plant sites and of the city of Oak Ridge.

The Oak Ridge National Laboratory lies in a verdant valley that runs approximately in an east-west direction (Fig. 3.3). Although the valley floor is highly developed within the main Laboratory area, the surrounding terrain to the east and west is wooded. A stream, Whiteoak Creek, passes to the south of the developed area and leaves the valley through a gap in the hills to the southwest.

From the eastern approach, the first buildings are a complex of warehouses and shops (Fig. 3.3). The adjacent red-brick buildings beside a small lake house the ORNL accelerators. A short distance further, the principal (East Portal) entry to the Laboratory is on the left. At this point, the road goes north and around a wooded hill that essentially obscures the Laboratory from view; a gap in the hill provides a glimpse of the facilities. Further on, a drive turns left to the West Portal, which was the principal entry when the Laboratory was first built. From this point a street, Central Avenue, bisects the Laboratory area and extends from the West Portal to the East Portal.

In the area between the East and West portals, the buildings are of both wartime and recent construction, about the same number of each. The eastern portion of the Laboratory, generally well landscaped, consists of modern brick-faced buildings. The facilities in the western portion of the Laboratory are predominantly of the early construction. Many, however, have been renovated to improve their appearance and to extend their useful lives.

The Engineering Division Building, a greenhouse complex and aquatic facility, and the Environmental Sciences Division Building are west of First Street and the West Portal.

South through a gap in the Haw Ridge within the next valley, roads extend east and west. Lagoon Road goes west to areas used principally for waste disposal. Melton Valley Drive goes east past two sites used in the past for demonstration reactor experiments. Just beyond the second site is the entry to relatively modern facilities including the High-Flux Isotope Reactor and two process facilities, one for transuranium-element separation and the other for fuel-reprocessing development.

Further south in Melton Valley and somewhat isolated are two research reactors. One is for experimentation with radiation shielding; the other is devoted to experiments in health physics.

The Oak Ridge National Laboratory covers a broad area and is somewhat dispersed. This dispersal permits the accommodation of a variety of experimental programs that require isolation. The natural areas beyond the central area are also used for research programs of ecology and forestry. ORNL employs approximately 5000 people.

3.1.3 HETP

The four buildings to be used in the proposed Hot Engineering Test Project (HETP) are briefly described below; a detailed description of each is given in Sect. 2.3.3. Building 7930, to be the major demonstration facility, is located in Melton Valley (Fig. 3.3). The building is commonly known as the TURF (Thorium-Uranium Recycle Facility) and has not been in use recently. The structure consists of hot cells in a steel and concrete-block building.

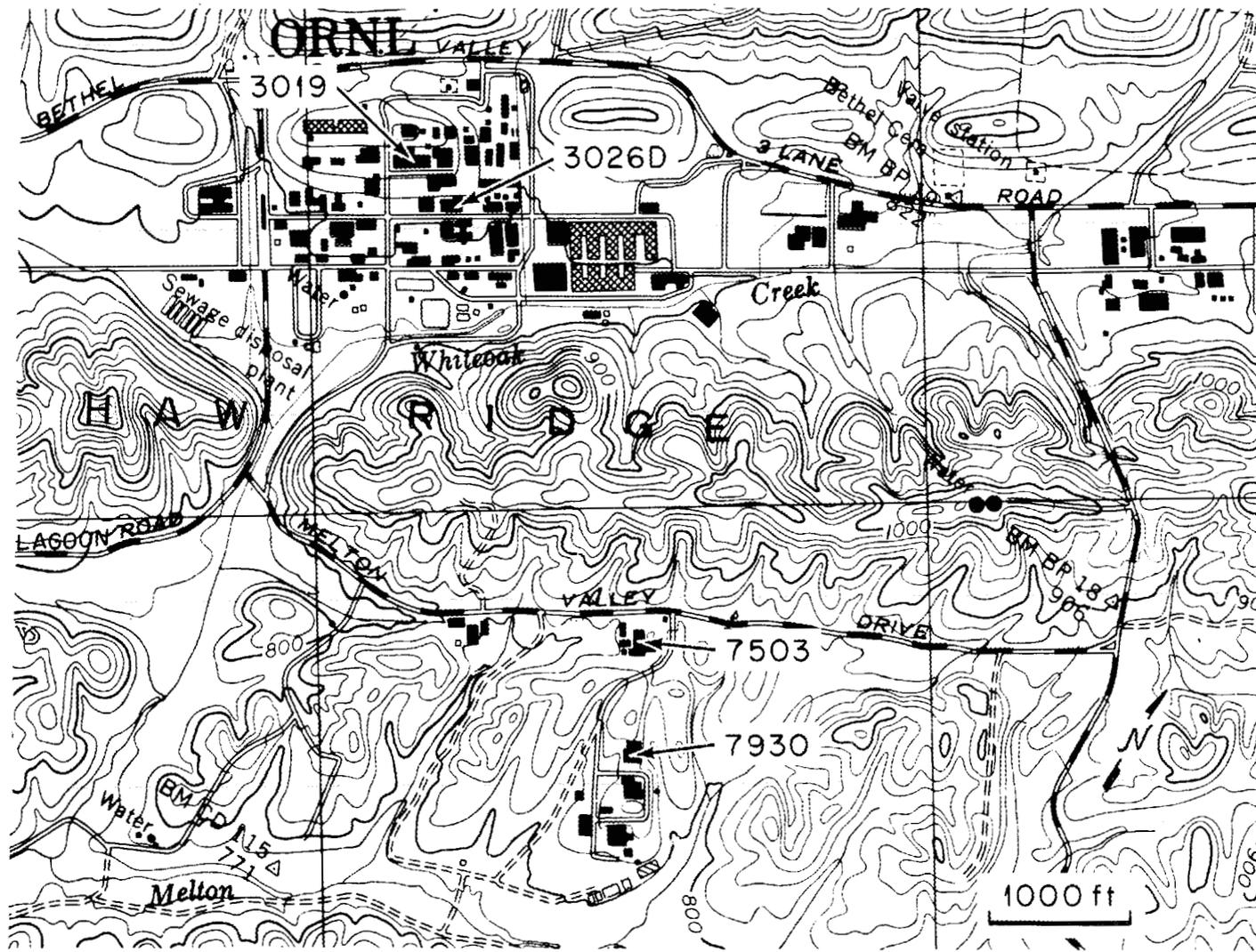


Fig. 3.3. Topographic map of Oak Ridge National Laboratory showing location of HETP facilities.

Building 7503, also in Melton Valley, will be used for storing the by-products and surplus materials from the project.

Building 3026D is located on Central Avenue and is almost centrally located within the main ORNL grounds (Fig. 3.3). Cell A of Building 3026D will be used for initial size-reduction of the Fort St. Vrain fuel element and is commonly called the segmenting facility. The facility is housed in a three-level wooden frame building.

Building 3019 has 3 floors, 15 offices, and 5 laboratories. UNH will be solidified and stored in this building. The Analytical Chemistry Division has facilities in the building for analyzing samples containing various levels of radioactivity.

3.2 TOPOGRAPHY

The area comprising the DOE reservation is dominated by a series of ridges and valleys formed during Early Cambrian to Early Mississippian times by the action of erosion on severely faulted and folded rocks.

The ridges of the more resistant sandstone, cherty dolomite, and shale run parallel in a northeast-to-southwest direction. Figure 3.3 is a topographic map of the area around ORNL. Altitudes of the ridges and valleys adjacent to the facility extend from 740 ft (226 m) to 1360 ft (415 m) above mean sea level (MSL), providing a maximum relief of 600 ft (183 m).

3.3 GEOLOGY

3.3.1 Stratigraphy

The HETP facility is located in the Valley and Ridge Province of the Appalachian Highlands Physiographic Division of the eastern United States. Proximity of the site to the various physiographic provinces within the Appalachian Highlands is shown in Fig. 3.4. As the name Appalachian Highlands implies, the area is characterized by rugged terrain that varies from rolling hills to mountains. Within 200 miles (~320 km) of the site, the physiographic provinces include Interior Low Plateaus, Appalachian Plateaus, Valley and Ridge, Blue Ridge, and Piedmont.

Different layers of Paleozoic sedimentary rock, primarily limestone, dolomite, and shale, comprise the ridges and valleys of the area. The four major bedrock types are Rome, Conasauga, Knox, and Chickamauga.

The Rome formation is a generally well cemented sandstone with a shaly fine grain. It has a relatively low ability to transmit groundwater because of the presence of unenlarged fractures. The Conasauga group consists of thin limestone units interbedded with silty and slightly calcareous shale; fractures are evenly distributed. Permeability is associated with weathering changes of the rock above and below the water table. A more uniform flow of groundwater occurs here than in the other formations.

The Knox group primarily consists of thick beds of dolomite and limestone; permeability and porosity of the formation are unevenly distributed. As a result, there have been water localizations from fracturing and solution by groundwater movement in this formation.

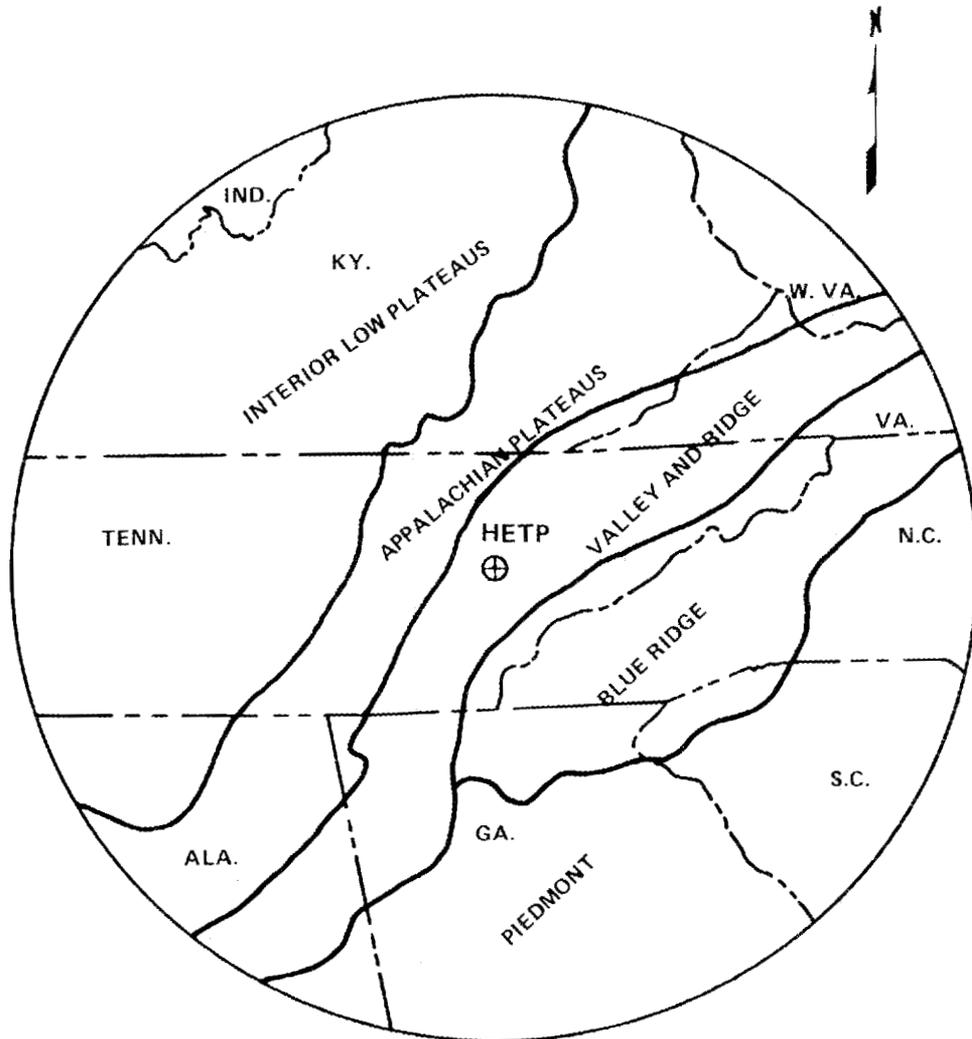


Fig. 3.4. Regional physiographic map of the site of the Hot Engineering Test Project at Oak Ridge National Laboratory. Source: Project Management Corporation and the Tennessee Valley Authority, *Clinch River Breeder Reactor Plant Environmental Report*, vol. 1, Construction Permit Stage, Docket No. 50-537, issued April 7, 1975, p. 2.4-23.

The Chickamauga limestone is composed of thin beds of shaly limestone and shale. Porosity is low, and fractures have been enlarged by solution, although not as extensively as in the cavernous Knox group. Such fractures and solution channels permit the free movement of ground-water through a network of channels.

Table 3.1 lists the principal bedrock formations in the Oak Ridge area.

3.3.2 Seismology

Two major-thrust faults, the Copper Creek and the Whiteoak Mountain, are recognized in the area. Both are traceable for a distance greater than 160 km (100 miles) within the Valley and Ridge province¹ and are shown in Fig. 3.5, which is a fault map of the vicinity. In both faults

Table 3.1. Generalized geologic section of the bedrock formations in the Oak Ridge Area

| System | Group | Formation | "Member" or Unit | Thickness (feet) | Characteristics of Rocks |
|---------------|-------------------|-------------------|-------------------------|------------------|--|
| Mississippian | ? | Ft. Payne "chert" | | | Impure limestone and calcareous siltstone, with much chert |
| | | Chattanooga shale | | | Shale, black, fissile |
| Devonian | | | | | |
| | | | | | |
| Silurian | Rockwood group | Brassfield | | 1000+ | Shale, sandy shale, sandstone; calcareous; red, drab, brown |
| | | Sequatchie | | | |
| Ordovician | Chickamauga group | | ? | | Limestone, shaly limestone, calcareous siltstone, and shale; mostly gray, partly maroon; with cherty zones in basal portions |
| | | | H | 300+ | |
| | | | G | 300 | |
| | | | F | 25 | |
| | | | E | 380 | |
| | | | D | 160 | |
| | | | C | 115 | |
| | | | B | 215 | |
| Cambrian | Knox group | | | 2600 | Dolomitic limestone; light to dark gray; with prominent chert zones |
| | | Conasauga group | Maynardsville limestone | | |
| | | | Conasauga shale | Pumpkin valley | |
| | | | Rome formation | | |

Source: P. B. Stockdale, *Geologic Conditions at the Oak Ridge National Laboratory (X-10) Area Relevant to the Disposal of K. Isotopic Waste*, ORO-55, Oak Ridge Operations, Oak Ridge, Tenn., Aug. 1, 1951, Plate 11.

the Middle Cambrian Rome formation is thrust over the Middle Ordovician Chickamauga limestone. The Copper Creek fault occurs along the northwestern side of Haw Ridge and extends northeast across Tennessee. Further to the north is Whiteoak Mountain fault, which lies on the northwestern side of Pine Ridge and can be traced southwest across Tennessee. The Pilot Knob syncline is a northeast extension of the Whiteoak Mountain fault in East Fork Ridge. Numerous secondary tectonic displacements have also occurred in the area.²

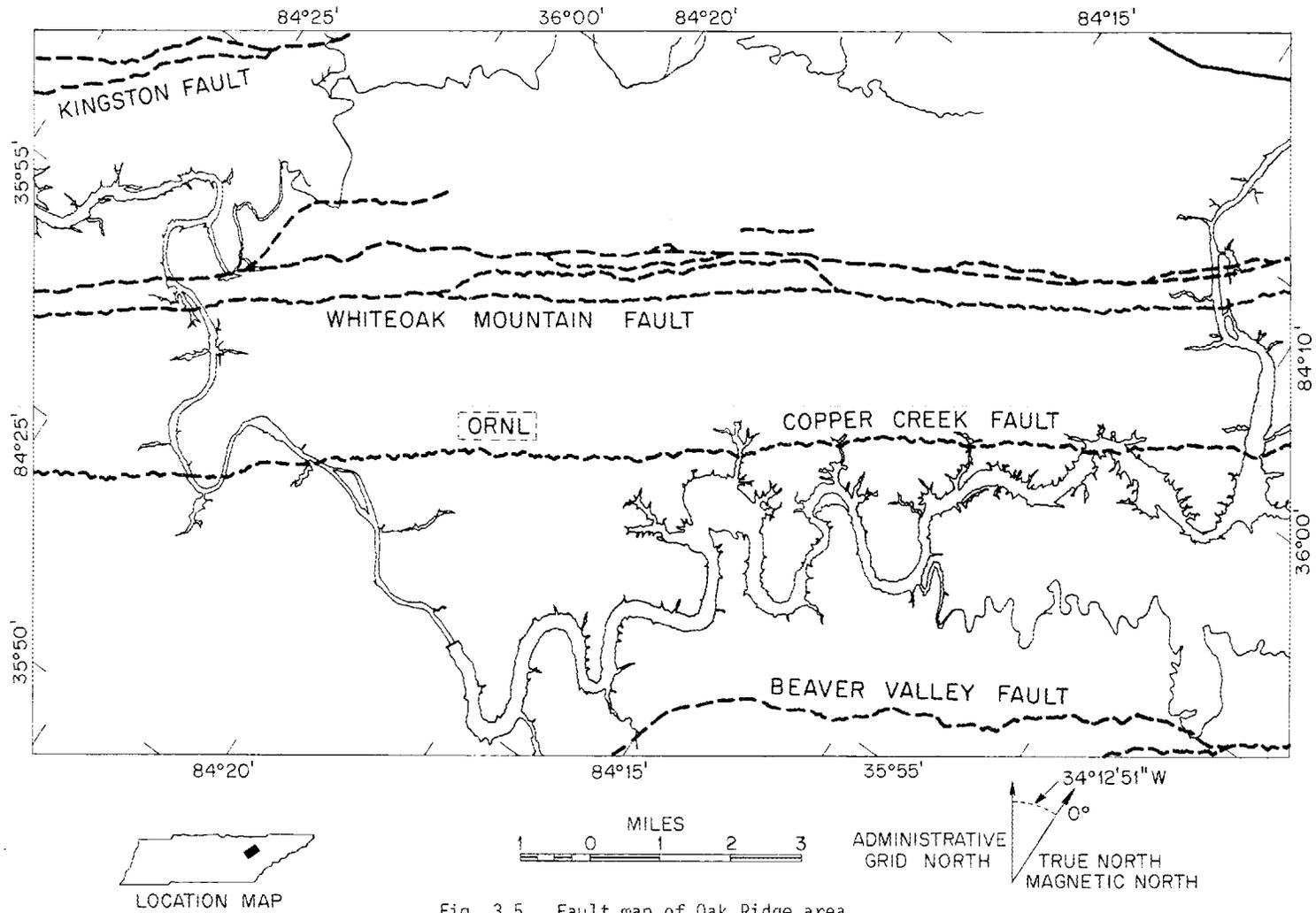


Fig. 3.5. Fault map of Oak Ridge area.

Since the youngest stratigraphic units mapped in the Valley and Ridge province of southern Appalachia are of Pennsylvanian age, geologists believe that all the structural features of the primary Appalachian system were formed by the end of the Paleozoic era during what is now called the Appalachian Revolution. Although numerous faults exist within the area, they all originated long ago during that orogenic period; apparently, major tectonic activity ceased completely thereafter. No physiographic evidence indicating tectonic activity, such as stream offsets, displacement of alluvial deposits, or dislocations of Plio-Pleistocene terrace materials, has been observed along any of these thrust-fault areas. Consequently, there is no reason to expect current or future translocations of these tectonic relics.^{1,3,4}

Recent seismic events that were capable of producing a shock in the Oak Ridge area and that were recorded in the literature since 1800 are listed in Table 3.2. Data for the older earthquake incidents are largely estimates extrapolated from nonspecific newspaper reports. In addition, these 19th-century records generally show a definite bias toward earthquakes of considerable intensity, an attitude that reflects the inherent limitations of intensity measurements during that period. The inability to record low-intensity earthquakes also explains the fewer tectonic incidences recorded in the earlier time interval.

The more recent seismic records indicate that the Appalachian region extending from Chattanooga to southwestern Virginia averages one to two earthquakes per year. This seismic activity is not uniform, but consists of extended periods with no shocks, followed by a burst of earthquakes. The maximum shock experience in the Oak Ridge area was of intensity VI on the Modified Mercalli scale (MM) recorded on March 28, 1913.⁴ Great distant earthquakes, such as the New Madrid series of 1811 and 1812 and the Great Charleston Earthquake of 1886, have affected the site with intensities greater than or equal to the maximum intensity of shocks involving regions that surround the site.³ From a plot made on a map of the southeastern United States (Fig. 3.6) of the epicenters of earthquakes, the areas of continuing seismic activity can be identified.⁵ The following four areas of major current tectonic mobility are:

1. The Mississippi Valley encompasses the New Madrid region of Arkansas, Kentucky, Missouri, and Tennessee. This seismic province includes the epicenter of the great series of New Madrid earthquakes, which repeatedly attained an MM intensity of XII. This area lies more than 400 km (250 miles) northwest of the HETP site. The New Madrid quakes attained an intensity of V to VI in the Oak Ridge area.
2. The Lower Wabash Valley is located in the southern regions of Illinois and Indiana. A southern Illinois earthquake of MM intensity VII in 1968 was felt over a 400,000-sq-mile area including a mild shock of intensity II to III in the Oak Ridge vicinity. The HETP site lies more than 370 km (230 miles) southeast of this region of active seismicity.
3. Charleston, South Carolina, was the site of one of the greatest historic earthquakes experienced in the eastern United States. The August 31, 1886, shock of MM intensity IX was felt over the entire eastern coast and registered an intensity of V to VI in the Oak Ridge region. Recurrent seismic activity continues in this area, which is 520 km (325 miles) southeast of the HETP site.

Table 3.2. Annotated list of earthquakes that have affected the Oak Ridge Reservation or the eastern Tennessee vicinity

| Date | Geodetic coordinates | | Epicenter area | Maximum MM intensity at epicenter | Estimated MM intensity at Oak Ridge | Notes |
|---------------|----------------------|------|------------------------------|-----------------------------------|-------------------------------------|--|
| | °N | °W | | | | |
| 1811, Dec. 16 | 36.6 | 89.6 | New Madrid, Mo. | XII | V--VI | Strongest shocks of a great series collectively known as the New Madrid Earthquake. Topographic changes effected over an area of 3000 to 5000 sq mile in Mississippi Valley. |
| 1812, Jan. 23 | 36.6 | 89.6 | New Madrid, Mo. | XII | V--VI | |
| Feb. 7 | 36.6 | 89.6 | New Madrid, Mo. | XII | V--VI | |
| 1843, Jan. 4 | 35.2 | 90.0 | Western Tennessee | VIII | III--IV | Shock felt over 12 states, including the entire Tennessee Valley. |
| 1844, Nov. 28 | 36.0 | 84.0 | Knoxville, Tenn. | VI | V | 25 mi from Oak Ridge area. |
| 1861, Aug. 31 | 36.6 | 78.5 | Virginia | VI | III--IV | Described as "heavy shock" in the Oak Ridge area. |
| 1886, Aug. 31 | 32.9 | 80.0 | Charleston, S.C. | IX--X | V--VI | The Great Charleston Earthquake felt over the entire eastern U.S. |
| 1895, Oct. 31 | 37.0 | 89.4 | Charleston, Mo. | XI | III--IV | Shock felt over 23 states, including the entire Tennessee Valley. |
| 1897, May 31 | 37.3 | 80.7 | Giles County, Va. | VII | III--IV | Shock felt throughout east Tennessee. Heaviest shock in historic time in southern Appalachia. |
| 1902, May 29 | 35.1 | 85.3 | Chattanooga, Tenn. | V | ? | Not reported to have been felt in the Oak Ridge area. |
| Oct. 18 | 35.0 | 85.3 | Chattanooga, Tenn. | V | ? | Not reported to have been felt in the Oak Ridge area. |
| 1904, Mar. 4 | 35.7 | 83.5 | Maryville, Tenn. | V | II--III | Low intensity except at epicenter. |
| 1905, Jan. 27 | 34.0 | 86.0 | Gadsden, Ala. | VII | II | Large "felt" area, but probably very low intensity shock. |
| 1913, Mar. 28 | 36.2 | 83.7 | Strawberry Plains, Tenn. | VII | V--VI | One of the strongest shocks in southern Appalachia. |
| Apr. 17 | 35.3 | 84.2 | Ducktown, Tenn. | V | ? | Not reported to have been felt in the Oak Ridge area. |
| 1914, Jan. 23 | 35.3 | 84.2 | Southeastern Tennessee | V | ? | Only felt reports are from the epicenter, so probably local. |
| 1916, Feb. 21 | 35.5 | 82.5 | Asheville, N.C. | VI | III--IV | Felt over whole state of Tennessee, especially mountains of east Tennessee. |
| Oct. 18 | 33.5 | 86.2 | Easonville, Ala. | VII | III | Felt over seven state area, but only light shock in Oak Ridge. |
| 1918, June 21 | 36.0 | 84.1 | Lenoir City, Tenn. | V | IV | 15 mi from Oak Ridge area. |
| 1920, Dec. 14 | 36.9 | 85.0 | Rockwood, Tenn. | V | III | 35 mi from Oak Ridge area. |
| 1921, Dec. 15 | 35.8 | 84.6 | Kingston, Tenn. | V | III--IV | Shock of "considerable intensity" only 15 mi from Oak Ridge area. |
| 1924, Oct. 20 | 35.0 | 82.6 | Pickens County, S.C. | V | II | Large felt area, but little effect in eastern Tennessee. |
| 1927, Oct. 8 | 35.0 | 85.3 | Chattanooga, Tenn. | IV--V | II | Not reported to have been felt in the Oak Ridge area. |
| 1928, Nov. 2 | 35.8 | 82.8 | Madison County, N.C. | VII | III | Large felt area, including all of eastern Tennessee. |
| 1930, Aug. 30 | 35.9 | 84.4 | Kingston, Tenn. | V | V | 5 mi northwest of Oak Ridge Reservation. |
| 1938, Mar. 31 | 35.6 | 83.6 | Little Tennessee River Basin | III | I--III | Centered in mountains and felt widely in eastern Tennessee. |
| 1940, Oct. 19 | 35.0 | 85.0 | Chattanooga, Tenn. | V | ? | Not reported to have been felt in the Oak Ridge area. |
| 1941, Sept. 8 | 35.0 | 85.3 | Chattanooga, Tenn. | IV--V | ? | Not reported to have been felt in the Oak Ridge area. |
| 1945, June 14 | 35.0 | 84.5 | Cleveland, Tenn. | V | II | Felt area over southeast Tennessee and northwest Georgia. |

Table 3.2. (continued)

| Date | Geodetic coordinates | | Epicenter area | Maximum MM intensity at epicenter | Estimated MM intensity at Oak Ridge | Notes |
|---------------|----------------------|-------|-----------------------------|-----------------------------------|-------------------------------------|---|
| | °N | °W | | | | |
| 1946, Apr. 6 | 35.2 | 84.9 | Cleveland, Tenn. | III | ? | No reports of shock outside of the city. |
| 1947, Dec. 27 | 35.0 | 85.3 | Chattanooga, Tenn. | IV | ? | Not reported to have been felt in the Oak Ridge area. |
| 1954, Jan. 1 | 36.6 | 83.7 | Knoxville, Tenn. | V--VI | IV--V | Large shock area including all of eastern Tennessee; no damage at Oak Ridge. |
| Jan. 22 | 35.4 | 84.4 | McMinn County, Tenn. | V | ? | No reports of shock outside of the county. |
| 1956, Sept. 7 | 35.5 | 84.0 | Corbin, Ky. | VI | IV--V | Two shocks, 14 min apart, felt over most of southern Appalachia. |
| 1957, June 23 | 35.9 | 84.3 | Knox County, Tenn. | V | IV | 5 mi from Oak Ridge area. |
| 1959, June 12 | 35.3 | 84.3 | Tellico Plains, Tenn. | IV | II--III | Widely felt over eastern Tennessee and western North Carolina. |
| 1960, Apr. 15 | 35.8 | 83.9 | Knoxville, Tenn. | V | IV | 20 mi from Oak Ridge area. |
| 1968, Nov. 9 | 38.0 | 88.5 | Southern Illinois | VII | II--III | Felt over 400,000-sq mile area including 23 states and areas of Canada |
| 1969, July 3 | 36.1 | 83.7 | Knoxville, Tenn. | V | III--IV | 30 mi from Oak Ridge area. |
| Nov. 19 | 37.4 | 81.0 | Southern West Virginia | VI | II--III | Large felt area but small intensity. |
| 1971, July 12 | 35.9 | 84.3 | Knoxville--Oak Ridge, Tenn. | III--IV | III--IV | Shock felt with full intensity in Oak Ridge area; no personal injuries or property damage reported. |
| 1973, Oct. 5 | 35.5 | 83.7 | Maryville, Tenn. | IV--V | III--IV | 25 mi from Oak Ridge area. |
| Nov. 3 | 35.5 | 83.7 | Maryville, Tenn. | V--VI | IV--V | 25 mi from Oak Ridge area. |
| 1975, Feb. 10 | 36.1 | 83.6 | Knoxville, Tenn. | ? | ? | Not reported to be felt in Oak Ridge, 60 mi from Oak Ridge |
| May 2 | 36.07 | 84.41 | Roane Co., Tenn. | ? | III | 10 mi from Oak Ridge area. |

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 - e. *Preliminary Determination of Epicenters, 1972* (monthly listing).
 - f. *Earthquake History of the United States*, Publication 41-1 (Rev. ed. through 1970), Washington, D.C., 1973, pp. 21-58.
4. The Appalachian Mountains of eastern Tennessee and western North Carolina are centers that exhibit moderate seismic activity at the frequency of one to two shocks per year. Part of this seismic area lies only 80 km (50 miles) east of the HTEP site and account for most of the seismicity native to the eastern Tennessee region.

As discussed previously, no correlation has been observed between recorded earthquakes on the Oak Ridge reservation and superficial tectonic structures of the Valley and Ridge province. During historic times, the zone of relatively high seismicity in the adjacent Blue Ridge province has involved only movements of low intensity that probably represent minor adjustments of highly disturbed rock formations.⁵

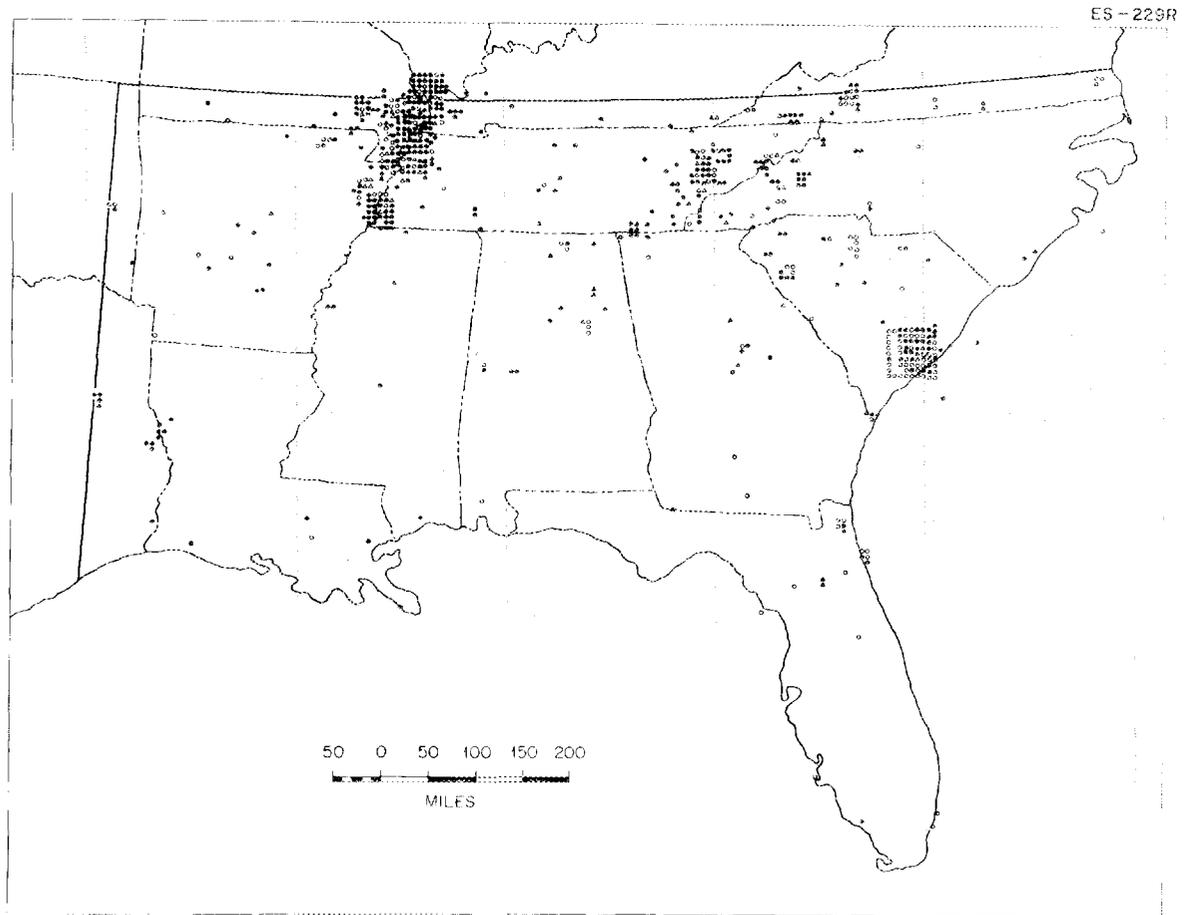


Fig. 3.6. Epicenter locations for all events in the seismic history of the Southeast Region. Source: W. C. McClain and O. H. Myers, *Seismic History and Seismicity of the Southeastern Region of the United States*, ORNL-4582, Oak Ridge National Laboratory, Oak Ridge, Tenn., June 1970, Fig. 1.

Algermissen⁵ prepared a seismic-risk map of the United States (Fig. 3.7) to assist in the establishment of design requirements for buildings in various segments of the country. Seismicity ratings were based either on a historical earthquake of considerable intensity or on frequency of seismic incidences regardless of intensity. The Oak Ridge reservation lies in what Algermissen designated as Seismic Zone 2, which is an area of moderate activity.

Algermissen and Perkins⁶ provide probabilistic estimates for the frequency of occurrence of earthquakes of a given horizontal acceleration. It must be emphasized that their estimates apply only to foundations that are coupled to bedrock. Foundations on unconsolidated alluvium may experience up to three times as much horizontal acceleration. For foundations coupled to bedrock at any location within the southern Appalachian region (as, for example, ORNL), there is a 90% probability that the horizontal acceleration will not exceed 7% of gravity (equivalent to a Modified Mercalli intensity of VII) in a 50-year period. The equation

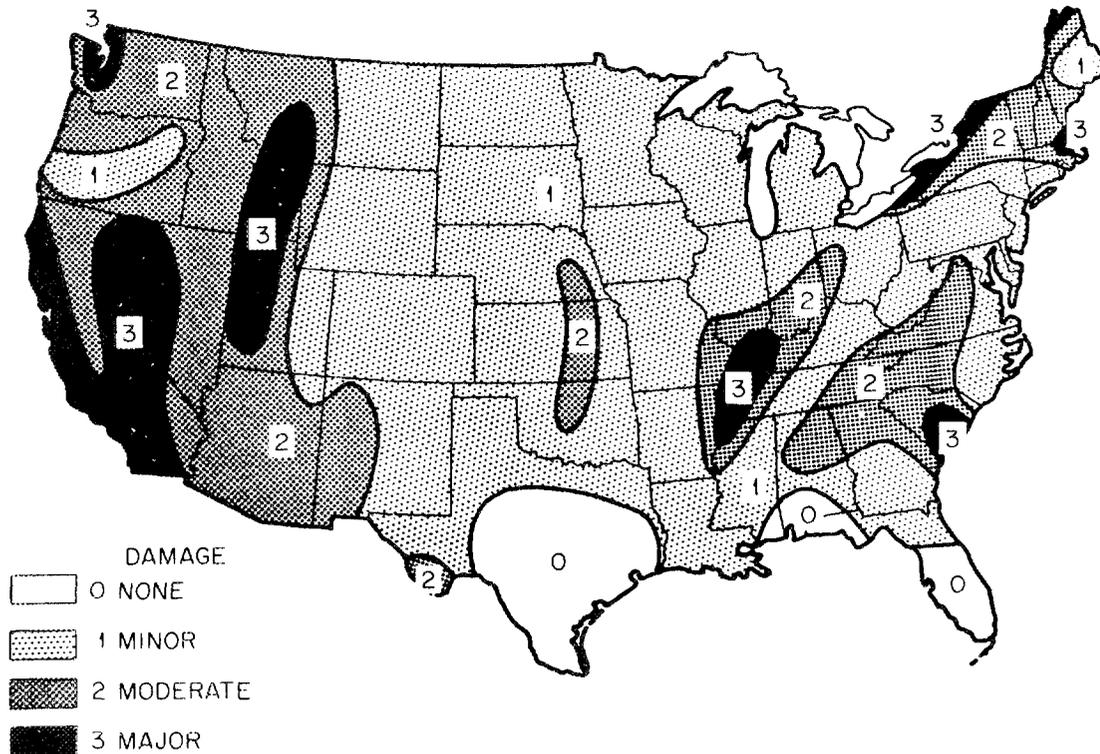


Fig. 3.7. Seismic risk map of the United States. Source: After S. T. Algermissen, "Seismic Risk Studies in the United States," *Proc. 4th World Conf. Earthquake Engineer*, Santiago de Chile, January 13-18, 1969, vol. 1, 1969.

$$\log a = \frac{I}{3} - \frac{1}{2}$$

is a universally recognized empirical relationship between horizontal acceleration (a) and Modified Mercalli intensity (I).⁷ Accordingly, a horizontal acceleration of 70 cm/sec² (7% of gravity) is equivalent to a Modified Mercalli intensity of VII.

Algermissen and Perkins' probabilistic estimate agrees reasonably well with the seismic history of the ORNL site. Table 3.2 lists five earthquakes in the last 165 years that produced a Modified Mercalli intensity of V to VI within the vicinity of Oak Ridge. During the same time interval no earthquakes of Modified Mercalli intensity VII or higher were reported. Intensity VII earthquakes occur approximately one order of magnitude less frequently than intensity V to VI earthquakes. This suggests a recurrence interval on the order of 300 years for intensity VII earthquakes, an estimate that is consistent with Algermissen and Perkins' probabilistic estimate.

Damage caused by intensity VII earthquakes is not severe. Examples of damage to be expected are:⁷ (1) weak chimneys broken off at the roof line, (2) damage to weak masonry of low standards of workmanship, (3) some cracks in masonry of ordinary workmanship, (4) fall of plaster, loose bricks and stones, and (5) damage to concrete irrigation ditches. Earthquake damage as described above is expected to recur once in approximately 300 years, or it has a 10% probability of being exceeded once within a 50-year period at ORNL.

Although the Oak Ridge area experiences a moderate level of seismic activity, no incidence of surface deformation has been documented. Earthquakes of the types that occur within the region are common throughout the world. The shocks are of normal focus -- 40 to 50 km (25 to 30 miles) deep. However, hypocenters of such shocks do penetrate through bedrock to crystalline basement, since sedimentary strata extend to a depth of only 5 km (3 miles).⁸ It is highly improbable that a shock of major focus will occur in the Oak Ridge area for several thousand years to come.² Forces from more seismically active areas will probably be dissipated by distance. Consequently, earthquake forces have generally not been considered in the design of facilities on the Oak Ridge reservation by either DOE Oak Ridge Operations or the Tennessee Valley Authority. Earthquake forces have been considered in the HETP, and the buildings to be used will meet seismic-design criteria (Sect. 2.3.3).

3.3.3 Soil description

Since groundwater flow on the Oak Ridge reservation is described primarily by water-table conditions rather than by artesian conditions, the soils of the area play a major role in regulating water flow to the various spheres of the hydrological environment.

Despite these important hydrological considerations, a thorough investigation of the soils of the Oak Ridge reservation has not yet been completed. However, certain sections of the area have been mapped. Swann and associates⁹ completed a soil survey of Roane County, Tennessee, for the U.S. Department of Agriculture in 1942, but the survey has not been revised to conform with recent nomenclature changes. Moneymaker¹⁰ of the U.S. Soil Conservation Service is currently attempting to record the soils of Anderson County, Tennessee. Carroll¹¹ made a very general analysis of the soils of the Oak Ridge vicinity for the U.S. Geological Survey. The soils of the Walker Branch Watershed have been analyzed extensively in conjunction with a project to measure nutrient cycling within this experimental ecosystem.^{12,13} McMasters and Waller¹⁴ have described the soils of the Whiteoak Creek Basin. Although the information from these studies is insufficient to permit the construction of a detailed soil map, the data of Swann and associates, of Moneymaker, and of Carroll have been combined and correlated to produce the general soil-association map given in Fig. 3.8.

The broad soil associations suggested in Fig. 3.8 can be subdivided further into three major soil classes. All the major soils in a given association fall within the category of upland residual soils. Residual soils are defined as those soils formed by the in-situ weathering of the rocks and minerals of the underlying geology.¹⁵ Thus, corresponding with each of the four major stratigraphic units that occur extensively in this part of the Valley and Ridge Province is an association of residual soils.

Minor soils include residual soils that have arisen from minor geological strata and also two other soil classes -- colluvial and local alluvial. Colluvium is a heterogeneous deposit of rock fragments and soil material accumulated primarily through gravitational forces at the bases of comparatively steep slopes. An azonal group of soils -- developed from recently deposited materials, transported mainly by water, and characterized by a weak modification of the original material by soil-forming processes -- is known as alluvium.¹⁵ This group settles primarily along narrow drainageways and stream depressions. Table 3.3 indicates the percentage distribution, by geological unit and by soil class, of each soil series of the Whiteoak Creek Basin. Similar proportions may be assumed for the remainder of the Oak Ridge reservation. Soils analagous to those

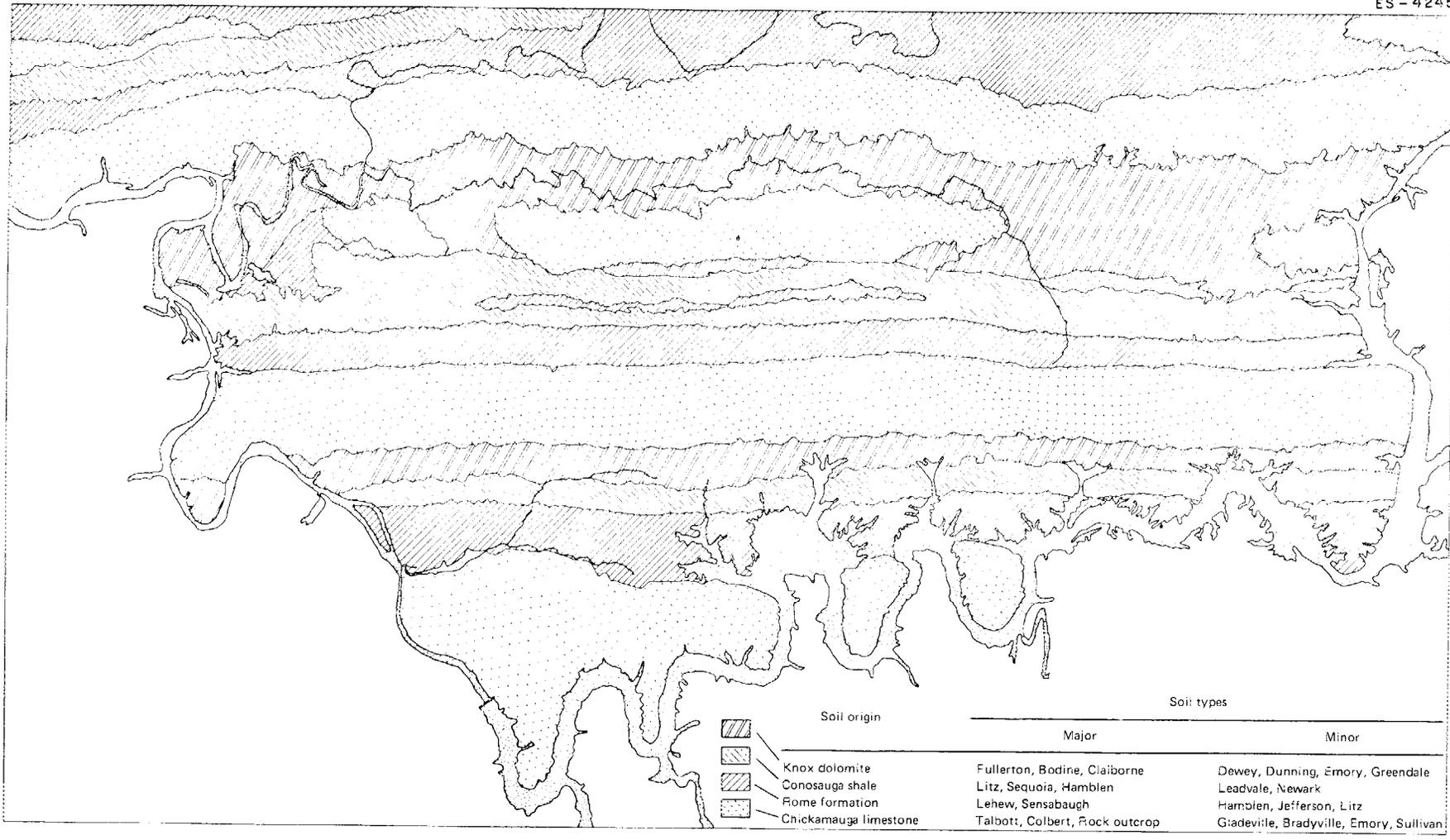


Fig. 3.8. General soil association map of the Oak Ridge reservation.

Table 3.3. Distribution of the soil series of the Whiteoak Creek Basin by geological unit and by soil class

| Geologic unit ^a | Soil series | | | Geologic unit by physiographic position (%) | | | Occurrence of upland soil series (%) |
|----------------------------|--------------------|------------------------|------------------------------|---|-----------|----------------|--------------------------------------|
| | Upland | Colluvial | Local alluvial | Upland | Colluvial | Local alluvial | |
| Ock ^b | Fullerton | Minvare | Emory | 82 | 10 | 8 | 70 |
| | Bodine | Landisburg | Greendale | | | | 5 |
| | Clabome | | | | | | 5 |
| | Dewey | | | | | | 2 |
| Och a ^c | Fullerton | | | 100 | | | 30 |
| | Bodine | | | | | | 20 |
| Och b | Bland ^d | Bland | | 80 | 20 | | 60 |
| | Colbert | Colbert | | | | | 20 |
| Och d | Talbott | Leadvale | Leadvale | 80 | 20 | | 35 |
| Och e | Colbert | Hamblen | Hamblen | | | | 35 |
| Och f | Rock outcrop | | | | | | 15 |
| Och g | | | | | | | |
| Och h | Sequoia | Muse ^e | | 80 | 20 | | 15 |
| | Litz | Jefferson ^e | | | | | 25 |
| | Rock outcrop | | | | | | 40 |
| Cr ^f | Muskingum | Jefferson | | 90 | 10 | | 50 |
| | Lehaw | Muse | | | | | 25 |
| | Hartsells | | | | | | 5 |
| Eca ^g | Montevallo | Muse | | 85 | 15 | | 60 |
| | Litz | Jefferson | | | | | 25 |
| | | Sensabaugh | | | | | |
| Ecb | Litz | Leadvale | Leadvale | 85 | 15 | | 50 |
| | Sequoia | Muse | | | | | 35 |
| | | Hamblen | | | | | |
| Ecc | Litz | Leadvale | Leadvale | 85 | 15 | | 70 |
| | Sequoia | Hamblen | | | | | 15 |
| Ecd | Rock outcrop | | | 90 | 10 | | 75 |
| | Litz | | | | | | 15 |
| Whiteoak Creek alluvium | | | Hamblen Newark Dunning | | | | |
| Clinch River | | | Notchucky Waynesboro | | | | |

^a Refer to Fig. 3-8 for soil locations.

^b Ock denotes Knox dolomite.

^c Och denotes Chickamauga limestone, whereas subsequent letters indicate the various substrata (Sect. 3.3.1).

^d This group also includes portions of rock outcrop, which is restricted to soils that have more than 25% of their areas covered by undissolved rock.

^e These colluvial soils originated from upland Rome formation strata.

^f Cr denotes Rome formation.

^g Ec denotes Conasauga shale, whereas subsequent letters indicate the various substrata (Sect. 3.3.1).

Sources:

1. W. M. McMaster and H. D. Waller, *Geology and Soils of Whiteoak Creek Basin, Tennessee*, ORNL-TM 1108, Oak Ridge National Laboratory, Oak Ridge, Tenn., May 1965.

2. R. P. Sims, State Soil Scientist, Soil Conservation Service, U.S. Department of Agriculture, letter to W. C. Abbott, Oak Ridge National Laboratory, Aug. 1, 1974, regarding data of R. H. Moneymaker, U.S. Soil Conservation Officer, Anderson County, Tenn.

described in Table 3.3 occur extensively throughout the southeastern United States in the Coastal Plains, the Piedmont, the Appalachian Plateau, and the Valley and Ridge Province.¹⁵ Such soils have developed under forests and contain an A-horizon that is typically light colored and covers a tougher, clayey subsoil of red, yellow, or mottled color.¹¹ The major soils are generally silty (grain size 0.06 to 0.002 mm) rather than sandy or clayey. However, considerable clay may be present in the B-horizon.^{11,14} The Knox soils contain kaolinite as their principal clay, whereas illite and vermiculite constitute the bulk of Conasauga clay.

3.4 HYDROLOGY

3.4.1 Tennessee River valley

All waters that drain from the Oak Ridge reservation eventually reach the Tennessee-Ohio-Mississippi water system (Fig. 3.9).^{16,17} The headwater tributaries for the Tennessee River arise from points in Virginia, North Carolina, and Georgia. Initially, the river flows generally southwestward and receives inputs from eastern Tennessee and northern Alabama before bending sharply northwest to continue a winding path across western Tennessee to the river mouth at Paducah, Kentucky. The total drainage area of 40,910 sq miles (106,000 km²) includes about 80% of the state of Tennessee, a major segment of northern Alabama, and regions of Kentucky, Mississippi, Georgia, Virginia, and North Carolina. Many multipurpose dams regulate flow on this river system -- the Tennessee River alone is dotted with nine mainstream reservoirs from Knoxville to Paducah, Kentucky.

3.4.2 Clinch River

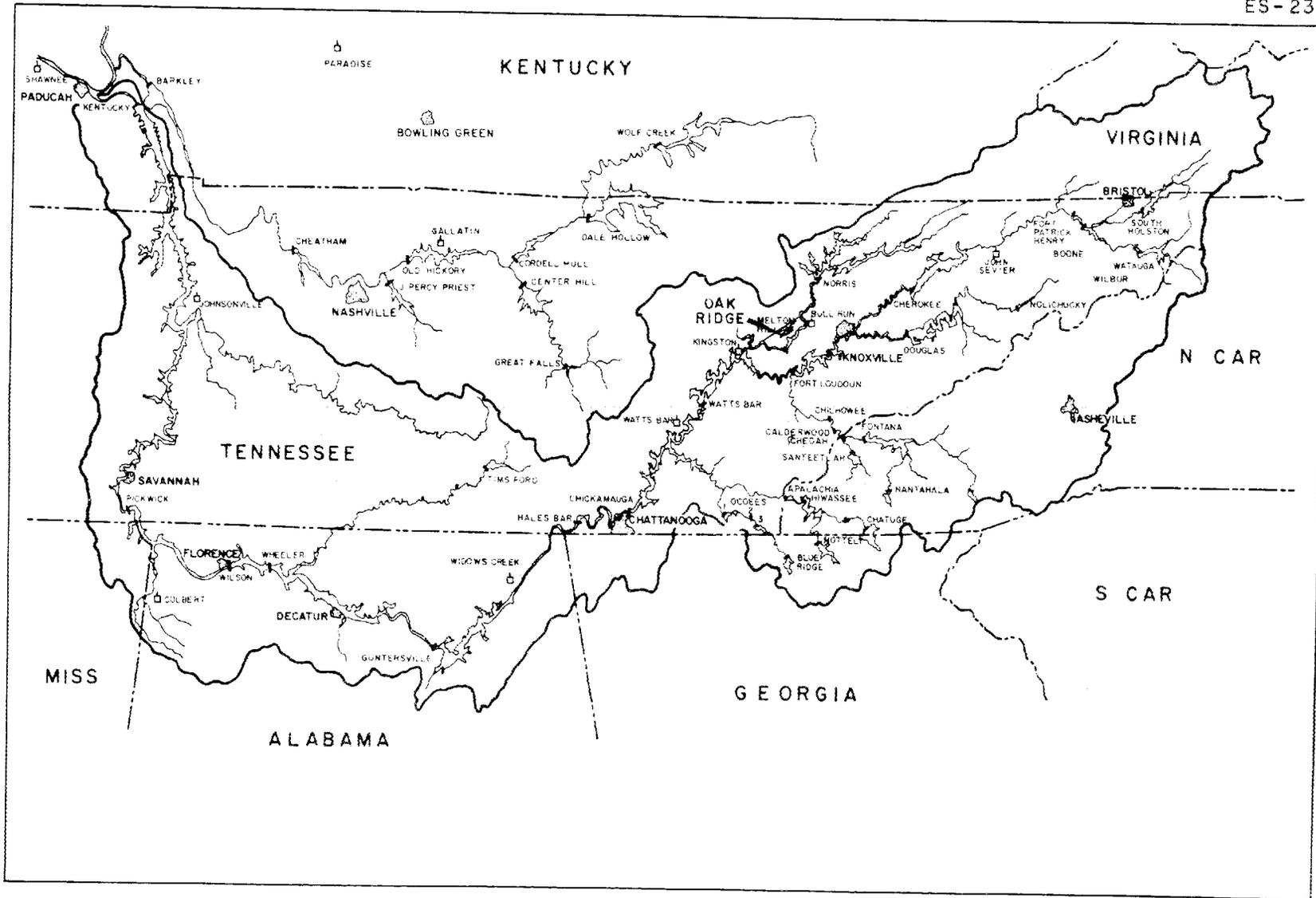
The Clinch River provides the immediate receptacle for waters discharged from the Oak Ridge reservation. The Clinch originates in Tazewell County, which is in the southwest corner of Virginia near the Kentucky border, 280 air km (175 air miles) northeast of Oak Ridge. The river proceeds in an approximately southwestward direction for more than 560 km (350 miles) before merging with the Tennessee River near Kingston at Tennessee River Mile (TRM) 567.7.¹⁸ The Clinch drainage basin encompasses an area of 4413 sq miles (11,400 km²) with an average width of 30 km (18 miles). It is bounded on the northwest by the Cumberland Mountains and on the southeast by the Clinch Mountains and Blackoak Ridge.

A dam at CRM 23.1 has created the Melton Hill Reservoir, which furnishes the eastern and southeastern boundary of the Oak Ridge reservation. This reservoir extends 71 river km (44 river miles) to Eagle Bend, which lies about 13 km (8 miles) above Clinton. A volume of 118,600 acre-ft of water is impounded at the normal maximum elevation of 242 m (795 ft). The Melton Hill Dam, completed in May 1963, was constructed for power production, navigation, recreation, and some low-flow regulation, but it functions little in flood control.

Backwaters from the Watts Bar Dam (impounded in 1942) on the Tennessee River define part of the southwestern and western boundaries of the DOE property. The Watts Bar Dam is located at TRM 529.8, about 61 km (38 miles) downstream from the mouth of the Clinch. Before the Melton Hill Reservoir, Watts Bar Dam regulated flows at the Oak Ridge reservation to CRM 28. The dam's primary purposes include flood control, navigation, electric-power generation, and recreation. Minimum and maximum reservoir elevations have been established, which are based on navigation and flood-control requirements. The minimum elevation recorded to date is 223.3 m (recorded on March 20, 1945), whereas the maximum elevation was measured at 227.0 m (745.40 ft) on March 17, 1973.¹⁹ In the vicinity of the Oak Ridge reservation, the reservoir ranges in width from 90 to 180 m (300 to 600 ft) and in depth from 6.7 to 7.3 m (22 to 24 ft) at the full-pool elevation of 227 m (745 ft).

3.4.3 Clinch River tributaries

The largest tributaries of the Clinch are the Powell and Emory rivers. The Powell arises southeast of the headwaters of the Clinch, flows parallel to the Clinch, receiving water from a



3-19

Fig. 3.9. Map of the Tennessee River Valley and vicinity showing important dams and steam plants. Source: E. G. Struxness (Chairman) et al., Clinch River Study Steering Committee, *Comprehensive Report of the Clinch River Study*, ORNL-4035, Oak Ridge National Laboratory, Oak Ridge, Tenn., April 1967, Fig. 3-7.

938-sq-mile area (2420-km²), and intersects the Clinch above Norris Dam at CRM 88.8. Northwest of the reservation, the Emory River drains a basin of 865 sq miles (2240 km²) before joining the Clinch at CRM 4.4 near Kingston.

The Oak Ridge reservation is composed of a series of limited drainage basins through which small streams traverse and ultimately reach the Clinch River. These watersheds generally fall 183 m (600 ft) from the ridge crests to their mouths. Brief descriptions of the major watersheds on the reservation are given below.²⁰

The Whiteoak Creek Basin of 6.37 sq miles includes Bethel Valley (site of Buildings 3019 and 3026D) and Melton Valley (site of Buildings 7503 and 7930). Melton Valley is also the location of ORNL's disposal areas for solid and liquid radioactive wastes. Whiteoak Creek flows south into Melton Valley from Bethel Valley through a gap in Haw Ridge. Elevations in the watershed range from 372 m (1220 ft) at the crest of Chestnut Ridge to 226 m (741 ft) at the creek mouth at CRM 20.8. The primary tributary of Whiteoak Creek is Melton Branch, which permits flows from Haw and Copper ridges to unite with the main stream at Whiteoak Creek Mile (WOCM) 1.55. The waters of Whiteoak Creek are impounded by Whiteoak Dam located 1.0 km (0.6 mile) above the stream mouth. The dam is an earthen structure with a steel cofferdam and gate built as a highway fill where White Wing Road (Tennessee State Highway 95) crosses the creek. Whiteoak Lake was constructed in October 1943 to regulate the dispersion of radionuclides and chemical pollutants discharged from ORNL. Whiteoak Lake is now a standing pool that can function as an emergency storage pond in the event of a major accidental release of contaminants.

Poplar Creek²¹ receives drainage from a 136-sq-mile area (350-km²), including the northwestern sector of the Oak Ridge reservation. The topographic relief of this basin exceeds that of all other water systems in the Oak Ridge area. Waters flow from the western half of the watershed (in the Cumberland Mountain section of the Appalachian Plateau Province) at elevations exceeding 975 m (3200 ft) to valleys in the Valley and Ridge Physiographic Unit at elevations of 226 m (741 ft) near the mouth. The creek flows through a basin that is about 65% wooded; the remainder is farmland. Some contamination occurs from the extensive surface coal mining that has been undertaken in the Cumberland Mountain district. The creek also receives effluents from several small communities, including Oliver Springs.

The East Fork of Poplar Creek drains a 29.8-sq-mile (77 km²) roughly rectangular watershed, which is 15 km (9 miles) long and 5.5 km (3.5 miles) wide and intersects Poplar Creek at Poplar Creek Mile (PCM) 5.5. The East Fork originates on Chestnut Ridge, which separates this drainage area from the Whiteoak Creek catchment. The headwaters are collected in the Y-12 Plant area, where they receive wastes (primarily) in the form of cooling-tower blowdown, waste-stream condensate, and process cooling water. The creek then flows northwestward roughly paralleling Tennessee State Highway 62 into the residential areas of Oak Ridge.

The 7.4-mile-long (12-km) drainage basin of Bear Creek begins at the southwest boundary of Y-12. This creek meanders westward through Bear Creek Valley until it reaches McNew Hollow, where it slices abruptly northwest to cross Pine Ridge and the valley that lies between McKinney Ridge and East Fork Ridge. In its course, it parallels Bear Creek Valley Road and White Wing Road through the ridge hollow. Bear Creek then flows beyond the intersection of White Wing Road and Oak Ridge Turnpike to join the East Fork of Poplar Creek. The catchment is about 65% wooded;

the remainder consists of old fields. Although the creek does not serve as a watershed for the main site of the Y-12 Plant, drainage from the plant's waste-disposal and refuse areas are collected in this basin.

The Walker Branch Watershed is currently being used by the ORNL Environmental Sciences Division in experiments on nutrient cycling in an undisturbed ecosystem;²² consequently, it has been the subject of detailed hydrological analysis.^{23,24} The drainage basin lies 3.6 km (2.6 miles) east of the X-10 site and originates on Chestnut Ridge. Water from two catchments, a larger East Fork and a smaller West Fork, discharges the drainage from a 960-acre (388-ha) basin into the Clinch River at CRM 33. Before the construction of the Oak Ridge facilities, about 25% of this watershed was used for agricultural purposes. However, these agricultural lands have reforested in the intervening 30 years, and the basin is presumed to represent an undisturbed ecosystem typical of the Eastern Deciduous Forest Biome of the Valley and Ridge Province.

The lower reaches of Scarboro Creek basin are included in the site of Tennessee's first arboretum, developed by the University of Tennessee's Forestry Department. To provide pooled water for certain species of trees, a series of dams has been constructed on the 1.13-sq-mile catchment. No major records are maintained for this stream.

3.5 METEOROLOGY

3.5.1 Regional climate

Oak Ridge National Laboratory is located in a broad valley between the Cumberland Mountains northwest of the area and the Great Smoky Mountains to the southeast. These mountain ranges are oriented northeast-southwest, and the valley between is corrugated by broken ridges 300 to 500 ft high (90 to 150 m) parallel to the main valley. Storm tracks appear to travel from northwest to southeast; associated wind velocities are somewhat decreased by the mountains and ridges. Tornadoes rarely occur in the valley between the Cumberlands and the Smokies.²⁵ In winter the Cumberland Mountains have a moderating influence on the local climate by retarding the flow of cold air from the north and west.

Relatively warm summers and cool winters characterize continental climatic regions in the southeastern United States. Cold, dry air masses from Canada predominate in the winter. They usually undergo modification and warming as the air crosses the ridges of the Cumberlands and moves down the eastern slopes. Anticyclonic circulation of the atmosphere about the Bermuda-Azores high-pressure system results in a predominance of warm, moist air from the Gulf during the rest of the year.²⁶ For about 33 days each year, temperatures reach 90°F (32.2°C) or higher, and temperatures of 0°F (-17.8°C) or lower are expected one day each year. Temperatures of 32°F (0°C) or lower normally occur on 82 days annually. Precipitation amounts are greatest during winter and early spring and are lowest in early autumn. A secondary precipitation maximum, associated with thundershower activity, occurs in July. The annual relative humidity averages 70%.

3.5.2 Local climate

The climate of Oak Ridge is typical of the humid southern Appalachian region. The local climate is noticeably influenced by topography.²⁷ Prevailing winds are usually either up-valley from southwest to northeast (daytime) or down-valley from northeast to southwest (nighttime).

Differences in elevation have a measurable influence on the changes in climate along a northeast-southwest axis; stations at similar elevations have similar annual mean temperature and precipitation normals. The mean area annual rainfall is approximately 53.5 in. (136 cm), and the mean temperature is 57.9°F (14.4°C). Precipitation is predominately in the form of rainfall, although snowfall is occasionally a significant contributor. The annual precipitation pattern is characterized by wet winters and comparatively dry springs followed by relatively wet summers and dry autumns. July rainfall [5.9 in. (15 cm)] normally approaches that of the wet winter months, but June [3.2 in. (8.1 cm)] is as dry as the autumn months.

Intense localized weather consists mainly of severe thunderstorms in warm seasons and large-scale storms in the winter. Remnants of hurricanes, weakened by loss of moisture, occasionally affect the area. Between 1953 and 1974, 54 tornadoes occurred within the 10,000-sq-mile site area.²⁵ There were 15 reports of hail, 0.75 in. (1.9 cm) diam or greater, and 46 reports of windstorms with speeds of 50 knots (58 mph) or greater within the 1-degree latitude-longitude square (approximately 62 x 75 miles) of the site during the period 1955 through 1967. During the period 1871 through 1973, four tropical storms or hurricanes passed within 50 miles (80 km) of the area. Freezing precipitation can be expected about five times each year, and a severe ice storm [accumulation of 1 in. (2.5 cm) or more], once every 5 years. High air pollution potential can be expected on 7 days annually.

3.5.3 Meteorology stations

There are five meteorology stations in the HETP and surrounding area. These are: (1) X-10 weather station located approximately 1 mile (1.6 km) southeast of ORNL, (2) Oak Ridge City weather station, about 8 miles (12.8 km) north-northeast of the site, (3) Clinch River Breeder Reactor Plant (CRBRP) site weather station, about 5.5 miles (8.8 km) southwest of the site, (4) Oak Ridge Gaseous Diffusion Plant weather station, about 6 miles (9.6 km) west-northwest of the site, and (5) the Knoxville Airport weather station about 20 miles (32 km) east-southeast of the site. The Knoxville Airport weather station is a first-order weather station. (First-order weather stations are usually located at major airports and are manned 24 hr a day. These stations record hourly visual observations as well as wind, temperature, dewpoint, etc. Second-order stations record and/or transmit data on physical phenomena only.) The X-10 weather station was a first-order station from 1944 to 1964. From 1964 to 1972 only wind, temperature, dewpoint, and differential temperature were recorded. The station was discontinued in December 1972. Data from the X-10 weather station, as assembled by Hilsmeier (1963),²⁸ supplemented by CRBRP and Knoxville Airport data, were used to characterize airborne radionuclide distributions in this report. Locations of area weather stations are shown in Fig. 3.10.

3.5.4 Temperature

The coldest month in the ORNL area is normally January, but differences between the mean temperatures of the three winter months of December, January, and February are comparatively small. The lowest mean monthly temperature of the winter has occurred in different years in each of the months of December, January, and February. July is usually the hottest month, but differences between the mean temperatures of the summer months of June, July, and August are also relatively small. The highest mean monthly temperature can occur in June, July, or August; the highest temperature of the year has occurred in the months of June, July, August, and September in different years. Mean temperatures of the spring and fall months progress in an orderly fashion

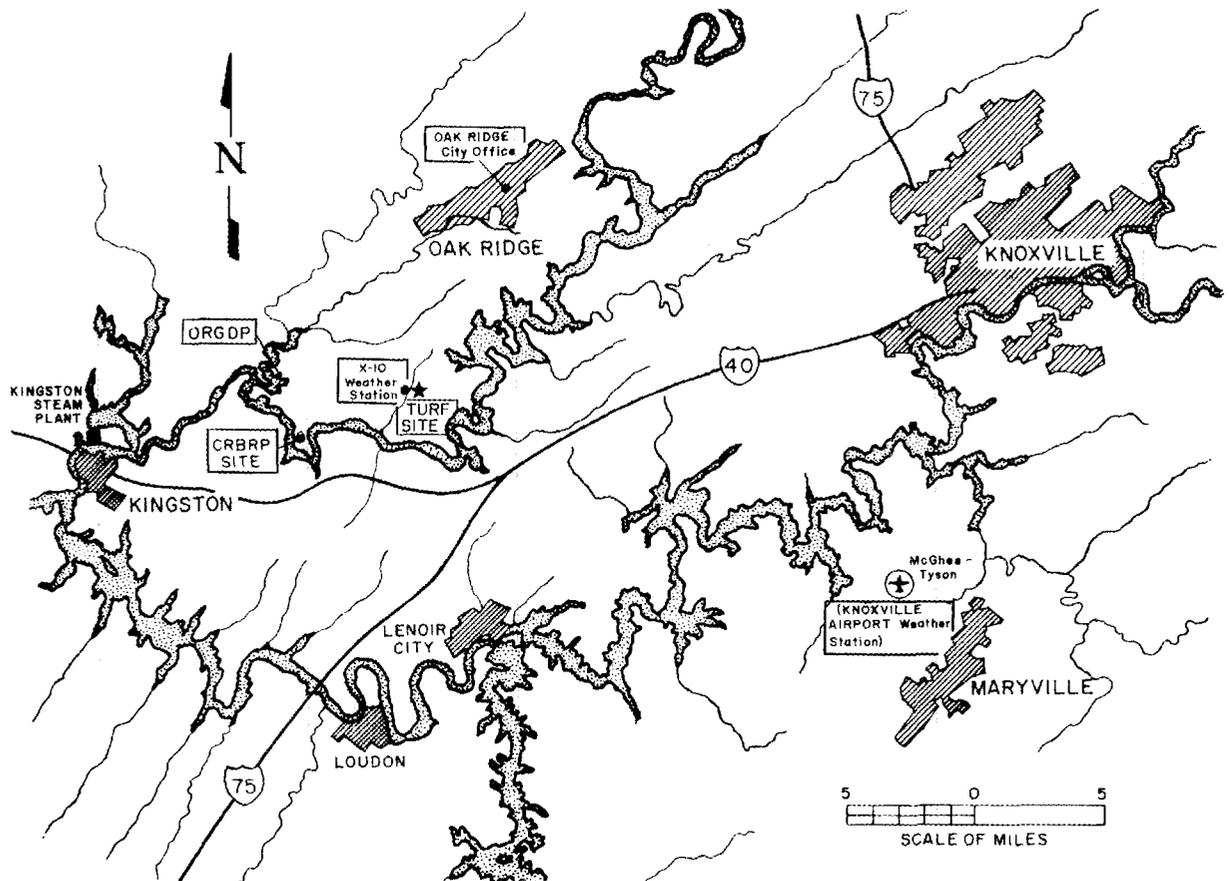


Fig. 3.10. Locations of weather stations near site. Source: Project Management Corporation, *Clinch River Breeder Reactor Plant Environmental Report*, vol. 1, 179 Washington St., Chicago, Ill., April 1975, p. 2.6-82.

without a secondary maximum or minimum. Temperatures of 100°F (37.8°C) or higher are unusual, as are temperatures of zero or below. The average number of days between the last freeze of spring and the first freeze of fall is approximately 200. Low-elevation temperature inversions occur during approximately 56% of the hourly observations.²⁷ Fall is usually the season with the greatest number of hours of low-level inversion, with the number decreasing progressively through spring and winter to a summertime minimum. Table 3.4 presents area temperature summary data.

3.5.5 Precipitation

March is normally the wettest month and October the driest. Precipitation is heaviest from December through March when cyclonic activity is high and in July and August when convective showers occur. Regional-scale weather systems move through eastern Tennessee with irregularity. These storm systems are most frequent during December and January and cause a maximum monthly number of cloudy days and extensive precipitation. Summer storm systems are usually weaker

Table 3.4. Temperature and precipitation — Oak Ridge Area

| Station X-10 | | | | | | | | | |
|--|--|--------------------|--------------------|--------------------------|-------------------------|------------------------------------|-----------------------|-----------------------|--------------------------|
| Temperature, 1945 to 1964 | | | | | | | | | |
| Month | Climatological standard normals 1931 to 1960 | | | Extremes 1945 to 1964 | | Precipitation, 1944 to 1964 | | | |
| | Mean monthly (°F) | Daily maximum (°F) | Daily minimum (°F) | Highest temperature (°F) | Lowest temperature (°F) | Monthly average ^a (in.) | Monthly maximum (in.) | Monthly minimum (in.) | Maximum in 24 hour (in.) |
| December | 40.4 | 49.4 | 31.3 | 76 | -5 | 5.22 | 10.28 | 1.98 | 4.38 |
| January | 40.1 | 48.9 | 31.2 | 77 | -8 | 5.24 | 12.37 | 1.11 | 3.96 |
| February | 41.7 | 51.6 | 31.8 | 77 | 0 | 5.39 | 10.01 | 1.89 | 3.23 |
| Winter | 40.7 | 50.0 | 31.4 | 77 | -8 | 15.85 | | | |
| March | 48.0 | 58.9 | 37.0 | 87 | 4 | 5.44 | 9.69 | 2.05 | 3.84 |
| April | 58.2 | 70.0 | 46.3 | 89 | 24 | 4.14 | 8.54 | 1.25 | 2.39 |
| May | 66.9 | 79.0 | 54.8 | 94 | 32 | 3.48 | 7.01 | 0.90 | 2.09 |
| Spring | 57.7 | 69.3 | 46.0 | 94 | 4 | 13.06 | | | |
| June | 74.7 | 86.1 | 63.3 | 99 | 41 | 3.39 | 7.55 | 1.19 | 3.08 |
| July | 77.4 | 88.0 | 66.7 | 103 | 49 | 5.31 | 10.19 | 2.14 | 3.74 |
| August | 76.5 | 87.4 | 65.6 | 95 | 44 | 4.02 | 10.31 | 0.50 | 3.31 |
| Summer | 76.2 | 87.2 | 65.2 | 103 | 41 | 12.71 | | | |
| September | 71.1 | 83.0 | 59.2 | 103 | 33 | 3.59 | 12.84 | 0.21 | 7.75 |
| October | 60.0 | 72.2 | 47.7 | 91 | 21 | 2.82 | 6.43 | 0.00 | 2.32 |
| November | 47.6 | 58.6 | 36.5 | 83 | 4 | 3.49 | 12.00 | 1.01 | 3.20 |
| Fall | 59.6 | 71.3 | 47.6 | 103 | 4 | 9.90 | | | |
| Annual | 58.5 | 69.4 | 47.6 | 103 | -8 | 51.52 | 12.84 | 0.90 | 7.75 |
| Oak Ridge city office | | | | | | | | | |
| Climatological standard normals 1941 to 1970 | | | | | | | | | |
| Annual | 57.8 | 68.6 | 47.0 | 105 ^b | -9 ^b | | | | |
| Knoxville vicinity | | | | | | | | | |
| Climatological standard normals 1941 to 1970 | | | | | | | | | |
| Annual | 59.7 | 69.8 | 49.5 | 104 ^c | -15 ^c | | | | |

^aClimatological standard normals — 1931 to 1960.

^bMay 1947 and October 1974.

^cJuly 1930 and January 1984.

Source: Project Management Corporation and the Tennessee Valley Authority, *Clinch River Breeder Reactor Plant Environmental Report*, vol. 1, Construction Permit Stage, Docket No. 50-537, issued April 7, 1975, Tables 2.6-4 and 2.6-8.

and tend to pass to the north, leaving eastern Tennessee with sunshine interspersed with thunderstorm activity. Between 50 and 60 thunderstorm days occur per year, with a peak number of storms in July.²⁷ Precipitation is highly variable; a few of the larger monthly amounts recorded in the vicinity have occurred in the normally drier fall months. Periods of 5 consecutive days without measurable precipitation occur about four or five times per year, periods of 10 consecutive dry days average one to two per year, and dry periods of more than 11 days average less than one per year. Light snow usually occurs in all months from November through March, but the total monthly snowfall is often only a trace. Snowfalls sufficiently heavy to interfere with traffic and outdoor activities occur infrequently. A summary of precipitation data for the area is presented in Table 3.4. Mean monthly precipitation averages for the Oak Ridge area are presented graphically in Fig. 3.11.

3.5.6 Glaze

Glaze (freezing rain) occurred from three to six times per year during a 28-year-survey period ending in 1953. Glaze can occur during the normally colder months whenever rain falls through a very shallow layer of cold air from an overlying warm layer. Rain then freezes on contact with the ground or other objects to form a glaze. December through early March is the period with the highest frequencies of glaze storms. Based on limited periods of data collection, significant glaze storms producing glaze thicknesses of 0.25 in. (0.6 cm) or more on wires occur in eastern Tennessee on an average of once every two years. Occurrences for glaze storms in the area including the site are as follows:¹⁹

| Thickness (in.) | Occurrence period (years) |
|--------------------|------------------------------|
| 0.25 | 2 |
| 0.50 | 5 |
| 0.75 | 10 |

3.5.7 Tornadoes

The site is located in an area infrequently subjected to tornadoes.¹⁹ For the purpose of comparison, Tennessee ranked 25th among all states in the number of tornadoes from 1955 to 1967. Dividing along the 86th meridian, the western half has reported three times as many tornadoes as the eastern half of the state. The Oak Ridge area has one of the lowest probabilities of tornado occurrence in the entire state. Tornado frequencies calculated by Thom for each one-degree square of latitude and longitude for the period 1953 to 1962 show the site to be situated in a one-degree square with an annual frequency of 0.5. Probability that a tornado will strike any point in a particular one-degree square, such as the site, is calculated as 3.65×10^{-5} per year; recurrence interval is once in 27,400 years. Roane County itself has not recorded a tornado in the 57-year period of 1916 to 1972.

3.5.8 Local wind patterns

As previously discussed the local area and the region experience a largely bimodal wind direction pattern that consists of up-valley and down-valley flows. The stability characteristics of these two directional channels are also nearly identical and represent the critical dispersion conditions. It is likely, however, that the similar flows are caused by differing meteorological phenomena.²⁹ The down-valley draft, identified with drainage of gravitational flow down local

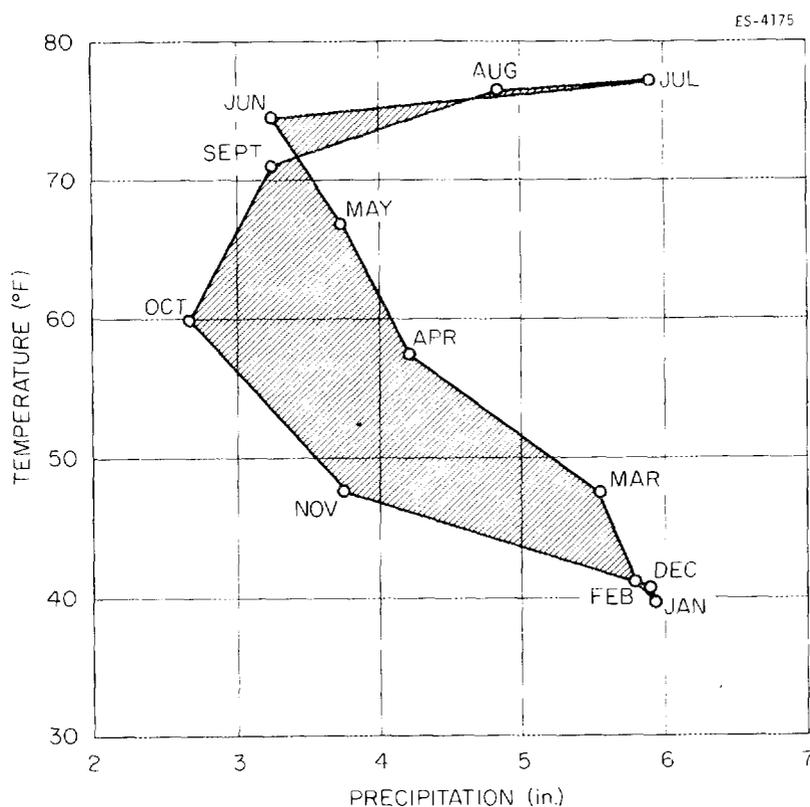


Fig. 3.11. Climograph of the Oak Ridge area. Source: J. W. Curlin and D. J. Nelson, *Walker Branch Watershed Project: Objectives, Facilities, and Ecological Characteristics*, ORNL/TM-2271, Oak Ridge National Laboratory, Oak Ridge, Tenn., September 1968, p. 17.

slopes and the broader Tennessee valley, prevails during the inversion conditions of late evening through midmorning, at which time regional pressure patterns dependent on solar inputs are very weak. However, in the daytime up-valley flow results when the regional flows aloft become sufficiently strong to dominate over the opposing flows. Since these higher altitude regional winds do not exert as pronounced an influence on valleys, the local valley wind regime can even maintain its structure and flow in a direction opposite to that of the regional wind. A normally quoted average wind speed for Oak Ridge of 4.4 mph (7 km/hr) is the mean value of annual measurements taken over a 16-year period at the Oak Ridge city office. Inversion conditions occur about one-third of the time throughout the year. This type of vertical temperature distribution occurs primarily as a diurnal response to radiative and convective heat transfers at the earth's surface, but may be secondarily modified by both seasonal solar energy input and cloudiness. A relatively high potential for significant air pollution results, as illustrated in Fig. 3.12.

3.5.9 Wind and stability class

All-season area wind-rose data are presented in Fig. 3.13. The data were assembled from 107,000 observations taken over a period of 12-1/4 years.²⁸ Seasonal differences in the wind data are insignificant; area wind data are tabulated in Table 3.5.²⁵

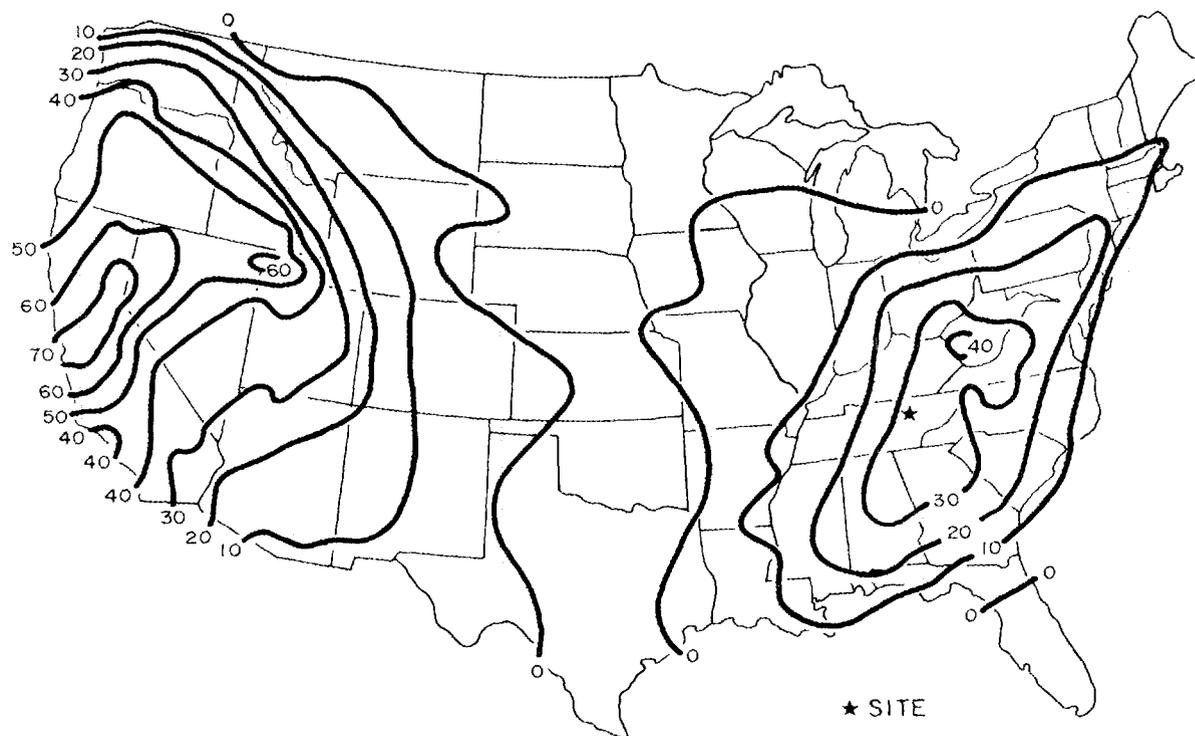


Fig. 3.12. Total number of forecast days of high meteorological potential for high air pollution in a 5-year period. Source: Project Management Corporation, *Clinch River Breeder Reactor Plant Environmental Report*, vol. 1, 179 W. Washington St., Chicago, Ill., April 1975, p. 2.6-84.

Pasquill stability-class data for the ORNL area are summarized below.

| <u>Pasquill stability class</u> | <u>Definition of class</u> | <u>Fraction of the year in each stability class</u> |
|---------------------------------|--------------------------------|---|
| A | Extremely unstable conditions | 0.07 |
| B | Moderately unstable conditions | 0.14 |
| C | Slightly unstable conditions | 0.13 |
| D | Neutral conditions | 0.28 |
| E | Slightly stable conditions | 0.20 |
| F | Moderately stable conditions | 0.14 |
| G | Extremely stable conditions | 0.04 |

Source: W. F. Hilsmeier, *Supplementary Meteorological Data for Oak Ridge*, ORO, Atomic Energy Commission, Division of Technical Information, Office of Technical Services, Department of Commerce, Washington, D.C., 1963.

A more detailed summary of wind speed and direction data has been prepared by the Atmospheric Turbulence and Diffusion Laboratory of the National Oceanic and Atmospheric Administration, Oak Ridge, Tennessee, and includes ORGDP observations over a period of 13 years, as noted in Table 3.6.²⁷ The National Oceanic and Atmospheric Administration has operated the ORGDP meteorological observation program at Oak Ridge for more than 20 years. The peak gust (wind velocity) of record was 59 mph (95 km/hr) during this period. Calm conditions prevailed approximately 10% of the time; partly cloudy, 25%; and cloudy, 45%.

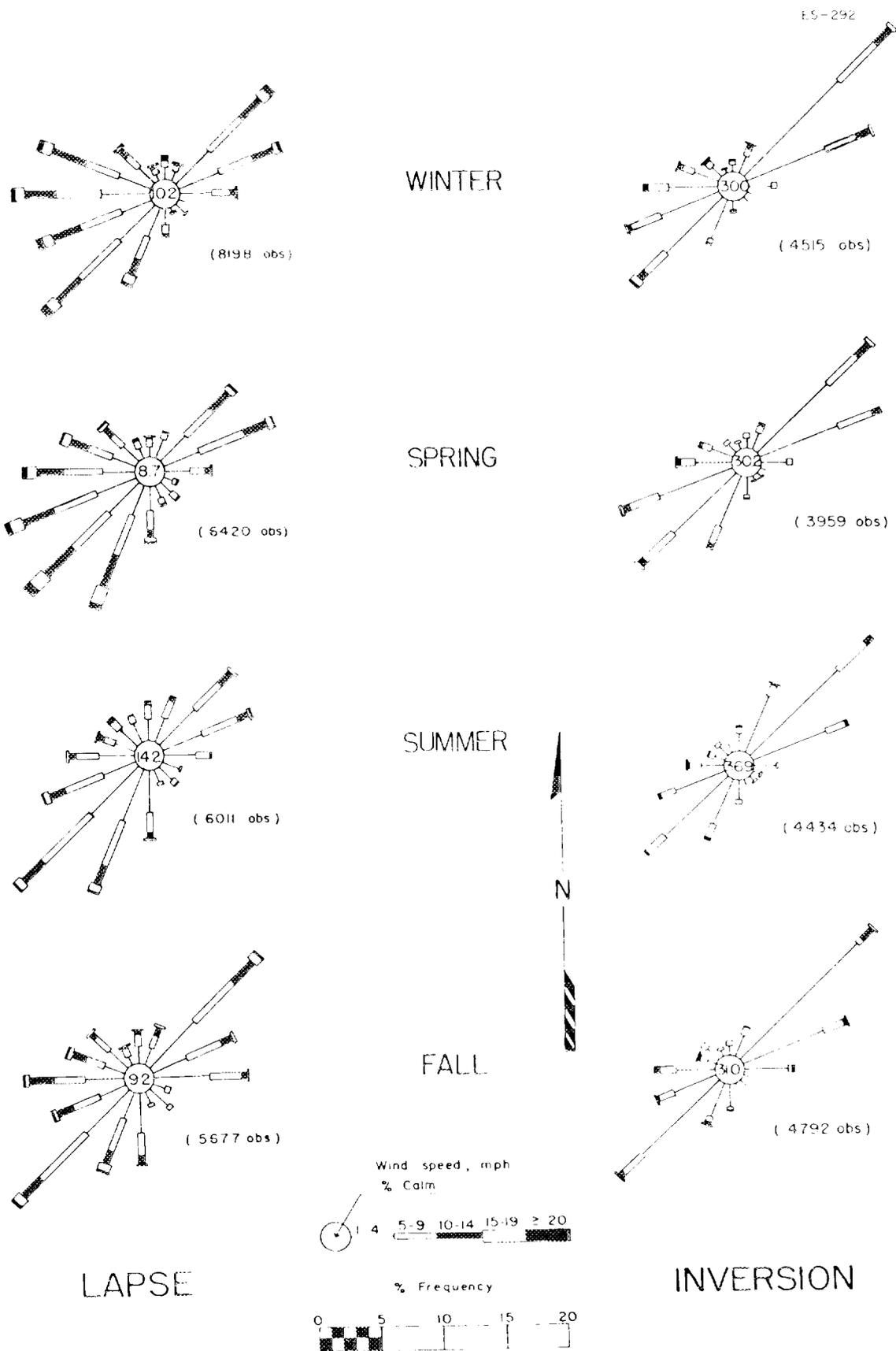


Fig. 3.13. Wind-rose data, 1956-1960. Source: W. F. Hilsmeier, *Supplementary Meteorological Data for Oak Ridge*, ORO-199, Atomic Energy Commission, Division of Technical Information, Office of Technical Services, Department of Commerce, Washington, D.C., 1963.

Table 3.5. Monthly wind data

| Month | Oak Ridge city office ^b | | Knoxville airport ^c | | Area station X-10 ^d | | CRBRP meteorological tower ^a | | | |
|-----------|------------------------------------|----------------------|--------------------------------|----------------------|--------------------------------|----------------------|---|----------------------|---------------------|----------------------|
| | Average speed (mph) | Prevailing direction | Average speed (mph) | Prevailing direction | Average speed (mph) | Prevailing direction | 75-ft level | | 200-ft level | |
| | | | | | | | Average speed (mph) | Prevailing direction | Average speed (mph) | Prevailing direction |
| January | 4.8 | SW | 8.2 | NE | 5.3 | SSW | 4.7 | SW | 8.7 | SW |
| February | 5.0 | ENE | 8.7 | NE | 6.0 | SSW | 7.6 | WNW | 8.3 | SW |
| March | 5.3 | SW | 9.2 | NE | 6.8 | WSW | 7.6 | SW | 14.3 | SW |
| April | 5.7 | SW | 9.3 | WSW | 7.0 | SSW | 7.6 | SW | 11.6 | SW |
| May | 4.5 | SW | 7.4 | SW | 6.2 | NE | 7.8 | SW | 8.4 | SW |
| June | 4.2 | SW | 6.7 | SW | 6.2 | WSW | 6.0 | SW | 8.7 | SW |
| July | 3.9 | SW | 6.3 | WSW | 4.2 | SSW | 7.2 | SW | 8.1 | SW |
| August | 3.7 | E | 5.7 | NE | 1.5 | SSW | 3.8 | SW | 4.3 | SW |
| September | 3.8 | E | 5.9 | NE | 2.9 | NNE | 3.1 | E | 3.4 | ENE |
| October | 3.6 | E | 5.9 | NE | 2.9 | NNE | 3.0 | SW | 3.6 | SW |
| November | 4.1 | E | 7.2 | NE | 3.2 | N | 4.7 | SW | 8.3 | SW |
| December | 4.5 | SW | 7.6 | NE | 4.3 | NNE | 4.6 | WNW | 6.0 | ENE |
| Annual | 4.4 | SW | 7.3 | NE | 4.7 | SSW | 4.9 | SW | 6.7 | SW |

^aOne-year record.

^bSixteen-year record on wind speed, 13-year record on prevailing direction.

^cThirty-one-year record on wind speed, 14-year record on prevailing direction.

^dOne-year record (102 ft, sensor elevation).

Source: Project Management Corp., *Clinch River Breeder Reactor Plant Environmental Report*, vol. 1, 179 W. Washington St., Chicago, Ill. 1975, Table 2.6-5.

Table 3.6. Wind rose data — percent occurrence of wind speed for all wind directions (ORGDP weather station, 1957 to 1969)^a

| Compass point direction | Wind speeds (mph) | | | | | | Total |
|-------------------------|-------------------|-------|-------|-------|-------|-------|-------|
| | 1-3 | 4-7 | 8-12 | 13-19 | 20-24 | 25+ | |
| N | 1.17% | 0.75% | 0.42% | 0.13% | 0.01% | 0.00% | 2.49% |
| NNW | 0.85 | 0.81 | 0.60 | 0.17 | 0.02 | 0.00 | 2.46 |
| NW | 1.01 | 1.37 | 1.67 | 0.78 | 0.14 | 0.01 | 4.99 |
| WNW | 0.53 | 0.88 | 1.23 | 0.70 | 0.11 | 0.02 | 3.47 |
| W | 0.78 | 1.20 | 1.31 | 0.72 | 0.15 | 0.03 | 4.19 |
| WSW | 0.71 | 1.12 | 0.98 | 0.38 | 0.08 | 0.02 | 3.29 |
| SW | 1.84 | 3.45 | 3.22 | 1.07 | 0.17 | 0.04 | 9.79 |
| SSW | 1.33 | 1.84 | 1.29 | 0.34 | 0.08 | 0.01 | 4.90 |
| S | 1.84 | 1.97 | 0.97 | 0.28 | 0.05 | 0.02 | 5.13 |
| SSE | 0.58 | 0.40 | 0.12 | 0.04 | 0.01 | 0.00 | 1.15 |
| SE | 1.03 | 0.50 | 0.12 | 0.02 | 0.00 | 0.00 | 1.67 |
| ESE | 0.63 | 0.20 | 0.05 | 0.01 | 0.00 | 0.00 | 0.89 |
| E | 2.18 | 0.80 | 0.26 | 0.06 | 0.01 | 0.00 | 3.30 |
| ENE | 3.07 | 1.44 | 0.51 | 0.11 | 0.01 | 0.00 | 5.14 |
| NE | 12.07 | 7.24 | 2.05 | 0.54 | 0.05 | 0.00 | 21.96 |
| NNE | 3.90 | 2.12 | 0.66 | 0.16 | 0.01 | 0.00 | 6.85 |

^aWind speed and frequency values are for wind blowing from the compass point direction noted.

Source: Air Resources Atmospheric Turbulence and Diffusion Laboratory (ATDL), Environmental Research Laboratories, "Daily, Monthly and Annual Climatological Data for Oak Ridge, Tn, Townsite and area stations, January 1951 — December 1971." U.S. Department of Commerce, National Oceanic and Atmospheric Administration, ATDL Contribution File 61. July 1972.

3.6 ECOLOGY

3.6.1 Terrestrial

3.6.1.1 Overview

The Oak Ridge reservation of the Department of Energy consists of approximately 15,000 ha (37,000 acres) within the Ridge and Valley Physiographic Province of eastern Tennessee. The reservation was predominately agricultural land prior to Federal acquisition in 1942 for use in the wartime Manhattan Project. With Federal ownership, the land was withdrawn from public access, and much of it was allowed to revert to natural plant cover. About 10,500 ha (26,000 acres) are managed currently for environmental research, wood-fiber production, or both.

3.6.1.2 Vegetation^{30,31}

The dominant oak-hickory association in the Ridge and Valley Province contains elements of the mixed mesophytic association commonly found in the adjacent Cumberland Mountains. Plant communities of the Oak Ridge 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 Cumberland Mountains in northern Alabama. On the reservation, the oak-hickory association is typified by extensive stands of pine, oak, and hickory as well as other hardwoods. Yellow poplar (*Liriodendron tulipifera*) often forms nearly pure stands on well-drained bottomlands and lower slopes, and willow (*Salix discolor*), sycamore (*Platanus occidentalis*), and box elder (*Acer negundo*) border streams and are dominant on poorly drained floodplains. Species more commonly found in the mixed mesophytic association, such as beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), magnolia (*Magnolia acuminata*), buckeye (*Aesculus* spp.), and basswood (*Tilia americana*) often occur in the coves and on the sheltered slopes. In addition, approximately 1740 ha (4300 acres) of the reservation were planted in loblolly pine (*Pinus taeda*) between 1947 and 1956, and smaller areas have since been planted in loblolly pine, black walnut (*Juglans nigra*), river birch (*Betula nigra*), sycamore, and yellow poplar.

For discussion, it is convenient to group the mosaic of plant communities on the reservation into three categories, which roughly correspond to identifiable successional stages: old-field grasslands, pine forests, and hardwood forests.

Old-field grasslands

Old-field grasslands are found where land has recently been abandoned or where periodic mowing or other cultural practices maintain an early successional stage, such as under power lines and along roads. Plants found in old fields consist of annual forbs and grasses (e.g., *Ambrosia artemisiifolia*, *Digitaria sanguinalis*), biennial and perennial forbs (e.g., *Conyza canadensis*, *Oenothera* spp., *Aster* spp.), perennial grasses (*Andropogon virginicus*, *Festuca elatior*, *Panicum* spp.), and woody species (*Diospyros virginiana*, *Juniperus virginiana*, *Sassafras albidum*, *Campsis radicans*, *Rhus* spp., *Pinus* spp., and *Lonicera japonica*).

Pine forests

Both pine plantations and native seral pine forests occur on the reservation. Natural seres are dominated by Virginia pine (*Pinus virginiana*) and short-leaf pine (*P. echinata*), but the plantations are of loblolly. Loblolly pine plantations are managed (thinning and controlled burning)

to minimize understory vegetation, whereas the natural seres produce an understory of native hardwoods that gradually replace the pines.

Hardwood forests

Upland hardwood forests are dominated by various oaks (*Quercus prinus*, *Q. alba*, *Q. velutina*, *Q. rubra*, *Q. coccinea*, and *Q. stellata*) and hickories (*Carya* spp.). Other hardwoods are ash (*Fraxinus* spp.), yellow poplar, red maple (*Acer rubrum*), tupelo (*Nyssa sylvatica*), beech, and dogwood (*Cornus florida*). A characteristic lowland forest occurs on floodplains and consists of cottonwood (*Populus deltoides*), sycamore, elm (*Ulmus americana*), ash, willow, sugar maple, and river birch.

Rare and endangered plants

Two plant species have recently been found on the DOE reservation which are on the *Federal Register* list of threatened or endangered plants.³² These are *Cimicifuga rubifolia* (Ranunculaceae) and *Saxifraga careyana* (Saxifragaceae). *Conradina verticillata* (Lamiaceae) has been recorded from nearby Morgan County³⁰ and could possibly occur on the reservation. Sixteen species have been identified as rare on the reservation, but all are locally abundant within the state of Tennessee.³³

3.6.1.3 Animals^{30,31}

The diversity of plant communities of the successional mosaic has made possible a rich fauna that has been intensively studied.

Fauna of upland forests

Common small mammals of upland forests include white-footed mouse (*Peromyscus leucopus*), chipmunk (*Tamias striatus*), golden mouse (*Ochrotomys nuttalli*), short-tail shrew (*Blarina brevicauda*), flying squirrel (*Glaucomys volans*), and house mouse (*Mus musculus*). The white-footed mouse is the most common small mammal, with up to 8.4 individuals per ha (3.4 per acre). Chipmunk is the next most common, with up to 2.4 individuals per ha (1.0 per acre).

Predators include red fox (*Vulpes fulva*), gray fox (*Urocyon cinereoargenteus*), skunk (*Mephitis mephitis*), bobcat (*Lynx rufus*), and weasel (*Mustela frenata*). There is a large deer herd (*Odocoileus virginianus*) on the reservation.

Sixty bird species, 10 amphibian species and 19 reptilian species have been recorded for upland forests. The arthropod fauna has been extensively studied and is well known for taxonomic levels above the species.

Fauna of pine forests

Pine forests are used by fauna to a lesser extent than upland deciduous forests or old fields.³⁰ Small-mammal studies showed only low populations of three rodents. Two bird species, pine warblers (*Dendroica pinus*) and white-throated sparrows (*Zonotrichia albicollis*), commonly use pine forests; but few, if any, others do so on a regular basis. Reptiles and amphibians are not found in pine forests, and arthropod populations may be depressed.

Fauna of old-field grasslands

Small mammals are abundant and diverse in old fields and include cotton rats (*Sigmodon hispidus*), white-footed mouse, golden mouse, rice rat (*Oryzomys palustris*), short-tail shrew, and eastern harvest mouse (*Reithrodontomys humilis*). More than 100 bird species have been recorded from reservation old fields, as have 12 amphibian species and 26 reptilian species.³⁰

Rare and endangered animals

The southern bald eagle (*Haliaeetus l. leucocephalus*) and the eastern cougar (*Felis concolor souan*) have both been sighted on the reservation. Both are endangered.³⁴ The endangered Indiana bat (*Myotis sodalis*) has been recorded from nearby Campbell County, Tennessee, and suitable habitat exists on the reservation; none has been sighted, however. The American osprey (*Pandion haliaetus carolinensis*) is included in the Audubon Blue List³⁵ and has been seen on the reservation.

3.6.1.4 Project sites

HETP will occupy four existing buildings on the Oak Ridge reservation. Buildings 3019 and 3026D are located within the Oak Ridge National Laboratory in what is essentially an urban-industrial setting. Buildings 7503 and 7930 are located in a smaller site, but still in what is basically an industrial setting. No building is in close proximity to undisturbed natural ecosystems, and there are no plans for buildings to be expanded into natural areas.

3.6.2 Aquatic ecology

3.6.2.1 Clinch River (including Melton Hill Reservoir)

The Clinch River is the major source of water used in the Oak Ridge area. Water pumped by the Oak Ridge pumping station (CRM 41.5) is delivered to ORNL, Y-12, and the city of Oak Ridge. Wastewater from ORNL is returned to the Clinch River via Whiteoak Creek; from Y-12, via the East Fork of Poplar Creek; and from ORGDP, directly. The section of the river primarily affected by DOE operations extends from CRM 41.5 on Melton Hill Reservoir to CRM 11.5 just downstream from the mouth of Poplar Creek. The section of river primarily affected by ORNL operations extends downstream from CRM 20.8, the entrance of Whiteoak Creek into Melton Hill Reservoir (Fig. 3.14).

Water quality

Water quality data are summarized in Tables 3.7 and 3.8. The data in Table 3.7 indicate that Clinch River water is moderately hard (hardness, 78 to 208 mg/liter as CaCO₃), alkaline (pH, 7.6 to 8.7), generally turbid (turbidity, 5 to 70 Jackson turbidity units; suspended solids, 6 to 42 mg/liter), and well oxygenated (dissolved oxygen, 6.1 to 11.2 mg/liter).

In general, all physical and chemical parameters measured for Clinch River water in the vicinity of the reservation comply with EPA and Tennessee State water quality criteria.^{36,37} Occasionally, however, levels of some parameters exceed the proposed criteria (Table 3.7). Nitrate concentrations (as N) at CRM 11.3 in 1973 ranged from 0.5 to 2.8 mg/liter (mean, 1.15 mg/liter).³⁸ A source of these high nitrate levels (values are high relative to upstream concentrations of



Fig. 3.14. Map showing streams of the Oak Ridge area (with Clinch River miles 10 to 45 indicated).

Table 3.7. Summary of Clinch River water quality data (CRM 11-18) and water quality criteria (concentrations measured as milligrams per liter unless otherwise noted)

| Parameter | Maximum | Minimum | Mean | For protection of aquatic life | For public water supplies | Tennessee receiving water maximum stream limit unless otherwise noted ^a | Percent criteria (mean value/minimum criteria) |
|---------------------------------------|---------|---------|--------|--------------------------------|---------------------------|--|--|
| Dissolved oxygen | 11.2 | 6.1 | 8.1 | 5.0 (minimum) | 3.0 (minimum) | 5.0 (minimum) ^b | |
| pH | 8.7 | 7.6 | 8.1 | 6.0-9.0 ^c | 5.0-9.0 ^c | 6.5-8.5 | |
| Specific conductance (µmhos/cm) | 245 | 130 | 207 | | | | |
| Total alkalinity (CaCO ₃) | 106 | 76 | 92 | | | | |
| Hardness | 208 | 78 | 126 | | | | |
| Turbidity (Jackson turbidity units) | 70 | 5 | 16 | 50 ^d | | | 32 |
| BOD | 3.0 | <1 | 2.1 | | | 5.0 | 42 |
| Chlorine residual | 0.05 | <0.05 | <0.05 | 0.003 ^c | | 0.1 | |
| Total dissolved solids | 510 | 76 | 177 | | 500 | 500 | 35 |
| Suspended solids | 42 | 6 | 18 | 80 ^e | | | 23 |
| Nitrite (as N) | 0.065 | <0.001 | <0.014 | | 1 | | <1.4 |
| Nitrate (as N) | 2.80 | <0.1 | 0.56 | 0.5 ^c | 10 | 10 | 113 |
| Ammonia (as N) | 0.90 | 0.09 | 0.34 | 0.02 ^c | 0.5 ^c | 1.6 (0.5) | 1700 |
| Total phosphate (as P) | 0.46 | <0.003 | <0.13 | 0.05 ^c | | | <265 |
| Ortho phosphate (as P) | 0.10 | <0.003 | 0.022 | | | | |
| Sulfate | 165 | 4 | 37 | | 250 ^c | 250 | 15 |
| Fluoride | 2.6 | <0.1 | 0.57 | 1.5 ^e | 1.4-2.4 ^c | 1.0 | 57 |
| Al | 3.32 | <0.1 | <0.8 | 0.1 ^{c,f} | | 1 | <800 |
| Cd | <0.005 | <0.002 | g | 0.03-0.004 ^c | 0.01 ^c | 0.01 | |
| Cr | 1.94 | <0.005 | <0.45 | 0.05 ^c | 0.05 ^c | 0.05 | <890 |
| Cu | <0.013 | <0.004 | <0.007 | ~0.015 ^c | 1 | 0.02 | <48 |
| Mn | 0.079 | 0.02 | 0.06 | | 0.05 | 1.0 (0.05) | 110 |
| Pb | <0.03 | <0.01 | g | ~0.03 ^c | 0.05 | 0.05 | |
| Zn | 0.5 | <0.005 | 0.06 | ~0.1 ^c | 5 ^c | 0.1 | 50 |
| Hg (ppb) | <4 | <0.5 | <1.4 | 0.05 ^c | 2 ^c | 5 | |
| U | <0.01 | <0.01 | g | | | | |
| Fe | 0.68 | 0.08 | <0.3 | | 0.3 | 1.5 (0.3) | <100 |
| Ni | <0.04 | <0.01 | g | ~0.1 ^c | | 0.1 | |

^aDivision of Water Quality Control, Tennessee Department of Public Health, *Guidelines for Effluent Criteria for Sewage and Industrial Wastewater*, mimeo, January 1973.

^bTennessee Water Quality Control Board, *General Water Quality Criteria for the Definition and Control of Pollution in the Waters of Tennessee*, mimeo, adopted on 26 Oct. 1971, Amended on 14 Dec. and 30 Oct. 1973.

^cNational Academy of Sciences and National Academy of Engineering, *Water Quality Criteria - 1972*, Environmental Protection Agency, U.S. Government Printing Office, Washington, D.C., 1973.

^dFederal Water Pollution Control Administration, *Water Quality Criteria*, U.S. Government Printing Office, Washington, D.C., April, 1968.

^eJ. E. McKee and H. W. Wolf, eds., *Water Quality Criteria*, 2nd ed. The Resources Agency of California, State Water Resources Control Board Publ. No. 3-A, 1963.

^fR. A. Freeman and W. H. Everhart, "Toxicity of Aluminum Hydroxide Complexes in Neutral and Basic Media to Rainbow Trout," *Trans. Amer. Fish. Soc.* 100: 644-658 (1971).

^gAll measurements below levels of detection.

Table 3.8. Chemical water quality data in the Clinch River for 1975 and 1976

| Substance | Average concentration (mg/liter) | | | | | | Standard ^d |
|----------------------------------|-----------------------------------|----------------|-----------------------------------|----------------|-----------------------------------|-----------------|-----------------------|
| | Sampling station C-2 ^a | | Sampling station C-3 ^b | | Sampling station C-4 ^c | | |
| | 1975 | 1976 | 1975 | 1976 | 1975 | 1976 | |
| Cd | | | <0.005 | <0.005 | <0.005 | <0.005 | 0.01 |
| Cr | <0.01 ± 0.007 | <0.003 ± 0.002 | <0.006 ± 0.001 | <0.008 ± 0.006 | <0.03 ± 0.04 | <0.01 ± 0.008 | 0.05 |
| CN ⁻ | | | <0.001 | <0.003 ± 0.002 | <0.002 | <0.003 ± 0.002 | 0.01 |
| NO ₃ ⁻ (N) | 0.3 ± 0.1 | 0.1 ± 0.1 | 1.2 | 0.5 ± 0.1 | 3.4 | 0.4 ± 0.1 | 10 |
| Pb | | | <0.01 ± 0.003 | <0.01 ± 0.003 | <0.03 ± 0.04 | <0.01 ± 0.003 | 0.05 |
| SO ₄ ⁻ | | | 10 | 21 ± 3 | 12 | 20 ± 2 | 250 |
| T.D.S. | | | 124 | 169 ± 36 | 129 | 191 ± 45 | 500 |
| Zn | <0.01 ± 0.03 | 0.02 ± 0.02 | <0.04 ± 0.03 | 0.04 ± 0.02 | <0.02 ± 0.01 | 0.016 ± 0.005 | 0.1 |
| F ⁻ | | | <0.5 | <0.1 | 0.15 | <0.1 | 1.0 |
| Hg | <0.0001 | <0.0001 | <0.001 | <0.001 | <0.002 ± 0.002 | <0.001 ± 0.0002 | 0.005 |
| Ni | | | 0.07 ± 0.06 | <0.015 ± 0.009 | <0.04 ± 0.03 | <0.012 ± 0.008 | 0.1 |

^a Located at Melton Hill Dam 2.3 miles above Whiteoak Creek.

^b Located at the ORGDP sanitary water intake 6.3 miles downstream from entry of Whiteoak Creek.

^c Located at the ORGDP recirculating water intake downstream from Poplar Creek outfall 9.2 miles downstream from Whiteoak Creek.

^d Tennessee Stream Guidelines.

Sources: Energy Research and Development Administration, *Environmental Monitoring Report, United States Energy Research and Development Administration, Oak Ridge Facilities, Calendar Year 1975, Y/UB-4*, Union Carbide Corporation, May 1, 1976; *Environmental Monitoring Report, United States Energy Research and Development Administration, Oak Ridge Facilities, Calendar Year 1976, Y/UB-6*, Union Carbide Corporation, May 1, 1977.

<0.1 to 0.64 mg/liter) could be effluents and leachates from the Y-12 Plant via Bear and Poplar creeks. Ammonia and turbidity levels in the Clinch River (CRM 11 to 15) peaked in March at 0.9 mg/liter and 70 Jackson turbidity units respectively.³⁸ Phosphate concentrations were also high during winter and early spring (<0.1 to 0.46 mg/liter), but dropped to acceptable levels during late spring through fall (<0.003 to 0.02 mg/liter).³⁸ These variations in nutrient and turbidity levels in the Clinch River are probably related to runoff from surrounding agricultural lands. Therefore, during periods of excessive runoff, these concentrations may temporarily exceed those recommended to prevent excessive eutrophication and water quality degradation in rivers and reservoirs (Table 3.7). The relatively high background concentrations of Al, Mn, and Fe in the Clinch River are probably a natural phenomenon due to the high content of Al, Mn, and Fe in the clay soils of the Oak Ridge area. Although maximum concentrations of 0.4 to 0.5 mg/liter of zinc were recorded during 1973,³⁸ mean levels of zinc for the Clinch River are generally less than 0.1 mg/liter, which is the maximum stream limit established as part of Tennessee State water quality guidelines.³⁷ Concentrations in the Clinch River of radionuclides of primary concern to radiological dose are listed in Table 3.9. The samples taken at location C-2 (Melton Hill Dam 2.3 miles above Whiteoak Creek) would be representative of ambient levels for the Oak Ridge vicinity because contaminants from Whiteoak Creek have not yet entered the channel.

Aquatic biota

Phytoplankton. A total of 132 phytoplankton taxa were collected during the Clinch River Breeder Reactor Program (CRBRP) monitoring effort;¹⁹ major genera were *Melosira* and *Oscillatoria*. Total numbers of phytoplankton cells per liter ranged from 406 in March to a maximum of 2170 in August.

Phytoplankton in the Clinch River probably originate from a number of different habitats, particularly from populations in low-flow areas and from benthic communities. River plankton populations are, in general, highly variable in time and in space.³⁹ However, the basic successional

Table 3.9. Average concentrations (in microcuries per milliliter) of radioactive pollutants of primary concern in the Clinch River, 1975 and 1976

| Contaminant | Sampling station | | | | | |
|-------------------|----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| | C-2 ^a | | C-3 ^b | | C-5 ^c | |
| | 1975 | 1976 | 1975 | 1976 | 1975 | 1976 |
| ⁹⁰ Sr | 7×10^{-11} | 8×10^{-11} | 4.2×10^{-10} | 2.6×10^{-10} | 3.1×10^{-10} | 2.4×10^{-10} |
| ¹³⁷ Cs | $<2 \times 10^{-11}$ | 2×10^{-11} | 7×10^{-11} | 3×10^{-11} | 5×10^{-11} | 2×10^{-11} |
| ¹⁰⁶ Ru | 9×10^{-11} | 1.3×10^{-10} | 1.3×10^{-10} | 1.4×10^{-10} | 1.9×10^{-10} | 1.5×10^{-10} |
| ³ H | 7.3×10^{-7} | 6.1×10^{-7} | 2.5×10^{-6} | 1.7×10^{-6} | 1.1×10^{-6} | 1.9×10^{-6} |

^a At Melton Hill Dam 2.3 miles above Whiteoak Creek.

^b Located at the ORGDP sanitary water intake 6.3 miles downstream from the entry of Whiteoak Creek.

^c Located at Center's Ferry near Kingston, Tennessee.

pattern observed from March through September 1974 (Fig. 3.15) is probably typical for Tennessee. Chrysophyta (mainly diatoms) dominate the phytoplankton during winter and decrease in both numbers of species and proportions of total individuals per species in summer.¹⁹ Cyanophyta (blue-green algae) can increase and become dominant during the summer, but this increase depends on rainfall and river-water levels. A summer increase in Chlorophyta (green algae) is also common. In early to mid-autumn, blue-green and green algae decrease, and the diatoms again become the dominant phytoplankton group. Collections of phytoplankton in the Clinch River are typical for large, relatively slow-moving rivers with extensive reservoir development.³⁹

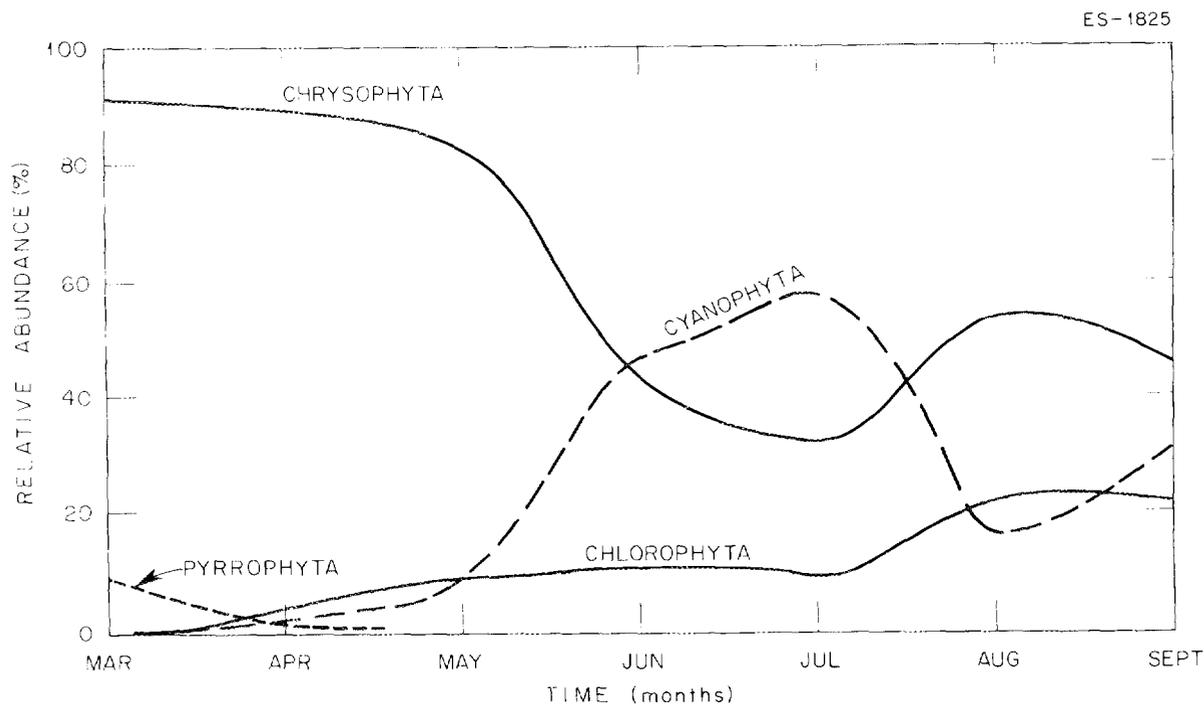


Fig. 3.15. Seasonal succession of phytoplankton in the Clinch River, CRM 15.

Zooplankton. A total of 56 zooplankton species were identified in sampling done from March to September 1974, of which 16 were arthropods and 40 were rotifers.¹⁹ Numbers of individuals collected per liter varied from 1.89 to 113.9; mean biomass estimates ranged from 22.3 to 297.4 g/liter, with the lowest zooplankton densities and lowest biomass recorded during the March sampling period.

Species composition and abundance of zooplankton in the Clinch River in the vicinity of ORNL are dependent primarily on recruitment of zooplankton from quiet areas such as creeks, main impoundment areas, and backwaters. Rotifers are almost always the dominant zooplankton in large rivers and are commonly represented by typically planktonic forms such as *Keratella*, *Synchaeta*, *Polyarthra*, *Asplanchna*, and *Brachionus*. Crustaceans are rarely numerous in the open-water areas of rivers, and those that are found usually belong to the genera *Cyclops* or *Bosmina*.³⁹

Macrophytes. The growth of macrophytes in the Clinch River below Melton Hill Dam (CRM 11 to 18) is generally sparse,³⁹ probably due to limited light penetration into the water, steep shorelines along much of this area, occurrence of hard substrate, and considerable fluctuations of the river-water level. Occasional growths of the aquatic moss *Fontinalis* occur on submerged branches, and a leafy liverwort has been collected. Scattered patches of *Myriophyllum* occur in areas of suitable substrate and water depth. In Melton Hill Reservoir, however, macrophytes can obtain reasonably large standing crops; common taxa include *Potamogeton*, *Chara*, *Najas*, *Anacharis*, and *Myriophyllum* species. Fluctuating water levels and relatively high turbidities preclude the development of extensive stands, however.

Periphyton. Periphyton samples were collected in the Clinch River (CRM 15 to 18) from March through October 1974 on plexiglass slides exposed for 2 to 4 weeks. Of the 123 species and varieties collected, the greatest number (65 species and 4 varieties) belonged to the Division Chrysophyta, and most were diatoms.³⁹

The mean number of algal cells per square centimeter on the plexiglass slides increased from a low of about 89,000 in March to a high of about 2,400,000 in August. The Chrysophyta (mostly diatoms) reached a high density early in the spring and maintained their abundance throughout the summer. Densities of Cyanophyta (blue-green algae), on the other hand, increased during summer and peaked in October. Generally, algae are opportunists; each species flourishes when and where conditions are optimal and then yields to other species as the environment changes.⁴⁰ Periphyton therefore occur as an irregular mosaic on stream and river beds and are subject to great seasonal changes. Major controlling factors include substrate, temperature, light, and current.³⁹

Benthic macroinvertebrates. Macroinvertebrates collected from March to September 1974 included mollusks, annelids, insects, and coelenterates.¹⁹ Insects comprised the greatest number of species. Asiatic clams and oligochaetes (earthworm-like) were abundant throughout the sampling period. *Nais* was dominant in March and June, *Limnodrilus* in June through September, and coelenterate polyps (*Hydra*) in early June and August. Although Chironomidae were numerous in all samples, *Polypedilum*, *Cricotopus*, and *Disrotendipes* were the only abundant genera. Ten members of the family Chironomidae, listed by the EPA⁴¹ as intolerant to decomposable organic wastes, were collected in the Clinch River benthic dredge samples; eight genera were collected on artificial substrates. Therefore, the survey area (CRM 15 to 18) is apparently not heavily contaminated with decomposable organic wastes, according to this index.

In terms of biomass, the Asiatic clam was the dominant benthic macroinvertebrate in the study area (CRM 11 to 18).¹⁹ The Asiatic clam was introduced into this country prior to 1938, and by 1963 it had spread throughout the Tennessee River and lower Cumberland basins.⁴² In Tennessee, these small bivalves feed on phytoplankton and do not appear to be substrate selective. From an economic viewpoint, the clam is generally a liability; the larvae can be drawn into water intakes and cause fouling. Very little is known about the use of this clam as a food item by other organisms. Analysis of stomach contents of fish collected at CRM 15 to 18 indicates that these clams may be a common food for carp and smallmouth buffalo.

Fish. Numerically dominant species collected in 1974 and 1975 at CRM 15 to 18 (by electroshocking) included threadfin shad, gizzard shad, skipjack herring, golden redhorse, carp, bluegill, sauger, and white bass.¹⁹ Additional important species collected included largemouth bass and shiners. Nongame species (i.e., forage and rough species) accounted for 87.6% of the total number of fish collected at CRM 15 to 18. In terms of biomass, rough fish comprised 70% of the fish collected, and forage fish comprised 18%; sauger and white bass were the dominant game fish.

In addition to sampling adult populations of fish, ichthyoplankton (fish eggs and larvae) were collected by stationary netting at CRM 15 to 18 from March 28 through August 29, 1974.¹⁹ Significant numbers of eggs were collected on May 16 and June 2 only, which denotes the onset of spring spawning for the species represented. Samples taken on all other dates yielded few, if any, eggs. However, a second spawning peak (although of lesser magnitude than the spring peak) is probable in early fall.

Quantitative data on the fisheries in the Clinch River in the vicinity of the Oak Ridge reservation are not available. The two most important species caught commercially in the Clinch River are smallmouth buffalo and channel catfish. Other species such as bigmouth buffalo, black buffalo, black redhorse, golden redhorse, shorthead redhorse, blue catfish, and flathead catfish are also taken, but in lesser quantities. Carp are taken by some fishermen whenever a market can be established. The biomass of fish caught commercially is negligible compared with that obtained by sport fishing.¹⁹

A large number of sport fishermen use the Clinch River and its tributaries in the Oak Ridge vicinity every year. The spring migrations (February through June) of walleye, white bass, white crappie, black crappie, and sauger stimulate a peak in angling activity. During the hot summer months (June through August), panfish (bluegill in particular) are the most common fish caught.

Summary

Figure 3.16 illustrates the dominant species and major pathways of the food web projected for the aquatic community in the Clinch River. A turbid moderately hard water system, the physical and chemical water-quality characteristics of the Clinch River are typical of many large rivers in the southeastern United States. Aquatic biota are relatively diverse and productive.

Endangered species

None of the fish species collected in either the CRBRP baseline environmental survey or the ORNL sampling programs are designated as endangered under the Endangered Species Act of 1973.⁴³

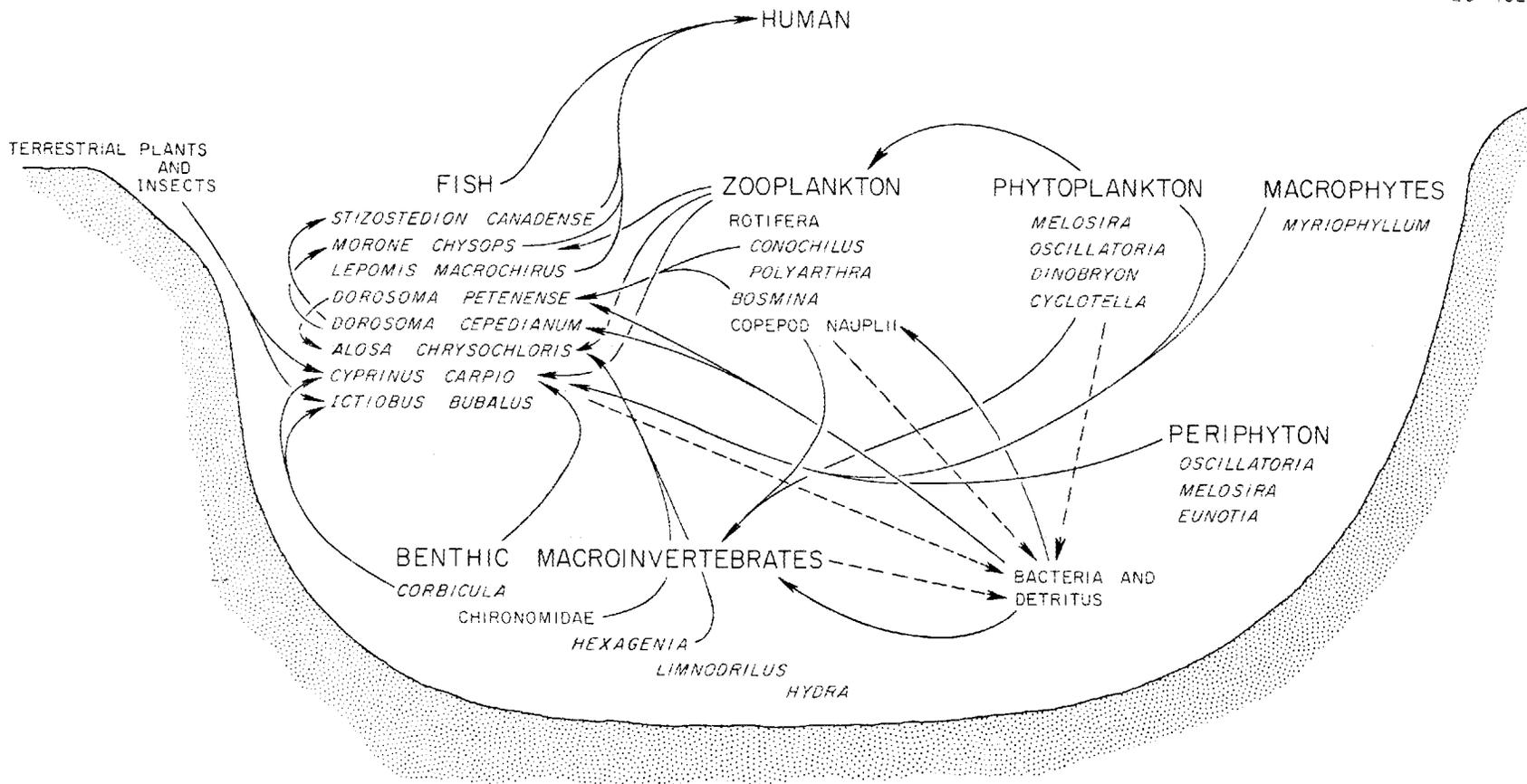


Fig. 3.16. Aquatic food web in the Clinch River in the vicinity of ORNL.

3.6.2.2 Whiteoak Creek, Whiteoak Lake, and Melton Branch

Whiteoak Creek basin has an area of 16.5 km² (6.37 sq miles).²⁰ The headwaters occur on the forested slopes of Chestnut Ridge, north of ORNL (Fig. 3.14); numerous springs intersecting with the upper reaches of Whiteoak Creek combine to yield a relatively stenothermic aquatic environment. Stream width varies from 0.6 to 1.2 m (2 to 4 ft), and depth varies from 10 to 25 cm (4 to 10 in.). The stream-bed substrate is predominantly rocks (5 to 8 cm diam), with some exposed bedrock.

Base-flow of Whiteoak Creek is low, and at times in late fall, periods of no natural flow have occurred. The belt of Knox dolomite underlying Chestnut Ridge, which forms the northwestern drainage divide of the basin, is the principal water-bearing formation. Several springs along the base and in the ridge valleys are tributaries to Whiteoak Creek. Ninety percent of dry-weather discharge originates as groundwater discharge from the Knox dolomite of Chestnut Ridge, from the Chickamauga limestone of Bethel Valley, and from effluents at ORNL.²⁰

The Melton Branch tributary of Whiteoak Creek drains 3.83 km² (1.48 sq miles) in Melton Valley and enters the creek 2.5 km (1.5 miles) above its juncture with the Clinch River.

Liquid wastes from ORNL facilities that are discharged to Melton Branch or Whiteoak Creek consist of cooling-tower blowdown that contains chromates and phenols, effluents from a primary sewage treatment facility, waste from ion-exchange resin regeneration, and effluent from the treatment of low-level radioactive wastes. Nonradioactive chemical wastes from ORNL operations, including a large number of discharges collected from research laboratory drains, are discharged into Whiteoak Creek without substantial treatment.

In addition to receiving routine discharges of various effluents, both Melton Branch and Whiteoak Creek receive drainage and leachates from ORNL waste disposal areas (Fig. 3.17).

At a point about 1.6 km (1 mile) above the confluence with the Clinch River, Whiteoak Creek enters Whiteoak Lake, an 8-ha (20-acre) reservoir constructed in 1943 for impounding liquid wastes from ORNL. The waters of Whiteoak Lake discharge over the dam at a rate of 0.4 m³/sec (15 cfs) about 80% of the time.²⁰

Water quality

Water analyses from five stations on Whiteoak Creek and Melton Branch are summarized for 1970 and 1971 in Tables 3.10 and 3.11. Water quality data measured in 1975 and 1976 at Whiteoak Dam are presented in Table 3.12.

Upstream from ORNL, Whiteoak Creek is a small, clear, hardwater stream of good water quality. Phosphate, nitrate, and heavy-metal concentrations are generally low. Laboratory discharges, leachates, and drainage from waste disposal areas combine to render the stream significantly poorer in quality in the lower reaches of the waterway.

Concentrations of ⁹⁰Sr, ¹³⁷Cs, ¹⁰⁶Ru, and ³H at the confluence of Whiteoak Creek and the Clinch River are presented in Table 3.13 for 1976. These values are calculated values based on the concentrations measured at Whiteoak Dam and the dilution afforded by the Clinch River. The

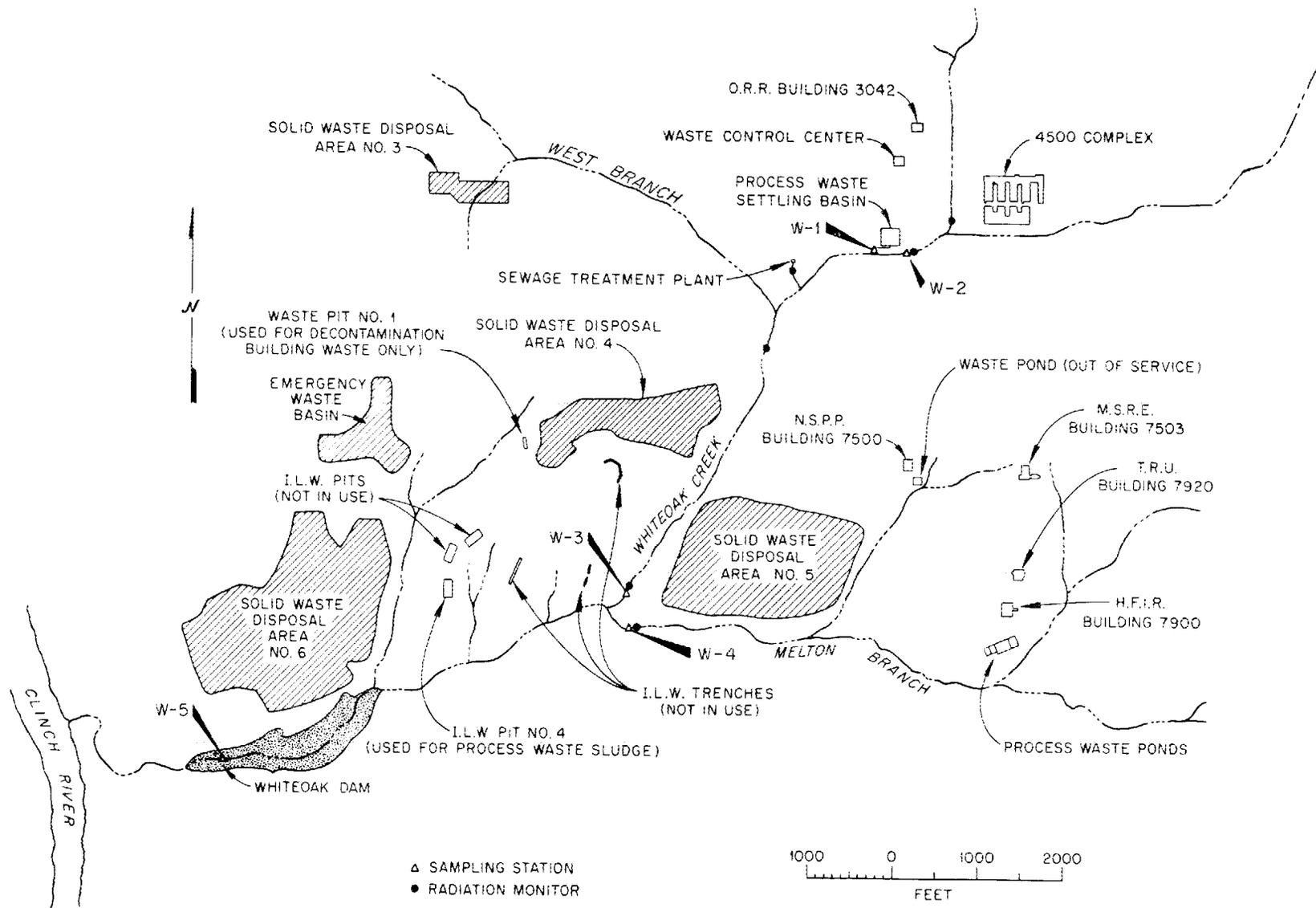


Fig. 3.17. Location of Whiteoak Creek, Whiteoak Lake, and Melton Branch in relation to ORNL facilities.

Table 3.10. Average concentrations (in mg/liter) of nonradioactive pollutants for Whiteoak Creek in 1970

| Contaminant | EPA standard | Sampling station ^a | | | | |
|-------------------------------|--------------|-------------------------------|--------------------|---------------------------|-------------------|------------------|
| | | W-1 Flume | W-2 Settling basin | W-3 Whiteoak Creek (ORNL) | W-4 Melton Branch | W-5 Whiteoak Dam |
| Cl ⁻ | 250 | 14 | 34 | 21 | 41 | 11 |
| F ⁻ | 1.7 | 1.1 | 1.6 | 0.8 | 1.2 | 0.9 |
| NO ₃ ⁻ | 10 | 1.7 | 23.3 | 1.1 | 2.2 | 1.3 |
| Phenols | 0.001 | 0.0017 | 0.0013 | 0.0015 | 0.0011 | 0.0004 |
| SO ₄ ²⁻ | 250 | 34 | 22 | 31 | 71 | 29 |
| TDS ^b | 500 | 152 | 202 | 121 | 371 | 99 |
| COD ^c | | | | | | 7.5 |
| Ag | 0.05 | <0.002 | <0.002 | <0.002 | <0.002 | <0.008 |
| As | 0.01 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 |
| Ba | 1.0 | 0.036 | 0.03 | 0.026 | 0.083 | 0.053 |
| Be | 1.0 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 |
| Cd | 0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 |
| Cr ⁺⁶ | 0.05 | 0.124 | 0.047 | 0.076 | 0.538 | 0.10 |
| Cu | 1.0 | 0.049 | 0.120 | 0.088 | 0.026 | <0.032 |
| Fe | 0.3 | 0.04 | 0.10 | 0.09 | 0.02 | 0.17 |
| Mn | 0.05 | <0.007 | <0.02 | <0.007 | <0.008 | <0.01 |
| Se | 0.01 | | | | | |
| Zn | 5 | <0.05 | <0.05 | <0.05 | <0.03 | <0.05 |
| Alkaline metals (pH) | 6-9 | 8.3 | 8.7 | 8.2 | 8.2 | 8.0 |

^aSee Fig. 3.17 for locations of sampling stations.

^bTDS = total dissolved solids.

^cCOD = chemical oxygen demand.

Table 3.11. Average concentrations (in mg/liter) of nonradioactive pollutants for Whiteoak Creek in 1971

| Contaminant | EPA standard | Sampling station ^a | | | | |
|-------------------------------|--------------|-------------------------------|--------------------|---------------------------|-------------------|------------------|
| | | W-1 Flume | W-2 Settling basin | W-3 Whiteoak Creek (ORNL) | W-4 Melton Branch | W-5 Whiteoak Dam |
| Cl ⁻ | 250 | 2 | 6 | 5 | 6 | 4 |
| F ⁻ | 1.7 | 0.3 | | 1.1 | 1.2 | 1.0 |
| NO ₃ ⁻ | 10 | 51.8 | 20.5 | 10.3 | 7.2 | 5.3 |
| Phenols | 0.001 | 0.0001 | 0.0003 | 0.0002 | 0.0003 | 0.0005 |
| SO ₄ ²⁻ | 250 | 29 | 33 | 28 | 49 | 34 |
| TDS | 500 | 199 | 357 | 157 | 245 | 159 |
| COD | | | | | | 7.1 |
| Ag | 0.05 | <0.011 | 0.015 | <0.008 | <0.008 | <0.006 |
| As | 0.01 | <0.053 | <0.053 | <0.053 | <0.053 | <0.053 |
| Ba | 1.0 | 0.036 | <0.016 | 0.033 | 0.036 | 0.050 |
| Be | | <0.001 | <0.0013 | <0.001 | <0.001 | <0.0007 |
| Cd | 0.03 | <0.03 | <0.030 | <0.030 | <0.030 | <0.030 |
| Cr | 0.05 | 0.53 | 0.33 | 0.33 | 0.56 | 0.43 |
| Cu | 1.0 | 0.02 | 1.046 | 0.012 | 0.013 | 0.006 |
| Fe | 0.3 | 0.10 | 0.16 | 0.05 | 0.07 | 0.04 |
| Hg | 0.0002 | <0.0027 | <0.005 | <0.0022 | <0.0016 | <0.0019 |
| Mn | 0.05 | <0.01 | 0.026 | <0.01 | <0.01 | <0.01 |
| Pb | 0.05 | 0.02 | 0.060 | 0.015 | <0.016 | <0.016 |
| Se | 0.01 | | | | | |
| Zn | 5.0 | <0.07 | <0.13 | <0.07 | 0.10 | <0.10 |
| Alkaline metals (pH) | 6-9 | 7.7 | | 7.6 | 7.9 | 7.9 |

^aSee Fig. 3.17 for locations of sampling stations.

Table 3.12. Chemical water quality data at White Oak Dam for 1975 and 1976

| Substance | Standard concentration ^a (mg/liter) | 1975 | | 1976 | |
|----------------------------------|---|-------------------------------------|------------|-------------------------------------|------------|
| | | Average concentration (mg/liter) | % Standard | Average concentration (mg/liter) | % Standard |
| Cr | 0.05 | <0.06 ± 0.05 | <120 | 0.02 ± 0.02 | 40 |
| Zn | 0.1 | 0.02 ± 0.03 | <20 | 0.03 ± 0.02 | 30 |
| NO ₃ ⁻ (N) | 10 | 0.7 ± 0.2 | 7 | 0.7 ± 0.3 | 7 |
| Hg | 0.005 | 0.0002 ± 0.0001 | 4 | 0.0002 ± 0.00005 | 4 |

^aTennessee Stream Guidelines.

Sources: Energy Research and Development Administration, *Environmental Monitoring Report, United States Energy Research and Development Administration, Oak Ridge Facilities, Calendar Year 1975*, Y/UB-4, Union Carbide Corporation, May 1, 1976; *Environmental Monitoring Report, United States Energy Research and Development Administration, Oak Ridge Facilities, Calendar Year 1976*, Y/UB-6, Union Carbide Corporation, May 1, 1977.

Table 3.13. Radionuclide concentrations in the Clinch River contributed by White Oak Creek in 1976

| Nuclide | Concentration of radionuclides of primary concern (10 ⁻⁹ μCi/ml) | | |
|-------------------|--|---------|-------------|
| | Maximum | Minimum | Average |
| ⁹⁰ Sr | 2.6 | 0.17 | 1.28 ± 0.23 |
| ¹³⁷ Cs | 0.20 | 0.01 | 0.07 ± 0.02 |
| ¹⁰⁶ Ru | 0.08 | 0.01 | 0.04 ± 0.01 |
| ³ H | 4000 | 320 | 2000 ± 317 |

Source: Energy Research and Development Administration, *Environmental Monitoring Report, United States Energy Research and Development Administration, Oak Ridge Facilities, Calendar Year 1976*, Y/UB-6, Union Carbide Corporation, May 1, 1977.

yearly average dilution for 1976 was 422. Radioactive materials (e.g., fallout) that may enter the Clinch River upstream of the Whiteoak Creek outfall are not included in this calculation (see Table 3.9, Station C-2).

Aquatic biota

Flora. The creek system as a whole is comprised of two distinct habitat types: (1) fast-flowing waters of the stream proper and (2) relatively static impounded areas.

Phytoplankton of Whiteoak Lake were studied in a qualitative manner by Krumholz⁴⁴ from 1950 to 1953 and by Andrews^{45,46} in 1973. Seventy-nine genera were recorded, the majority of which belong to the Chlorophyta.

Quantitative data for Whiteoak Lake phytoplankton are limited. In collections available, dominant genera were *Pleodorina*, *Closterium*, and *Euglena*. For samples taken July 25, 1973, three neustonic species of *Euglena* were dominant. Macroscopic filamentous mats were principally *Spirogyra* sp., *Oedogonium* sp., and *Hydrodictyon reticulatum*.

From 1950 to 1953 Krumholz⁴⁴ sampled (qualitatively) attached algae from Whiteoak Lake and periphyton and phytoplankton in Whiteoak Creek above and below ORNL.

The macrophytes of Whiteoak Creek and Whiteoak Creek-Whiteoak Lake have not been studied.

Fauna. Qualitative samplings of zooplankton in Whiteoak Lake were taken from 1950 to 1953.⁴⁴ Rotifers were the most common organisms collected; densities were highest during the summer.

Zooplankton in Whiteoak Creek have not been extensively studied. Populations in the creek would likely be less dense and less diverse than those found in the lake.

Benthic macroinvertebrates were collected (qualitatively) by Krumholz⁴⁴ from Whiteoak Lake-Whiteoak Creek above and below the ORNL settling basin, Melton Branch, Lagoon Creek, and a small spring-fed stream on the south side of Whiteoak Lake. Surber samples taken in Whiteoak Creek above ORNL indicate a diverse fauna. The mayfly, *Baetis*, an insect common in small rocky streams, was the predominant species. The snail *Goniobasis claviformis* and the isopod *Lirceus* were also common in collections. Freshwater isopods are primarily inhabitants of unpolluted shallow waters.

Krumholz⁴⁴ collected 23 species of fish from Whiteoak Creek at unspecified locations. Fish were sampled from the mouth of the creek to 200 m upstream; from July 1974 to February 1975, a total of 11 species (607 individual fish) were collected. Gizzard shad, threadfin shad, and carp were predominant.

3.7 SOCIOECONOMIC PROFILE

3.7.1 Area population

Oak Ridge National Laboratory is part of the DOE reservation located in Anderson and Roane counties. Five counties surround the site: Anderson, Knox, Loudon, Roane, and Morgan. The combined population of the five counties in 1970 was 413,359; most of the population (336,593) was located to the east of the site in Anderson and Knox counties. The 1975 estimated population for the five counties was approximately 437,600, a 6% increase since 1970.

There are two major population centers within 75 km (47 miles) of the site: Oak Ridge, located in both Roane and Anderson counties, with the nearest residential section being 8 km (~5 miles) north; and Knoxville, located in Knox County, being approximately 35 km (22 miles) east. Figure 3.18 shows all communities with a population above 1500 within 100 km (62 miles) of the DOE reservation. Table 3.14 lists the 1960 and 1970 population figures and projections for 1980 and 1990 for all the counties containing communities within a 75-km (47-mile) radius of the site. Also included is the rural-urban population for each county in 1960 and 1970.

3.7.1.1 Anderson County

In 1970 Anderson County had a population of 60,300 residents, 54% of whom were urban. The 1975 population estimate of Anderson County's population was 61,200, a 1.5% increase over the 1970 figures. Oak Ridge, Anderson County's largest city, had a 1970 population of 26,829, a figure estimated to be essentially unchanged as of 1975.

Anderson County has two fairly distinct population groups. This distinction exists because of the unique way in which the city of Oak Ridge was formed. In the 1940s, the Federal government acquired approximately 23,600 ha (58,500 acres) in Anderson and Roane counties for a reservation

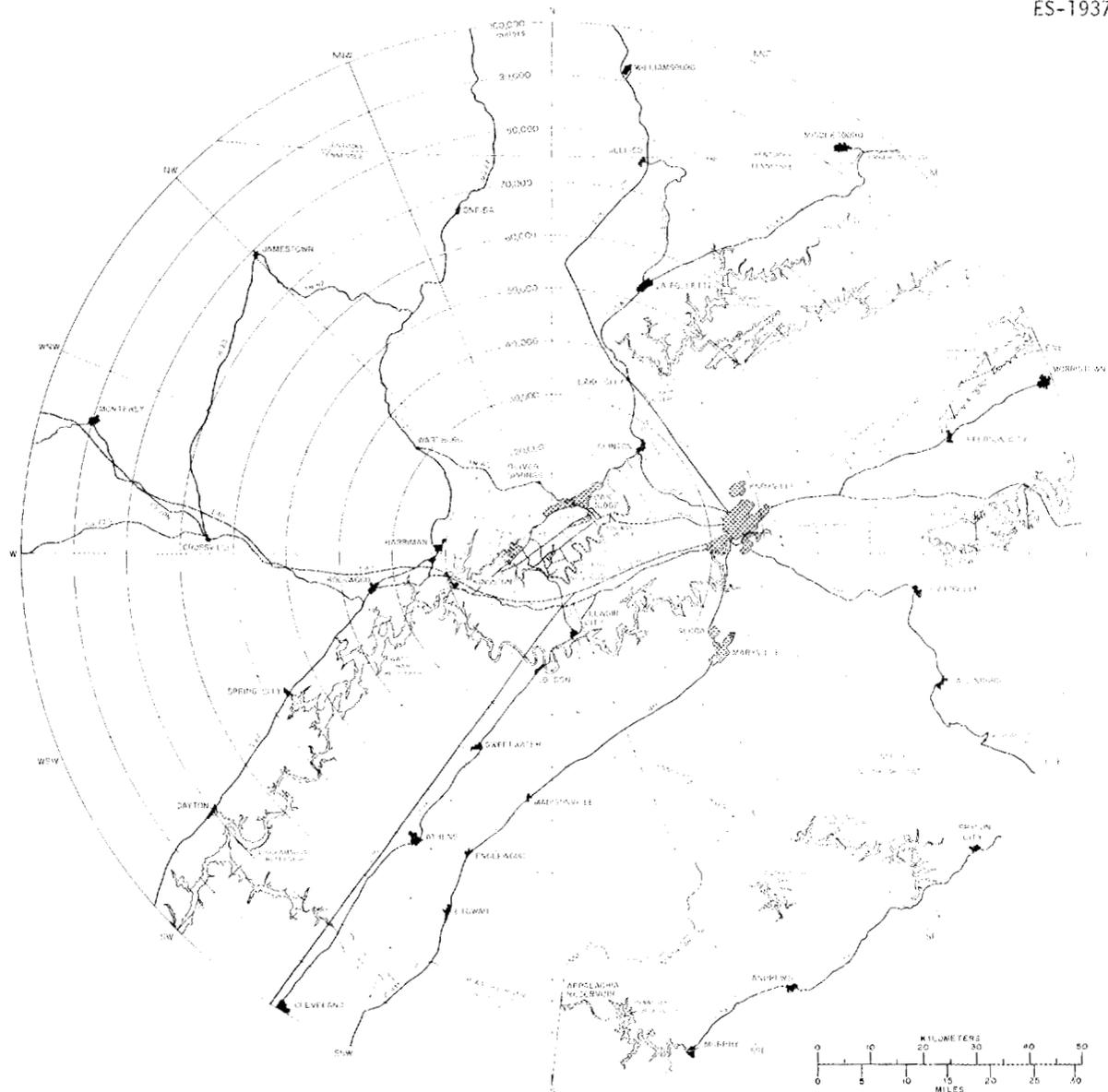


Fig. 3.18. Communities with a population greater than 1500 within a 60-mile radius (100 km) of the DOE reservation.

to be used for weapons development during World War II. One small part of this parcel of land was set aside for residential and support-service use by employees of the government. The remainder of the land was used for industrial and research purposes. In 1959, the community part of the reservation, Oak Ridge, became self supporting and self governing. At that time, the entire "Oak Ridge reservation" was designated as the city of Oak Ridge, although approximately 15,000 ha (37,000 acres) remained in the custody of AEC.

Anderson County residents, exclusive of Oak Ridge, share many common traits and characteristics with the surrounding rural Tennessee population. Oak Ridge, on the other hand, has demographic

Table 3.14. 1960, 1970, and projected population for counties containing communities within 50 miles of the ORNL site

| County and subdivisions | 1960 ^a | 1970 ^a | 1980 ^b | 1990 ^b |
|---------------------------------------|-------------------|-------------------|-------------------|-------------------|
| Impacted counties | | | | |
| Anderson County | 60,032 | 60,300 | 64,909 | 74,988 |
| Urban | 32,067 | 33,831 | | |
| Rural | 27,965 | 26,469 | | |
| Clinton | 4,943 | 4,794 | | |
| Lake City | 1,914 | 1,923 | | |
| Norris | 1,389 | 1,359 | | |
| Oak Ridge ^c | 27,124 | 26,829 | | |
| Oliver Springs ^c | 336 | 2,208 | | |
| Knox County | 250,523 | 276,293 | 313,126 | 353,364 |
| Urban | 172,734 | 190,502 | | |
| Rural | 77,789 | 85,791 | | |
| Knoxville | 111,827 | 174,587 | | |
| Loudon County | 23,757 | 24,266 | 26,685 | 30,359 |
| Urban | 8,791 | 9,052 | | |
| Rural | 14,966 | 15,214 | | |
| Greenback | 285 | 318 | | |
| Lenoir City | 4,979 | 5,324 | | |
| Loudon | 3,812 | 3,728 | | |
| Philadelphia | | 554 | | |
| Morgan County | 14,304 | 13,619 | 13,860 | 15,082 |
| Urban | | 34 | | |
| Rural | 14,304 | 13,585 | | |
| Oliver Springs ^c | | 34 | | |
| Oakdale | 470 | 376 | | |
| Wartburg | | 541 | | |
| Roane County | 39,133 | 38,881 | 40,741 | 44,728 |
| Urban | 14,205 | 20,788 | | |
| Rural | 24,928 | 18,093 | | |
| Harriman | 5,931 | 8,734 | | |
| Kingston | 2,010 | 4,142 | | |
| Oak Ridge ^c | 45 | 1,490 | | |
| Oliver Springs ^c | 827 | 1,163 | | |
| Rockwood | 5,345 | 5,259 | | |
| Other counties and communities | | | | |
| Blount County | 57,525 | 63,744 | 74,524 | 85,293 |
| Urban | 21,811 | 26,892 | | |
| Rural | 35,714 | 36,852 | | |
| Alcoa | 6,395 | 7,739 | | |
| Eagleton Village | 5,068 | 5,345 | | |
| Friendsville | 606 | 575 | | |
| Maryville | 10,348 | 13,808 | | |
| Townsend | 283 | 267 | | |
| Campbell County | 27,936 | 26,045 | 26,394 | 27,806 |
| Urban | 6,204 | 6,902 | | |
| Rural | 21,732 | 19,143 | | |
| Caryville | | 648 | | |
| Jellico | 2,210 | 2,235 | | |
| Jacksboro | | 689 | | |
| La Follette | 6,204 | 6,902 | | |
| Cumberland County | 19,135 | 20,733 | 23,232 | 26,308 |
| Urban | 4,668 | 5,381 | | |
| Rural | 14,467 | 15,352 | | |
| Crossville | 4,668 | 5,381 | | |
| Pleasant Hill | 267 | 293 | | |

Table 3.14 (continued)

| County and subdivisions | 1960 ^a | 1970 ^a | 1980 ^b | 1990 ^b |
|-------------------------|-------------------|-------------------|-------------------|-------------------|
| Fentress County | 13,288 | 12,593 | 13,616 | 14,944 |
| Urban | | | | |
| Rural | 13,288 | 12,593 | | |
| Allardt | | 610 | | |
| Jamestown | 1,727 | 1,899 | | |
| McMinn County | 33,662 | 35,462 | 38,803 | 43,325 |
| Urban | 15,326 | 15,526 | | |
| Rural | 18,336 | 19,936 | | |
| Athens | 12,103 | 11,790 | | |
| Calhoun | | 624 | | |
| Englewood | 1,574 | 1,878 | | |
| Etowah | 3,223 | 3,736 | | |
| Niota | 679 | 629 | | |
| Meigs County | 5,160 | 5,219 | 6,017 | 6,752 |
| Urban | | | | |
| Rural | 5,160 | 5,219 | | |
| Decatur | 681 | 698 | | |
| Monroe County | 23,316 | 23,475 | 25,445 | 28,256 |
| Urban | 4,145 | 6,954 | | |
| Rural | 19,171 | 16,521 | | |
| Madisonville | 1,812 | 2,614 | | |
| Sweetwater | 4,145 | 4,340 | | |
| Tellico Plains | 794 | 773 | | |
| Vonore | | 524 | | |
| Rhea County | 15,863 | 17,202 | 19,100 | 20,706 |
| Urban | 3,500 | 4,361 | | |
| Rural | 12,363 | 12,841 | | |
| Dayton | 3,500 | 4,361 | | |
| Graysville | 838 | 951 | | |
| Spring City | 1,800 | 1,756 | | |
| Scott County | 15,413 | 14,762 | 15,939 | 17,518 |
| Urban | | 2,602 | | |
| Rural | 15,413 | 12,160 | | |
| Huntsville | | 337 | | |
| Oneida | 2,480 | 2,602 | | |
| Sevier County | 24,251 | 28,241 | 34,004 | 39,533 |
| Urban | 2,890 | 2,661 | | |
| Rural | 21,361 | 25,580 | | |
| Gatlinburg | 1,764 | 2,329 | | |
| Pigeon Forge | | 1,361 | | |
| Sevierville | 2,890 | 2,661 | | |
| Union County | 8,498 | 9,072 | 10,081 | 10,644 |
| Urban | | | | |
| Rural | 8,498 | 9,072 | | |
| Luttrell | | 819 | | |
| Maynardville | 620 | 702 | | |

^aU.S. Bureau of the Census, *U.S. Census of Population: 1970 Number of Inhabitants*, Final Report PC(1)-A44, Tennessee.

^bThe Tennessee State Planning Office, *Tennessee Migration, Population, Families, Income, and Manpower Demand Projections to 1990 for Development Districts and Counties*, 1974.

^cIn more than one county.

characteristics that set the community apart from other communities in the area and from the rural population. For example, in 1970 Anderson County had a rural black population of 228 (less than 1%), which is similar to the rural population of the region. Although only 5.5% of Oak Ridge citizen's are black, Oak Ridge contains over 75% of all blacks in Anderson County. Additional differences between the two groups are that the Anderson County residents outside Oak Ridge are more normally distributed by age groups, whereas Oak Ridge has proportionally more working-aged and proportionally fewer retirement-aged people; only 52.8% of Oak Ridge's citizens are native Tennesseans, compared with 85.9% native Tennesseans in the remainder of Anderson County; virtually all foreign-born residents in Anderson County live in Oak Ridge.

The creation of Oak Ridge was the main contributing factor in the urbanization of the previously rural area. Population growth in Anderson County was most dramatic between 1940 and 1950 as a consequence of the establishment of the Federal reservation. Between 1950 and 1970 the population has increased by only a small amount, from 59,407 to 60,300.

3.7.1.2 Knox County

Knox County has by far the largest population of any county in the area. Knox County grew steadily in the 1960s from 250,523 in 1960 to 276,293 in 1970, a 10% increase. This growth has continued into the 1970s, with a population estimated at 310,000 as of November 1, 1976, an average annual increase of 4935 persons. If this growth rate continues, Knox County's population will exceed by a substantial amount the 1980 estimate of 313,126 as proposed by the Tennessee State Planning Office. West Knox County is currently the main growth area of Knoxville. This growth is due to a variety of factors. Interstate 40 has provided residents easy access to either Knoxville or Oak Ridge for employment opportunities. Additionally, the availability of suitable land has encouraged substantial residential and commercial development.

3.7.1.3 Roane County

The population of Roane County grew steadily from 1940 to 1960, but declined slightly by 1970. According to the 1970 census, Roane County had 38,881 residents. Recent 1975 population estimates suggest a 1975 population of approximately 40,600 residents, a 4.5% increase since 1970. Like Knox County, if Roane County's growth pattern continues, the population will exceed the 1980 estimate proposed by the Tennessee State Planning Office.

The county is undergoing a change from rural to urban, with slightly over half of the population (53.5%) in the 1970 census classified as urban residents. The urban areas are Kingston (4142), Harriman (8734), Rockwood (5259), and parts of Oliver Springs and Oak Ridge, which comprise the balance of urban areas within the county.

3.7.1.4 Loudon County

Loudon County is a small predominantly rural county; it contains two small cities, Lenoir City and Loudon. Loudon County had a fairly uniform growth rate from 1950 to 1970, with 23,182 in 1950, 23,757 in 1960, and 24,266 in 1970. A recent population estimate suggests a 1975 population of 26,300 residents, an 8.6% increase since 1970. The growth of both urban and rural areas of the county has been about the same, with both categories showing approximately the same growth from 1960 to 1970. However, the urban areas of the county, Lenoir City and Loudon, have not grown equally. The city of Loudon lost population from 1960 to 1970, while

Lenoir City gained (Table 3.14). Lenoir City is closer to the ORNL site, being on the route from Oak Ridge to Loudon (Fig. 3.18).

3.7.1.5 Morgan County

Of the five counties surrounding the reservation, Morgan County is the largest in land area but the smallest in population. The 1970 census records a population of 13,619 residents; a recent state estimate shows a 1975 population of approximately 14,400, a 5.9% increase since 1970. This 1975 estimate already exceeds the 1980 population estimate of 13,860 as proposed by the Tennessee State Planning Office.

Except for a small part of Oliver Springs (34 people), all of Morgan County is classified as rural (Table 3.14). The largest community is Wartburg, with a population of 571.

The five-county impact area is growing at a rate that is faster than that proposed by the Tennessee State Planning Office. If the 1970-1975 growth trend continues, four of the five designated communities will have 1980 populations that exceed the estimated populations as proposed. Currently, the Knox County standard metropolitan statistical area (SMSA) is the fastest growing SMSA in the state.

3.7.2 Current DOE profile in communities

The development and operation of the DOE installations (previously the Manhattan Project, U.S. AEC, and ERDA) have greatly influenced the region. The plants have recruited numerous workers from outside the region, created long-term permanent employment for many local citizens, contributed to the development and growth of towns and cities, and affected the operation of a variety of social and political institutions. The following discussion describes the current profiles of many of these influences.

3.7.2.1 Current DOE and DOE-contractor employment profile

Employment in the atomic energy program at Oak Ridge is divided among DOE (prior to February 1975, the Atomic Energy Commission; from February 1975 to October 1977, ERDA) and its principal operating contractors: Union Carbide Corporation, Nuclear Division (UCC-ND), which operates the Oak Ridge Gaseous Diffusion Plant (ORGDP), the Oak Ridge Y-12 Plant, and the Oak Ridge National Laboratory (ORNL); Oak Ridge Associated Universities (ORAU); and the University of Tennessee, which operates the Comparative Animal Research Laboratory (CARL). In 1976, these installations employed an average of 17,400 persons distributed among the installations as shown in Table 3.15.

Overall, the three major installations operated by UCC-ND under contract with DOE have provided a rather stable source of employment for 30 years, averaging about 13,000 employees annually (Table 3.16). These figures do not include the people employed to construct the plants; at the peak construction period in mid-1945, an estimated 70,000 workers were involved in the construction of the three plants. Since 1973 total employment at the three plants has grown substantially (by about 4000 workers); however, of the three plants only ORNL and ORGDP have actually expanded.

Table 3.15. Employee distribution among ERDA contractor installations, 1976

| Installation | Number employed | Percent |
|--------------|-----------------|---------|
| ORGDP | 6,000 | 35 |
| ORNL | 5,200 | 30 |
| Y-12 | 4,800 | 28 |
| CARL | 102 | <1 |
| ORAU | 355 | 2 |
| ERDA | 927 | 5 |
| Total | 17,384 | |

Table 3.16. Employment levels at ORGDP, ORNL, and Y-12 - 1943 to 1976^a

| Facility | 1943 | 1947 | 1952 | 1955 | 1958 | 1960 | 1963 | 1966 | 1969 | 1973 | 1974 | 1975 | 1976 |
|----------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| ORGDP | 4,900 | 4,900 | 4,900 | 4,280 | 4,952 | 4,150 | 2,700 | 2,570 | 2,750 | 3,000 | 4,300 | 5,000 | 6,000 |
| ORNL | 3,000 | 3,000 | 3,000 | 3,120 | 3,735 | 4,200 | 4,480 | 5,190 | 5,100 | 4,100 | 4,500 | 5,000 | 5,200 |
| Y-12 | <u>3,560</u> | <u>3,560</u> | <u>3,560</u> | <u>3,560</u> | <u>6,225</u> | <u>5,203</u> | <u>5,420</u> | <u>4,440</u> | <u>5,400</u> | <u>6,000</u> | <u>5,400</u> | <u>5,000</u> | <u>4,800</u> |
| Total | 11,460 | 11,460 | 11,460 | 10,960 | 14,912 | 13,553 | 12,600 | 12,200 | 13,250 | 13,100 | 14,200 | 15,000 | 16,000 |

^a Yearly averages.

Source: C. R. Meyers, Jr., *Spatial Distribution and Employment Trends of Manufacturing Industries in East Tennessee, 1943-1973*, ORNL/NSF/EP 38, Oak Ridge National Laboratory, Oak Ridge, Tenn., June 1974, pp. 16-17.

3.7.2.2 Employee residence

In recent years, less than half of the work force resided in Oak Ridge; for example, in 1975, 34.6% lived in Oak Ridge, 21.4% lived in Knoxville, and the remaining 44% lived in the surrounding counties or in smaller outlying towns and communities (Table 3.17).

The impact of geographical distance and access on residence location of employees is not easily discernible from data available (Table 3.18). With respect to ORGDP personnel, there is a slightly higher probability for them to live in Kingston or Harriman than for employees of the other two plants; however, fewer Y-12 employees live in Oak Ridge than do employees of ORNL and ORGDP, a situation suggesting that occupational classification is probably a better indicator of residence location than is geographical distance to the plant.

3.8 LAND USE

The Oak Ridge reservation consists of approximately 15,000 ha (37,000 acres). Three separate industrial sites (Y-12 Plant, Oak Ridge Gaseous Diffusion Plant, Oak Ridge National Laboratory), an agricultural research complex (Comparative Animal Research Laboratory), ecological research areas, and managed forests provide for intensive use of the reservation. Within 16 km (10 miles) of the HETP facilities are three incorporated towns (Oak Ridge, Oliver Springs, and Lenoir City) with a combined population of 37,000.¹⁹ Major highways include Interstate 40 about 1.5 km (1 mile) south of the reservation and Interstate 75 about 3.2 km (2 miles) southeast of the reservation. State Highways 95, 58, and 62 pass through or adjacent to the reservation. The Tennessee Valley Authority Melton Hill and Watts Bar reservoirs form most of the southern and western boundaries of the reservation and attract both fishermen and boaters. Only one airport (the Oak Ridge Air Park, a general aviation facility) is within 16 km (10 miles) of the facilities. No commercial air routes pass over the reservation.¹⁹ A formal land use plan⁴⁷ for the reservation was formulated in 1975.

Table 3.17. Payroll and residence information Oak Ridge area
(ERDA and CPFF contractors), December 1975^a

| Residence | Number of employees ^b | Percent of employees | Payroll ^b | Percent of payroll |
|--|--|----------------------------|----------------------|--------------------------|
| Total (includes all CPFF contractor employees except construction) ^c | 16,007 | 100.0 | \$232,850,134 | 100.0 |
| <u>Place of residence</u> | | | | |
| City of Oak Ridge | 5,536 | 34.6 | 90,846,524 | 39.0 |
| Anderson, outside Oak Ridge | 2,115 | 13.2 | 27,602,356 | 11.9 |
| Roane, outside Oak Ridge | 2,054 | 12.8 | 26,320,368 | 11.3 |
| Other locations | 6,302 | 39.4 | 88,080,886 | 37.8 |
| <u>Counties</u> | | | | |
| Roane and Anderson | 9,705 | 60.6 | 144,769,248 | 62.2 |
| Knox | 4,357 | 27.2 | 63,617,021 | 27.3 |
| Loudon | 868 | 5.4 | 11,164,685 | 4.8 |
| Morgan | 269 | 1.7 | 3,180,276 | 1.4 |
| Blount | 235 | 1.5 | 3,013,727 | 1.3 |
| Campbell | 170 | 1.1 | 2,089,220 | 0.9 |
| Monroe | 125 | 0.8 | 1,430,678 | 0.6 |
| McMinn | 51 | 0.3 | 650,874 | 0.3 |
| Other | 227 | 1.4 | 2,934,405 | 1.2 |
| <u>Selected cities^d</u> | | | | |
| Knoxville | 3,424 | 21.4 | 49,331,269 | 21.2 |
| Clinton | 1,198 | 7.5 | 16,016,854 | 6.9 |
| Kingston | 965 | 6.2 | 13,217,354 | 5.7 |
| Lenoir City | 700 | 4.4 | 9,194,683 | 3.9 |
| Harriman | 638 | 4.0 | 7,721,505 | 3.3 |
| Oliver Springs | 592 | 3.7 | 6,846,767 | 2.9 |
| Rockwood | 252 | 1.6 | 3,076,001 | 1.3 |

^aThe Atomic Energy Commission (AEC) was succeeded by the Energy Research and Development Administration (ERDA) on January 19, 1975. CPFF--Cost plus fixed fee.

^bEmployees on the payrolls for pay period ending December 31, 1975, or nearest to that date. Payroll data include actual annual salaries and wages paid to such employees in calendar year 1975 except in cases of new hires for which an annualized December monthly salary or wage is reported.

^cIncludes ERDA--Oak Ridge Operations and Headquarters Extensions in Oak Ridge, UCC-ND, ORAU, UT-CARL, and Rust (nonmanual and manual maintenance employees).

^dEmployees live in these cities or on rural postal routes served from these cities.

3.9 WATER USE

Major water uses in the vicinity of ORNL include water withdrawals for industrial and public water supplies, commercial and recreational water traffic, and other recreational activities such as swimming and fishing.

Major water withdrawals from the Clinch River are for DOE Oak Ridge Operations (5.5 Mgd at CRM 11.5 and 2.5 Mgd at CRM 14.4), the city of Oak Ridge and DOE (22 Mgd at CRM 41.5 -- ORNL obtains its water from this source), TVA Bull Run Steam Plant (572 Mgd at CRM 47.6), and West Knox Utility District (1 Mgd at CRM 46.9).

Groundwater use (wells) within an approximate 20-mile (32-km) radius includes not only industrial (~0.33 Mgd) and public water supplies (~0.30 Mgd) but also a large number of small-capacity

Table 3.18. Residence location for UCC-ND employees 1974

| | ORGDP | | Y-12 | | ORNL | |
|-----------------|--------|---------|--------|---------|--------|---------|
| | Number | Percent | Number | Percent | Number | Percent |
| Urban | | | | | | |
| Oak Ridge | 1,339 | 33.7 | 1,592 | 29.2 | 2,024 | 42.7 |
| Clinton | 284 | 7.2 | 514 | 9.4 | 221 | 4.7 |
| Oliver Springs | 177 | 4.5 | 229 | 4.2 | 98 | 2.1 |
| Harriman | 227 | 5.7 | 249 | 4.6 | 88 | 1.9 |
| Kingston | 377 | 9.5 | 275 | 5.0 | 233 | 4.9 |
| Knoxville | 671 | 16.9 | 1,221 | 22.4 | 1,113 | 23.5 |
| Lenoir City | 185 | 4.7 | 225 | 4.1 | 224 | 4.7 |
| Rural | | | | | | |
| Within 20 miles | 267 | 6.7 | 457 | 8.4 | 360 | 7.6 |
| 20 to 30 miles | 233 | 5.9 | 355 | 6.5 | 183 | 3.9 |
| 30 to 40 miles | 118 | 3.0 | 193 | 3.5 | 111 | 2.3 |
| 40 to 50 miles | 35 | 0.9 | 74 | 1.4 | 21 | 0.4 |
| Over 50 miles | 58 | 1.5 | 75 | 1.4 | 66 | 1.4 |
| Total outside | | | | | | |
| Oak Ridge | 2,632 | 66.3 | 3,867 | 70.8 | 2,718 | 57.3 |

Source: Union Carbide Corp., *Industrial Relations Report*, Nuclear Division, Oak Ridge, Tenn., 1975.

individual and multiunit domestic wells. ORNL uses between 0.15 and 0.30 Mgd of local-well groundwater (depending on the time of year) in its fish-research laboratories.

The Clinch River is the major groundwater sink for the area. Discharge from the aquifer system at ORNL flows directly into the river or its tributaries (i.e., Melton Branch, Whiteoak Creek). Because the incised meander of the Clinch River is a major topographic feature set in bedrock,⁴⁸ it is unlikely that a significant groundwater flow passes beneath the river. No groundwater wells are located where they could potentially intercept seepages from the plant site before discharge into the Clinch River system.

The Clinch River (Melton Hill Reservoir) adjacent to the ORNL property is a component of the Inland Waterway System, which allows commercial navigation to the Gulf of Mexico. Commercial traffic locked through Melton Dam amounted to 3000 tons (2720 metric tons) in 1975. In 1974, 631 recreational craft passed through Melton Hill locks.

Recreational use of the lands and waters in the Oak Ridge region is heavy (Sect. 3.8). Although no quantification of recreational use such as swimming, fishing, and localized recreational boating is available, a large proportion of these recreational areas are located along waterways, and frequent recreational interactions with water are assumed.

3.10 REGIONAL LANDMARKS

3.10.1 Historic

Among the early settlers in what is now the Oak Ridge reservation were William Tunnell, Anne Howard, Isaac Freels, and Collins Roberts. The descendants of these families were still in

the area when the Corps of Engineers acquired the land for the Manhattan Project in 1942. Many current place names on the reservation, such as Freels Bend and Robertsville, were derived from these early settler families.⁴⁹

A grist mill existed on the East Fork of Poplar Creek before 1796 when Tennessee was still a part of North Carolina. Walker's Mill was built where the East Fork empties into Poplar Creek near the present site of the Oak Ridge Gaseous Diffusion Plant.⁵⁰

Sparingly written history of the area indicates that a Methodist church existed in the early days of settlement. Mt. Zion Baptist Church was founded in the early 1850s, and Cumberland Presbyterian Church followed along with George Jones Memorial Baptist Church (the only structure left in the group).⁵⁰

Also located in the area at the time of the 1942 acquisition by the U.S. Government were the East Fork Masonic Lodge, Robertsville School, Wheat High School, Adam's Store and Post Office, and many clapboard houses and log cabins. A ferry existed at the present Gallaher Bridge site until the late 1930s.

A research team from the Department of Anthropology, University of Tennessee, Knoxville, conducted an archaeological survey⁵¹ of the proposed gas centrifuge plant site at the western end of the Oak Ridge reservation adjacent to Oak Ridge Gaseous Diffusion Plant. The purpose of the survey was to locate, inventory, and evaluate the prehistoric and historic cultural resources in the proposed impact area. One conclusion⁵¹ was that there are no historic structures or sites that require preservation or mitigation of adverse impact under the criteria of the *National Register of Historic Places*.

The only historic site listed in the *National Register of Historic Places* in the Oak Ridge area is the Graphite Reactor Building at Oak Ridge National Laboratory. Constructed during World War II as part of the Manhattan Project, the Graphite Reactor is the world's oldest existing nuclear reactor and is now open to the public on a routine basis.

3.10.2 Archaeological

An earlier archaeological survey⁴⁹ of the Oak Ridge reservation was conducted by the Department of Anthropology, University of Tennessee, Knoxville, from March 15 to June 30, 1974. Sites of aboriginal occupation that might be affected by future activities on the reservation were located and evaluated.

Reconnaissance and testing were done in several different physiographic zones, including the Clinch River and its larger tributary-stream terraces, the interior valleys, selected forested ridges, and specific facility areas. Previously recorded sites, known but unrecorded sites, and previously unknown sites were investigated. The survey techniques included collecting surface artifactual materials, examining subsurface soil strata, and interviewing longtime residents and employees.

Altogether, 45 sites of prehistoric aboriginal occupation and several historic Euroamerican homestead sites were examined. The primary emphasis of the study was on the prehistoric sites.

Most of the major archaeological periods in the eastern Tennessee chronological sequence were represented in the material collected during the survey. The sites were distributed along the drainage system of the Clinch River, with the majority located on the main stream. Several sites, however, were located on the tributary streams of Poplar Creek, East Fork of Poplar Creek, and Whiteoak Creek.⁴⁹

3.10.3 Cultural

The tremendous diversity of interests and activities of Oak Ridgers is indicated by the number of organizations (nearly 300 currently) listed each year by the local newspaper. The Oak Ridge Music Association schedules nationally known musicians during the fall and winter seasons. These performances are interspersed with concerts by the Oak Ridge Symphony Orchestra and the Oak Ridge Chorus, both directed by a professional conductor. In Knoxville, the University of Tennessee's University Concerts series brings Broadway shows, ballet companies, and noted personalities to the Knoxville Municipal Coliseum and Auditorium.

The Oak Ridge Playhouse is a community-wide activity, with its own theatre, a professional director, and a business manager.

The Oak Ridge Art Center houses a gallery, a studio, and a gift shop. Both local and traveling art shows are on display almost continually at the Center, and courses are offered in ceramics, lithography, oils, watercolors, drawing, and sculpture.

The American Museum of Atomic Energy is a major attraction for tourists in eastern Tennessee. The \$3.5 million building features models, movies, demonstrations, devices, and machines, all designed to describe and explain concepts relating to energy phenomena.

Another point of interest is the University of Tennessee Arboretum, which includes one of the Southeast's largest and most complete collections of trees and plants from the Appalachian region and serves as a living source of information about trees and shrubs.

3.10.4 Scenic

Oak Ridge is situated in the middle of scenic East Tennessee, surrounded by mountains, rivers, lakes, and heavily forested ridges. Within an hour's driving distance of Oak Ridge are five of the 22 reservoirs built by the Tennessee Valley Authority on the Tennessee River and its tributaries. These five reservoirs have a total shoreline of 3700 km (2320 miles) and with other lakes and streams provide fishing, boating, swimming, and other water sports.

Oak Ridge is about 100 km (60 miles) from the nation's most visited national park, the Great Smoky Mountains. The park embraces about 200,000 ha (500,000 acres) in Tennessee and North Carolina.

Oak Ridge has four city-maintained parks: Chestnut Ridge (off of Melton Lake Drive), Ridgewood Park (near the Municipal Building), Key Springs Park (off of Outer Drive), and Scarboro Village Park (in the Scarboro community). In addition to municipal parks, Clark Center Park, developed by Union Carbide Corporation for its employees, offers boating, swimming, and other facilities.

A substantial part of the land in and around Oak Ridge is undeveloped. Currently there are about 510 ha (1260 acres) in city-owned and an almost equal amount in institutionally owned open space. Open space in the urban area can be attributed partly to pockets in residential developments left open due to rough terrain; green belts along the urban fringe provide additional natural surroundings.

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4. ENVIRONMENTAL IMPACTS

4.1 RADIOLOGICAL IMPACTS

4.1.1 Impacts on man

4.1.1.1 Assessment methodology

Radiological impacts on man are assessed by calculating the dose to the maximally exposed individual and to the population living within a 50-mile radius of the HETP site. Radionuclides released to the environment through airborne or aquatic means can result in exposure to man via several different pathways. Significant potential pathways for internal and external radiation exposure to man from radionuclides released by a nuclear facility are illustrated in Fig. 4.1.

Radiological impact is estimated as the 50-year dose commitment to individuals or populations in units of millirems or man-rems per year of facility operation (the HETP is expected to run for 2 years). The dose commitment is calculated for a specified intake of radionuclide and is defined as the total dose to a reference organ (resulting from one year of intake) which will accrue during the remaining lifetime of an individual. The exposed person is assumed to be an adult (20 years of age) at the time of intake who will live to an age of 70 years. Thus the dose commitment is calculated by integrating the dose rate over a 50-year period; the result is called the 50-year dose commitment. In this report dose and dose commitment are used interchangeably, and each implies a 50-year dose commitment. Doses to specific organs can vary considerably for internal exposure from ingested or inhaled materials because some radionuclides concentrate in certain organs of the body. Estimates of radiation dose to the total body and major organs are therefore considered for all pathways of internal exposure and are based on parameters applicable to an average adult.

Radiation doses to the internal organs of children in the population vary from those received by an average adult because of differences in radionuclide metabolism, organ size, and diet. Differences between the organ doses of a child and those of an average adult may be significant. The estimated atmosphere-forage-cow-milk pathway dose to the thyroid of a one-year-old child from radioiodine in milk is about five times that for an average adult.^{1,2}

Population dose estimates for the total body are sums of the total-body doses to individuals within 50 miles of the plant. It is assumed that radiation dose to the total body is relatively independent of age;³ therefore, man-rem estimates are based on total-body doses calculated for adults. Similarly, the population dose estimates for the various organs are the sums of specific organ doses of the individuals within 50 miles of the plant. The man-organ-rem estimates are also based on adult organ doses.

Dose calculations for aqueous radioactive effluents are based on an individual who is drinking water (1200 ml/day) and eating fish (20 g/day) taken from the Clinch River at the point where Whiteoak Creek intersects downstream from Whiteoak Lake. Several conservative assumptions were made in order to facilitate the computations; therefore, dose estimates are probably

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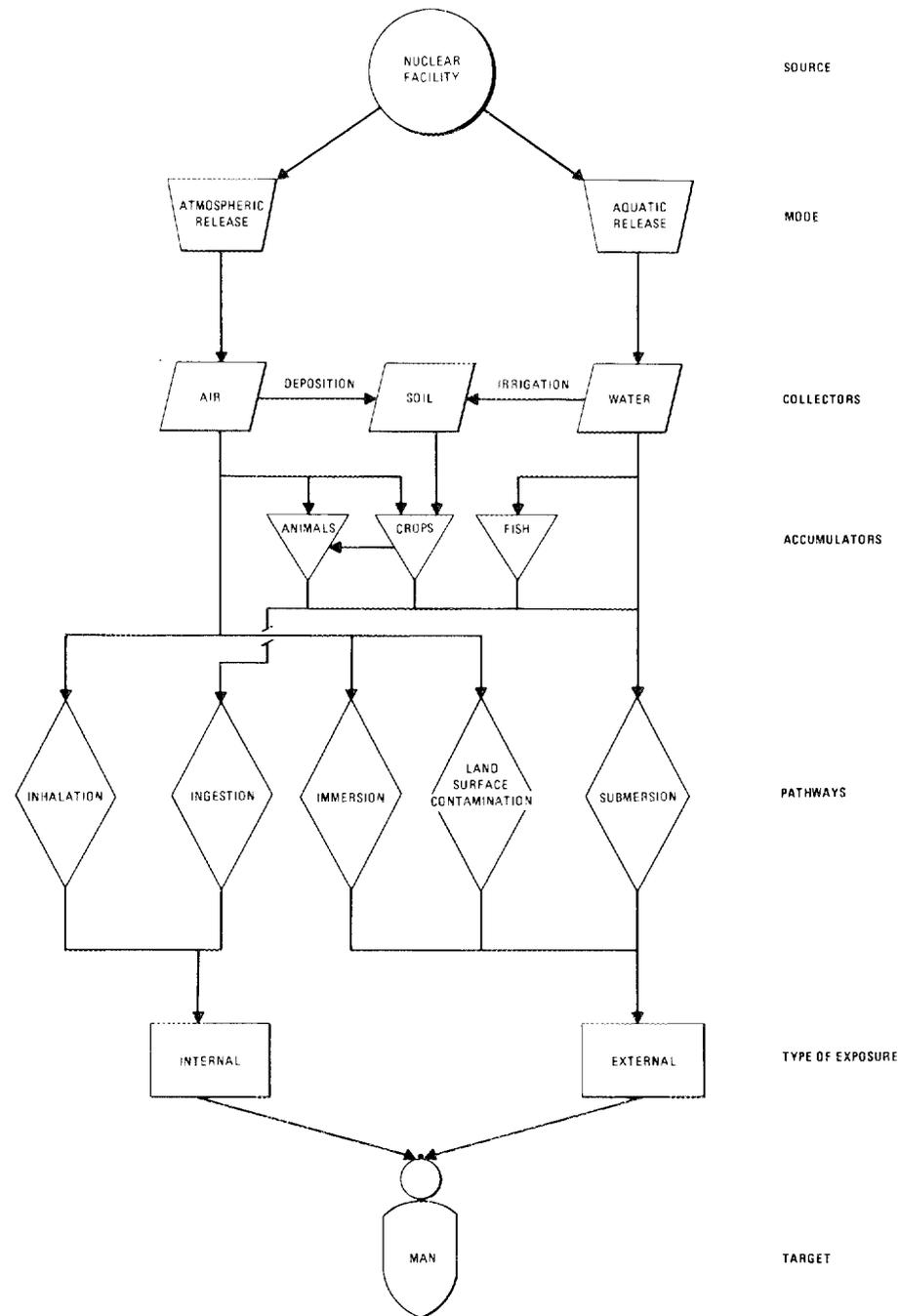


Fig. 4.1. Schematic representation of assessment methodology used to calculate the radiological impact on man.

higher than those that actually occur. The flow rate out of Whiteoak Lake is assumed to be 1×10^{13} ml/year and is 3.5×10^{15} ml/year for the Clinch River at the point of intersection. Instantaneous and complete mixing is assumed in the Clinch River. Also, it is assumed that no precautionary measures are taken to prevent anyone from drinking the water or eating fish caught in the area. Bioaccumulation factors for radionuclides in fish are taken from ORNL-4992.⁴

4.1.1.2 Analysis of liquid effluents

Table 2.6 lists radioactive aqueous effluents released to the environment and their corresponding concentrations in Whiteoak Lake. Radionuclides of primary significance to the dose were obtained by dividing the Radiation Concentration Guide (RCG) listed in Table II, Column 2 of 10 CFR 20 by the concentration in Whiteoak Lake. If this ratio was less than 10^5 (i.e., the concentration in Whiteoak Lake was within 100,000 of the recommended RCG), a dose was calculated. The radionuclides that meet this criteria are ^{89}Sr , ^{90}Sr , ^{95}Zr , ^{95}Nb , ^{134}Cs , and ^{147}Ce .

Radiation doses to the maximally exposed individual for eating fish and drinking water (Sect. 4.1.1.1) are listed in Table 4.1. All dose commitments are very small and would not contribute significantly to the total dose man receives from natural sources. Liquid effluent doses are also insignificant when compared to the doses received from atmospheric radionuclide releases, as will be seen in the following section.

Table 4.1. Maximum individual 50-year dose commitments to total body and various organs from aqueous radioactive effluents during 1 year of HETP operations

| Pathway | Dose commitments (millirems) | | | | |
|----------------|------------------------------|----------------------|----------------------|----------------------|----------------------|
| | Total body | GI tract | Bone | Thyroid | Kidneys |
| Eating fish | 8.1×10^{-4} | 2.8×10^{-4} | 1.2×10^{-3} | 8.1×10^{-4} | 5.3×10^{-1} |
| Drinking water | 2.4×10^{-4} | 6.6×10^{-3} | 6.4×10^{-3} | 2.4×10^{-4} | 1.9×10^{-4} |
| Total | 1.1×10^{-3} | 9.4×10^{-4} | 7.6×10^{-3} | 1.1×10^{-3} | 7.2×10^{-4} |

The impact of increased ^3H releases from the waste burial ground (Table 2.7) has also been evaluated. It is assumed that 10% of the 820 Ci of ^3H from HETP operations would escape from the burial ground each year. The steady-state concentration in Whiteoak Lake would be 8.0×10^{-6} $\mu\text{Ci/ml}$, and the Clinch River concentration would be 2.3×10^{-8} $\mu\text{Ci/ml}$ (assuming a dilution factor of 350). Corresponding dose commitment to total body is 6.3×10^{-4} millirems. Again, this dose is small when compared to that from other sources (~1% of ORNL ^3H discharges).

4.1.1.3 Analysis of airborne effluents

The AIRDOS-II computer code⁵ was used to estimate 50-year dose commitments from effluents released to the atmosphere. The AIRDOS-II code is a FORTRAN-III computer code that calculates the dose commitment to individuals and populations for as many as 36 radionuclides released from one to six stacks. HETP gaseous effluents are released from stacks 3039, 7911, and a stack for combustible off-gases on the roof of Building 7930 (Sect. 2.3.3.4). Annual average meteorological data are supplied for the surrounding area as input to the computer code. Output data

include ground-level concentrations in air and rates of deposition on ground and water surfaces for each radionuclide at various distances and directions from the release point. From these values, doses to man at each distance and direction specified are estimated for total body, GI tract, bone, thyroid, lungs, muscle, kidneys, liver, spleen, testes, and ovaries through each of the five pathways depicted in Fig. 4.1. The dose calculations are made with the use of dose-conversion factors supplied as input data for each radionuclide and exposure mode. Dose-conversion factors for submersion in the gas-borne effluent, exposure to contaminated ground surface, and intake of radionuclides through inhalation and ingestion are calculated by use of dosimetric criteria of the International Commission on Radiological Protection (ICRP) and other recognized authorities. These factors are computed and summarized in two computer codes, one for external exposure, EXREM-III,⁶ and one for internal exposure, INREM.⁷

Radioactive particulates are removed from the atmosphere and deposited on the ground through mechanisms of dry deposition and scavenging. Dry deposition, as used in this analysis, represents an integrated deposition of radioactive materials by processes of gravitational settling, adsorption, particle interception, diffusion, and chemical electrostatic effects and is calculated from the deposition velocity for a 1-year time interval. Deposition velocity values for particles and reactive gases commonly range from 0.1 to 6.0 cm/sec.⁸ Based on an analysis of the effect of deposition velocities on estimates of radiological impact, a value of 1 cm/sec is used for calculation of ground concentrations of radioactive particles for this facility. Scavenging of radionuclides in a plume is the process through which rain or snow washes out particles or dissolves gases and deposits them on the ground or water surfaces. Methods for estimating the scavenging coefficient can be found in *Meteorology and Atomic Energy* (1968).⁸ A scavenging coefficient of $2.0 \times 10^{-5} \text{ sec}^{-1}$ is used for particulates, ³H, ¹⁴C, and radioiodines.

Many of the basic incremental parameters used in AIRDOS-II are conservative; that is, values are chosen to maximize intake by man. Many factors that would reduce the radiation dose, such as shielding provided by dwellings and time spent away from the reference location, are not considered. It is assumed that an individual lives outdoors at the reference location 100% of the time. Moreover, in estimating the doses to individuals via ingestion of vegetables, beef, and milk, all the food consumed by the individual is assumed to be produced at the reference location specified in the calculation. Thus the dose estimates calculated by these methods are likely to be higher than the doses that would actually occur.

A summary of the assumptions, models, and codes used to estimate radiation doses is given in ORNL-4992.⁴

4.1.1.4 Demographic assumptions

Oak Ridge National Laboratory is located in an area of relatively high average population density. The AIRDOS-II population dose-calculation methodology includes provision for a specific and detailed numerical description of the population within a given radius of the laboratory. The description used is based on an updated version of the 1970 U.S. census for the area and includes a population of 690,000 individuals. This population is subdivided by residence within one of 16 wedges, visualized as radiating outward to a distance of 50 miles from the laboratory and centered on the 16 compass points. The population is further subdivided by residence within one of 10 concentric discs, visualized as centered on the laboratory, with radii increasing to a maximum of 50 miles.

Population dose estimates in this document are therefore based on summations of average doses to subpopulations residing within these 160 subdivisions, using conservative dose-estimation procedures as described.

4.1.1.5 Analysis of maximum individual dose commitments

The majority of the anticipated exposure to man results from radioactivity released to the atmosphere. The 7911 stack located at the TURF is estimated to be the major point of release to the atmosphere for radionuclides generated by the HETP. The stack height is 76 m (250 ft) with a diameter of 1.5 m (5 ft) and an effluent velocity of 9.3 m/sec (30 fps). Source terms for radioactivity releases to the environment from the 7911 stack are listed in Table 2.5. The point of maximum exposure occurs 3660 m (2-1/4 miles) southwest of the TURF stack.

The other release point of radioactivity to the atmosphere from the Hot Engineering Test Project is at the 3039 stack in Bethel Valley. This stack is 76 m (250 ft) high, 2.4 m (8 ft) in diam, and has an effluent velocity of 13.7 m/sec (45 fps). The source terms for this stack are listed in Table 2.5. The point of maximum exposure occurs 4115 m (2-1/2 miles) southwest of the 3039 stack.

Dose commitments for the maximally exposed individual to the total body and to various organs resulting from radioactivity releases from the Hot Engineering Test Project are listed in Table 4.2. By comparison of these data, it is obvious that essentially all of the radiation exposure would be due to releases from the 7911 stack. Releases of radioactivity from the 3039 stack during HETP operation contribute only about 0.0025 millirem to the total body and other organs. A breakdown of contributors to organ doses is listed in Table 4.3. The three primary contributors to each organ are ^{14}C , ^{33}P , and ^{35}S .

Ingestion is the critical pathway, contributing more than 98% of the dose to each organ listed in Tables 4.2 and 4.3.

4.1.1.6 Comparison of maximum individual exposures with those from other Oak Ridge National Laboratory operations

Maximum annual total-body and organ doses resulting from radionuclides released to the atmosphere by other ORNL operations have been calculated. Quantities of radionuclides released to the atmosphere are listed in Table 4.4. Table 4.5 gives the estimated maximum annual total-body and organ doses resulting from exposure to these ORNL airborne effluents. These calculated doses are the most recent data of this kind available and are still representative of the radiological impact of ORNL operations. The maximum estimated total-body dose is 0.94 millirem per year, and this corresponds to ~0.2% of the statutory limit for individuals living in unrestricted areas.⁹ Organ dose estimates are comparable to total-body doses with the exception of the thyroid dose, which is 21 millirems per year. Tritium is responsible for ~84% of the estimated total-body dose and from 79 to 90% of the individual organ doses, except the thyroid. Ninety-five percent of the dose to the thyroid and 4% of the total-body dose is from ^{131}I . The noble gases ^{85}Kr and ^{133}Xe contribute 12% to the total-body estimate. Assuming that the total-body estimate of 0.94 millirem per year approximates present radiological impact from ORNL operations, the addition of the HETP source term (Table 4.2) is an increase of about 15% in the total-body dose to the maximally exposed individual. This increase is expected to last for only 2 years.

Table 4.2. Maximum individual 50-year dose commitments to total body and various organs from radioactivity released to the atmosphere during 1 year of HETP operations^a

| Release point | Fifty-year dose commitments (millirems) | | | | | | |
|----------------------------------|--|----------|--------|---------|--------|--------|---------|
| | Total body | GI tract | Bone | Thyroid | Lungs | Muscle | Kidneys |
| Building 7911 stack ^b | 0.14 | 0.57 | 1.10 | 0.12 | 0.11 | 0.14 | 0.11 |
| Building 3039 stack ^c | 0.0025 | 0.0025 | 0.0025 | 0.0025 | 0.0025 | 0.0025 | 0.0025 |

^aHETP is expected to operate for 2 years.

^bThe point of maximum exposure occurs 3660 m from the stack.

^cThe point of maximum exposure occurs 4115 m from the stack.

Table 4.3. Primary contributors to the dose commitment to various organs for individuals exposed during HETP operation^a

| Radionuclide | Contribution to dose commitment (%) | | | | | | |
|------------------|-------------------------------------|----------|------|---------|-------|--------|---------|
| | Total body | GI tract | Bone | Thyroid | Lungs | Muscle | Kidneys |
| ³ H | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| ¹⁴ C | 45 | 9 | 10 | 24 | 26 | 46 | 32 |
| ³³ P | 23 | 72 | 80 | 27 | 30 | 23 | 29 |
| ³⁵ S | 30 | 19 | 10 | 35 | 40 | 30 | 38 |
| ⁸⁵ Kr | 1 | <1 | <1 | 2 | 4 | <1 | 1 |
| ¹²⁹ I | <1 | <1 | <1 | 11 | <1 | <1 | <1 |
| ¹³¹ I | <1 | <1 | <1 | 1 | <1 | <1 | <1 |

^aConsidering releases from the 7911 stack only.

Table 4.4. Quantities of radionuclides released to the atmosphere from ORNL during 1973

| Release point | Radionuclide ^a | Quantity (Ci) |
|--------------------------|---------------------------|---------------|
| Building 3039 stack | ³ H | 9,000 |
| | ⁸⁵ Kr | 12,000 |
| | ¹³¹ I | 1.5 |
| | ¹³³ Xe | 59,000 |
| Building 7911 stack | ⁸⁵ Kr | 2,000 |
| | ¹³¹ I | 0.7 |
| | ¹³³ Xe | 9,590 |
| Building 7025, roof vent | ³ H | 10 |

^aRadionuclides contributing <0.02% of dose are not listed.

Table 4.5. Contribution of radionuclides to the estimated maximum annual total-body and organ doses to individuals from ORNL airborne effluents during 1973

| Radionuclide ^b | Dose ^a (millirems) | | | | | |
|---------------------------|-------------------------------|-------|---------|---------|-------|----------|
| | Total body | Bone | Kidneys | Thyroid | Lungs | GI tract |
| ³ H | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 |
| ⁸⁵ Kr | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| ¹³¹ I | 0.04 | 0.05 | 0.04 | 20 | 0.04 | 0.02 |
| ¹³³ Xe | 0.10 | 0.17 | 0.07 | 0.12 | 0.08 | 0.06 |
| Total | 0.94 | 1.0 | 0.91 | 21 | 0.92 | 0.88 |

^aAt or near the ORNL boundary.

^bRadionuclides contributing <0.02% of dose are not listed.

This dose is small compared with the natural background exposure, which for the Oak Ridge area is about 115 millirems per year, 40% from cosmic radiation and 60% from natural terrestrial radioactivity.¹⁰

4.1.1.7 Analysis of population dose commitments

Table 4.6 lists population dose commitments to the total body and to various organs in man-rems, assuming a population of approximately 690,000 persons living within a 50-mile radius. The bone receives the highest organ dose to the population for releases from the TURF stack, 7.0 man-rems. As with the maximum individual doses, population doses from 3039 stack releases are not significant compared with those from the TURF.

Table 4.6. Population dose commitments to total body and various organs from radioactivity released to the atmosphere during 1 year of HETP operations

| Release point | Fifty-year dose commitments (man-rems) | | | | | | |
|---------------------|--|----------|-------|---------|-------|--------|---------|
| | Total body | GI tract | Bone | Thyroid | Lungs | Muscle | Kidneys |
| Building 7911 stack | 1.6 | 3.7 | 7.0 | 1.1 | 1.1 | 1.6 | 1.1 |
| Building 3039 stack | 0.054 | 0.054 | 0.054 | 0.054 | 0.054 | 0.054 | 0.054 |

Ingestion is again the dominant mode of exposure for the organs listed in Table 4.6, contributing more than 95% of the dose to each organ with the exception of the lungs (for this organ, 87% of the dose is by the ingestion pathway). The three most important radionuclides for population exposures are again ¹⁴C, ³³P, and ³⁵S.

An estimate of the health effects to the population within a 50-mile radius can be obtained using cancer and genetic risk factors recommended by Cohen.¹¹ These factors are 180×10^{-6} cancer deaths per man-rem and 150×10^{-6} genetic defects per man-rem, and they are based on data published in the BEIR¹² and UNSCEAR¹³ reports. Multiplying the total body dose listed in Table 4.5 by the risk factors yields 2.9×10^{-4} cancer deaths and 2.5×10^{-4} genetic defects within a 50-mile radius per year of HETP operation.

Corresponding total-body population doses estimated for radioactivity releases from all Oak Ridge facilities for 1973 (assumed to be about the same as current releases) have been calculated to be 30 man-rems (Table 4.7). Therefore, the addition of HETP operations would increase the annual total-body dose by ~5%.

Table 4.7. Contribution to estimated annual population doses from Oak Ridge facilities^a

| Facility | Principal radionuclide ^b | Dose (man-rem) | | | | | | |
|-------------------------|-------------------------------------|----------------|----------|------|---------|-------|--------|---------|
| | | Total body | GI tract | Bone | Thyroid | Lungs | Muscle | Kidneys |
| ORGP ^c | ⁹⁹ Tc | 0.02 | 4.7 | 0.06 | 0.02 | 0.03 | | 1.1 |
| | ²³⁴ U | 1.1 | 1.0 | 5.4 | 1.1 | 4.9 | | 1.9 |
| | ²³⁵ U | 0.49 | 0.49 | 0.65 | 0.49 | 0.63 | | 0.52 |
| | ²³⁶ U | <0.01 | <0.01 | 0.01 | <0.01 | 0.01 | | <0.01 |
| | ²³⁸ U | 0.04 | 0.03 | 0.68 | 0.04 | 0.59 | | 0.15 |
| Subtotal | | 1.7 | 6.2 | 6.8 | 1.7 | 6.2 | | 3.7 |
| Y-12 Plant ^c | ²³⁴ U | 4.5 | 42 | 19 | 4.5 | 23 | | 7.2 |
| ORNL ^c | ³ H | 15 | 15 | 15 | 15 | 15 | | 15 |
| | ⁸⁵ Kr | 0.07 | 0.07 | 0.07 | 0.07 | 0.14 | | 0.07 |
| | ¹³¹ I | 0.66 | 0.48 | 0.66 | 230 | 0.71 | | 0.66 |
| | ¹³³ Xe | 7.8 | 7.8 | 7.8 | 7.8 | 8.0 | | 7.8 |
| Subtotal | | 24 | 23 | 24 | 250 | 24 | | 24 |
| Three plant total | | 30 | 71 | 50 | 260 | 53 | | 35 |
| HETP | ¹⁴ C | 0.72 | 0.33 | 0.7 | 0.26 | 0.29 | 0.74 | 0.35 |
| | ³³ P | 0.37 | 2.7 | 5.6 | 0.3 | 0.33 | 0.37 | 0.32 |
| | ³⁵ S | 0.48 | 0.7 | 0.7 | 0.39 | 0.44 | 0.48 | 0.42 |
| | ⁸⁵ Kr | 0.02 | | | 0.02 | 0.04 | | 0.01 |
| | ¹²⁹ I | | | | 0.12 | | | |
| | ¹³¹ I | | | | 0.01 | | | |
| Subtotal | | 1.6 | 3.7 | 7.0 | 1.1 | 1.1 | 1.6 | 1.1 |

^aPopulation within 50 miles of facility.

^bRadionuclides contributing <0.01 man-rem to the total-body or organ dose are not listed.

^cContributions from airborne effluents for 1973 (assumed to be representative of present effluents).

4.1.2 Impacts on biota other than man

No adequate methodology exists for the estimation of cumulative doses to terrestrial animals; therefore, doses have not been estimated in this report. It may be generally assumed, however, that the radiosensitivity of organisms other than man is less than that for man himself, and that if man is protected from the potentially harmful effects of radiation, other organisms will also be protected.

Because no direct liquid radionuclide releases from the HETP facilities occur during normal operations, the potential for impact via liquid effluents needs to be assessed only for materials calculated to pass through the ORNL Intermediate-Level Waste (ILW) System. Table 2.6 lists calculated releases to the ILW (column 2) via the aqueous waste streams of solvent extraction during reprocessing. Quantities and concentrations released via other HETP aqueous waste streams from both reprocessing and refabrication are estimated to be insignificant in relation to solvent extraction.

Carryover of radionuclides into the condensate of the ILW evaporator is conservatively estimated to result in a decontamination factor (DF) of 10^7 . This DF is assumed to be nonspecific with respect to the radionuclides listed and results in the column 3 (Table 2.6) estimates of annual radionuclide releases to Whiteoak Creek.

Assuming an annual flow of 10^{13} ml in Whiteoak Creek and making the conservative assumptions of (1) no dilution in Whiteoak Lake and (2) no removal from solution via biophysical mechanisms, dilution of the condensate in Whiteoak Creek results in creek (HETP-related) radionuclide concentrations as listed in column 4 (Table 2.6).

To estimate the hazard level of these radionuclide concentrations, reference is made to the ERDA Manual, "Standards for Radiation Protection," Chapter 0524 (April 1975). Comparisons made to limiting waterborne radionuclide concentrations listed in this manual for population groups in uncontrolled areas indicate that ^{90}Sr concentrations at the Whiteoak Dam may approach 0.2% of the 3×10^{-7} $\mu\text{Ci/ml}$ limits recommended. Other nuclides, ^{89}Sr , ^{134}Cs , and $^{137\text{m}}\text{Ba}$, approach 0.01 to 0.02% of their respective limits. The remaining radionuclides listed are present only in very low estimated concentrations relative to their respective standards, even under these conservative conditions.

Department of Energy standards for radiation protection are therefore not expected to be exceeded by HETP-related liquid releases, even under conservative conditions. Monitoring of Whiteoak Dam effluents into the Clinch River should be continued. Should excessive radionuclide concentrations be measured, specific pretreatment procedures (precipitation, ion exchange, etc.) would be performed on specific campaigns prior to introduction of liquid effluents into the ILW system. The campaign nature of HETP operations permits sequestering nuclides such as ^{90}Sr prior to transfer of liquid wastes to the ORNL ILW.

4.2 NONRADIOLOGICAL IMPACTS

4.2.1 Impacts on land use and terrestrial ecosystems

Impact on land use

The HETP will modify and use four existing buildings within the ORNL complex. None is being significantly enlarged. The activities of HETP are not generically different from activities at the ORNL site since the Manhattan Project of World War II and are well removed from public-access areas. It is therefore concluded that there will be no impact on land use or land-use potential from the proposed project.

Impacts from construction

Although remodeling will be extensive in the various buildings, only one of the four will be expanded to unoccupied land. Building 7930 will have a stairwell added, which will consume $<18 \text{ m}^2$ (200 ft^2) of lawn. The impact is considered to be insignificant.

Laydown areas for construction materials will be required. The exact area required is unknown at present. HETP will be a rather small construction project compared with others in progress at ORNL. No significant additional or unique impacts are anticipated.

Impact from operation

The buildings and systems to be used for HETP are designed for handling and containment of highly radioactive materials. Consequently, nonradioactive materials that might impact the nearby terrestrial ecosystems will also be contained. It has been estimated (Table 2.4) that

the major nonradioactive gaseous effluent will be CO₂ (~13,000,000 liters per year). A forest ecosystem on the Oak Ridge reservation¹⁴ respire approximately 2500 liters of CO₂ m⁻² year⁻¹. The expected release from HETP is therefore equivalent to the annual respiration of 0.52 ha (1.3 acres), an insignificant amount.

Additionally (see Table 2.4), 210 liters per year of NO_x and 230 liters per year of NH₃ (equivalent to 280 g of nitrogen per year) are expected to be emitted. One forest on the Oak Ridge reservation¹⁵ has a normal annual input from all sources of 5.4 g of nitrogen per square meter. That released from HETP would be equivalent to the normal input to 52 m² (0.01 acres), an insignificant amount. Other stack releases are expected to be of lesser quantities and are not expected to result in a measurable impact on terrestrial ecosystems.

4.2.2 Impacts on water use and aquatic ecosystems

Because the majority of the buildings required for the HETP already exist, new construction will be minimal and will consist largely of alterations to the existing structures (Sect. 2.3.3). Thus the quantity of land disturbed will be very small (Sect. 4.2.1). Runoff from the construction site into nearby waters will not be contaminated and will be controlled to minimize impacts and should not result in significant adverse impacts for downstream water users or to aquatic ecosystems.

There are no direct operational discharges to surface streams (Sect. 2.3.2.2). All discharges are through other systems (ILW and low-level process wastes) which treat the wastes before discharge. The staff expects that the small increments of pollution resulting from HETP operations will have no effect on water use and aquatic ecosystems and concludes that construction and operation of the project are acceptable.

4.3 COMMUNITY EFFECTS

Modifications and additions to four existing buildings at ORNL will require a total of 278 man-years of work over a 5-year period (1981 to 1985). The peak labor requirement will occur in 1983, when a total of 88 construction personnel will be employed. Much of this construction work force will consist of existing ORNL or Rust Engineering Company personnel.

Operation of the test facilities will employ 30 to 35 people from 1984 to 1987. This should not result in an increase in employment because most of the positions will be filled by current ORNL staff. The total construction and operation personnel requirements are small compared with the existing DOE work force (Sect. 3.7.2) and the area population (Sect. 3.7.1); therefore no detectable impacts on the area communities should be caused by the work force.

Because the DOE facilities are tax exempt, construction and operation of the test facilities will not result in any direct tax payments.

4.4 POTENTIAL EFFECTS OF ACCIDENTS

In the absence of a formal safety analysis for the HETP, several types of accidents have been postulated, all of which have a low probability of occurrence. The major hazards associated with accidents are radiological in nature. Quantities of nonradioactive chemicals likely to be released in any one accident are expected to be small.

4.4.1 Radiological accidents

Radiological hazards to an individual living at the plant boundary in the accident scenarios given below have been calculated by use of dose-estimation techniques as described previously (Sect. 4.1). The assumption that an individual remains at the boundary for more than a few hours after an accident is conservative because coordination of the ORNL emergency plan with local authorities includes evacuation of potentially affected offsite individuals to minimize exposures.

Some of the postulated accidents are original to this study (cases A to F), but others are extracted from previous safety analyses or environmental impact statements for other projects using the same ORNL facilities. Extracted scenarios are clearly indicated.

The facilities and system and process designs are such that, should an accident occur, offsite effects would be minimal. The campaign nature of the pilot operation ensures that at any given time only a relatively small quantity of irradiated Fort St. Vrain (FSV) fuel would be in process and therefore potentially subject to accidental release. Shutdown and isolation of the plant would prevent most uncontrolled releases to the environment, should an accident occur.

As the locale experiences predominantly northeast-southwest winds of low average speed, conditions during an accidental release for the scenarios original to this report were assumed to include 1-meter-per-second wind velocity in a southwest direction, the direction of the nearest site boundary.

Pasquill stability condition B was found to maximize dose in all accident cases analyzed. As releases were postulated from the 7911 stack, from the 3039 stack, and from a transportation fire occurring enroute between Melton and Bethel Valleys, distances to the site boundary from points of release were chosen to be 3660 m, 4115 m, and 3500 m respectively. The corresponding offsite location of a hypothetical maximally exposed individual is near the southwest bank of the Clinch River, approximately 1/2 to 3/4 mile (800 to 1200 m) downstream from the TVA Melton Hill Dam. Several families are living at this approximate location. Calculations were made to confirm this as the location of the maximally exposed individual for releases under the assumed conditions of meteorology, stack height, plume rise, radionuclide decay, plume depletion, and plume meander. The assumption that an individual remains in the area for the duration of his lifetime, subsists on foods harvested entirely from the area, and drinks water from an area source probably results in a conservative estimate of the dose commitment. Releases of significant hazard would result in evacuation of the affected area. All accident-related 50-year radiological dose commitments are calculated via the AIRDOS-II code⁵ for an adult living in the area described above. Estimated increased radionuclide releases (over and above operational releases given in Table 2.5), with corresponding 50-year dose commitments, are presented for cases A through F in Tables 4.8 through 4.11. To illustrate (case A, Table 4.8), tritium from handling four fuel elements in cell A, Building 3026D, is routinely released through the 3039 stack. The case A fire would release this quantity of tritium plus an additional 0.16 Ci.

Dose commitments from operational releases are given in Sect. 4.1.

Table 4.8. Estimated increased releases of radionuclides to atmosphere from postulated accidents and increased 50-year dose commitment to maximally exposed individual

| Case | Radionuclide | Increased quantity released (Ci) | Increased dose commitment (millirem) | |
|---|------------------|----------------------------------|--------------------------------------|----------------------|
| | | | Total body | Thyroid |
| A—Fire in cell A of Building 3026D, which engulfs (but does not consume) four spent fuel elements | ^3H | 1.6×10^{-1} | 2.2×10^{-5} | 2.2×10^{-5} |
| | ^{129}I | 6.4×10^{-4} | 3.6×10^{-3} | 8.6×10^{-1} |
| | ^{131}I | 1.3×10^{-3} | 2.3×10^{-4} | 1.1×10^{-1} |
| B—Failure of tritium-removal system in TURF | ^3H | 7.6×10^0 | 1.4×10^{-3} | 1.4×10^{-3} |
| C—Failure of iodine-removal system in TURF | ^{129}I | 5.8×10^{-4} | 3.9×10^{-3} | 9.9×10^{-1} |
| | ^{131}I | 9.1×10^{-4} | 3.9×10^{-4} | 1.0×10^{-1} |
| D—Fire in cell D of TURF, which engulfs (but does not consume) 12 spent fuel elements | ^3H | 4.7×10^{-1} | 8.3×10^{-5} | 8.3×10^{-5} |
| | ^{129}I | 1.9×10^{-3} | 1.4×10^{-2} | 3.2×10^0 |
| | ^{131}I | 3.8×10^{-3} | 8.7×10^{-4} | 4.2×10^{-1} |
| E—Vehicle accident and fire during onsite transportation of one spent fuel element | ^3H | 3.9×10^{-2} | 6.6×10^{-6} | 6.6×10^{-6} |
| | ^{129}I | 1.6×10^{-4} | 1.2×10^{-3} | 2.8×10^{-1} |
| | ^{131}I | 3.2×10^{-4} | 7.6×10^{-5} | 3.7×10^{-2} |

Table 4.9. Estimated increased radionuclide releases to atmosphere from secondary burner burn-through accident (case E)

| Radionuclide | Quantity released (Ci) |
|-------------------|------------------------|
| ^3H | 7.6×10^0 |
| ^{89}Sr | 3.8×10^{-5} |
| ^{90}Sr | 5.1×10^{-6} |
| ^{95}Zr | 6.8×10^{-5} |
| ^{95}Nb | 1.3×10^{-1} |
| ^{103}Ru | 1.6×10^{-4} |
| ^{106}Ru | 5.5×10^{-4} |
| ^{129}I | 5.8×10^{-4} |
| ^{131}I | 9.1×10^{-4} |
| ^{134}Cs | 1.7×10^0 |
| ^{141}Ce | 1.2×10^{-6} |
| ^{144}Ce | 2.7×10^{-5} |
| ^{147}Pm | 2.7×10^{-6} |
| ^{219}Rn | 6.6×10^{-4} |
| ^{220}Rn | 2.5×10^{-1} |
| ^{238}Pu | 1.2×10^{-6} |
| ^{241}Pu | 6.4×10^{-7} |
| ^{242}Cm | 1.3×10^{-7} |
| ^{244}Cm | 1.6×10^{-7} |

Table 4.10. Increased 50-year dose commitment to each organ to maximally exposed individual through all pathways from secondary burner burn-through accident (case E) ^a

| Organ | Dose (Millirem) |
|------------|-----------------|
| Total body | 20 |
| GI tract | 13 |
| Bone | 19 |
| Thyroid | 20 |
| Lungs | 13 |
| Muscle | 25 |
| Kidneys | 15 |
| Liver | 24 |
| Spleen | 23 |
| Testes | 20 |
| Ovaries | 14 |

Table 4.11. Radionuclide contributors to increased dose commitments from secondary burner burn-through accident (case E) (%)

| Nuclide | Total body | GI tract | Bone | Thyroid | Lungs | Muscle |
|-------------------|------------|----------|---------|---------|---------|---------|
| ³ H | 0.0068 | 0.0102 | 0.0071 | 0.0069 | 0.0105 | 0.0053 |
| ⁸⁹ Sr | 0.0000 | 0.0000 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| ⁹⁰ Sr | 0.0001 | 0.0001 | 0.0076 | 0.0001 | 0.0002 | 0.0001 |
| ⁹⁵ Zr | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| ⁹⁵ Nb | 0.0000 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| ¹⁰³ Ru | 0.0001 | 0.0026 | 0.0001 | 0.0001 | 0.0002 | 0.0001 |
| ¹⁰⁶ Ru | 0.0012 | 0.1478 | 0.0027 | 0.0013 | 0.0032 | 0.0009 |
| ¹²⁹ I | 0.0208 | 0.0028 | 0.0282 | 5.0314 | 0.0211 | 0.0149 |
| ¹³¹ I | 0.0011 | 0.0009 | 0.0011 | 0.5102 | 0.0016 | 0.0008 |
| ¹³⁴ Cs | 99.9694 | 99.8348 | 99.9409 | 94.4496 | 99.9621 | 99.9775 |
| ¹⁴¹ Ce | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| ¹⁴⁴ Ce | 0.0000 | 0.0005 | 0.0001 | 0.0000 | 0.0001 | 0.0000 |
| ¹⁴⁷ Pm | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| ²¹⁹ Rn | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| ²²⁰ Rn | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| ²³⁸ Pu | 0.0003 | 0.0000 | 0.0104 | 0.0003 | 0.0005 | 0.0002 |
| ²⁴¹ Pu | 0.0000 | 0.0000 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| ²⁴² Cm | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| ²⁴⁴ Cm | 0.0001 | 0.0002 | 0.0015 | 0.0001 | 0.0001 | 0.0001 |

4.4.1.1 Accident scenarios for Building 3026D

Case A – Fire engulfing four spent fuel elements

A fire engulfing one or more fuel elements is probably the maximum credible accident that can be postulated for the HETP operations in Building 3026D (Sect. 2.3.3.2). The worst fire is assumed to engulf but not consume four fuel elements standing open in cell A. The effect of the fire would be to bake out gases trapped in the graphite and in the broken fissile and fertile particles. Because the fire would be within the cell, there would be no iodine control by the CO₂ loop off-gas system. However, the building off-gas system and the 3039 stack off-gas system to which the building off-gas system vents would remain intact and operating normally. A fire continuing for more than a few minutes would be controlled by the cell's CO₂ fire-protection system described elsewhere.¹⁶ For these calculations, however, it was conservatively assumed that the fire lasted 30 min.

Isotopes and increased quantities of gases expected to be released in such a fire are presented as case A in Table 4.8, as are increased dose estimates associated with these releases. The increases in the doses are low and due largely to release of radioiodines.

Other accidents

Other accidents such as criticality excursions, flooding, tornado, and earthquake disasters were also considered for Building 3026D, but were concluded to be either incredible or of negligible radiological hazard.

4.4.1.2 Accident scenarios for Building 3019

Most of the processes and equipment to be used by the HET in Building 3019 (Sect. 2.3.3.1) already exist, having been used for many years in support of several programs. In a recent safety analysis¹⁷ for the Light-Water Breeder Reactor Program (LWBR), the facilities and the safety and environmental-protection measures employed in Building 3019 were described in detail and will not be repeated here.

Hydrogen explosion in reduction furnace

A hydrogen explosion (postulated as a part of recent ongoing environmental analysis of all operations in the Oak Ridge area) in the reduction furnace in the ²³³U dioxide powder line in the basement of the building is presented here as representative of an HETP accident involving ²³³U. The explosion is assumed to breach the HEPA filters in the process equipment system, releasing 10 to 100 mg/m³ of ²³³U dioxide to the filter bank at the 3020 stack. Reported information¹⁸ shows that the predicted concentration of particulates in the effluent from absolute filters is 0.02 mg/m³, which is based on the maximum concentration of particulates as a function of particle size, assuming that the efficiency of HEPA filters is 100% for particles >0.3 μm in diam and 99.95% for particles <0.3 μm in diam. On the basis of the above information, about 700 mg of ²³³U as UO₂ would be released from the stack to the environment over an assumed 5-min period. Maximum individual doses from this postulated accident are estimated to be 5.0 x 10⁻² millirems to the total body, 4.0 x 10⁻¹ millirems to the bone, 1.0 millirem to the lungs, and 1.1 x 10⁻¹ millirems to the kidneys. Surface exposure and inhalation contribute 56 and 44% of the total body dose, respectively.

Criticality excursion

A separate report¹⁹ on the criticality hazards in Building 3019 was also prepared for the LWBR Program. A criticality incident was postulated as part of the recent environmental analysis of the Oak Ridge Operations to occur in a 240-gal stainless-steel tank in the storage area in Building 3019. Consequences were calculated for both nonrupture and rupture of the containment vessel. A burst of 10^{18} fissions was calculated in the worst case to produce a maximum downwind dose commitment (for an individual located at a distance of about 400 m from the stack) of 0.0043 millirem from particulates and 0.22 millirem from gaseous emissions.

Other accidents

In view of the small probability of a tornado (Sect. 3.5.7) and/or earthquake (Sect. 3.3.2) in the Oak Ridge area, the alterations to be made to Building 3019, the limited time of the test, and the relatively small amounts of material to be handled in 3019, the consequences of releases due to such natural disturbances were not assessed. Because building location flooding was concluded not credible, the consequences of flooding were not assessed.

4.4.1.3 Accident scenarios for Building 7930

The bulk of the operations in the HETP will be conducted in the Thorium-Uranium Recycle Facility, Building 7930 (Sect. 2.3.3.4). The building was specifically designed for tests of reprocessing and refabrication operations involving thorium-based fuels. A formal safety analysis of the facility has been prepared²⁰, as has a full environmental impact statement²¹ for HTGR refabrication tests of a much greater scale than those proposed for HETP. Environmental impact statements have also been prepared for similar large-scale HTGR reprocessing tests²² and for a commercial facility for fresh fuel refabrication.²³ These documents establish that the accidents with the maximum consequences are criticality, fires, explosions, and failures of certain critical pieces of operating equipment. Probabilities were not determined for these principal hazards.

Case B -- Failure of tritium-removal system in reprocessing

In this scenario the tritium-removal system used in the burner off-gas system (Sect. A.9.1) was assumed to fail during the secondary burning of the fissile stream from one fuel element. The system consists essentially of a heater preceding a catalyst bed that oxidizes the tritium to water and a condenser-adsorption bed that removes the water from the off-gas stream. The estimated increased tritium release and the associated increase in the dose commitment due to this system failure are presented in Table 4.8, case B.

Case C -- Failure of iodine-removal system in reprocessing

The reprocessing burner off-gas system is equipped with a silver zeolite bed for removal of 99.9% of the gaseous iodine from the off-gas streams from several processes, particularly the primary and secondary burning (Sect. A.9.1). The system was assumed to become inoperable during the worst case of the secondary crushing and burning. The quantity released was assumed to be all the iodine in the fissile-particle stream from a single fuel element. Quantities of radioiodine released and the resulting increases in the doses are presented in Table 4.8, case C.

Case D -- Fire involving 12 segmented fuel elements

A fire lasting 30 min is assumed to engulf but not consume 12 segmented fuel elements in storage. The resulting effluents are exhausted through the cell ventilation system to the 7911 stack. The primary effect would be the loss of gases from the graphite and from the broken particles within the elements. No loss of materials which are volatile at elevated temperatures, such as oxides of ruthenium and cesium, was assumed. The increase over routine releases is then due to losses of tritium and iodine normally removed by the burner off-gas systems. The increased quantities of radionuclides released under these hypothetical conditions are listed in Table 4.8, case D. The increased thyroid dose is 3.7 millirems.

Case E -- Secondary burner burn-through

An accident was considered in which the contents of the secondary burner were assumed to burn through the sides of the furnace vessel, fall on the floor of the cell, and continue burning for a period of 30 min. The quantity assumed to be involved was the fissile particles from one spent fuel element. It was assumed that the amount of radioactivity made airborne by this accident was essentially the same as that made airborne in a routine secondary burning operation. However, in the postulated accident the protection usually provided by the filters of the secondary burner and the burner off-gas system (Sect. A.9.1) would be absent. The only protection available was assumed to be that provided by the cell's exhaust roughing filter and the two-stage HEPA filters at the 7911 stack. It was assumed that 5% of the particulate matter, 96% of the ruthenium, and 35% of the cesium were released and entrained in the cell off-gases but decontaminated by the cell and stack filters (an overall decontamination factor of 10^7 was assumed, 10^2 for the cell roughing filter and 10^5 for the stack HEPA filters). All fission-product and decay-product gases, including iodine present in the fissile particle stream, were assumed to become airborne in the cell. The radionuclide releases over and above routine are listed in Table 4.9.

The estimated dose commitment to the maximally exposed offsite individual is presented in Table 4.10. Total-body dose is approximately 20 millirems, with integrated organ doses as high as 25 millirems estimated for a 50-year period. As is evident in Table 4.11, ^{134}Cs is responsible for essentially all of the estimated increased doses.

Criticality incident

Effects on the general population from a criticality incident involving 10^{19} fissions has been hypothesized.²¹ It was assumed that the critical mass occurred either in a solution or in a water-moderated bed of microspheres (a "dry" criticality was concluded to be incredible). 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 min 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 windspeed of 4.4 m/sec in the northeast direction.

The maximum individual doses for all pathways of exposure except prompt neutrons and secondary gammas would occur 3000 m from the TURF. The external dose from submersion would be 0.45 millirems. A person residing continuously at this location would receive an external dose of 0.39 millirem 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 millirem to the whole body, 0.011 millirem to bone, 3.2 millirems to thyroid (iodine radionuclides), and 0.082 millirem to the lung.

Maximum credible fire

The consequences of a fire were assessed in the safety analysis for TURF.²⁰ In this analysis, it was assumed that 4% of the nonvolatile fission products and fuel material would be released into the cell atmosphere as smoke and that 1% of the smoke (0.01- to 0.1-micron particles) would be released through the filters to the stack. The maximum downwind dose was calculated²¹ to be less than 200 millirems to the total body, 3 rems to bone, and 7 rems to the lungs.

Explosion

The consequences of a maximum credible accident involving a chemical explosion were assessed in the TURF safety analysis report.²⁰ The accident was assumed to disperse an aerosol of irradiated fuel-element dissolver solution into the cell air. One cell air volume, or about 100 m³, was assumed to exhaust through the cell ventilation system and out the 7911 stack. The maximum personnel dose downwind was shown to be less than 1 millirem.

4.4.1.4 Accidents in Building 7503

Building 7503 (Sect. 2.3.3.3) will be used to store only whole or segmented fuel elements and burned-back fissile and fertile particles. Neither the fuel elements nor the burned-back particles are combustible or explosive, and no other combustible or explosive material will be present within the cells or the building. The likelihood of a fire or explosion is virtually nonexistent.

There will be no liquids present in the cells, so that the possibility of a water-moderated criticality does not exist. The possibilities of a "dry" criticality involving such material was considered in the Safety Analysis Report for the Idaho Irradiated Fuels Storage Facility.²⁴ Based on the findings in that report and given the limited quantities of material to be stored in 7503 during HETP, the likelihood of such a "dry" criticality is extremely remote.

The likelihood of accidents, including flood, tornado (Sect. 3.5.7), and earthquake (Sect. 3.3.2), was judged extremely low. Because of the physical form of the materials stored in Building 7503, radiological hazards resulting from natural disasters would probably be small.

4.4.1.5 Transportation accidents

Offsite transportation accidents involving irradiated FSV fuel elements have been considered elsewhere.²⁵ Only two onsite trucking accidents, which are considered to represent the greatest potential hazards, are assessed below.

Case F -- Fire involving spent fuel element

Spent fuel elements will be trucked singly between buildings 3026D, 7503, and 7930. Each element will be sealed in a welded steel drum contained in a shielded transport cask. An accident is postulated in which both containers are punctured; a gasoline fire of 30-min duration engulfs the containers, and released gaseous effluents rise with the fire plume to an effective height of 230 m and disperse into the atmosphere. It is assumed that the fuel element remains intact,²⁴ that no particulates are released, that the graphite block does not burn, and that the high-temperature volatiles are not driven off. The effect of the fire is essentially a bake-out of gases trapped within both the graphite and the broken fuel particles. The resultant increased annual doses as displayed in Table 4.8, case F, are small and are due primarily to release of radioiodine.

Rupture of solution cask in transport

Acidic nitrate solutions of ²³³U and Th will be trucked in casks between Buildings 3019 and 7930. The maximum quantity moved in any one cask will be 80 liters containing 16 kg of ²³³U. It is conceivable that a rupture could occur during a transport accident and result in spillage of the contents.

Two possible paths to the general environment are apparent, namely, surface water and the ground. The surface-water pathway would be more severe if the rupture should occur during a heavy rain or if the spill was directly into Whiteoak Creek or a drainage ditch leading to Whiteoak Creek or Melton Branch. In such an event, much of the solution would enter Whiteoak Lake in which it would be contained by closure of Whiteoak Dam.

Conservatively, assuming drainage of the entire 16 kg of ²³³U into Melton Branch and transport of the bolus down Whiteoak Creek into Whiteoak Lake during a two-hr period, dilution of the material in the 10¹¹-ml lake volume can be postulated, which would result in a peak concentration of 1.64 nCi/ml in the lake. Assuming no action is taken to prevent the ²³³U contaminated water from escaping into the Clinch River and assuming all of the ²³³U remains in solution, the maximum doses to an individual who drinks water and eats fish taken from the point of intersection of Whiteoak Creek and the Clinch River are 333 millirems to bone and 20 millirems to total body.

If the spill occurred onto dry ground, it would ultimately soak into the soil and spread via ground seepage. A study of the consequences of the potential seepage of radioactive acid solution has been made for the soil conditions found at ORNL.¹⁸ The study showed that the exchange properties of the underlying shale would permit the acidic solution to be neutralized about 30 ft from the point of spillage. Uranium, for example, would precipitate from solution and deposit in the ground. Further movement would be by weak ion exchange with groundwater and would move the bulk of the radioactivity from the spillage site at rates of 10 to 100 ft per year. A spillage of this magnitude would require removal of much of the soil around the affected area, but the results show that there would be ample time to accomplish such removal.

4.4.2 Nonradiological accidents

The major nonradiological accident hazards in the HETP would be associated with the use of various process chemicals. Quantities of chemicals designated for the 2-year program are given in Tables 2.1 and 2.2. Gases will be stored in individual cylinders, and most of the liquids will be stored in 55-gal drums or 100-gal tanks within the buildings. The quantities released in any one incident would therefore likely be only a small fraction of the totals listed.

Gases would be rapidly dispersed and diluted in the air; there might be some temporary concern for ORNL personnel, but the effects on the general population outside the complex are estimated to be insignificant.

The effects of spillage of the liquids would be mitigated by holdup and dilution in Whiteoak Lake; the spillage could be treated within the lake (i.e., acids could be neutralized, etc.) if necessary.

Solids will not be present in readily air-entrained forms; therefore, dispersal to the general population via the atmosphere is considered negligible. The possibility exists for dispersal by dissolution and subsequent spillage, in which case the above discussion for liquids would apply.

The likelihood of environmental effects on the general population as a consequence of nonradiological accidents is therefore considered negligible.

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5. UNAVOIDABLE ADVERSE ENVIRONMENTAL EFFECTS

5.1 RADIOLOGICAL EFFECTS

The HETP would increase the total individual body dose received offsite and attributable to ORNL operation by 15% (current ORNL operations contribute 0.94 millirem per year compared with the area background dose of 115 millirems per year). The project will therefore result in only a minimal increase in the total dose. Similarly, total body population doses (50-mile radius) will increase the contribution from all Oak Ridge facilities by about 5% (current DOE operations result in a population dose of about 30 man-rems). Radionuclide releases are similarly not expected to result in significant impacts to terrestrial ecosystems. Releases from the HETP to aquatic systems may result in concentrations of ^{90}Sr in Whiteoak Lake approaching 0.2% of the recommended limit. HETP wastes will be combined with other ORNL wastes, but concentrations of radionuclides in receiving waters are expected to be well below recommended limits. Radiological impacts are discussed in detail in Sect. 4.1.

5.2 NONRADIOLOGICAL EFFECTS

The HETP will require only a minimum of construction activity, not exceeding normal construction routinely occurring at ORNL. Therefore, no significant adverse effects are expected from such construction on land and water use or on aquatic and terrestrial ecosystems.

The only effluents to be released during the routine operation of the HETP are Ar, CO_2 , NO_x , NH_3 , (Table 2.4) and a few other gases in very small quantities. The amounts to be released are judged to be insignificant, and no adverse impacts should occur. No direct releases are to be made to surface or groundwaters; the small incremental releases from the HETP will result in no impacts on water use or on aquatic ecosystems from project operation.

6. IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

In general, those resources that might be irreversibly committed or rendered irretrievable by a project such as the HETP include: (1) biological species destroyed, (2) construction materials that cannot be recovered, (3) materials rendered radioactive which cannot be decontaminated, (4) materials consumed or converted to unrecoverable waste, (5) atmosphere and water bodies used for disposal of heat and waste effluents to the extent that other beneficial uses are curtailed, (6) land areas rendered unfit for other uses, and (7) manpower resources.

Because significant impacts are not expected from construction or routine operation of the project, the number of organisms destroyed will be minimal. Similarly, the atmosphere and water bodies will not be rendered unfit for other uses. Only a very small land area (<1 ha) will be consumed by new construction, and only a limited quantity of materials will be necessary for the construction activity. Some material will be rendered radioactive and will require disposal, but the overall goal of the project and the program of which it is a part is to recycle materials that would otherwise be wasted. The project's waste and the materials that are consumed during the process (Tables 2.1 and 2.2) are necessary to prevent the waste of potentially usable spent HTGR fuel. Construction work effort totaling 278 man-years will be allocated to the project (over a 5-year period), and operation of the facility will require up to 35 persons for 4 years. These manpower needs are small compared to the average active work force at ORNL.

No large quantities of strategic or rare resources are to be consumed or rendered useless by the project. Furthermore, building modifications, instrumentation, etc. will probably be useful to future projects conducted at ORNL and will therefore not become obsolete upon termination of the HETP.

7. RELATIONSHIP OF LAND-USE PLANS, POLICIES, AND CONTROLS

Prior to 1942 the principal land uses of the area were small-farm agriculture (pasturing cattle and hogs) and limited tobacco and vegetable growing. Between 1942 and 1950 the Federal government acquired about 23,600 ha (58,500 acres) in Anderson and Roane counties for three plants (X-10, K-25, and Y-12) and an employee housing community. In 1959 the city of Oak Ridge was incorporated. AEC retained control of approximately three-fourths of the original 23,600 ha, but allowed individuals to buy their homes and land and gave the city the municipal facilities, including utilities, streets, sewers, schools, and a hospital. Currently, about 15,000 ha (37,000 acres) remain under the control of the Department of Energy.

Ownership and control of this 15,000-ha reservation has been retained by the government to accommodate projects of interest to the government. No conflicts presently exist between DOE's current use of the land and local land-use plans and policies. There is no reason to expect future conflict with local land-use plans and policies. Clearly, the reservation is land that cannot be developed privately or used by the city of Oak Ridge without special arrangements. Since 1968 several requests for land have been made and granted: two sites near Y-12, sites X and M of 93 and 11 ha respectively; a 35-ha site known as the Industrial Park; and 65 ha located behind the Federal Office Building in Oak Ridge. In 1974, however, the city's request for 4000 ha (10,000 acres) of AEC land for an unspecified purpose was denied. There is a distinct possibility that DOE might have to retain virtually all its remaining land for future energy-facility development.

The project operations are fully confined to the area inside the reservation designated for use by ORNL. Thus the HET Project presents no conflicts with present land-use policies or plans. The land is already controlled by ORNL.

In 1976, the Division of Water Quality Control of the Tennessee Department of Public Health published the official State Water Quality Management Plan for the Clinch River Basin. The material quoted below is taken from this report.¹

The presence of various radionuclides in the Clinch River downstream of its tributaries, White Oak Creek and Poplar Creek, has been noted for many years and studied in detail. Monitoring has been recently undertaken of waters above and below the confluence with White Oak Creek by the Tennessee Division of Occupational and Radiological Health, and by the U.S. Energy Research and Development Administration in conjunction with the proposed location of a breeder reactor plant near mile 18. A summary of these data is shown in Table 16, with the State water quality standards for each parameter also listed.

The radiation standards of the State of Tennessee entitled "State Regulations for Protection Against Radiation" (SRPAR) and standards of the U.S. Nuclear Regulatory Commission (NRC) apply at the location where a waste stream enters an unrestricted area. In this particular instance it is the confluence of White Oak Creek with the Clinch River. Under normal circumstances, i.e., with the State or NRC regulating contamination to a stream by private industry, such effluents as those released by the Oak Ridge National Laboratory via White Oak Creek would be required to conform to State or NRC standards prior to any mixing with the Clinch River.

However, as the Oak Ridge National Laboratory is a prime contractor of the Federal Government, it claims to be exempt from State regulations in respect to radioactive releases. Therefore, all the Oak Ridge facilities, designated as prime contractors, are regulated by separate and less stringent regulations adopted by the U.S. Energy Research and Development Administration (ERDA). These regulations are identified as Chapter 0524, "Standards for Radiation Protection." These ERDA regulations permit discharges to state streams as long as "average concentrations of radioactive material at the point of release are as low as practicable."

Monitoring data released by ERDA thus far appear to indicate that State standards are not being violated by the Oak Ridge facilities in their releases to the Clinch River. However, ERDA data published for the White Oak Creek discharge point takes credit for the dilution of the O.R.N.L. waste with the average flow of the entire Clinch River. Thus, ERDA monitoring data for this point is not reported as direct measurements of effluents released but as calculated numbers which take into account the ratio of the flow rates of the two streams. Neither State nor NRC regulations permit such manipulation of radioactivity data.

In order for citizens of Tennessee to be afforded the same protection from ERDA-regulated facilities as they are from State- and NRC-regulated private industry, it is recommended that ERDA further cooperate with the state by limiting the radioactive releases from its facilities, and not take advantage of the lenient requirements of its own regulations.

Because it is extremely difficult to monitor the effluents directly as they leave the O.R.N.L. reservation via White Oak Creek due to periods of no flow and back flow conditions of the White Oak Creek embayment (these flow conditions exist at certain times due to river level fluctuations caused by manipulations at Watts Bar and Melton Hill dams), the State will need to have direct access to monitoring data collected by ERDA at White Oak dam.

From the above, the discharges from ORNL appear to conflict with the Tennessee Water Quality Standards. We do not know of any measurements in the Clinch River that exceed State standards for concentrations of radionuclides and do not see any real conflict. The HET effluents will contribute to the ORNL discharges but will be only a small part of the total.

REFERENCE FOR SECTION 7

1. Tennessee Department of Public Health Division of Water Quality Control, *Water Quality Management Plan for the Clinch River Basin*, Oct. 27, 1976, pp. V-8, V-9.

8. RELATIONSHIP BETWEEN SHORT-TERM USES AND LONG-TERM PRODUCTIVITY

Since the HETP will operate for only a 2-year period, it will result in a short-term use of the facilities. Because of the minimal amount of construction necessary for the project, there will be only a small amount of land and construction resources which will be unavailable for other uses. The project will use facilities that are now largely unused or underused, and renovations of these facilities to accommodate the project will be useful for later projects conducted at ORNL.

No significant alterations to the environment around the HETP site are expected; therefore, no loss in long-term productivity of these areas should occur.

No critical resources will be consumed or rendered useless by the project, which would limit the productivity of future operations employing those resources.

9. ALTERNATIVES

Plausible alternatives for the HETP include: (1) relocation of the project site, (2) postponement of the current project schedule, (3) no action (project cancellation), and (4) chemical flowsheet variations.

9.1 RELOCATION

The range of activities called for by the project involves product storage, waste treatment, fuel element segmenting, and separate refabrication and reprocessing capabilities. In addition, project operations require receipt of irradiated Fort St. Vrain (FSV) reactor fuel as feedstock to the reprocessing operation and fresh uranyl nitrate as feedstock to the refabrication operation. The ORNL site is thought to be capable of accommodating these requirements with a minimum of environmental impact. As proposed, the project would largely use existing facilities; with the exception of FSV fuel receipts, all operations could be performed on DOE's Oak Ridge reservation.

Relocation of the HETP to another site (including another national laboratory site) would likely necessitate a major construction activity for new facilities. Thus a new site location's failure to satisfy equivalent ORNL capabilities would result in an increased impact on the environment via increased construction activity.

9.2 RESCHEDULE PROJECT AND NO ACTION

The HETP supports the National Program Plan objective for HTGR Fuel Recycle. It is the intent of the project to (1) determine the effects of significant levels of radiation on specific operations and equipment in the reprocessing, refabrication, and primary waste treatment of the HTGR fuel recycle process and (2) relate this information to the design of a follow-on facility called for in the National Plan [identified as the HTGR Recycle Reference Facility (HRRF)]. Detailed design of the HRRF is scheduled for the years 1985 through 1991. Thus timely input of HETP results to HRRF design does not permit rescheduling or deletion of the project; these alternatives are therefore not viable options in the context of the overall National Program Plan.

9.3 CHEMICAL FLOWSHEET VARIATIONS

Alternatives to the proposed chemical processing involve variations in the refabrication and reprocessing procedures. The following process design changes were considered as alternatives.

9.3.1 Refabrication

The alternatives to the fuel refabrication flowsheet for the proposed pilot plant involve the processes of kernel or microsphere preparation and coating and fuel-rod fabrication and carbonization. Although alternative 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.

9.3.1.1 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.

9.3.1.2 Microsphere coating

The reference microsphere-coating process in the pilot plant calls for the application of a multilayer 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 (Sect. B.4).

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 would be eliminated from the source term.

9.3.1.3 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.

9.3.1.4 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 cm³ of alumina per rod carbonized. Because the alumina would be contaminated, it would be added to solid waste storage.

9.3.2 Reprocessing

A fluoride volatility process was considered as an alternative to the dissolution, solvent extraction, and solidification portions of the proposed process. The theoretical advantage of the fluoride volatility process is the initially smaller volume of waste generated. However, the volatility process is not technically feasible at this time because the nonvolatile thorium tetrafluoride results in low uranium recovery.

Alternatively, a number of variations of the reference process are possible; for instance, (1) the secondary burner could be eliminated to convert the headend system to a so-called crush-burn-grind-leach system; (2) an alternative cycle of solvent extraction could be used, which would reduce the amount of waste but would not recover thorium; (3) the denitration system could be eliminated and the uranium product shipped as a liquid; (4) the uranyl nitrate could be converted to the recycle fuel particle (microsphere) by the sol-gel process; or (5) various processes could be used in the off-gas cleanup system.

Eliminating the secondary burner would drastically reduce the uranium-recovery efficiency of the process, and the unburned carbon would add to the amount of solid radioactive waste from the process. Also, dissolution of carbide leads to foaming problems in the dissolver and emulsification problems in the solvent extraction system.

An alternative cycle of solvent extraction could be used, which would reduce the amount of waste but would not allow recovery of thorium. This would not be a demonstration of the proposed commercial reprocessing system, because the economics for plants favor the recovery of thorium as well as uranium.

The uranyl nitrate product solution from the solvent extraction system could be converted to a solid and then transferred to the national uranium-233 repository at Oak Ridge National Laboratory. The reference process (shipping liquid) would be economically superior because the denitration process could be eliminated. The reference process is based on liquid shipment.

Various processes could be used for the off-gas cleanup system; no processing will be necessary to keep the off-gas within recommended guidelines for an uncontrolled area. Alternative processes to the proposed krypton absorption in liquid carbon dioxide (KALC) process for removing krypton — such as membrane permeation, sorption in charcoal or molecular sieves, and physical absorption by a third component — are precluded by the similarity of carbon dioxide behavior to that of krypton in these alternative processes. Alternative processes for iodine removal could be the KALC process, the zeolite bed process, and the mercuric nitrate process. The mercuric nitrate process was not selected because of the inherent environmental problem of mercury consumption and disposal.

Experimental testing will be done to determine the feasibility of iodine removal by the KALC and zeolite bed processes and to compare these processes with the Iodex process.

An alternative to molecular sieves for tritiated water removal could be the KALC process. Experimental investigations will be made to determine the technical feasibility of removing tritiated water by liquid carbon dioxide and to compare this process with the reference process.

In conclusion, the alternative process systems were not chosen for the following major reasons: (1) several components represent technology that is less proven than that currently proposed and (2) some components would result in greater environmental impacts.

10. ENVIRONMENTAL TRADE-OFF ANALYSIS

10.1 SUMMARY OF PURPOSE AND PRINCIPAL IMPACTS OF HETP

Section 2 of this Environmental Statement has described the proposal to modify and equip four existing buildings at Oak Ridge National Laboratory for demonstrating the feasibility of commercial-scale recycling of High Temperature Gas-Cooled Reactor (HTGR) fuel materials. The proposed program, Hot Engineering Test Project (HETP), will involve the reprocessing of spent HTGR fuel rods from the Fort St. Vrain reactor and the fabrication of fuel rods from uranyl nitrate solution obtained from NUR and makeup thorium. Section 2 also contains a description of the relatively small amount of materials consumed in the process (Tables 2.1 and 2.2) as well as the effluents released to the environment during the proposed two years of operation (Sect. 2.3.2). It is ORNL's practice to combine nonradioactive wastes (except sanitary) with radioactive wastes and process them together through ORNL's radioactive waste-handling facilities.

Section 3 describes the site location and characterizes the existing environment around the proposed site. This environmental description provides the baseline upon which environmental impacts of the proposed action are evaluated.

Section 4 analyzes the environmental impacts of the proposed action. Because the proposal consists of modification and use of existing buildings at ORNL, the staff has concluded that there is very little impact of construction on land or water use or on terrestrial and aquatic ecosystems (Sect. 4.2). In addition, the project's construction work force (maximum of 88) is expected to be only a portion of the construction manpower that is employed on the DOE reservation most of the time.

With respect to operation, the major nonradiological effluents from HETP which will be released after treatment in the ORNL waste-handling facilities will be CO_2 , NO_x , and NH_3 . Compared with the normal output or consumption from the forest on the reservation, the incremental effluent release attributable to HETP operations is insignificant (Sect. 4.2.1).

The principal impact of HETP operation will be the addition of radioactive material to the environment. Table 10.1 is a summary of the staff analysis for the radiological impact on man (Sect. 4.1.1) resulting from gaseous releases due to the proposed action for both the maximally exposed individual and the total population within a 50-mile radius of the site. The calculated exposures are also displayed as percentages of the estimated exposures as a result of all ORNL operations. The impacts of radioactive gaseous effluents due to HETP operation are shown to be generally less than the impacts of other ORNL operations. If total-body dose is considered as the measure of impact, HETP operations contribute only a small increase to the man-made dose commitment to man in the Oak Ridge area. The ORNL airborne effluent with HETP would result in a dose commitment to the maximally exposed individual of only about 0.2% of the statutory limit and only about 1% of the natural background exposure (Sect. 4.1.1.6).

Table 10.1. Radioinical impact on man resulting from one year of HETP operational gaseous effluent

| | Total body | GI tract | Bone | Thyroid | Lungs | Muscle | Kidneys |
|--|------------|----------|------|---------|-------|--------|---------|
| Maximum individual 50-year dose commitment | | | | | | | |
| Milirems | 0.14 | 0.57 | 1.10 | 0.12 | 0.11 | 0.14 | 0.11 |
| Percent of current ORNL activity | 15 | 65 | 110 | 0.6 | 12 | | 12 |
| Population 50-year dose commitment | | | | | | | |
| Man-remms | 1.6 | 3.7 | 7.0 | 1.1 | 1.1 | 1.6 | 1.1 |
| Percent of current DOE activity | 5 | 5 | 14 | 0.4 | 2 | | 3 |

Assuming that the sensitivity to radioactivity of organisms other than man is less than for man himself, the staff concluded that other biota will not be adversely affected by HETP-related gaseous effluents.

Liquid radioactive effluents related to the HETP in combination with other ORNL activities will increase the concentrations of certain radionuclides at Whiteoak Dam. Thus, continued monitoring of the releases from the Whiteoak Creek reservoir is required to avoid excessive release of radionuclides to the uncontrolled areas downstream of the dam. The monitoring results can also indicate whether or not specific HETP waste pretreatment should be undertaken before release to the ORNL waste-handling facilities. Both the analyses in this statement and the recommended limits are conservative, and radionuclide concentrations downstream of Whiteoak Dam are expected to be much less than the magnitude believed to have an effect on either man or other biota.

In summary, the staff finds that construction activities and operation of the proposed HETP results in an acceptable level of impacts on man and the natural environment.

Although finding the environmental impact of the proposed action to be acceptable, the staff did consider alternatives that would result in reduced or different impacts. These alternatives included project cancellation or postponement, site relocation, and process variations.

The HETP is an intermediate step in an existing National Program Plan for HTGR Fuel Recycle. The project is designed to obtain data on reprocessing and refabrication operations and equipment in a radiation environment. The resulting data will be used in the design of the HTGR Recycle Reference Facility (HRRF), which is scheduled for the late 1980s. Cost-effective, safe, environmentally sound, and timely design of the HRRF depends upon an improved information base. Therefore, rescheduling or cancellation of the HETP is not considered a viable alternative.

Conduct of the HETP at ORNL utilizes currently underused or unused buildings, personnel experienced in radioactive chemical operations, and support of an integrated research and development laboratory. Site relocation poses the problem of failure of another site to be equivalent to ORNL in terms of availability of buildings, equipment, and personnel and could result in increased environmental impacts.

A number of process variables in both the reprocessing and refabrication portions of the HETP were identified and assessed (Sect. 9.3). However, the staff found that these process alternatives were generally not as acceptable as the basic proposal for one or more of the following

reasons: (1) less proven technology, (2) potentially increased environmental impacts, (3) potentially increased financial cost, (4) reduced recovery of uranium and thorium, defeating the purpose of the National Fuel Recycle Program, and (5) no obvious environmental or economic advantage for an alternative over the reference design.

10.2 STAFF CONCLUSION

The staff has found that the proposed HETP generally results in an acceptable level of environmental impacts on man and the natural environment. In the case of increased radioisotope concentration at Whitecreek Dam, monitoring combined with additional waste treatment, when needed, within the HETP facilities can minimize this concern. In its assessment, the staff could not identify technologically available alternatives to reduce significantly and economically the already low level of impact of HETP.

HETP results to be obtained by 1989 (Fig. 2.1) are critical to the late 1980s design of the HTGR Reference Recycle Facility, and the environmental impacts are acceptably low. The staff therefore concludes that the HETP should be approved as proposed.

Appendix A
DESCRIPTION OF SPENT-FUEL REPROCESSING

Appendix A

DESCRIPTION OF SPENT-FUEL REPROCESSING

Spent fuel elements are reprocessed to reclaim and purify uranium and thorium. The various systems necessary to achieve the overall reprocessing objective (System 1000) are shown in Fig. A.1. The major steps used to process fuel elements in the reprocessing phase are listed below.

1. The fuel block is sawed into smaller segments, and each segment is crushed into particles of a specified size range.
2. The graphite matrix is burned to expose the silicon carbide (SiC) coating surrounding the fuel kernels.
3. The burned back fuel particles are then separated into fissile and fertile fractions which are subsequently processed separately.
4. The fissile and fertile fractions undergo particle crushing to fracture the SiC hulls, and the inner carbon coatings are burned away in the secondary burner.
5. The remaining materials are acid-leached in the dissolution steps to remove uranium or thorium.
6. The solutions are adjusted to specifications for solvent extraction, and uranium, thorium, and fission products are selectively removed.
7. The solvent extraction product solutions are concentrated; the uranium solutions are stored and the thorium solutions are either stored or discarded to the intermediate-level waste system.

Various support systems are associated with the above steps. The reprocessing systems described below are located in Building 7930 unless otherwise indicated.

A.1 SEGMENTING — SUBSYSTEM 4106

Both unirradiated and irradiated fuel elements from the Fort St. Vrain (FSV) reactor will be sawed remotely (Building 3026D) into six pieces, each approximately 8 in. (~20 cm) in diameter by 31 in. (~80 cm) long, so that they can be charged into the primary jaw crusher for size reduction. A containment shroud, with a circulating carbon dioxide loop and dust treatment system, will enclose the segmenting equipment to collect dust particles and gases produced by the segmenting operation. The cell containing the segmenting equipment will be maintained under negative pressure.

Small-volume high-capacity intake nozzles (~300 cfm or ~8.5 m³/min), arranged to follow the saw together with fixed and movable shrouds, will contain the bulk of the graphite dust as it is generated. The intake gas stream (CO₂) will be passed through a cyclone separator and a sintered metal filter. The filtered stream containing 5- μ m and smaller particles will be passed through NBS and HEPA filters and a charcoal adsorber to collect the small amount of gaseous fission

products present. An additional HEPA filter will be used for final purification before recirculating the CO₂ back to the segmenting shroud.

Cell ventilation air (~1200 cfm or ~34 m³/min) will be exhausted through existing HEPA filters, charcoal filters, and then through more HEPA filters to the 3039 stack.

In the unlikely event that the cutting process is done improperly and some fuel-bearing particles are cut, a conservatively high estimate of the activity released in one complete pass of a saw blade is 100 Ci. This is based on a fuel element discharged after one equivalent full-power year,¹ cooled 180 days, and containing 66,000 Ci of activity. Again, this activity is released to the off-gas treatment system and would be detected immediately (and operations halted) unless simultaneous instrumentation failure occurred. Even if the full 100 Ci is released, it would be contained by the off-gas treatment system.

A.2 FUEL SIZE REDUCTION -- SYSTEM 1100

Segmented fuel elements from the segmenting operation are fed into a crusher where they are crushed into a granular form suitable for primary burning. The solid product is <3/16 in. (~5 mm) ring-size material. To accomplish this task, the three subsystems shown in Fig. A.2 are necessary.

Segmented fuel elements first undergo jaw crushing to obtain ≤3/4-in. (~2-cm) ring-size particles. All particles >3/4 in. are separated and recycled for further crushing by a vibratory screen and a vibrating spiral elevator. Particles ≤3/4 in. are then roll-crushed to the final size of <3/16 in.

All operations are performed in an enclosed, air-tight dust shroud. A 1-cfm (~28-liter/min) flow of CO₂ purge gas provides both an inert atmosphere and a means of controlling dust generated during crushing operations. The purge gas is filtered through a bank of rough and HEPA filters before being released to the burner off-gas system (Sect. A.9.1).

A.3 PRIMARY BURNING -- SYSTEM 1200

Batches of crushed fuel elements are burned in a fluidized bed to oxidize exposed graphite and carbon coatings on fuel particle surfaces. The subsystems used in the primary burning operation are shown in Fig. A.3. The fluidizing gas is a mixture of O₂ and CO₂. The oxidation, in combination with a secondary O₂ stream, occurs above the bed where carbon fines elutriated from the burner are suspended. The solid product consists of burned-back fissile and fertile particles and ash containing <1 wt% carbon. All off-gas is vented to the burner off-gas treatment system (Sect. A.9.1).

A.4 PARTICLE CLASSIFICATION -- SYSTEM 1300

Particle classification is a central operational system with varied functional responsibilities that interfaces with other reprocessing operations as follows: (1) receives, weighs, and stores batches of crushed fuel elements (Sect. A.2) in storage hoppers; (2) transfers crushed fuel to the primary burner operation (Sect. A.3); (3) receives burned-back fissile and fertile particles from primary burning; (4) classifies fissile and fertile particles into two separate

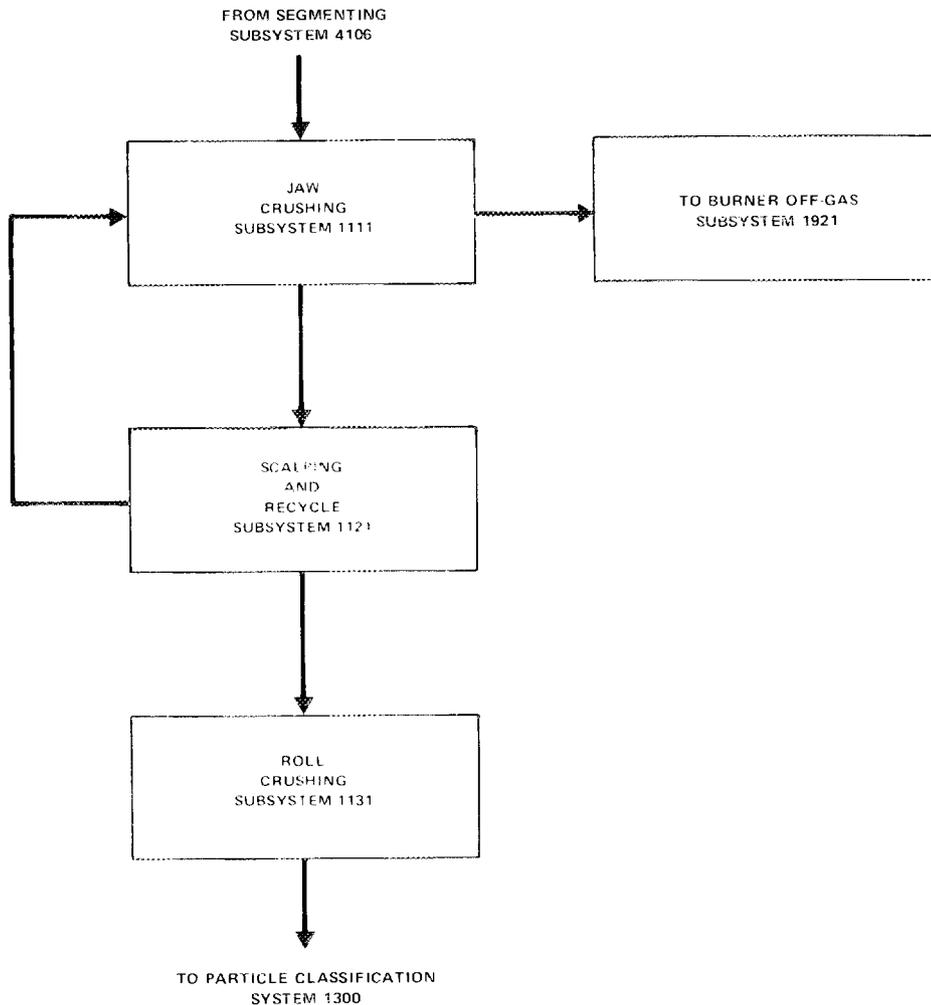


Fig. A.2. Fuel size reduction -- System 1100.

streams; (5) collects classified fertile and fissile particles in receiving hoppers. Some graphite and ash fines are collected and stored for discharge to solid waste and scrap disposal. The process block diagram is shown in Fig. A.4.

A.5 PARTICLE CRUSHING AND SECONDARY BURNING -- SYSTEM 1400

Batches of classified particles, both fissile and fertile, are crushed for a second time to crack the SiC coating of the once-burned fuel kernels and expose any inner carbonaceous material. Once crushed, the particles are fed directly to the second fluidized-bed burner. A block diagram showing subsystem relationships is shown in Fig. A.5.

Fuel-particle crushing is accomplished by either of two double-roll crushers: one for crushing fertile material and one for crushing fissile material. The roll gap must be precisely sized

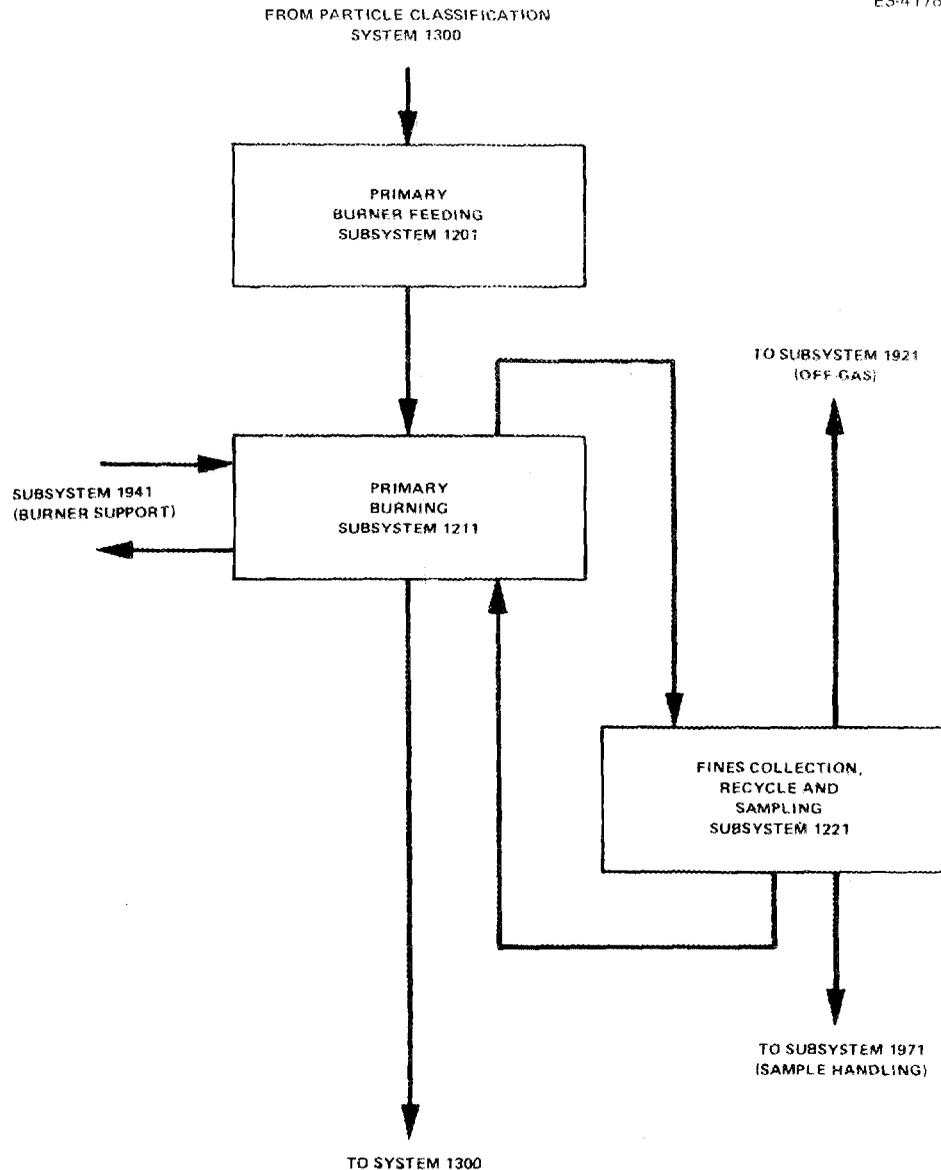


Fig. A.3. Primary burning - System 1200.

for each type of particle to prevent a large percentage of unbroken particles or overcrushing, resulting in a large quantity of fines and consequent poor fluidization characteristics in the fluidized-bed burner. Each roll crusher is completely enclosed, which allows for ventilation. The crushing operation is accomplished in a CO_2 atmosphere.

Crushed fuel kernels are gravity-fed to the burner from the particle crusher; all carbonaceous material is burned away while simultaneously converting heavy metals and fission products to the oxide form. Upon introduction into the burner, the crushed fuel particles are fluidized in a CO_2 stream to the height of the induction heater (located in the lower part of the burner). The temperature is raised by induction heating until the 600°C ignition temperature is reached. Oxygen is then added to the fluidizing gas to obtain a steady-state burn rate at approximately 900°C . The oxygen supply is controlled throughout the burning operation to maintain a low O_2

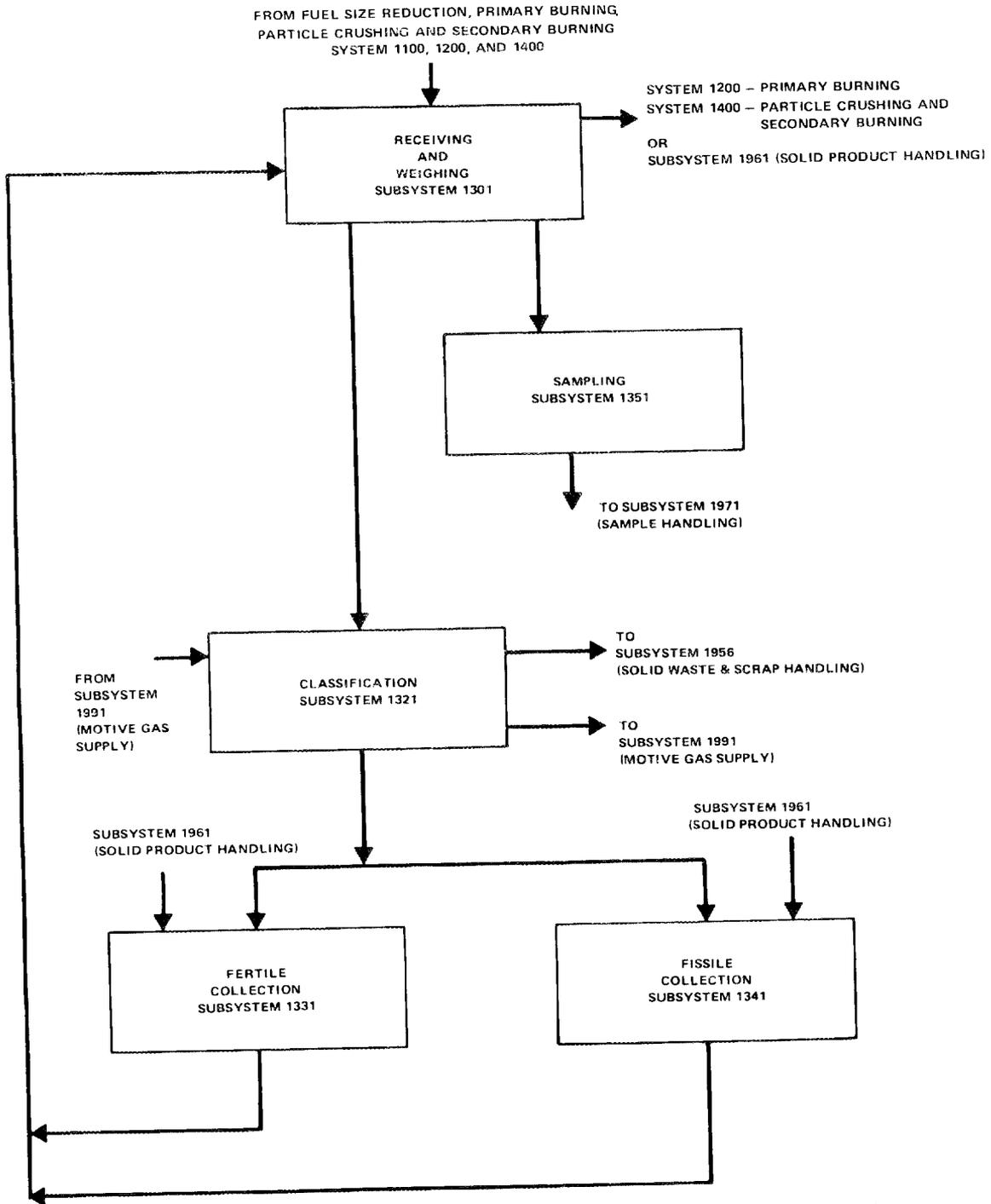


Fig. A.4. Particle classification and material handling – System 1300.

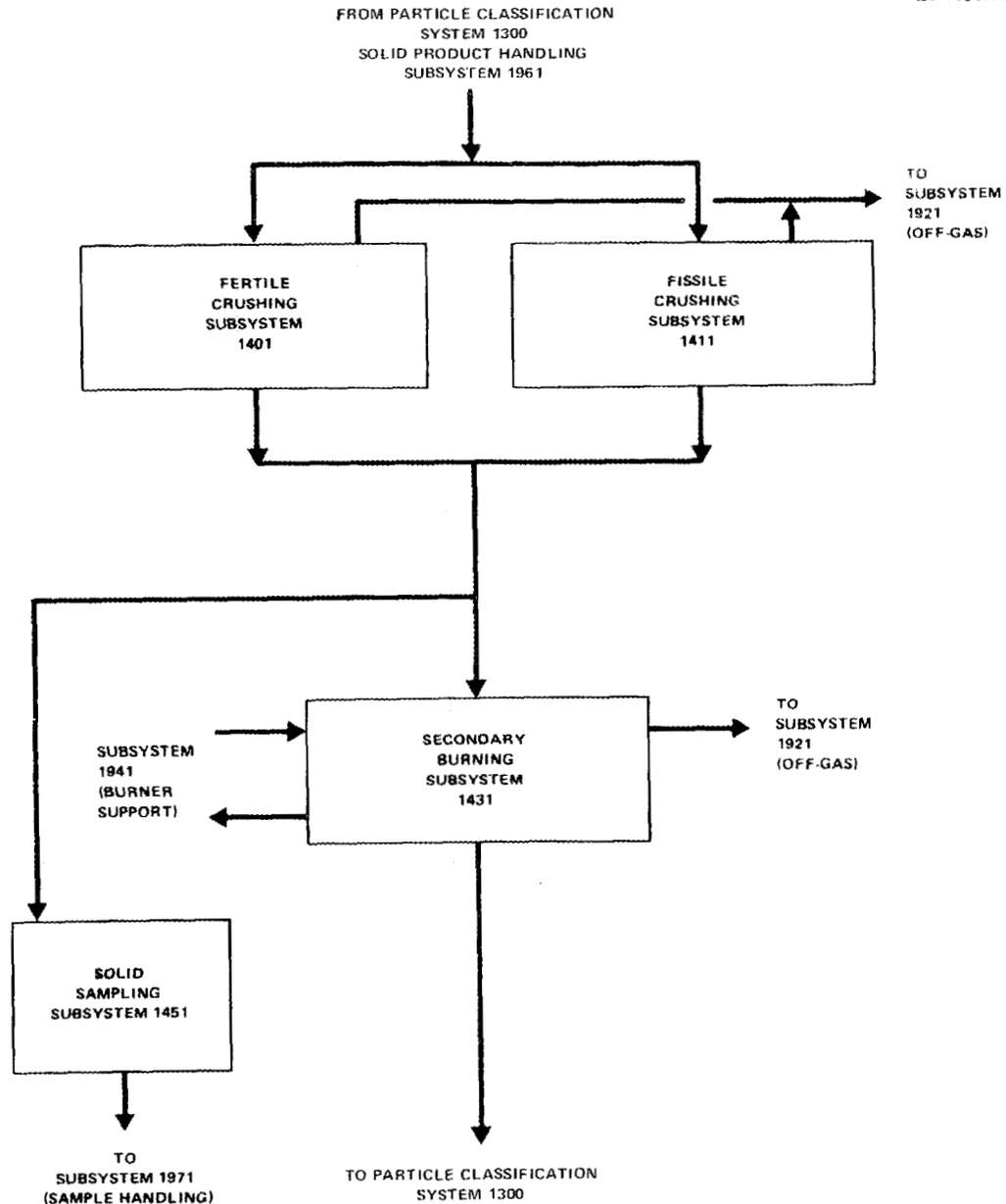


Fig. A.5. Particle crushing and secondary burning -- System 1400.

concentration in the off-gas. Oxidation is continued until a low carbon content is achieved, which is signaled by an oxygen breakthrough in the off-gas. Further carbon oxidation and fission-product volatilization from the bed is performed with induction heating. Off-gas is vented to the burner off-gas treatment system (Sect. A.9.1), after which the product burner ash is ready for the next phase of reprocessing.

A.6 DISSOLUTION AND FEED ADJUSTMENT -- SYSTEM 1500

A block diagram for the dissolution and feed adjustment steps is shown in Fig. A.6.

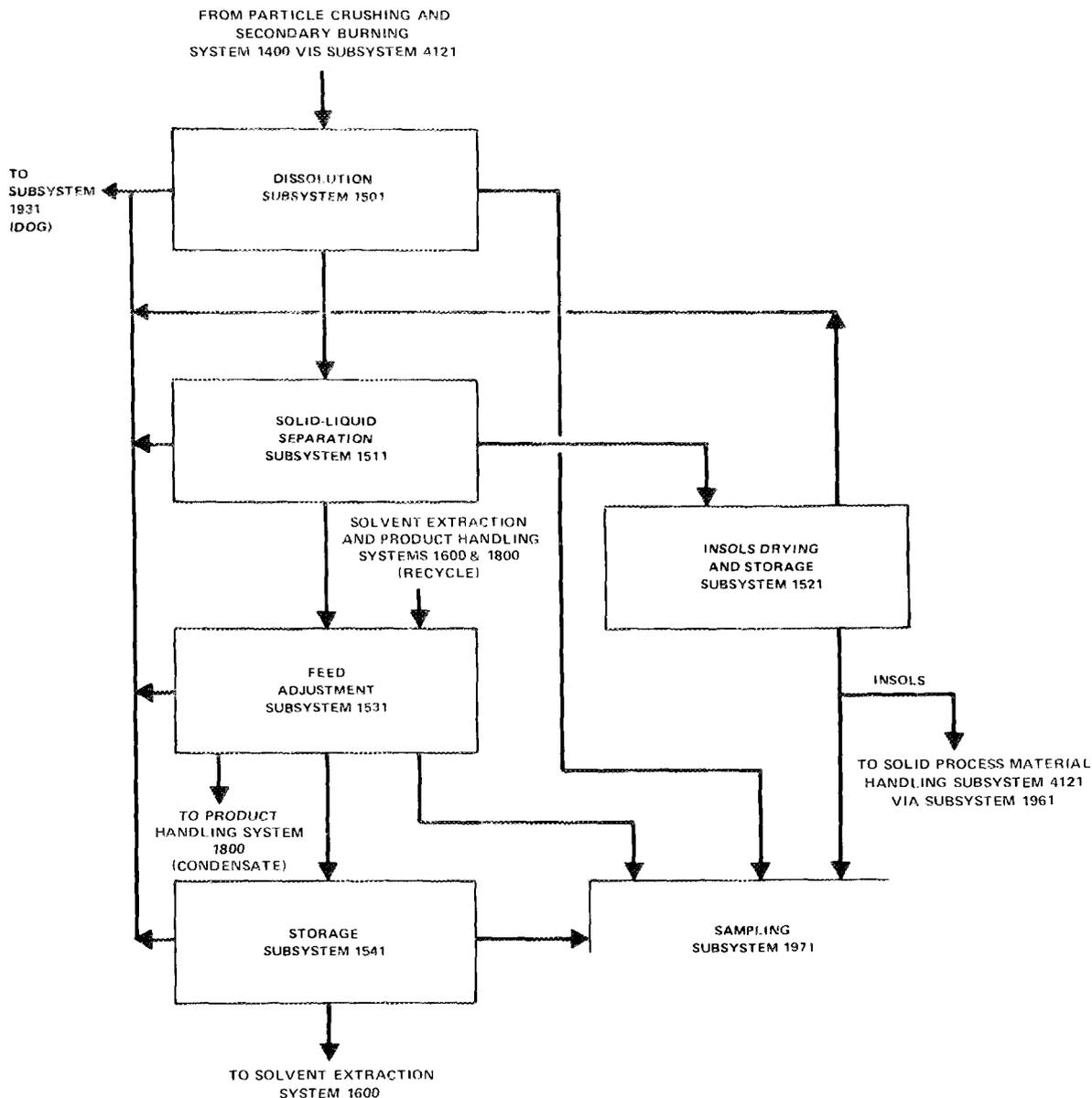


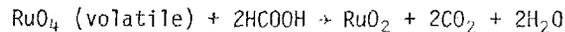
Fig. A.6. Dissolution and feed adjustment — System 1500.

Following the secondary burning, the product ash is treated with a nitric acid solution (fissile and fertile particle product ash are processed separately in the same equipment) to dissolve heavy metals and fission products from the insoluble SiC hulls. Nitric acid, hydrofluoric acid, and aluminum nitrate are proportionally added to obtain the dissolver acid composition for thorium-bearing fuel ash of 13 M HNO₃, 0.05 M F⁻, and 0.10 M Al³⁺, along with a soluble neutron poison, cadmium (0.8 g/liter for fissile, 3.6 g/liter for fertile), to ensure nuclear criticality safety. Enough acid is added to the dissolver to yield a 1 M thorium solution upon complete dissolution. For particles bearing uranium only, the acid volume is based on a final concentration of 0.06 M uranium, and the dissolver acid composition is 4.6 M HNO₃ plus a soluble neutron poison, cadmium or gadolinium. Dissolution occurs at the solution boiling point with the

condensable vapors being returned to the dissolver. Noncondensed gases are vented to the dissolver off-gas treatment system (Sect. A.9.1).

Upon completion of dissolution, the solution is cooled and fed to a continuous centrifuge along with the insoluble material (SiC hulls, residual graphite, and some fission products). The clarified dissolver solution is then collected and sent to the feed adjustment subsystem; the insoluble material is collected for washing, drying, and storage, preliminary to final disposal. The wash solution is combined with the dissolver solution, and the dryer off-gas is treated by the dissolver off-gas system.

The feed adjustment subsystem receives the fertile and fissile solutions from the centrifuge and prepares them for solvent extraction. The thorium-bearing dissolver solution is processed through feed adjustment to reduce the nitric acid concentration to 1 M and to increase the concentration to 1.5 M Th⁴⁺ (ag). The dissolver solution is concentrated batchwise by evaporation to a molten salt and then sparged with steam to vaporize the excess nitric acid. The capability for addition of formic acid is provided for the control of ruthenium volatility.



Vapors are condensed and collected for intermediate-level waste disposal. When sufficient nitric acid has been removed, the solution is diluted with distilled water to 1.5 M Th⁴⁺ (ag), and then sampled for composition determination.

Fuel containing only uranium does not require removal of excess nitric acid. The feed adjustment unit is used only to effect any necessary uranium concentration changes.

A.7 SOLVENT EXTRACTION — SYSTEM 1600

The solvent extraction system is designed to process, in separate campaigns, both thorium-bearing fuel and fuel containing uranium only. For thorium-bearing fuels, the acid Thorex process is used to recover, partially purify, and separate thorium and uranium from fission products and chemical impurities as well as to separate uranium and thorium from each other. For uranium fuels, the modified Purex process is used to separate uranium from fission products and chemical impurities. In the modified Purex process, a dilute feed is required, and the plutonium is not recovered. The quantity of plutonium (<10 g Pu/fuel element or <0.1 wt % of heavy metal content in a fuel element) not removed during extraction is left unremoved as part of the general waste, and is sent to the intermediate-level waste (ILW) system. Both processes use the same solvent, salting agent, and equipment, but the stream compositions and flow rates differ.

The five major subsystems of solvent extraction are: extraction, partition, scrub, stripping, and solvent regeneration. The subsystem relationship can be seen in Fig. A.7.

In the extraction column, uranium and thorium ions are preferentially extracted from the aqueous stream as it countercurrently contacts the nonaqueous solvent stream (30 vol % tributylphosphate in a normal paraffin hydrocarbon diluent). The bulk of the fission products and chemical impurities remain in the aqueous phase. A 13 M HNO₃ stream is metered into the lower portion of the extraction column to provide the salting strength needed for extracting uranium and thorium ions from the acidified aqueous solution into the nonaqueous phase. A 1 M HNO₃ stream

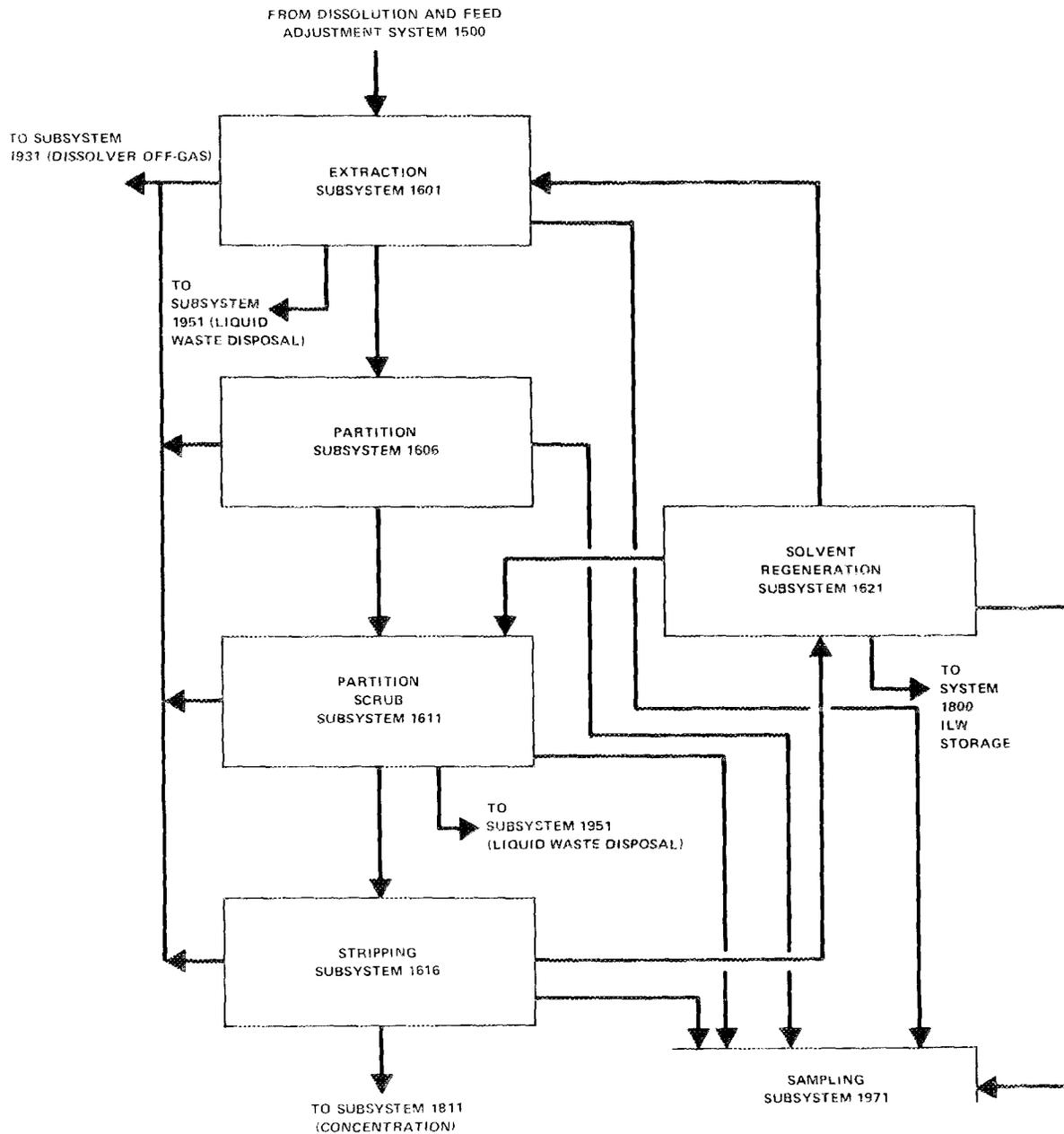


Fig. A.7. Solvent extraction - System 1600.

is metered into the top of the extraction column to scrub back into the aqueous phase the small fraction of the fission products that were extracted into the solvent in the lower portion of the column. The waste stream containing the fission products is then transferred for disposal to the ILW system (Sect. 2.3.2.2).

The uranium- and thorium-bearing solvent stream leaves the extraction column and enters the bottom of the partition column. Into the top of the partition column is metered $0.2 \text{ M HNO}_3 - 5 \times 10^{-3} \text{ M F}^-$ solution, which flows countercurrent to the organic solvent and preferentially strips all of the thorium and a small amount of the uranium from the solvent. It leaves the

bottom of the partition column and enters the top of the partition scrub column and is counter-currently contacted with clean solvent, which extracts the small amount of uranium (0.4 g/liter) stripped from the solvent in the partition column. This stream then exits the top of the partition scrub column and is introduced again to the bottom of the partition column in combination with the feed stream. The aqueous stream from the partition scrub column contains nearly all of the thorium and only a trace of uranium and is normally sent to the ILW system for disposal (Sect. 2.3.2.2).

The uranium-bearing solvent exits the top of the partition column and enters the bottom of the strip column where it countercurrently meets a $0.01 \text{ M HNO}_3 - 1 \times 10^{-3} \text{ M F}^-$ stream, which strips the uranium from the solvent. The uranium-bearing aqueous stream flows out of the bottom of the strip column and is circulated to the product concentrator for the next reprocessing step. The stripped solvent then leaves the strip column and enters the bottom of the solvent regeneration column and countercurrently contacts a $0.25 \text{ M Na}_2\text{CO}_3$ solution, which scrubs out solvent decomposition products (primarily dibutyl phosphate). The regenerated solvent is then recirculated to be used again throughout the solvent extraction process.

A.8 PRODUCT HANDLING -- SYSTEM 1800

The final step in the reprocessing phase of the HET is product concentration. The subsystem relationship is shown in Fig. A.8. The concentrator is a thermosiphon evaporator, with the condensate being sent to ILW for disposal (Sect. A.9.2). Thorium nitrate solution from solvent extraction is generally sent to ILW, but on occasion will be concentrated and blended with uranium to give a solution composition of 1.3 M heavy metal and 3 M HNO_3 . The final product is stored (Subsystem-1881) as uranyl nitrate or thorium nitrate solution.

A.9 REPROCESSING SUPPORT -- SYSTEM 1900

Waste treatment subsystems for gases, liquids, and solids are included in process support (System 1900) as shown in Fig. A.9.

A.9.1 Off-gas treatment

Burner off-gas (Subsystem-1921) and dissolver off-gas (Subsystem-1931) are treated separately. Off-gas from the fluidized-bed burners and from the dissolver comprises most of the volume of gas requiring treatment. Off-gas from vessels is treated with the dissolver off-gas.

The dissolver (and vessel) off-gas (DOG) train will treat the vented gases from aqueous process vessels in the dissolution, the solvent extraction, and the product concentration processes. The vented gases are passed through a de-mister to remove moisture and then a preheater before passing through an NO_x converter, which reduces the oxides of nitrogen to nitrogen with ammonia. Iodine will be adsorbed on silver zeolite and the radon held on a molecular sieve until decayed. The remaining gases will be vented through HEPA filters to Building 7930 hot off-gas system (Sect. 2.3.2.1).

The burner off-gas (BOG) train will treat the off-gas from the primary and secondary burners separately for the retention of the volatile fission products and of radioactive iodine and for the conversion of CO and tritium to CO_2 and water respectively. A common system will collect,

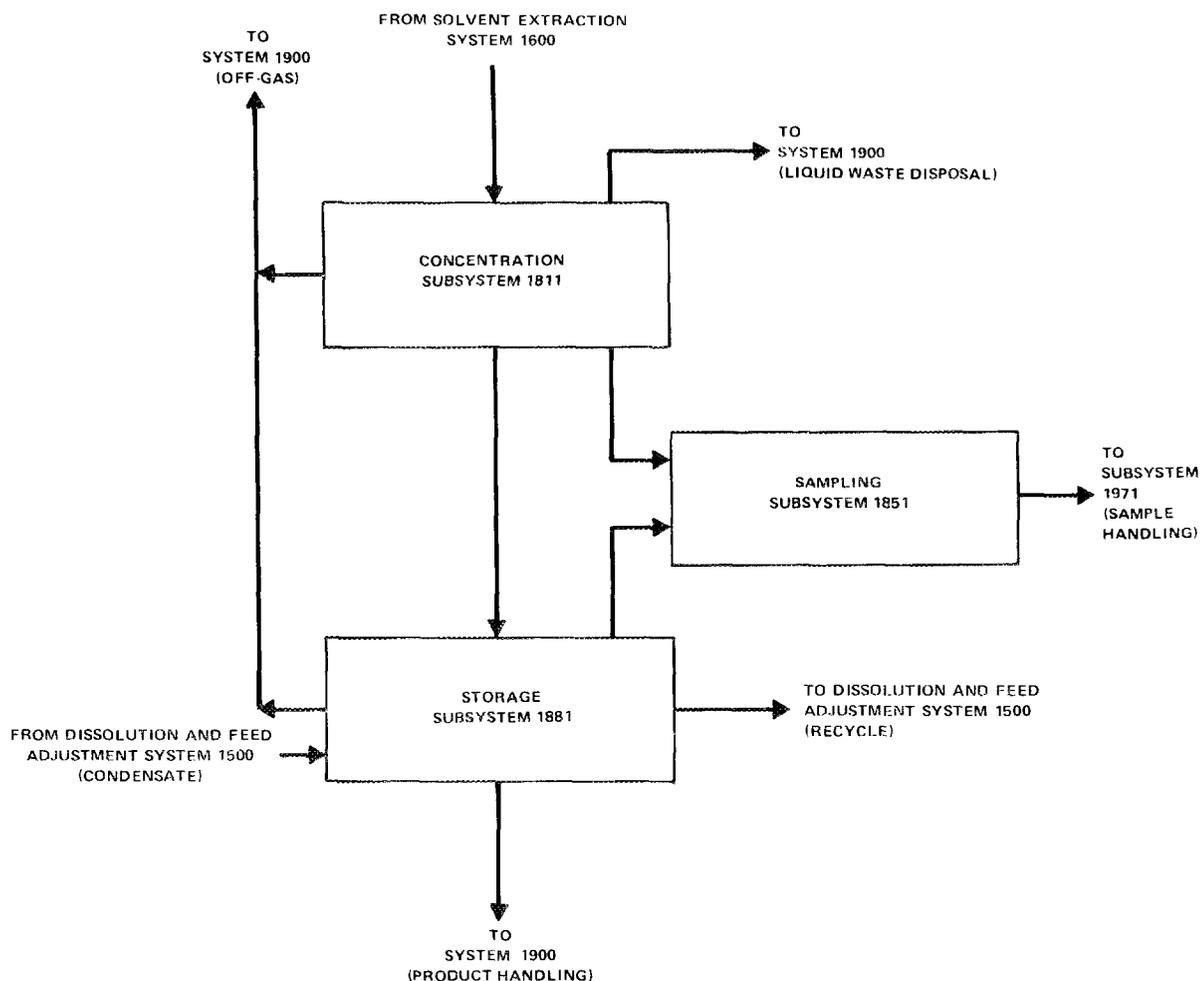


Fig. A.8. Product handling – System 1800.

in cartridges, tritiated water absorbed on molecular sieve and provide for radon adsorption and final HEPA filtration before the gas is discharged to the Building 7930 hot off-gas system (Sect. 2.3.2.1).

A.9.2 Liquid waste disposal – Subsystem 1951

Liquid wastes from reprocessing operations are as follows: steam condensate from vessel jackets and the product concentrator reboiler, intermediate-level waste from dissolution, solvent extraction, and product concentration, organic wastes from solvent extraction, and other process wastes. Liquid organic wastes are weighed, assayed, and absorbed on vermiculite which is encapsulated in concrete or plastic and placed in 30-gal containers. These 30-gal containers are sealed in 55-gal drums which are decontaminated and sent to the solid waste storage area (Sect. 2.3.2.3). Other process wastes are treated, if necessary, by the support facility (Sect. C.8) before being discharged to either the ILW or low-level process waste treatment facilities (Sect. 2.3.2.2).

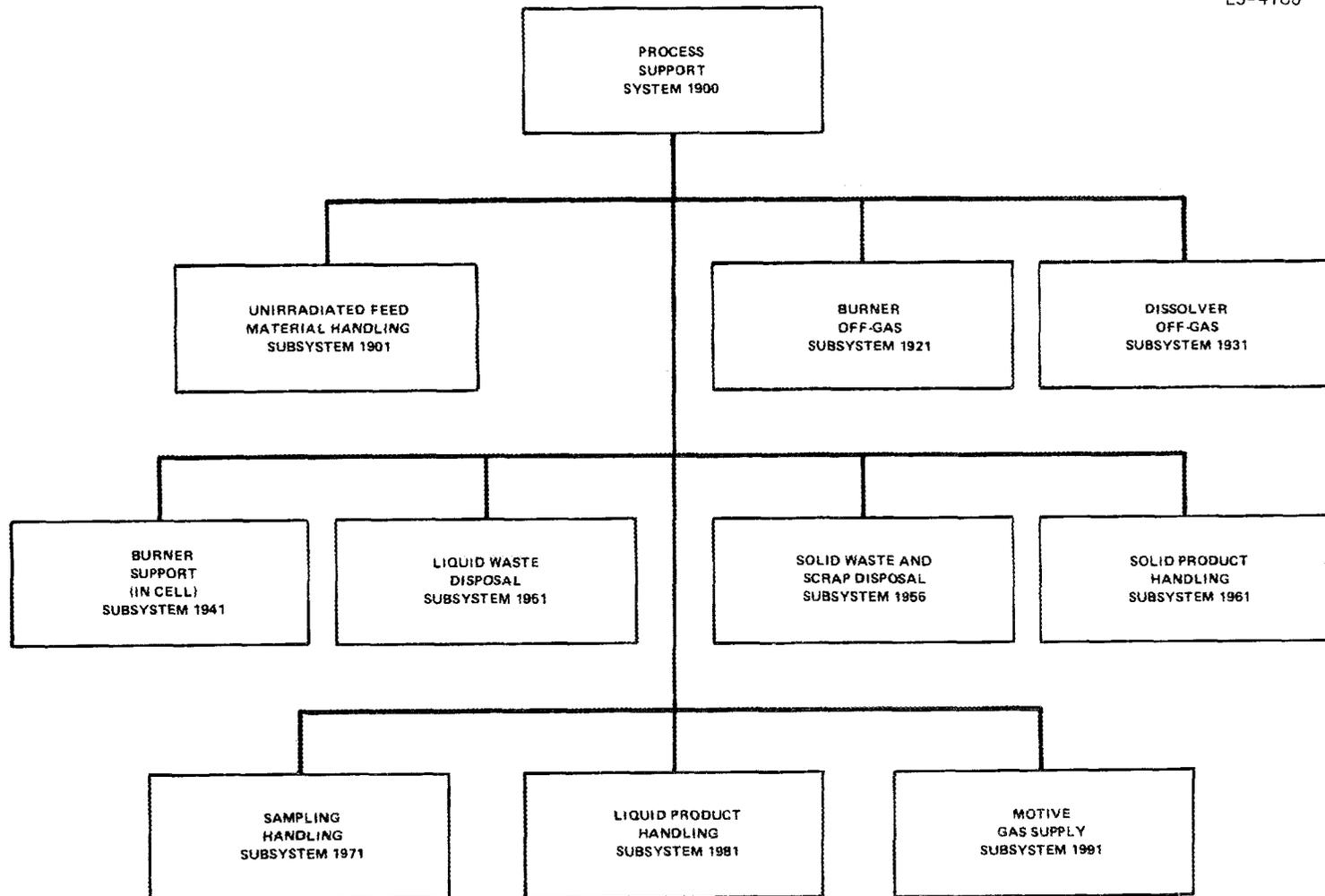


Fig. A.9. Process support - System 1900.

A.9.3 Solid waste disposal – Subsystem 1956

Solid wastes consisting of failed process equipment, spent filters, etc. are bagged and buried in trenches in the SWSA (Sect. 2.3.2.3). The organic liquids absorbed on vermiculite (Sect. A.9.2), tritiated water cartridges (Sect. A.9.1), and particle hulls from the dissolver insols dryer are placed in 30-gal or 55-gal drums and also buried in the SWSA.

Appendix B
DESCRIPTION OF FUEL-ROD REFABRICATION

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The refabrication section of the HET manufactures fresh fuel rods from fresh thorium and uranium obtained from the National Uranium-233 Repository. This is accomplished through seven major systems as noted in Fig. B.1.

Initially, the uranium feed system prepares uranyl nitrate to proper specifications for delivery to the resin fuel kernel preparation system, wherein uranium is transferred to resin beads via ion exchange. The loaded resin then undergoes carbonization in the resin carbonization system; the carbonized resin is then transferred to the microsphere conversion and coating system for conversion of the carbonized spheres from the UO_2 form to the UC_2 form and for application of four separate coatings involving various forms of carbon. These coated particles are then sent to the fuel-rod fabrication system for fresh fuel-rod formation. Complementing these systems are the process support system and the sample inspection system. The refabrication systems, described below, are located in Building 7930 unless otherwise indicated.

B.1 URANIUM FEED — SYSTEM 4400

The uranium feed system is a radiochemical processing facility located in Building 3019, which is designed to provide purified ^{233}U uranyl nitrate feed solution. The system is composed of four subsystems, as shown in Fig. B.2. All processing (solvent extraction and ion exchange) is accomplished in Subsystem 4421; the other subsystems involve only material transfer and storage.

The purification subsystem receives UO_3 powder and/or uranyl nitrate solution from the National Uranium-233 Repository. The UO_3 is dissolved in hot nitric acid and adjusted to yield a solution of ≤ 250 g/liter of uranium. Uranyl nitrate solutions are transferred to solvent extraction and/or ion exchange for purification or storage.

Once the feed solution has been adjusted to solvent extraction specifications (≤ 10 g/liter of U), it enters the heart of the solvent extraction subsystem, which consists of three pulse columns. In the first column, uranyl ions are selectively extracted by 5% di-sec-butyl-phenylphosphonate (DSBPP) in technical grade diethylbenzene (DEB). Extraction is accomplished by countercurrent contact of the aqueous feed stream and the immiscible solvent in the perforated-plate, air-pulsed column. Further purification is achieved in the scrub column, where the organic extract above is contacted with aqueous aluminum nitrate solution to scrub thorium and other impurities from the extract. In the third column, the uranium is stripped from the organic to the aqueous phase. The stripped product is passed through a static column of diluent (DEB) to remove any entrained solvent, then to a thermosiphon evaporator for concentration to specifications. The purified uranium is normally transferred to the ion exchange feed makeup tank, but may be transferred to storage when a solvent extraction run does not coincide with the need for an ion exchange batch.

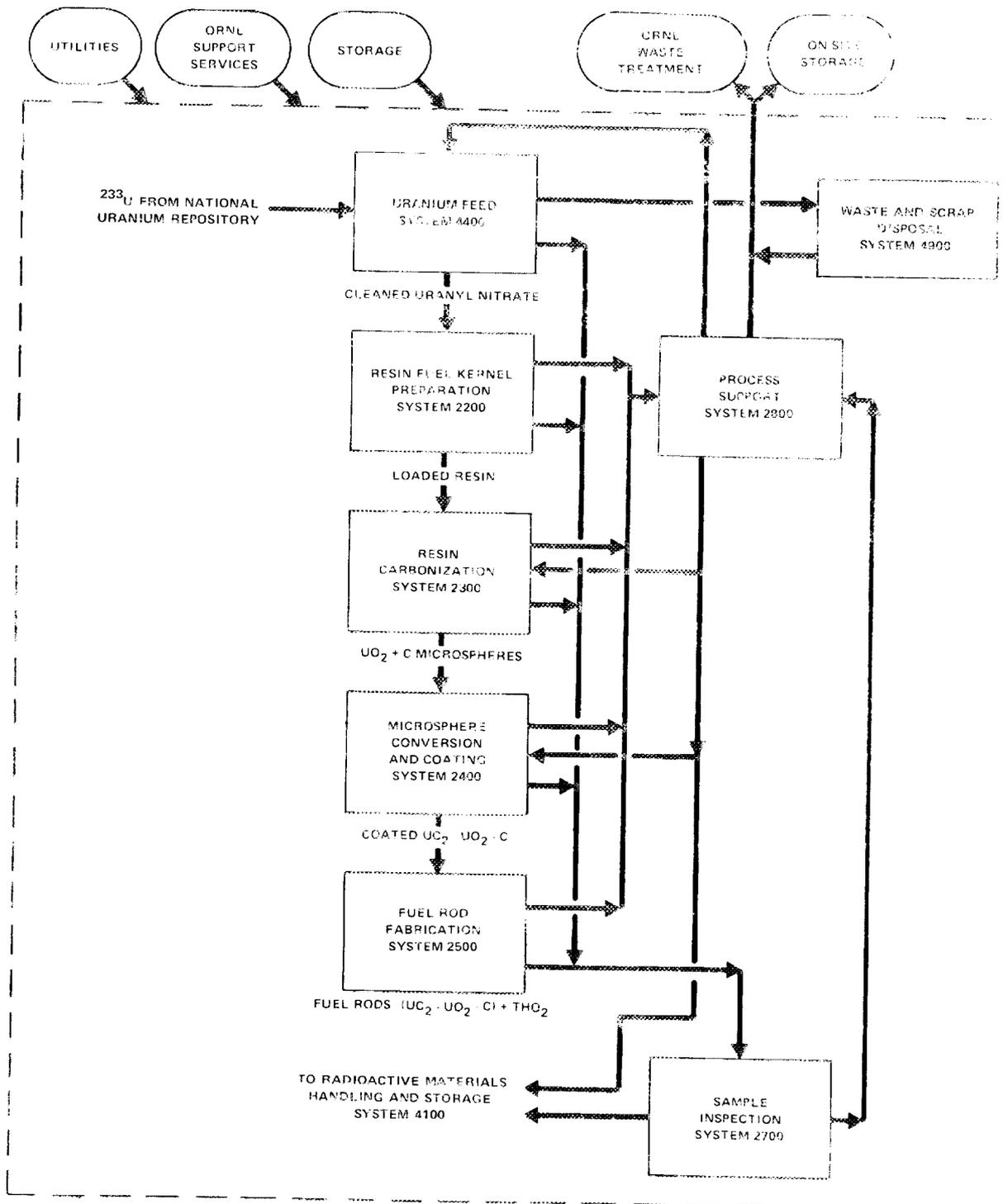


Fig. B.1. Generalized HET fuel refabrication process block diagram.

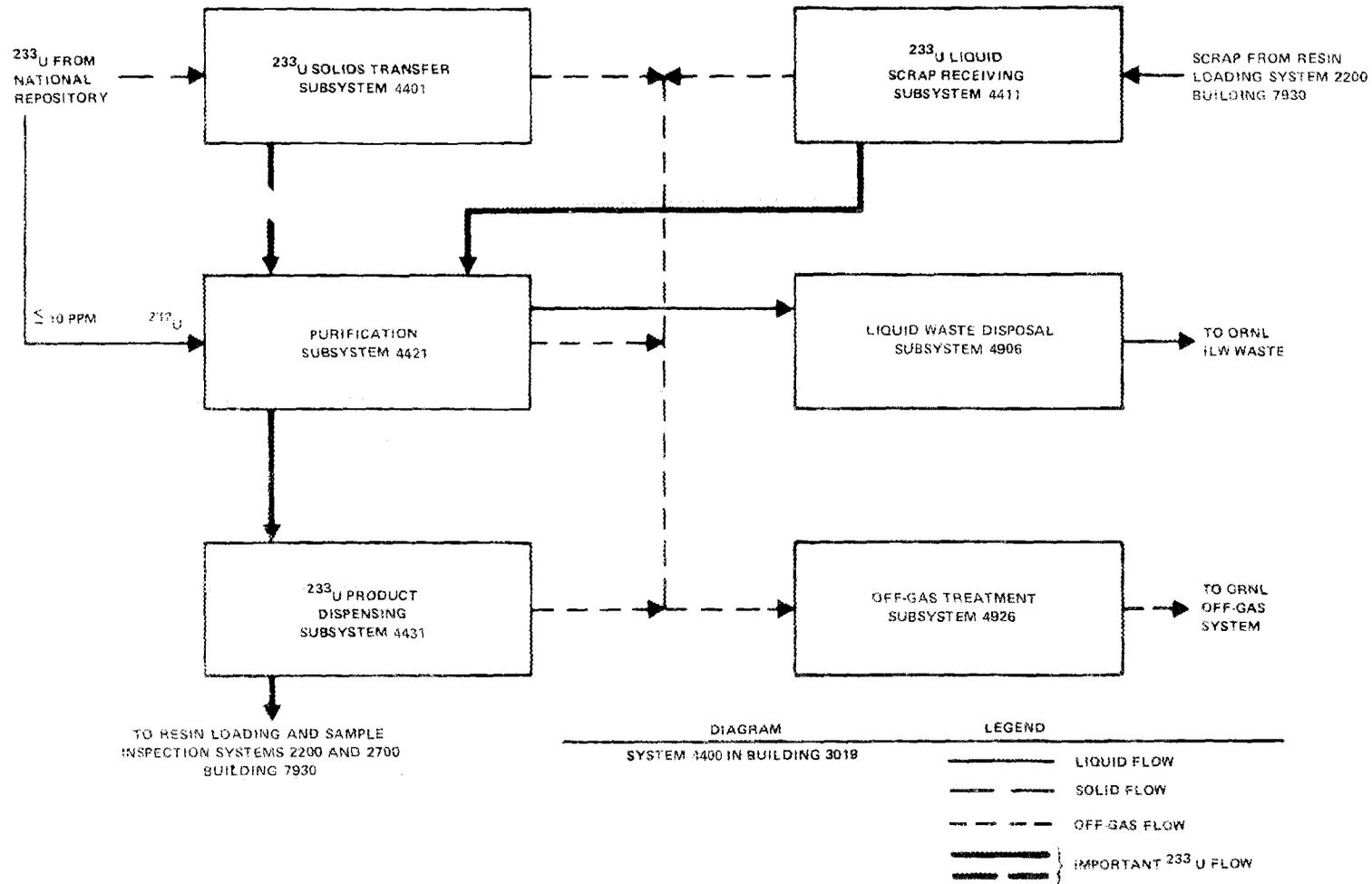


Fig. B.2. Uranium feed - System 4400.

If further purification is needed, ion exchange is employed. For each ion exchange run, approximately 20 kg of U at 110 g/liter of U is used for feed to the column, in which essentially 100% of the ^{228}Th and ^{224}Ra are selectively removed from the solution, breaking the ^{232}U -daughter decay chain. The product becomes the feed solution for the resin loading operation in the resin fuel kernel preparation system. After purification of each batch, the ion exchange column is eluted to regenerate its sorbing capacity, and the elutriant is recycled to solvent extraction for uranium recovery.

B.2 RESIN LOADING — SYSTEM 2200

Uranyl ion is loaded on resin beads via ion exchange in the resin fuel kernel preparation system. The system comprises five subsystems: UNH solution storage and feeding, nitrate extraction and solvent regeneration, resin loading, resin drying and transferring, and evaporation (Fig. B.3).

From the uranium feed system (via uranyl nitrate storage) uranyl nitrate feed solution is introduced to the central process point in this system (the process surge vessel) at an initial uranium concentration of 100 g/liter. To achieve optimum loading conditions, the feed solution is made acid deficient (molar ratio of $\text{HNO}_3:\text{UO}_2^+ < 2.0$) through solvent extraction using 0.4 M Amberlite LA-2 in diethyl benzene as the organic extractant. Acid is removed by extraction of nitric acid into the organic phase until the optimum ratio for loading is attained. Extraction of nitric acid is continued throughout the loading process. The organic is regenerated by rinsing with water, scrubbing with 1.5 M NaOH, and rinsing again with water.

Acid-deficient uranyl nitrate (ADUN) is circulated through protonated-form resin beads in the resin-loading subsystem, and uranium is loaded on these beads through an ion exchange involving UO_2^+ and H^+ ions. As the density of the bead increases during the loading operation, the ADUN flow rate increases accordingly until the resin beads are fully loaded. These loaded beads are then transferred for washing and microwave drying in the resin-drying subsystem.

The ADUN uranium concentration is controlled throughout the loading operation by semicontinuously evaporating water from the ADUN in a thermosiphon evaporator at an approximate rate of 30 liters/hr. Evaporation condensate is recycled to the solvent regeneration scrub contactors and to the microwave dryer for rinsing purposes. The fully loaded, dried resin beads are sent to the next step in the refabrication process, resin carbonization.

B.3 RESIN CARBONIZATION — SYSTEM 2300

The basic purpose of the resin carbonization system is to produce a fissile fuel kernel, uranium dioxide dispersed in an elemental carbon matrix, from the resin beads loaded with uranyl ions. This is accomplished (Fig. B.4) by heating the loaded resin particles in an inert-atmosphere, fluidized-bed induction furnace. Heating to a maximum temperature of 800°C is done at a controlled rate so that no hydrogenous material remains in the resin and such that the resin beads do not agglutinate. The loaded resin particles have a nominal diameter of 550 μm and a density of 1.7 g/cm³, and the carbonized resin particles have a diameter of 370 μm and a density of 2.5 g/cm³.

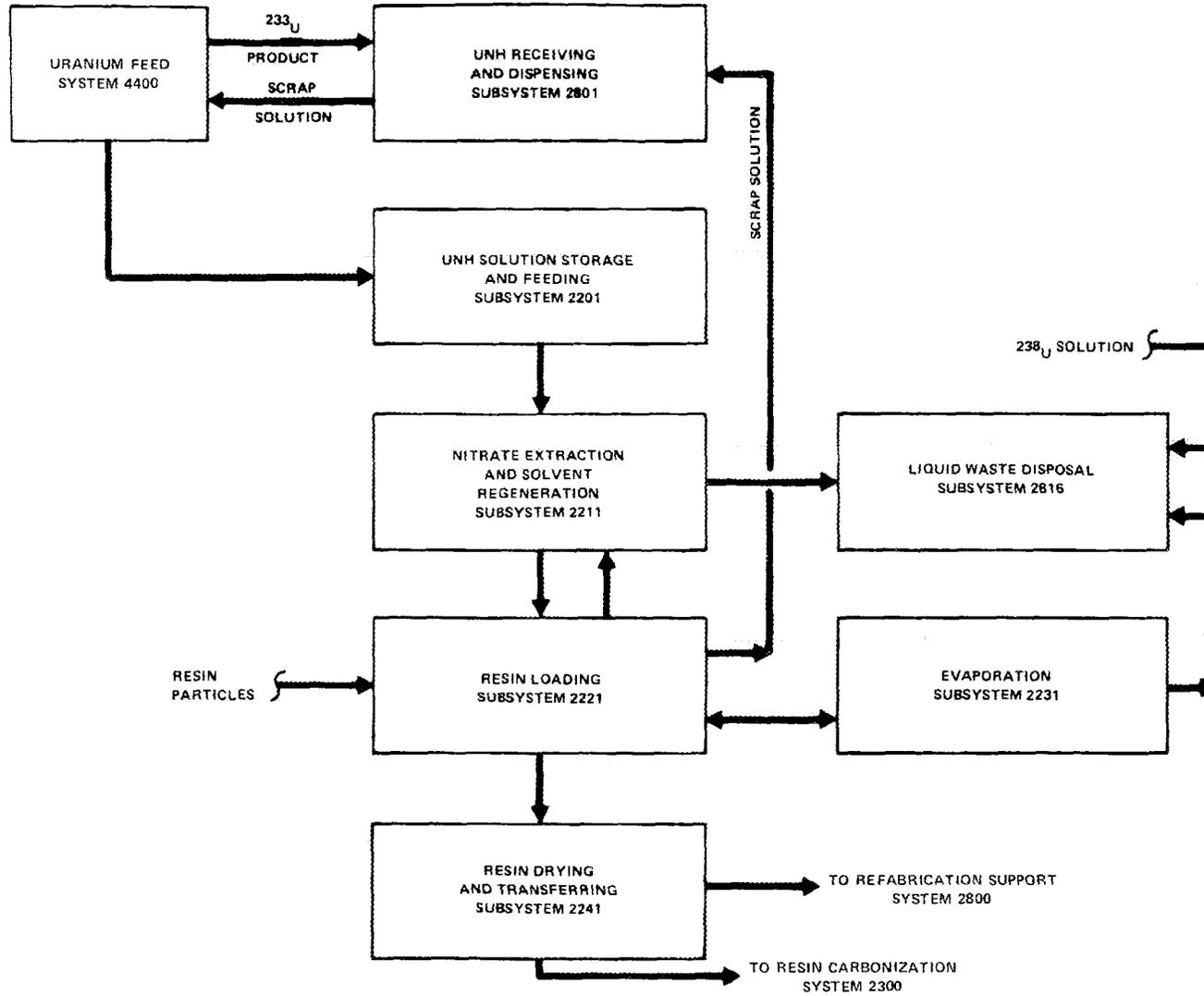


Fig. B.3. Resin fuel kernel preparation - System 2200.

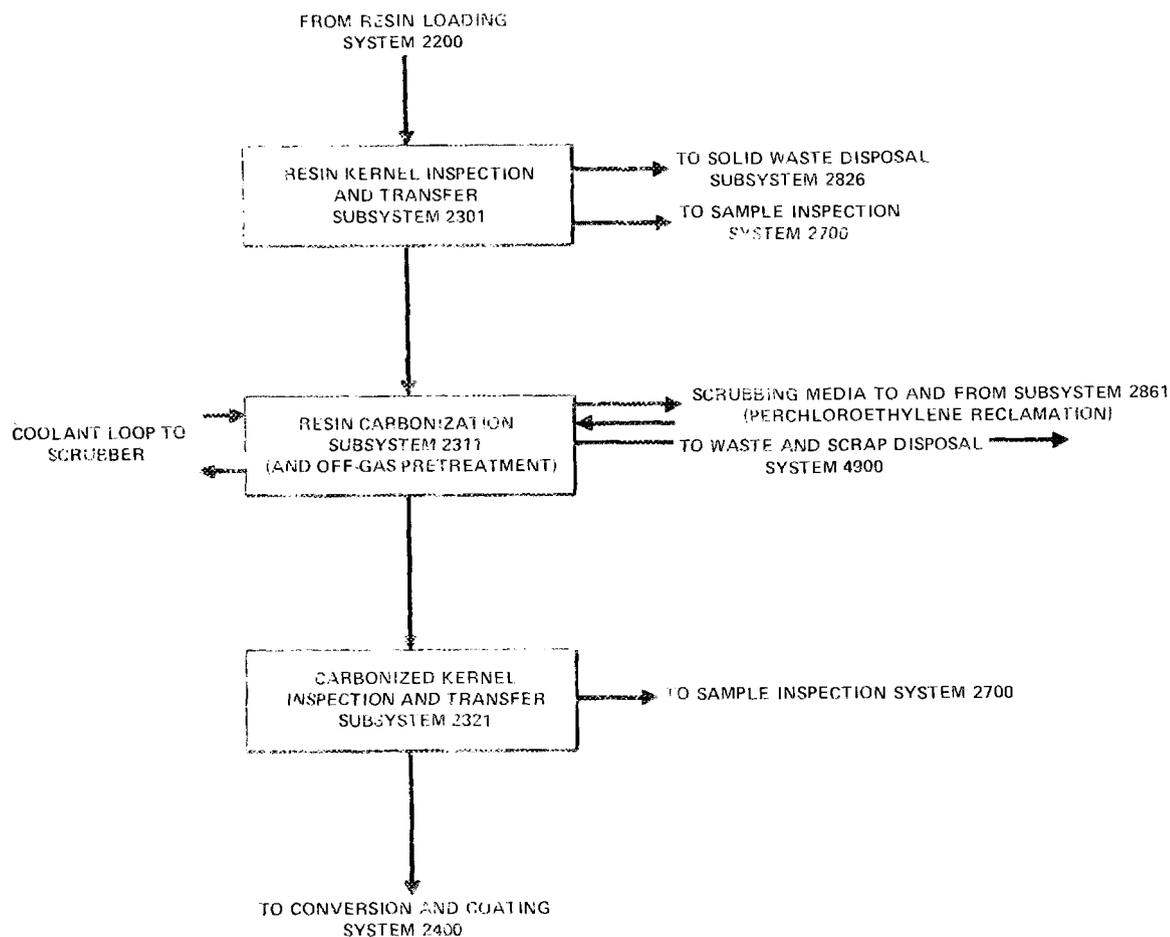


Fig. B.4. Resin carbonization -- System 2300.

In this heating or carbonizing step, many different hydrocarbon compounds are driven off. Since ^{220}Rn is a decay product of the ^{232}U present, the fluidizing gas (argon with less than 100 ppm oxygen because the carbonized resin is pyrophoric even at room temperature) will contain small amounts of ^{220}Rn . The specific radon concentration depends on the concentration of ^{232}U in the ^{233}U , the amount of time between loading and processing of the resin, and the rate at which radon diffuses from the resin. Air or argon used as a pneumatic transfer medium will also contain trace amounts of radon. After heating and cooling in the furnace, the particles are weighed and sampled.

The furnace effluent and the spent pneumatic transfer gas are treated in the off-gas treatment subsystem (Sect. B.4). The furnace effluent is considered a combustible off-gas, and the transfer gas is considered noncombustible. The transfer gas is filtered prior to discharge to the facility combustible off-gas handling equipment (Sect. B.7.4) for radon removal and further filtering. Furnace off-gas is cooled and scrubbed to remove hydrocarbons. Perchloroethylene is used as a scrubbing solvent because it is a poor neutron moderator. This subsystem includes an intermediate organic cooling loop to remove the waste heat from the scrubber and interfaces with the solvent reclamation equipment. The off-gas is passed through a detrainment column and

after-cooler to remove most of the entrained solvent and solvent vapors from the effluent and is then routed to the facility combustible off-gas equipment for filtration and radon removal.

B.4 CONVERSION AND COATING - SYSTEM 2400

The microsphere conversion and coating system produces coated fuel particles suitable for fabrication into fuel rods. The system is divided into three process subsystems as shown in Fig. B.5. The particles are processed five times in the conversion and coating furnace. After each step the fuel particles are removed from the furnace, weighed and sampled, and then returned to the furnace. The first process step converts, at a temperature of 1800°C, part of the uranium oxide in the fuel kernels to uranium carbide. The second through the fifth steps apply coatings (referred to as TRISO) to the converted fuel particles: A porous carbon buffer coating is deposited by pyrolysis (1300°C) of acetylene gas; next, a dense carbon coating (inner low-temperature isotropic) is deposited by pyrolysis (1300°C) of propene; the third coating is silicon carbide, deposited by pyrolysis (1550°C) of methyltrichlorosilane; the last coating is another dense carbon coating (outer low-temperature isotropic) using propene (1300°C).

During these coating steps, many aromatic hydrocarbons (including polynuclear aromatic hydrocarbons), unsaturated and saturated hydrocarbons, intermediate silane compounds, hydrogen, hydrogen chloride, carbon soot, and traces of ^{220}Rn can be found in the furnace off-gas. The amount of soot and carbonaceous wastes generated depends on the coating efficiency of the process. The pneumatic transfer gas (from particle transfers) will also have trace amounts of ^{220}Rn until the fuel kernels receive at least two coatings.

The off-gas treatment subsystem consists basically of two scrubbers: (1) a perchloroethylene scrubber to quench the off-gas and remove soot and hydrocarbons and (2) a caustic scrubber to remove hydrogen chloride gas. Each scrubber has a heat exchanger in the solvent loop to remove both sensible heat from the effluent and the heat of reaction in neutralizing hydrochloric acid. The perchloroethylene scrubber is used during all furnace operations, but the caustic scrubber is used only during silicon carbide coating and is by-passed during the other process steps. After treatment, the furnace off-gas is routed to the facility combustible off-gas equipment (Sect. B.7.4). The spent transfer gas and any vessel off-gas is routed to the facility noncombustible off-gas equipment (Sect. B.7.5) for radon removal and other processing. The spent perchloroethylene solvent is pumped to the process support system for reclamation (Sect. B.7.6). Spent sodium hydroxide scrub solution is also pumped to the process support system for disposal.

The furnace liner is cleaned periodically to remove carbonaceous soot that accumulates from the cracked coating gases. This soot is collected along with the waste carbon collected from screening the particles and is sent to the process support system (Sect. B.7.3).

B.5 FUEL-ROD FABRICATION - SYSTEM 2500

The purpose of the fuel-rod fabrication system is to form a limited number of "green" (uncarbonized) fuel rods as needed to test the suitability of conversion and coating (System 2400) product for continued processing and to prepare fuel rods to supply the needs of the nondestructive assay development program. This is accomplished (Fig. B.6) through the following system functions: (1) receiving coated fissile microspheres from conversion and coating system in

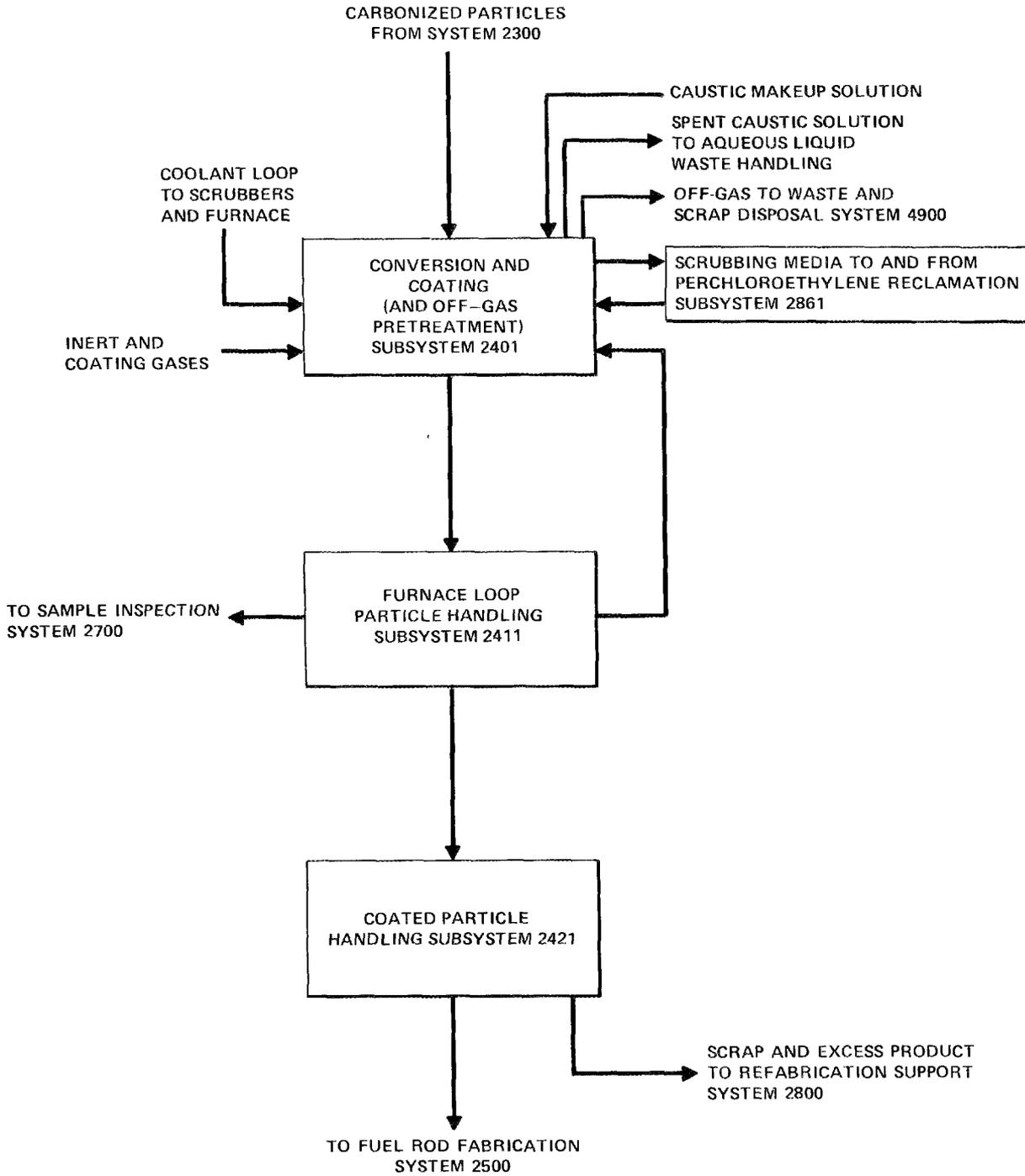


Fig. B.5. Conversion and coating – System 2400.

storage hoppers containing approximately 0.5 kg of uranium (2.5 kg of particles), (2) receiving coated fertile and shim particles in hoppers similar to the storage hoppers from out-of-cell sources, (3) dispensing controlled quantities of each particle type and blending these into a homogeneous mixture, (4) forming a 5/8 in.-diam x 2-1/2-in.-long (1.59-cm x 6.35-cm) green fuel rod by the slug-injection process in a mold loaded first with the homogeneous mixture of particles, (5) separating the mold components from the green rod, (6) transferring samples of the green rods to Sample Inspection (System 2700) for later inspection external to the Hot Engineering Test Facility, (7) providing a means of containment and shielded storage of product rods, (8) collecting all unused particles in storage hoppers, (9) cleaning all mold components for reuse, and (10) collecting all scrap and waste and transferring the material to Refabrication Support (System 2800).

B.6 SAMPLE INSPECTION SYSTEM — SYSTEM 2700

The sample inspection system (Fig. B.7) receives samples from all stages of refabrication and provides the required inspection activities such as: (1) transfer of samples; (2) division of particulate samples as required; (3) weighing, packaging, and dispatching samples to other ORNL laboratories; (4) performing particle-size analysis; (5) weighing, packaging, and dispatching archive samples to storage; (6) weighing and transferring excess sample material to waste and scrap handling. Three basic types of samples are taken from the refabrication equipment: (1) formed fuel rods from the fuel rod fabrication system, (2) particle samples from the resin carbonization, and conversion and coating systems, and (3) liquid samples from resin loading and refabrication support systems.

All sample transfers are performed under negative pressure with argon as the transfer medium to preserve inert atmosphere conditions throughout the system, which permits handling of pyrophoric material. Chemical analyses are transported to and performed in existing laboratory facilities. Particle-size analysis, sample subdivision, and packaging are performed in three inert-atmosphere glove boxes. Each box operates with a constant purge rate of 0.5 scfm (14 liters/min) of argon during normal work shifts. High purge rates of 3 to 4 scfm (85 to 110 liters/min) are required during initial purge and intermittently for bag in and bag out operations. The equipment itself has no significant flow requirements. No liquid effluent streams have been identified. All scrap and waste materials are handled by refabrication support (System 2800).

B.7 REFABRICATION SUPPORT — SYSTEM 2800

System 2800 handles feed materials between uranyl nitrate feed preparation (Sect. B.1) and resin kernel preparation (Sect. B.2) as well as a wide variety of wastes. A block diagram for the refabrication support system is shown in Fig. B.8. The wastes from Building 7930 are processed by five subsystems: (1) Liquid-waste treatment — Subsystem 2816, (2) Solid-waste handling — Subsystem 2826, (3) Combustible off-gas treatment — Subsystem 2841, (4) Noncombustible off-gas treatment — Subsystem 2851, and (5) Perchloroethylene reclamation — Subsystem 2861. Table B.1 lists the sources and types of waste handled by the subsystems serving Building 7930.

A brief description of the individual subsystems follows:

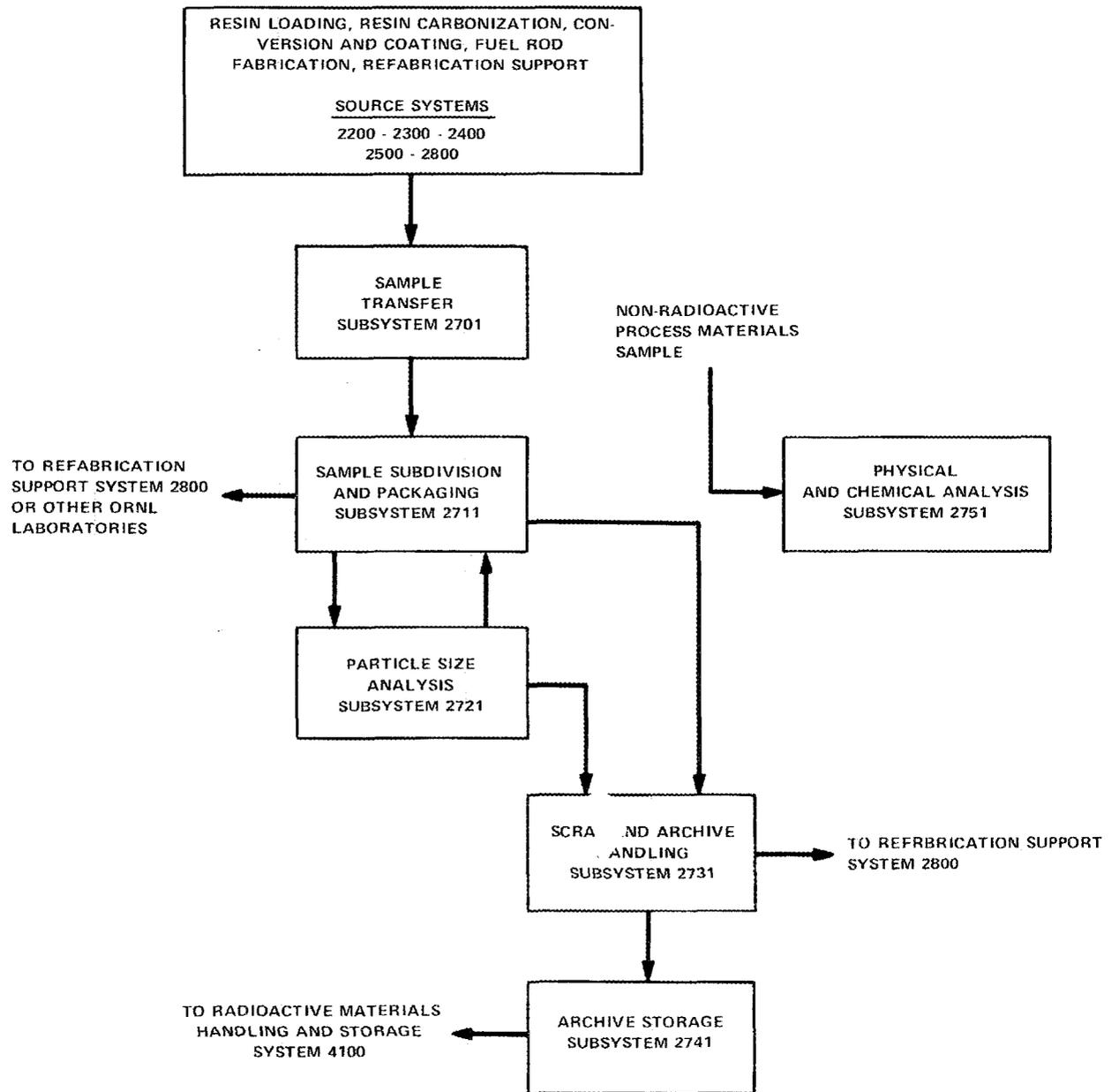
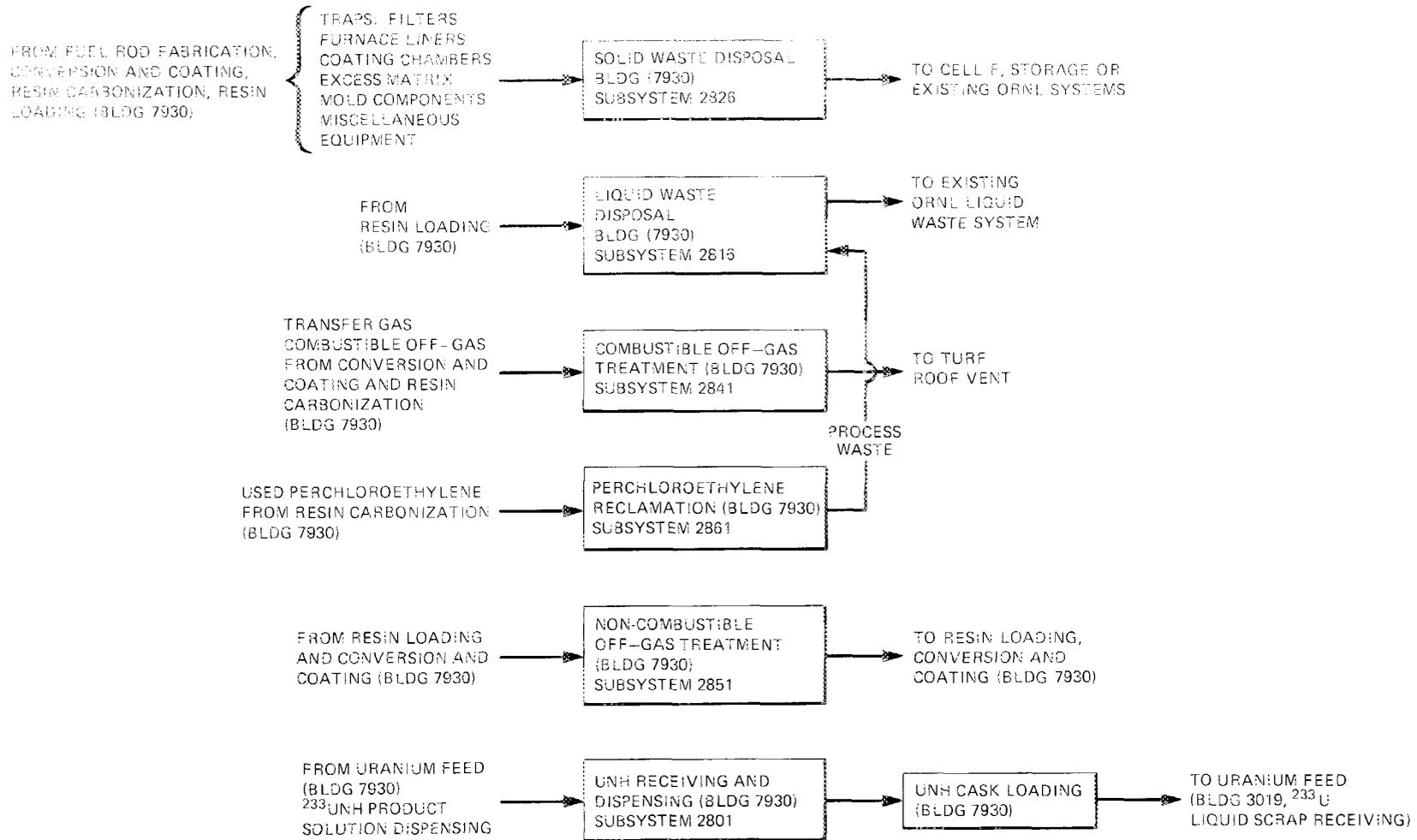


Fig. B.7. Sample inspection -- System 2700.

SYSTEM 2800 - PROCESS SUPPORT BLOCK FLOW DIAGRAM



B-14

Fig. B.8. Process support - System 2800.

Table B.1. Waste handled by process support (Building 7930)

| Subsystem source | Type of waste | Subsystem that handles |
|------------------|--|------------------------|
| 2211 | Aqueous liquid (sodium nitrate) | 2816 |
| 2200, 2801, 4400 | Scrap uranyl nitrate solution | 2816 |
| 2211 | Organic liquid (Amberlite and diethylbenzene) | 2826 |
| 2221 | Resin contactor filter elements | 2826 |
| 2300, 2400 | Traps and filters | 2826 |
| 2400 | Coated reject particles | 2826 |
| 2401 | Carbon clinkers from coating furnace | 2826 |
| 2500 | Mold parts and general waste-type scrap | 2826 |
| 2500 | Miscellaneous feed materials, out-of-specification fuel rods | 2826 |
| Several | Failed equipment | 2841 |
| 2311 | Effluent from carbonization furnace scrubber | 2841 |
| 2401 | Effluent from coating-furnace scrubber | 2851 |
| 2211 | Noncombustible organic gases | 2851 |
| 2816 | Vents from waste tank - aqueous and organic noncombustible gases | 2851 |
| 2300, 2400 | Dirty perchloroethylene | 2861 |

B.7.1 Uranyl nitrate receiving and dispensing - Subsystem 2801

After uranium feed (System 4400) (Sect. B.1) loads the ²³³U product solution transfer cask, it is transported by truck to Building 7930 and then brought by the 50-ton crane to the third floor receiving station of Subsystem 2801. By using compressed air, a siphon is set up, which empties the cask into the uranyl nitrate storage tank for subsequent transfer to resin loading (System 2200) as needed. When empty, the cask and lines are rinsed with demineralized water (the rinse water goes to TURF liquid waste disposal - Subsystem 2816). The cask is then ready to be disconnected and returned to Building 3019 for the next batch of uranyl nitrate feed.

B.7.2 Liquid waste disposal (TURF) - Subsystem 2816

Liquid waste treatment (Subsystem 2816) within Building 7930 (TURF) shall be limited to the minimum necessary to permit transfer to laboratory waste handling facilities via waste and scrap disposal - System 4900 (see Appendix C.8).

B.7.3 Solid-waste disposal (TURF) - Subsystem 2826

Subsystem 2826 receives three streams of materials: solid waste, scrap, and organic waste. These are collected, sampled if required, weighed, and packaged. The packaged material is then transferred through the roof access into a cask for further processing by waste and scrap disposal - System 4900 (Sect. C.8).

All product material from HEI refabrication operations becomes either scrap or archive samples. This material includes particles from resin carbonization and conversion and coating; molded products, trimmings, and excess material from fuel-rod fabrication; and residues from the sample inspection system. The materials are packaged, identified, and double sealed. The sealed containers are transferred by way of cell "B" to cell "F," where they are kept in storage.

Solid waste is transferred by manipulators to the waste-packaging station located on the west side of cell "C." The waste material, consisting of failed equipment, traps, filter elements,

coating chambers, etc., is sampled as required to satisfy disposal requirements. All waste is packaged so that either method of disposal, burial or long-term storage, may be selected. At this point, waste and scrap disposal (System 4900) continues the handling of the individual drums of waste material.

Scrap material is product or by-product material known to be high in uranium content that must be accounted for and ultimately recycled to a more usable form. Solid waste disposal (Subsystem 2826) performs the process functions of receiving the scrap material that comes from conversion and coating and fuel-rod fabrication, packaging it, and transferring the material to waste and scrap disposal (System 4900) for storage in cell "F."

Organic waste material comes to solid waste disposal (Subsystem 2826) from two sources, perchloroethylene reclamation (Sect. B.7.6) and resin kernel preparation (Sect. B.3). Organic liquid waste is placed in 30-gal drums that contain an absorbent such as vermiculite. After being absorbed into the vermiculite, the liquid waste is handled as solid waste. Further processing consists of decontaminating the outer surfaces of the waste containers.

B.7.4 Combustible off-gas treatment (TURF) — Subsystem 2841

Subsystem 2841 is essentially the interconnecting piping between the furnaces of resin carbonization (System 2300) and conversion and coating (System 2400) and the gaseous waste treatment (Subsystem 4921) (Sect. C.8).

B.7.5 Noncombustible off-gas treatment (TURF) — Subsystem 2851

Subsystem 2851 is essentially the interconnecting piping between the aqueous waste tank of resin loading (System 2200) and the perchloroethylene reclamation subsystem and the radon trap of gaseous waste treatment (System 4921) (Sect. C.8).

B.7.6 Perchloroethylene reclamation — Subsystem 2861

In operation, the perchloroethylene reclamation system receives dirty solvent from the carbon scrubbers (see B.4), filters out fuel particles, distills the dirty perchloroethylene, separates the water from the condensed solvent, and stores and transfers the clean solvent back to the carbon scrubbers as required. The system is a batch process.

Most of the equipment is vented to a scrubber system to remove possible chlorine gas contamination. The still-feed tank, condensate catch-tank coalescer, reclaim surge tank, and calcium oxide contactor are vented. From the scrubber, the noncombustible off-gas (Subsystem 2851) is heated to prevent condensation, is passed through a HEPA filter, and is sent to gaseous waste treatment, (System 4900) (Sect. C.8).

Appendix C
SUPPORT FACILITIES

Appendix C
SUPPORT FACILITIES

C.1 PROCESS SUPPORT -- SYSTEM 4000

Support facilities used for various HETP reprocessing and refabrication operations consist of seven major systems as shown in Fig. C.1. The support facilities interface with many operations to accomplish the following major responsibilities:

C.2 RADIOACTIVE MATERIALS HANDLING AND STORAGE -- SYSTEM 4100

Responsible for receiving, handling, segmenting, and storing radioactive materials. The segmenting (Subsystem 4106) of fuel elements is discussed in greater detail in Sect. A.1 as part of the reprocessing procedure.

C.3 MATERIALS HANDLING -- SYSTEM 4200

Responsible for providing equipment and facilities to receive, handle, and store (out-of-cell) all packaged cold materials such as chemicals, equipment, and spare parts; and to store and transfer these items in appropriate places, such as transferral to radioactive materials handling and storage (System 4100) for in-cell handling.

C.4 PROCESS MAKEUP -- SYSTEM 4300

Responsible for supplying measured quantities of cold chemicals required to feed the various processes within the shielded alpha area of the HET and to provide chemical solution treatment for the waste-storage tanks.

C.5 URANIUM FEED -- SYSTEM 4400

Responsibilities are discussed in Sect. B.1.

C.6 UTILITIES -- SYSTEM 4600

Responsible for furnishing the HET plant with all utility services for the test program: provides for the receipt, storage, and delivery of fuel chemicals, materials, and process gases required by the plant, the process, and support systems. Required services include: lighting, electricity, communications, utility gases such as plant and instrument air, water (chilled, heated, treated, demineralized, etc.), steam, heating and air conditioning ventilation, sanitary and "cold" industrial sewers and drainage, vacuum, other heating and cooling mediums, fuels, and equipment and services for decontamination purposes.

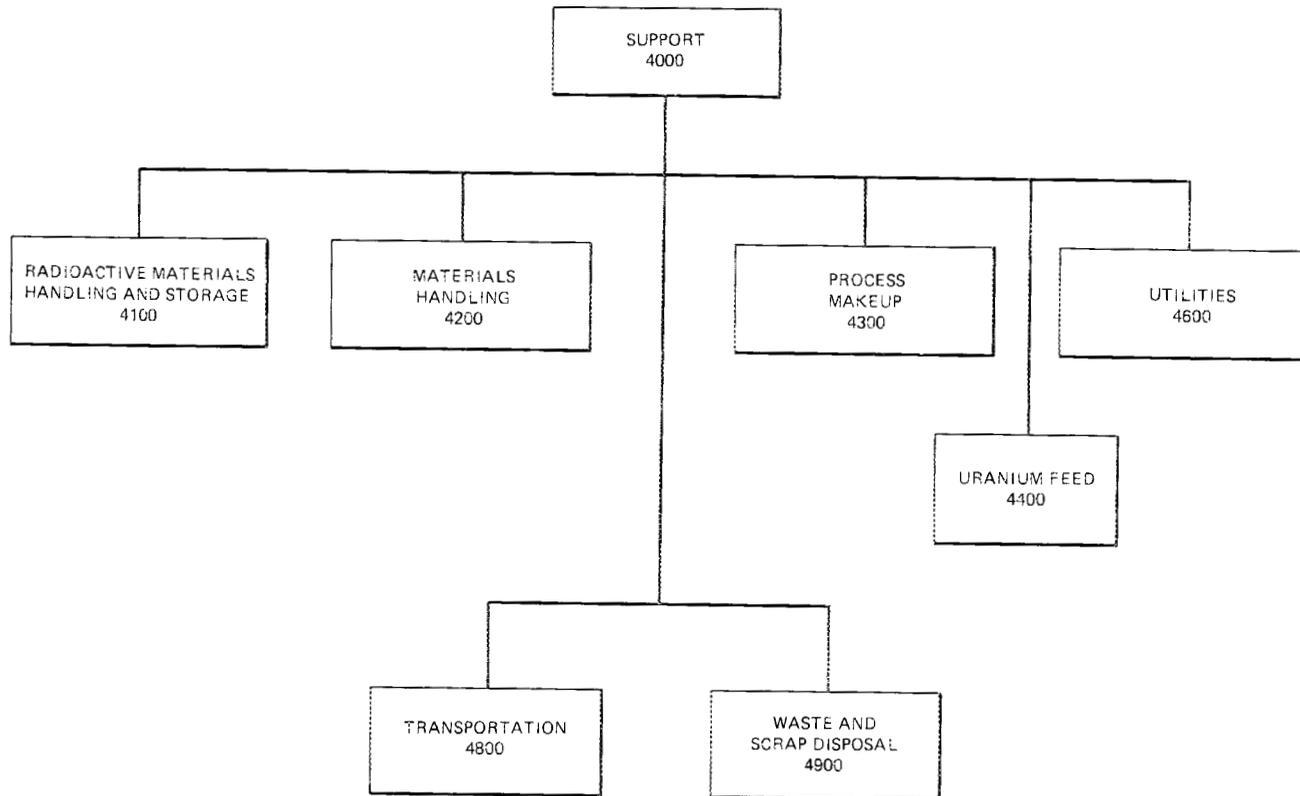


Fig. C.1. Support facilities systems.

C.7 TRANSPORTATION -- SYSTEM 4800

Responsible for providing a means of conveyance for safely transporting casks, containers, and packaged materials between buildings within the ORNL site. Further discussion appears in Sect. 2.4.

C.8 WASTE AND SCRAP DISPOSAL -- SYSTEM 4900

Responsible for providing equipment and facilities for receiving, decontaminating, sampling, monitoring, assaying, treating, and disposing of solid, liquid, and gaseous wastes generated by the reprocessing and refabrication operations and support facility functions. The main subsystems are (1) Subsystem 4901 (Subsystem 4906 in Building 3019) whose primary function is receiving and treating, if necessary, all aqueous waste for disposal through the ORNL waste collection and treatment system (Sect. 2.3.2.2), (2) Subsystem 4911 (Subsystem 4916 in Building 3019) whose primary function is receiving and properly disposing of all HET solid waste and failed equipment (Sect. 2.3.2.3), and (3) Subsystem 4921 (Subsystem 4926 in Building 3019) which treats, if necessary, noncombustible gaseous wastes before final discharge to the atmosphere (Sect. 2.3.2.1). Subsystem 4921 also separately treats combustible gaseous wastes from resin carbonization (Sect. B.3) and kernel conversion (Sect. B.4) and discharges these wastes through a vent on the roof of Building 7930 (Sect. 2.3.2.1). Argon is the principal diluent from the combustible waste gases.

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